JEHLUM & TAWI
FLOOD RECOVERY PROJECT

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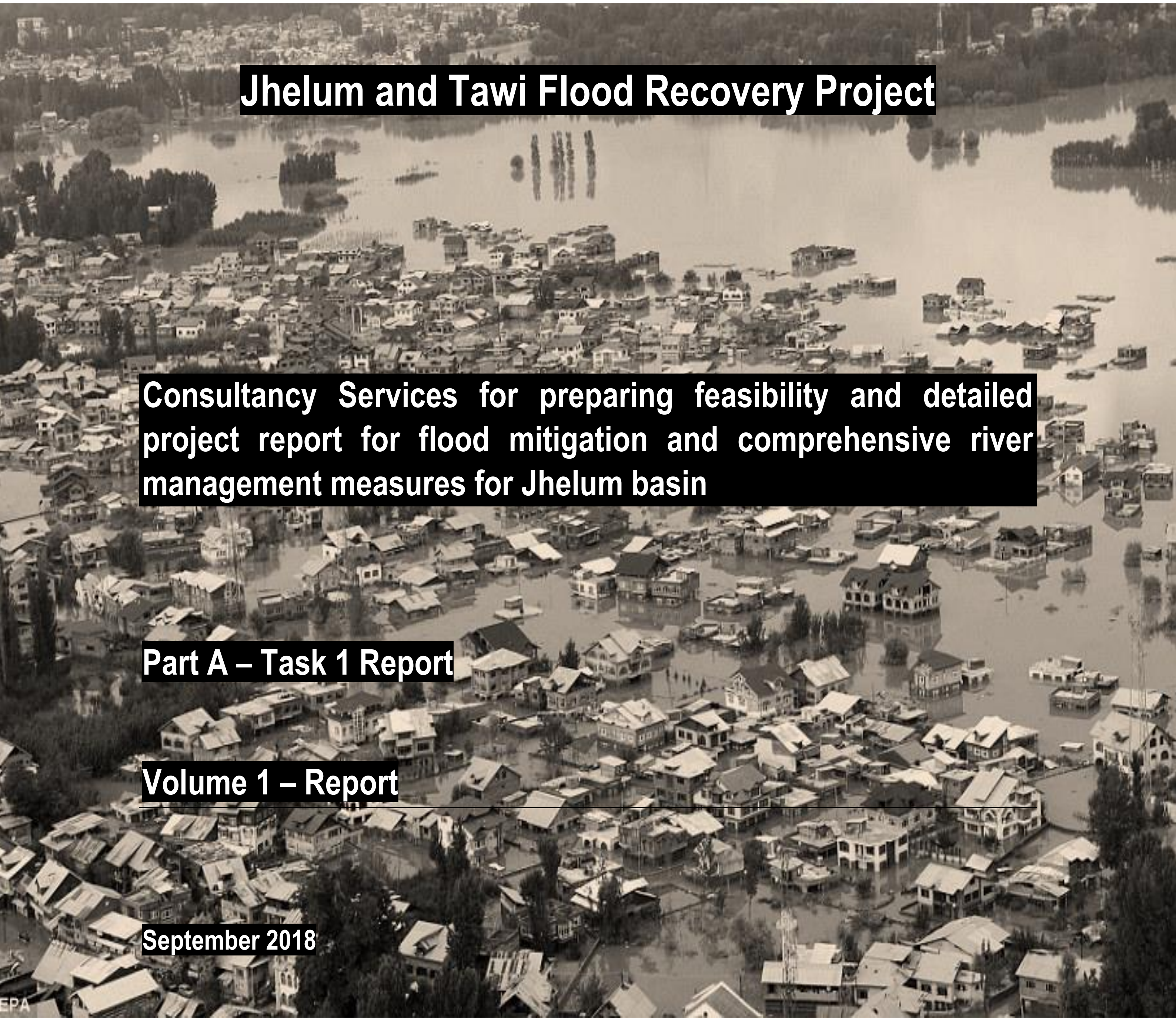
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Jhelum and Tawi Flood Recovery Project

Consultancy Services for preparing feasibility and detailed project report for flood mitigation and comprehensive river management measures for Jhelum basin

Part A – Task 1 Report

Volume 1 – Report

September 2018

eptisa

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Executive Summary

Introduction

This project *Consultancy Services for preparing feasibility and detailed project report for flood mitigation and comprehensive river management measures for Jhelum basin*, is one element of the overall *Jhelum and Tawi Flood Recovery Project* (JTFRP).

EPTISA Servicios de Ingenieria SL (Eptisa) has been commissioned to undertake this Study on behalf of JTFRP. This report is the **Task 1 Report** for these Consultancy Services, and it comprises the work undertaken during the Inception Phase and Task 1 as per the TOR for Part A.

The Jhelum River Valley suffered record flooding in September 2014 as a result of abnormally high and widespread rainfall particularly in the southern part of the catchment. The rainfall across the southern catchment in the first week of September averaged 433mm (Romshoo et al 2018). This resulted in widespread flooding along the Jhelum River from the confluence of the southern tributaries near Sangam, through Srinagar City, and downstream to Baramulla. The peak flow in the Jhelum River at Sangam was estimated by the Irrigation and Flood Control Department (IFCK) to be 3,260 m^3/s (1,15,000 cusecs). The area flooded was approximately 850km^2. In Srinagar, the floodwaters were up to about 1.5m above the river embankments and large parts of the city were inundated at depths of up to 6m. Some areas of the city were flooded for up to 4 weeks. In addition to damage to people's homes and livelihoods, there was a great deal of damage to public infrastructure including roads, bridges and hospitals.

Many factors have influenced flooding in the Jhelum River valley including increasing encroachment by urbanisation and the reduction of the natural flood storage provided by Wular Lake and other lakes and wetlands due to sedimentation. There is over 100 years of flood mitigation history in Srinagar with the Flood Spill Channel constructed about 1903 being the first major flood mitigation infrastructure. There are a number of existing and proposed flood mitigation measures which together with the lakes, wetlands and natural floodplain storage present a complex problem for the mitigation of future floods.

This study is undertaken against the background of the recent flooding and recent and ongoing impacts of development as briefly outlined above.

Study Area

For hydrologic modelling purposes and for consideration of catchment management, the study area comprises the whole of the Jhelum River Catchment to the India-Pakistan border. For the hydrodynamic model, the study area comprises the Jhelum River valley and its floodplain from Khanabal Bridge to Salamabad Bridge.

Objectives of the Study

The overarching objective of the study is to restore critical infrastructure, damaged primarily by 2014 floods, with upgraded resilient features including contingency planning for future disaster events.

This requires detailed flood inundation modelling in order to better understand the flooding processes occurring in the floodplain, and the interactions between its various components and also to investigate the effectiveness of a range of flood mitigation measures already under consideration and to identify and evaluate of potential measures such as tributary flood storage.

The various measures will be considered both individually and in various combinations to produce a resilient flood management plan, which will also include non-structural measures such as town planning/land use controls and catchment management to reduce sediment inflows into the river system.

The first stage of the Study (**Part A**) comprises the data collection, flood modelling, and concept design components leading to a feasibility study of options from which selected components will be taken up for inclusion in the proposed Flood Management Plan. This plan will be a blueprint for flood management and mitigation in the Jhelum River catchment for several decades.

Once the elements of the Flood Management Plan have been finalised, the second stage of the Study (**Part B**) will comprise the development of a Detailed Project Report for the planned works including detailed design drawings and tender documents.

Project Timing

Both **Part A** and **Part B** of the study are of 12 months duration, and with a starting date of 1st July 2018, the completion dates are 30th June 2019 for **Part A** and 30th June 2020 for **Part B**. The timing for the completion of **Part B** is provisional considering no delay between the completion of **Part A** and the commencement of **Part B**.

Report Structure

This report is structured into 2 Volumes, namely:

- Volume 1 Main Report: and
- Volume 2 Preliminary Morphology Mapping (1:25,000) scale.

Inception Phase

a) Mobilisation

The Contract between the Jhelum and Tawi Flood Recovery Project (JTFRP) and Eptisa was signed on 2nd July 2018 and several members of the Study Team were mobilised to Srinagar for the project "kick-off" meeting, which was held on 17th July 2018, by which time the project office had been established in accommodation provided by the Client in Hotel Ranchi.

b) Site Inspections

Three one-day site inspections were organised for members of the Study Team by the Irrigation and Flood Control Department (IFCK) during the Inception period (16th July – 15th August). These took place in the southern, central and northern parts of the Jhelum River main stream respectively. These were very useful in familiarisation of the Study Team to the Jhelum River, Flood Spill Channel, Outfall Channel, Wular Lake, and Anchar Lake.

c) Data Collection

During the Inception phase IFCK was the primary source of primary hydrologic and spatial data, and reports on flood management. Data collection from IMD was also initiated and is ongoing. Secondary spatial data were obtained from a variety of public domain sources together with various other data and reports. The collection of social and environmental data also commenced and is ongoing. More detail on the data collected is given in the body of the report.

d) Project Risks

The perceived risks and challenges to the timely completion of the project are listed in the report together with their level of risk, and proposed risk mitigation. These relate to river cross-section, bathymetric and floodplain surveys to be undertaken in Task 2: delays in these surveys will result in delay to the flood modelling and feasibility study tasks in particular.

Action has been taken to commence the field surveys earlier than originally planned which helps to address the potential delays but is also a practical move in order to complete these surveys before winter.

JTFRP's assistance in expediting any necessary clearances will greatly assist in minimising these risks.

e) Project Challenges

The principal challenge for this project is to develop a flood risk management plan for the Jhelum River that can deal with a flow at Sangam equivalent to that which occurred in September 2014, taking account of the fact that the current river capacity is only about 50% of that flow. The combination of the existing flood management works which have developed over the last 100 years, the ongoing sediment inputs and the largely uncontrolled development in the floodplain particularly at Srinagar, have led to a very complex flood management situation.

The development of a sustainable plan will require a combination of structural and non-structural measures which are then implemented and enforced.

This is expanded upon in the body of the report, which lists a number of possible considerations in addition to those included in the current Interim Scheme including:

Structural Measures: the provision of flood control storage in the southern tributaries; controlled floodplain storage upstream of Srinagar, the construction of a second flood diversion channel from Dogripora to Wular Lake, detention basins, partial diversion from the Jhelum River at Gagazu into Anchar Lake returning to the Jhelum River at Shadipora; dredging of Wular Lake to restore its capacity; flood control and sediment control storage on Pohru Nullah.

Non-structural measures: Development and enforcement of planning controls to exclude or severely restrict development in flood prone areas; specifying minimum floor heights of buildings with open structure below floor level; last resort demolition of the worst affected buildings; improvement of flood forecasting and warning system; improvement in the dissemination of flood warnings to the public; increase community awareness of flood issues and enabling meaningful interpretation of flood warnings; control of the ongoing sand mining of the Jhelum main channel by licencing in permitted areas; and catchment management measures – principally reforestation to reduce the sediment load from the upper catchment over time.

Climate change impacts are also an important challenge, which we will be taken into account in the hydrologic modelling on the basis of the research in this field, particularly that in respect of the Himalayan Region. One important practical aspect of the adaptation to climate change, is that works planned now be designed to be robust and resilient to the possible changes considered likely to take place by the end of the current century. To ensure resilience in this area, designs should go beyond the perceived change to consider the performance of the works in the case of a more extreme event, and that the works will survive without major damage in such an event.

Task 1 Review Flood and River Management Options

a) Observations on September 2014 Flood

This section of the report considers both physical and social aspects of the devastating September 2014 flood.

The Jhelum River flood of September 2014 was the highest at and upstream of Srinagar since records began in 1955 with a peak flow at Sangam of some 3,250m^3/s (1,15,000 cusecs), which is about double the channel capacity at that point and almost double the previous maximum recorded flow of 1,850m^3/s (65,000 cusecs) in October 1992.

Ray et al (2015) opine that the rainstorm which caused the flooding was the result of large scale disturbed atmospheric conditions as a consequence of the interaction between the westward-moving monsoon low and the eastward moving deep trough in the mid-latitude westerlies, causing extremely heavy rainfall over districts in the southwestern region of J&K.

An analysis was undertaken of river flows from along the Jhelum River and the major tributaries in the 2014 event compared to other floods, and the results are shown in **Table ES1.**

Table ES1 clearly shows the following:

- There was a very significant inflow from the major southern tributaries Lidder Nallah and Vishow Nallah in particular, which accounted for most of the difference in peak flow at Sangam and that upstream at Khanabal[1] -this is consistent with the rainfall distribution;
- This high flow from the south of the catchment resulted in the flow in the Jhelum River between Sangam and Srinagar being the highest recorded at 4 of the 5 gauging stations in this reach;
- The flows in the major southern tributaries, Sandran, Bringi, Vishow and Lidder all had record floods in this event;
- The rapid reduction in peak flow downstream of Sangam, from 3,260m^3/s (1,15,000 cusecs) at Sangam, to 1,700m3/s (60,100 cusecs) at Awantipora is consistent with the major overflows into the floodplain in this reach;

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[1] This assumes that the peaks are coincident but as these are mean daily flows this is reasonable – analysis of the timing of the peaks based on hourly flows will be undertaken in Task 2, as will checking of flow data generally

- The difference in flows between those recorded at Munshi Bagh and Padshahi Bagh gives a measure of the flow into the Flood Spill Channel, which, on this basis was only 244m^3/s (8,600 cusecs) confirming the reduction in capacity of the FSC by about 50% from its original 500m^3/s (17,500 cusecs)[2];
- Downstream of Srinagar and upstream of Wular Lake, the 2014 flood is no longer the flood of record:
  - at Shadipora it is the 2nd ranked flood being marginally lower than that in 1992; and
  - at Asham it slips to the 4th ranked flood being lower than floods in 1996, 1995 and 1992;
- Although the capacity of Wular Lake has reduced significantly over the years, it still has a major peak attenuation effect, with the peak flow reducing from 1384m^3/s (47,000 cusecs) at Asham to 984m3/s (32,500 cusecs) at Sopore;
- The peak flow attenuation of Anchar Lake is considerably less, not only due to the relative sizes of the two waterbodies but because at Anchar Lake only part of the flow of the Sindh Nallah passes through the waterbody, the rest flowing directly to the Jhelum River – in the 2014 flood the peak flows upstream and downstream of Anchar Lake were 311m^3/s (11,000 cusecs) and 253m^3/s (8,900 cusecs) respectively; and
- Downstream of Wular Lake, the 2014 flood slips further down the flood ranking being:
  - The 6th highest flood at Sopore; and
  - The 12th highest flood at Baramulla.;
- The latter indicates the importance of floods in the Pohru Nallah, which is the largest of the tributary catchments to flooding in the Jhelum River downstream of Wular Lake i.e. along the Outfall Channel (OFC).

All of the above observations indicate that the worst of the flooding was upstream of and around Srinagar resulting from the extreme rainfalls in the upper catchment. These flows are unprecedented, at least within the 62 year period of record, with the flow at Sangam being twice the channel capacity.

It is clear that meaningful mitigation along the Sangam to Srinagar reach requires flood control storage either within the upper tributaries or by controlled flooding of the floodplain. Hence, this will be one of the focuses of the flood mitigation component of the study.

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[2] As this estimate is a relatively small difference between 2 larger numbers, any errors in the latter would be accentuated in the difference, so this estimate may be of low accuracy.

Table ES1 Selected Flow Statistics regarding 2014 Flood

River	Location	Reach	Peak flow 2014 m^3/s	Flood of record m^3/s	Year	Rank 2014 flood
Jhelum	Kandabal RD ~-1.5km	Upstream of Lidder, Vishav & Rembriana Nallahs	944	944	2014	1
	Sangam RD 17.1km	Sangam - Srinagar	3263	3263	2014	1
	Awantipora RD 32.33 km		1703	1844	1992	2
	Pampore RD 52.20 km		1796	1796	2014	1
	Padshahi Bagh 66.93 km		2299	2299	2014	1
	Munshi Bagh 71.70 km	Downstream of FSC	2055	2055	2014	1
	Shadipora 96.98 km	Srinagar - Wular Lake	1321	1385	1992	2
	Asham 106.10km		1384	1494	1996	4
	Sopore 150.20 km	Downstream of Wular Lake	921	1112	1996	6
	Baramulla 167.00km		984	1525	1987	12
Lidder	Akura		744	744	2014	1
Lidder	Kirkadal		108	164	1975	2
Vishow	Arwani		866	866	2014	1
Rambiari	Wachi-Nayina		280	356	1976	3
Romshi	Pahoo		110	121	1975	2
Sindh	Dodoaharma		311	434	1995	3
Sindh	Narayan Bagh		253	546	1995	3
Bringi	Dantar		506	506	2014	1
Sandran	Vwrinag		126	126	2014	1
Pohru	Seuloo		239	808	1965	12

In respect of social impacts, *Sphere India* prepared the *Joint Rapid Needs Assessment* (JRNA). During the assessment survey team has covered 108 villages from the worst affected districts of Jammu and Kashmir. Out of 108 villages assessed by the team, water level was more than 3 feet in 62 villages and had entered into the houses in 87 villages. The team reported that 86% of the wards were affected and there was major damage to shelter, water and sanitation facilities, crop/agriculture land and education. However, the information related to existing situation before flood impact is yet to be collected to assess the status of impact. Further detail regarding these impacts is given in the body of the report.

b) Historic Development of Flood Management in the Jhelum Valley

The flood history of the Kashmir Valley goes back millennia and several rulers have undertaken flood control programs over many centuries.

The first major flood control works of recent times was the construction of the Flood Spill Channel (FSC) in 1903, following the major flood of 1893. The FSC was designed to carry about $500m^3/s$ (17,500 cusecs), but its current capacity is only about 50% of the original due to sedimentation and construction of low level crossings.

Since that time a number of reports have been prepared including Purves (1915), Dass (1928), Harris (c1930), Uppal (1955), CWPC (c1953) and the J&K Government (1958). The report summarises the recommendations of these reports but notes that none of the major recommendations have been implemented.

c) Currently Proposed Flood Control Measures – the Interim Scheme

Following the 2014 flood, the IFCK has developed an Interim Scheme to be implemented pending the outcomes from the current study, that enables the Jhelum River to convey $1,700m^3/s$ (60,000 cusecs) at Sangam through the system without significant flooding. A Detailed Project Report (DPR) is currently being developed for the Interim Scheme.

The interim scheme is, therefore, a starting point for the considerations of the current consultancy, and it is assumed that construction of the proposed measures will be implemented.

The interim scheme essentially comprises the following main components:

- Extending the channel of the Flood Spill Channel (FSC) through the Hokesar Lake effectively increasing the conveyance though the lake – sub options vary the width of this channel between 30m and 80m; and
- Increasing the width of the Outfall Channel (OFC) from Sopore Bridge (RD 150.25km) to RD 173.2km by an additional 40m along the thalweg line.

d) Review Flood Management Issues and Opportunities

As was introduced under the heading of *Project Challenges* in outlining work undertaken in the Inception Phase, the principal challenge for this project is to develop a flood risk management plan for the Jhelum River that can deal with a flow at Sangam equivalent to that which occurred in September 2014, taking account of the fact that the current river capacity is only about 50% of that flow, and that existing flood management works which have developed over the last 100 years, and the ongoing sediment inputs together with largely uncontrolled development in the floodplain, have led to a very complex flood management situation.

Upstream of Wular Lake, and particularly upstream of and through Srinagar, the lack of channel capacity is the main issue. Whilst it would be possible to construct a further diversion channel starting near Dogripora and continuing to Wular Lake, this channel would be some 80km in length and would be very expensive.

An alternative strategy would be to reduce peak flows in the river by the introduction of flood control storage in the southern tributaries. If sufficient flood control storage sites can be found and construction at those sites is feasible, it may be possible to reduce the peak flows to a sufficient extent that they are within the capacity of the Jhelum River. In the event that there are insufficient suitable sites, due to the steep gradients of the tributaries, a larger number of relatively small storages in cascade may be appropriate.

This alternative would also be very costly, but also has the benefit that the storages could be designed to trap sediment, in a way in which their capacity could be relatively easily maintained by the regular excavation of trapped sediment. Every effort will be made during the feasibility study phase to identify and evaluate potential flood storage sites.

Off-channel floodplain storage along the Sangam – Dogripora reach will also be considered and its comparative advantages/ disadvantages compared to upstream tributary storage will be evaluated. The economics of such storage will be compared with that of the Dogripora to Wular Lake channel.

The possibility of storage on the tributaries which flow directly into the FSC should also be considered but it is likely that these will be few opportunities for this. Enhancing the use of Dal Lake for flood storage will be considered although this is unlikely to be major contributor to flood management.

The potential of the detention basins recommended by CWPRS (2018) will also be considered, although it is noted that unapproved developments in these areas has reduced their availability for this purpose. Land acquisition issues will need to be addressed as part of this evaluation.

The possible construction of a new, considerably shorter outfall channel from the FSC to Wular Lake will also be investigated.

Enhancing the flood control role of Anchar Lake will also be investigated: this could involve diverting a larger proportion of flow from the Sindh Nallah into Anchar Lake; and revisiting the suggestion (from Purves 1915) of a partial diversion from the Jhelum River at Gagazu into Anchar Lake returning to the Jhelum River at Shadipora.

It is apparent from aerial photography that the volume of Wular Lake has reduced substantially over time as a result of sediment inflow. The bathymetric survey to be undertaken during the study will establish its current volume, and the utility of increasing this volume by large scale dredging will be evaluated with the hydrodynamic model. Dredging of Wular Lake may invoke an issue with the Indus Water Treaty regarding Jhelum River storage: the safe approach would be to limit the dredged capacity to that existing at the time the Treaty was passed (1960).

Currently the outlet from Wular Lake is constrained by a coffer dam which was constructed as part of a proposal to provide conservation storage within Wular Lake up to a certain level. However, as this would further reduce its flood mitigation capacity, this project has been on hold pending the outcome of the current study. It is also possible that the capacity of Wular Lake could be increased by bunding but increasing the maximum flood level would worsen any backwater effects, so this needs to be studied using the model, together with increasing the outlet capacity. Again, this would need to be limited by the bounds of the Indus Water Treaty.

Downstream of Wular Lake to Salamabad, the Jhelum River is known as the Outfall Channel (OFC). Whilst this channel has a higher gradient than that above Wular Lake, the capacity is still restricted, and the Interim Scheme included provision for a 40m widening of the OFC from the outlet from Wular Lake (RD 168.11km) to the Lower Jhelum hydropower barrage (RD 173.5km). The potential for further work on this reach may be limited but will be investigated.

Within this reach, the Pohru Nallah enters the Jhelum on its right bank. The Pohru Nallah with a catchment area of some 1850km^2 is the largest tributary of the Jhelum River within Kashmir and it produces a high sediment flow. Pohru River sediment, which is readily identified as it contains many seashells, extends along the Jhelum both upstream and downstream of the confluence for 3-4km. each successive flood brings more sediment which forms a constriction in the river channel.

Consideration will be given to the construction of flood control storage within the Pohru Nallah which would also act as a sediment trap preventing much of its sediment load reaching the Outfall Channel. This is, of course, dependant on being able to locate a suitable site or sites. This will certainly be investigated.

There are also a number of non-structural measures which need to be addressed, including:

- Development and enforcement of planning controls to exclude or severely restrict development in flood prone areas;
- Where development in floodplain areas is allowed, to specify minimum floor heights of buildings and where this is substantially above ground to require the building to be constructed on piles with no walls within the flood prone area to minimise the impact on floodplain flow;
- Acquisition and demolition of the worst affected buildings with adequate and appropriate compensation to owners – following demolition these areas should be preserved as open space such as parks;
- Improvement of flood forecasting and warning system by the installation of a SCADA based system;
- Upgrading of the provision of flood warning system to improve the dissemination of warnings to the public (possibly by SMS) and of interpretation of flood warnings (possibly by flood markers in streets);
- Use of floodplain mapping, to be developed by the study, to increase community awareness of flood issues and to enable meaningful interpretation of flood warnings;
- Control of the ongoing sand mining of the Jhelum main channel by a myriad of boats – whilst the sand mining is of benefit overall, there will be areas which are over-dredged which risks undermining of river banks and bridge piers – control by licencing, identification of areas in which sand mining is not permitted and enforcement could be undertaken either by IFCK or by a separate agency established for this purpose.; and
- Catchment management measures – principally reforestation to reduce the sediment load from the upper catchment over time.

e) Selection of Mathematical Models

We propose that the following mathematical models be used for the hydrologic and hydrodynamic modelling:

- Hydrologic model – HEC-HMS (current version 4.2.1); and
- Hydrodynamic model – HEC-RAS (current version 5.0.5).

These are both licence-free, public domain models developed by the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. The models are well respected and have both been widely used successfully across a wide range of environments. The relevant members of the Study Team have used these models and are fully familiar with their use.

Further detail on these models is given in the body of the report.

f) Compliance with Indus Water Treaty

The Indus Water Treaty (MEA 1960) as it effects development within the Jhelum River catchment has bene briefly reviewed. In summary terms, in relation to the Jhelum River, the Indus water Treaty contains the following provisions:

- Water used for flood control is regarded as a “non-consumptive” use providing the water is returned to the same river or its tributaries undiminished in volume;
- Annexure C- Agricultural Use by India from the Western Rivers restricts conservation storage in the Jhelum River system to 0.2 MAF (247Mm^3);
- Annexure E - India may construct on the Jhelum Main such works as it may consider necessary for flood control of the Jhelum Main provided that:
    - Any storage which may be affected by such works shall be confined to off-channel storage in side valleys, depressions or lakes and will not involve any storage in the Jhelum Main itself;
    - Except for the part held in lakes, borrow-pits or natural depressions, the stored waters shall be released as quickly as possible after the flood recedes and returned to the Jhelum Main lower;
- Annexure E - The design of any storage work shall conform to the following:
    - With respect to the flood storage provision above, the design of the works on the Jhelum Main shall be such that no water can spill from the Jhelum Main into the off-channel storage except when the water level in the Jhelum Main rises above the low flood stage.

The main points relevant to any recommendations to be made by this Study are:

- Any additional flood storage shall not be on the Jhelum Main Stream which includes Wular Lake;
- Any proposal for dredging of Wular Lake, or building of embankments to increase conservation storage could be in contravention of the Treaty – restoration to its capacity as of the date of the Treaty would be expected to be acceptable;
- Additional storage for flood control only does not contribute to the allowable conservation storage for agricultural use of 0.2 MAF (247Mm^3), but any conservation storage component included in a multi-purpose project would be included;
- It is not clear if the storage within Wular Lake, Anchar Lake, Dal Lake, Mansbal Lake and Nowgham Zeel are considered to be conservation storage for agricultural use under these provisions – if this were so their volumes would contribute to the allowable 0.2 MAF (247Mm^3);
- Offtakes for off-channel storage on the Jhelum main stream should be above *low flood stage* which needs to be defined at any prospective offtake location.

g) Catchment Management

The REFORM project of the European Union has developed a framework for river restoration projects designed to improve their success and sustainability. This includes the development of procedures to monitor the biological response of changes in geomorphology and in restoration interventions to provide sustainable, ecologically effective management within the socio-economic setting.

There are river restoration centres or agencies in EU, USA, UK, Australia, Russia and a number of other countries and a number of publications regarding this topic, including the UNESCO report (Speed et al 2016). Little work appears to have been done in India in this regard, although there is a realisation that such work needs to be done.

In the context of the Jhelum River, this relates principally to catchment management initiatives to reduce sediment generation and transport into the Jhelum. This issue will be addressed more fully in Task 4. It is anticipated that this will relate principally to reforestation but may also include recommending changes to farming practices.

Preliminary Hydrology Report

a) Study Area

From a hydrology perspective, the study area comprises the whole of the Jhelum River catchment downstream to the Inia-Pakistan border. The Khadanyar gorge divides the catchment into two areas: the upper segment which is the subject of the current study, drains the whole of the Kashmir Valley and comprises a catchment area of some 12,750km^2

The Jhelum River catchment is bounded by high mountains all around: The Great Himalayas on the east, rising to 5,300m; and the Pir Panjal Range on the west rising to 5,000m. Erosion from these catchments has resulted in the formation of a very flat valley floor formed by deposition of the eroded material, such that the Jhelum River has an average grade of only 1 in 10,000. Hence, there is a major contrast between the upper catchments and the Jhelum River Valley which is at an elevation ranging from about 1,400m to 1,650m.

There are a number of glaciers and glacial lakes at the higher altitudes and forests are dominant between about 1,650m and 3,500m. Due to the flat gradient of the valley floor, there are a number of lakes and wetlands the largest of which Wular Lake provides significant attenuation of flood flows. Wular Lake, Anchar Lake and other wetlands are major refuges for migrating water birds, (some of which are RAMSAR sites).

The Kashmir Valley which contains the Kashmiri capital Srinagar as well as a number of other towns and villages, is the economic heart of Kashmir. Srinagar is an ancient city built on the banks of the Jhelum River and whilst the old city is on higher ground, much of the modern city is within the Jhelum River Floodplain. The natural river banks have been raised at various times and are now of such a height that if overtopped, or breached, during flood extensive flooding occurs.

Precipitation generally increases with altitude and depending on the season, may fall as snow on the upper slopes. Whilst the catchment is sufficiently far north to miss most of the rainfall from the southwest monsoon, this does sometimes cause high rainfall in this region. The other major weather system is the westerly disturbance, a mid-latitude system which can bring rain systems from the west. The 2014 flood was the result of an unusual combination of both systems (Ray et al 2015).

Figure 10 **ES1** shows the catchment boundary and that of the major sub-catchments.

The Köppen climate classification for the Jhelum basin is *humid sub-tropical* (Cfa). Humid subtropical climates have a warm and wet flow from the tropics that creates warm and moist conditions in the summer months. The bulk of the precipitation occurs in winter and spring, when precipitation may fall as snow on the higher ground. There is a secondary, but smaller rainfall peak in late summer associated with the southwest monsoon.

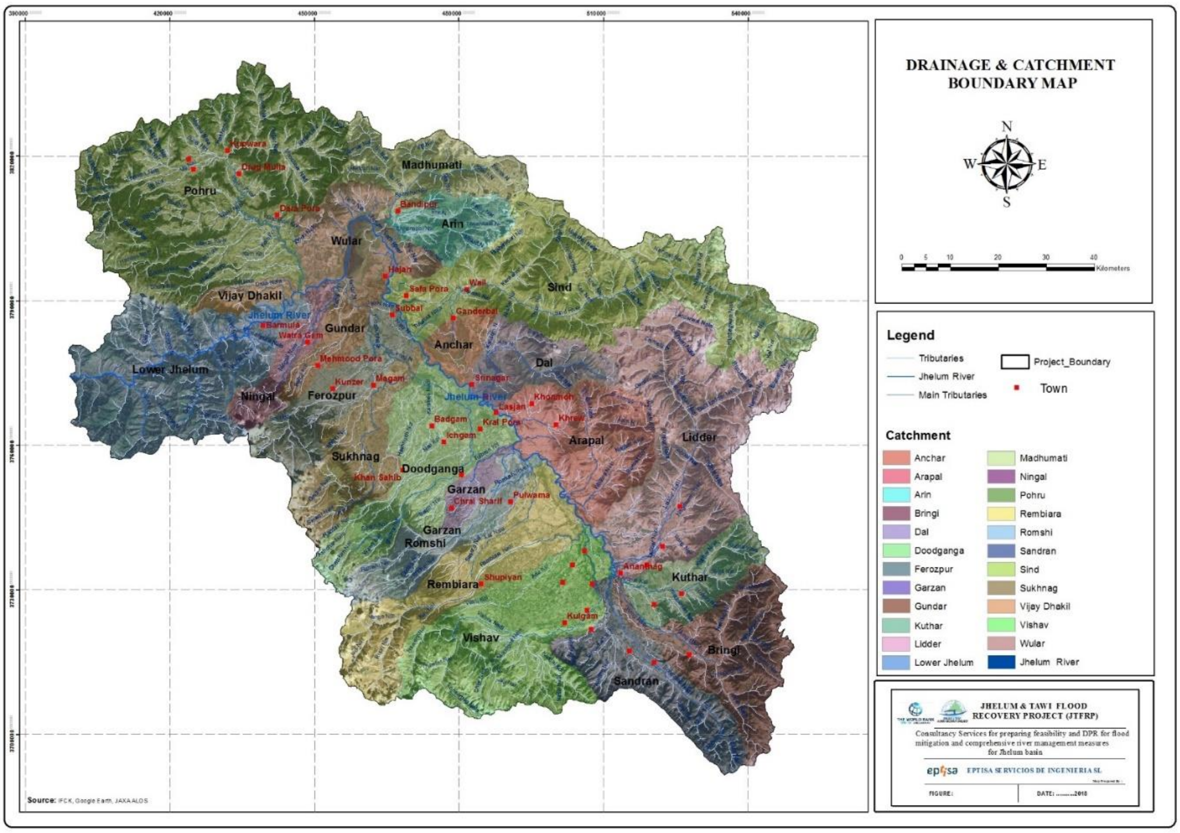

Figure ES1 Jhelum River Catchment showing Major Sub-catchments

b) Precipitation Data and Analysis

The analysis if precipitation data during Task 1 has been limited as a result of the data acquisition procedure of IMD which requires official requests and payment for data. It has not been possible to obtain the long period data required for analysis until this data request has been finalised.

Until the long term data are obtained from IMD, the analysis has been based on the following:

- Monthly rainfalls at Srinagar, Qazigund, Pahalgam and Kokernag for the period 1980 to 2017 provided by the Srinagar office of IMD; and
- Daily rainfall at Srinagar, Anantnag and Baramulla for the period 1901-1970 from the KNLI Climate Explorer website.

The analysis comprised some basic analysis of the long term daily rainfalls together with a frequency analysis of 1-day and 5-day annual maximum series – more detail is given in the body of the report.

Table 8 **ES2** summarises the outcome of the rainfall frequency analysis and also shows the approximate probability of the 5-day rainfalls for 2014 at the various locations from the fitted distribution. On this basis, the 2014 event was about 6.6% AEP (15 year ARI) at Srinagar, 1.25% AEP (80 year ARI) at Baramulla and 0.14% (700 year ARI) at Anantnag.

Table ES2 Summary of 1-day and 3-day rainfall frequencies

Annual Exceedance Probability (AEP)	**Average Recurrence Interval (ARI) Years**	**Srinagar**		**Anantnag**		**Baramulla**	
		1 day max (mm)	**5 day max (mm)**	**1 day max (mm)**	**5 day max (mm)**	**1 day max (mm)**	**5 day max (mm)**
0.1	1000	159	291	197	317	197	327
0.2	500	145	264	184	297	184	308
0.5	200	128	231	166	270	166	281
1	100	116	207	152	249	152	261
2	50	105	184	138	226	138	240
4	25	93	162	123	202	123	217
5	20	89	155	118	194	118	210
10	10	78	134	102	168	102	186
2014			148		309		256
			15yr		700 yr		80yr
			6.60%		0.14%		1.25%

c) *Streamflow Data and Analysis*

Daily streamflow data have been provided only in terms of mean daily stage: conversion of these records to flows will be undertaken in Task 2 once the stage-discharge relationships have been reviewed. Hence, the analysis undertaken in the preliminary hydrology report is in on the basis of stage records only.

Comparison of the stage records at Sangam, Munshi Bagh and Asham has shown that the minimum stage at Sangam reduced significantly between 2009 and 2014, and then more slowly since 2014. At Munshi Bagh, there has been a slight increase in minimum level over this period and none at Asham. This indicates that the river bed at Sangam was being eroded quite rapidly over 2009-2014, at an average rate of approximately 1m per annum, and about 0.25m per annum since 2014.

This could be a result of the sand mining which occurs along the river, but this high rate suggests that this may be due to a head cut moving upstream, which could have been initiated by the sand mining further downstream. The reduction in erosion rate since 2014 could be due to the head cut having passed upstream of Sangam, or the result of the large sediment inflow during the 2014 flood, or a combination of the two.

Figure ES2 clearly shows this reduction in minimum stage at Sangam.

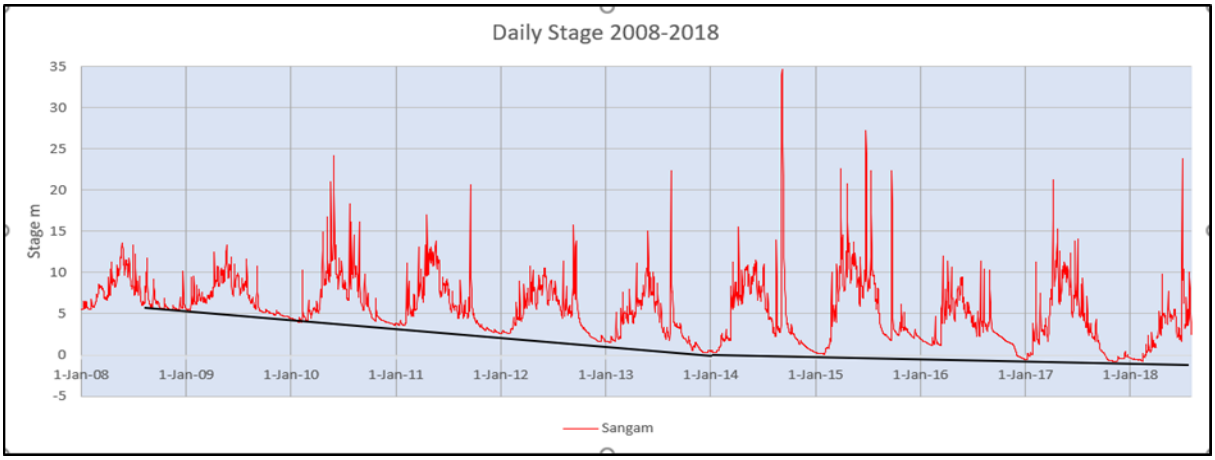

Figure ES2 Daily Stage 2008-2018 – Jhelum River at Sangam

The preliminary analysis has concentrated on flood frequency analysis (FFA) of the annual maximum series of daily flows for the Jhelum River and major tributaries, which is important in developing the relative contributions of the major tributaries to flood flows, in a statistical sense.

Table 9 summarises the fitted probability relationships for the Jhelum River gauging stations.

Table ES3 Estimated Flood Probabilities - Jhelum River

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years	Maximum 1 day flow (m^3/s)								
		Khanabal	Samgam	Awantipora	Padsashi Bagh	Munshi Bagh	Shadipora	Asham	Sopore	Baramulla
0.1	1000	2,191	5,273	5,195	3,607	2,170	1,964	1,967	1,519	1,847
0.2	500	1,633	4,525	4,180	3,139	2,049	1,824	1,875	1,441	1,768
0.5	200	1,092	3,634	3,097	2,573	1,876	1,633	1,741	1,331	1,653
1	100	795	3,030	2,438	2,183	1,734	1,484	1,629	1,244	1,556
2	50	570	2,481	1,894	1,823	1,581	1,330	1,505	1,151	1,450
4	25	400	1,984	1,446	1,490	1,414	1,171	1,367	1,053	1,331
5	20	356	1,835	1,319	1,389	1,357	1,119	1,320	1,019	1,289
10	10	241	1,401	973	1,090	1,169	950	1,159	908	1,149

Table 10 shows the probability of the 2014 flood at the various locations from the fitted distribution. Apart from Awantipora and Munshi Bagh, which appear to give an anomalous value, this table clearly shows the reducing probability of the 2014 flood in a downstream direction.

Table 11 shows the estimated probability of the September 2014 peak flow in the major tributaries. In terms of actual flows the largest flows were from the Lidder Nallah and Vishow Nallah, but in terms of probabilities, the most extreme was the Sandran Nallah in which the flow was approaching the 0.1% (1,000 year) event. The Lidder, Bringi and Sindh Nallahs all had flows in excess of the 1% AEP (100 year ARI) with the Lidder being at 0.5% (200 year ARI).

Table ES4 Indicated Probability of 2014 Flood – Jhelum River

Location	Peak flow (m$_3$/s)	Estimated Average Recurrence Interval (ARI) (Years)	Estimated Annual Exceedance Probability (AEP) %
Khanabal	944	137	0.8
Sangam	3263	125	0.73
Awantipora	1703	37	2.7
Padshahi Bagh	2299	120	0.83
Munshi Bagh	2055	500	0.2
Shadipora	1321	48	2.08
Asham	1348	23	2.35
Sopore	921	10	10
Baramulla	984	5	20

Table ES5 Summary of Flood Frequency Curves for Major Tributaries

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years	Maximum 1 day flow (m^3/s)							
		Bringi at Dantar	Lidder at Khanbal	Sandran at Muniwar	Vishow at Arwani	Rambiari at Nayina	Arapat at Dantar	Sindh at Preng	Pohru at Seuloo
0.1	1000	2,025	2,623	302	1,831	1,831	1,226	2,623	803
0.2	500	1,328	1,827	239	1,244	1,244	896	1,827	762
0.5	200	750	1,128	172	734	734	581	1,128	699
1	100	480	780	132	484	484	411	780	644
2	50	303	536	100	313	313	285	536	582
4	25	188	366	73	198	198	193	366	511
5	20	160	323	66	170	170	169	323	486
10	10	95	218	46	102	102	109	218	403
2014		506	944	298	866	356	300	896	239
ARI Years		106	200	900	70	60	50	120	3
AEP %		0.90%	0.50%	0.10%	1.40%	1.70%	2.00%	0.80%	32%

These results are consistent with those from the rainfall frequency analysis and the frequency analysis for the Jhelum River flows, all of which indicate that the most extreme events occurred in the southern tributaries all of which feed into the Jhelum in its upstream reaches around Sangam.

Preliminary Morphology Report

The 1:25,000 scale preliminary morphology maps of the Jhelum river floodplain have been prepared at A2 size (40 sheets) and have been printed separately, as Volume 2 of this report.

The preliminary morphology report is based on existing, mostly secondary information, and provides as summary of the principal fluvial geomorphological characteristics of the Jhelum River Valley. The report includes sections on: spatial geomorphology (topography, alignment of mountain ranges and of the Jhelum River Valley); seismic zoning; soils; slopes (erosion potential); characteristics of the Jhelum River main channel, Flood Spill Channel and tributaries; and lakes and other waterbodies.

The principal findings are:

- The main channel of the Jhelum River is generally stable having been fixed in place by the construction of high river banks along its whole length to Wular Lake, with minor instabilities on the outside of bends exacerbated by uncontrolled sand mining;
- There is no large-scale evidence of recent instability in the tributary channels, although these are inherently less stable than the Jhelum due to their steeper gradients, significant sediment loads and the absence of constructed banks;
- Sediment generation occurs generally at slopes greater than 15%, particularly above the tree line, with slopes between about 5% and 15% being essentially transport zones, and areas where slope is less than 5% are deposition zones;
- Due to its low gradient the Jhelum River has a meandering course, further development of which is constrained by the constructed river banks – the sinuosity of the meanders is highest on the south side of Srinagar;
- The FSC does not, in the main have increased banks but it does have a number of bed and bank constrictions – the capacity of the FSC is now only about 50% of its original design capacity as the result of sedimentation – it is possible that meander development could start in the future;
- The capacity of Wular Lake has also reduced significantly over recent decades reducing the flood attenuation capacity of the Jhelum River;
- Downstream of Wular Lake, significant sediment inflows from Pohru Nallah impact on the capacity of the Jhelum River and are being controlled by dredging;
- Catchment management, principally by reforestation needs to be expanded in order to reduce sediment generation; and
- Climate change over the remainder of the 21st century and beyond is expected to result in more intense rainfalls, which will exacerbate sediment generation.

Methodology and Work Plan

This section sets out the proposed methodology for Tasks 2 to 5 of Part A and of Part B. Only a brief summary of these sections is given here.

Task 2 Data Collection

The sub-tasks which comprise Task 2 are summarised below:

- Data Collection
- Identification of data gaps
- Bathymetric and cross-section surveys – work on this has already commenced with quotations obtained for this work – at the time of writing the quotations have been received and evaluation is underway – it is anticipated that work in the field will commence mid-September with the work to be completed by the end of November
- Preparation of digital elevation model (DEM) – initial work on this has concluded that:
    - Existing low resolution DEM (JAXA ALOS) which is a 30m x 30m grid DEM, vertical accuracy +/- 5m is sufficient for the non-valley parts of the Jhelum river catchment,

  for example for delineation of sub-catchment boundaries for hydrologic modelling, and estimation of slopes;
  - The development of a DEM from satellite imagery is unable to provide the vertical accuracy necessary to properly model flooding in the Jhelum River valley which requires high accuracy because of the very flat gradient, as vertical accuracy of only +/- 0.6m can be achieved;
  - As a result of the above JTFRP has agreed with Eptisa's recommendation that a new floodplain survey be undertaken using aerial LIDAR which can provide a 1m x1m DEM with vertical accuracy of +/-0.15m which is appropriate for the hydraulic model component of the study – at the time of writing quotations are being sought in this regard;
- Review of hydrometric network – whilst the hydrologic network is already quite extensive along the Jhelum mainstream and the tributaries, only a few stations are equipped with water level recorders and modern flow measurement technology is only used at a few site;
  - also there are no flow measuring stations along the FSC and further stations may be required to allow investigation of the possible diversion from Dogripora, and the better use of Anchar Lake for flood mitigation – these requirements will be reviewed and appropriate recommendations made;
  - the need for additional stations on the tributaries for flood forecasting and flood warning will also be a focus of the review;
  - the quality of flow data will also be reviewed in terms of the gauging history, stage-discharge curves and basic consistency analyses of the relationships between incident precipitation and streamflow volumes.
- Additional Hydrologic Stations - Based on the above review, recommendations will be made for procurement of equipment to enhance the hydro-meteorological network including rain gauges, water level recorders and ADCPs. This will include recommendations for telemetry whether this be via radio (RF) or satellite technology (such as Galileo) – this will include review of the current flood warning system arrangements in order to assist in establishing a Flood Warning Centre (FWC);
- Geotechnical, geomorphological and geological investigations - It is currently envisaged that the investigations under this task will primarily be geotechnical investigation of potential sites for structural works such as new flood control storage and/or diversion channels. This will require geotechnical investigations of both foundation materials and materials available for construction (borrow pits). Local geological mapping will be required around these sites, but no large scale geological mapping is envisaged;
- Community Surveys - this will include development of a questionnaire, checklist and draft template, recruitment and training of local survey teams, primary data collection and use of GIS for hazard mapping, resource mapping and vulnerability mapping – the aim is to survey approximately 5 or 10% of the impacted persons from identified affected districts;
- Development of geomorphological database – a well structured computer database will be developed for this purpose and user friendly tools will be developed in order to provide access for viewing, search and reporting from the database. This will include a wide range of data

including: spatial, flood, morphometric, hydrometric, hydraulic, geotechnical, geological, environmental, natural hazard and socio-economic data;

- Data Collection Report (Deliverable 2) - a comprehensive report will be compiled which will describe the work undertaken in Task 2 under the sub-headings outlined above. The data collected in each sub-task will be included in Appendices to the report and will form the basis of the database.

Task 3 – Establishment of Hydrologic and Hydrodynamic Models

The timing of Task 3 is totally dependent on the timely completion of the river cross-section, bathymetry and LIDAR surveys for the development of the hydrodynamic model. Any delay in completion of these surveys will inevitably delay Tasks 3 and 4 and the submission dates of their deliverables.

In Task 3, the models are to be setup and calibrated primarily against the records from the 2014 flood. Another major flood and possibly a smaller flood will be used to validate the model (selection will be based on data availability). The model will then be used for design conditions such as the 1% annual exceedance probability (AEP) (or 100 year average recurrence interval (ARI) flood.

Modification of the model to investigate various flood management options will be undertaken in Task 5.

It is proposed to use the HEC-HMS hydrologic model to estimate flood hydrographs on a sub-daily (probably hourly) basis into the Jhelum River from each of the tributaries for these flood events. These hydrographs then become the inflows into the hydrodynamic model. We propose to use the 2D version of the HEC-RAS model for this purpose.

These are both licence-free, public domain models developed by the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. The models are well respected and have both been widely used successfully across a wide range of environments. The relevant members of the Study Team have used these models and are fully familiar with their use.

Deliverable 3, the report on the establishment of the hydrologic and hydrodynamic modelling of the calibration and validation floods will be prepared and submitted according to the revised Work Plan. This will provide a full description of the model development, data used, calibration and validation performance.

Task 4 Preparation of River Hydrology and Morphological Report

Primarily, Task 4 will comprise updating of the preliminary hydrology and morphology reports prepared under Task 1 based on the outcomes of Tasks 2 and 3.

Task 4 also includes a review of national and international guidelines on flood modelling and reporting on the hydrology and geomorphology of floods; this will be undertaken to ensure that the reports prepared by this study represent current best practice in this regard.

We will prepare user manuals for the hydrologic and hydrodynamic models and for the morphologic database and provide training in their use. The training will be tailored to the needs of JTFRP and IFCK in particular.

This Task will include a stakeholder workshop to present the findings of Tasks 1 -3. Following receipt of comments from the draft report and from the stakeholder consultation and any ideas from the guideline review, we will prepare the Final (Revised) Hydrology and Morphology Report.

Task 5 – Feasibility Study

The feasibility study phase will include the identification and evaluation of a range of potentially effective flood mitigation options. These will be initially evaluated individually and short listed when the remaining options may be considered in combination.

The hydrodynamic model will be modified to include a range of potential structural flood mitigation measures including the following identified to date:

- Proposals for dredging of Wular Lake and other waterbodies;
- Proposals for a new diversion channel creating a shorter route from the FSC to Wular Lake;
- The effectiveness of current proposal to widen the OFC;
- The possible additional diversion channel from Dogripora to Wular Lake;
- Development of detention basins within the floodplain;
- Potenital for meander cutoffs and other river management measures;
- Possible development of flood control storage on southern catchments;
- Possible development of flood control storage on Pohru Nallah and Sindh Nallah;
- Various operational strategies to increase the use of Dal Lake and Nagin Lake.

Initially, these and any other identified measures will be modelled individually and their effectiveness in flood mitigation evaluated. In addition to their flood control benefit this will include consideration of their environmental and socio-economic impacts, cost and constructability risk. Short-listing of these measures will be undertaken based on the above considerations and those potential measures with little or no merit, or with significant negative impacts will be discounted from further consideration. A stakeholder workshop will be held to short list the options.

The short-listed options will then be subject to further investigation including concept design, further geotechnical investigation (if required), EIA and EMP.

In addition to considering the individual proposals individually, at this point various, appropriate combinations will also be considered and evaluated.

The outcomes from the options evaluation will be used to prepare the Draft Feasibility Report (D5). A further stakeholder workshop will be held to discuss the findings of the draft feasibility report. The Final Feasibility Report (D6) will then be prepared taking account of the discussions and outcomes of the stakeholder workshop, reporting from which will be included in an Appendix to the report.

The feasibility study will also include the consideration of a range of non-structural measures which have been listed above in regard to Task 1.

The outcomes from these investigations will be used to prepare the Draft Feasibility Report (D5)- this will be presented in the form of a Flood Management Plan and will include a recommended investment schedule. The Flood Management Plan will also take account of possible future changes to catchment hydrology and morphology resulting from currently estimated impacts of climate change.

The Final Feasibility Report will form the basis for the work to be undertaken in **Part B** of the study.

Task 5 also includes a report on the proposed SCADA system for flood forecasting/warning and control of gates. The requirements for the SCADA system will be evaluated so that appropriate technology can be applied. Except at gates or other control structures which require significant power input, upstream detection equipment requires only solar cell with battery storage. Nonetheless access issues may be important in remote, upstream locations.

The choice of communication system is also an important consideration - this can be via the telephone system, UHF or VHF radio and by satellite. These options will be reviewed and appropriate recommendations will be made in this regard. This will include review of the control centre hardware and software requirements.

Part B

Part B of the project comprises the preparation of the Detailed Project Report (DPR) for the structural works recommended as the outcome of the Flood Management Plan developed under **Part A**. The DPR will be prepared to comply with the requirements of the CWC's *Guidelines for Preparation of DPR for Flood Management Works* (CWC 2018). If necessary additional topographic survey, geological, geotechnical and geomorphological site investigations will be undertaken in **Part B**.

The DPR will also be prepared in compliance with CWC's requirements for submission, appraisal and acceptance of flood control projects. The main components of this will be:

- Concept report including the preliminary design, drawings and cost components of the final scheme; and
- Draft Detailed Project Report which will include the detailed design, detailed drawings, detailed cost estimate and unit rate analysis;
- Final Detailed Project Report after incorporating stakeholder comments on the Draft Report;
- Tender documents for proposed scheme.

Part B will include the provision of clarifications to queries raised during the DPR process by CWC or other agencies and will provide require technical support. The complete clearance of the Dpr should be achieved by the end of the project.

Following the approval of the DPR, tender documents for construction will be prepared including Specifications and Bills of Quantities.

Work Plan

The Work Plan has been updated to reflect the Methodology outlined above.

It is not practical to include tributary surveys, the installation of additional hydrometric stations, or the geotechnical investigations required for the feasibility study within the timeframe of Task 2. These items have been left in Task 2 but will need to be reported upon later. In all other respects, the updated work plan complies with the timing of deliverables as stated in the Contract.

The total months of the individual experts, as given in the Staffing Schedule, has not been varied from its original version, although there are changes to the timing of their various inputs.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler (for flow measurement)
AEP	Annual exceedance probability - (the probability (chance) that a given event will be equalled or exceeded each year)
ALOS	Advanced Land Observing Satellite
ARI	Average recurrence interval (the average period in years between an event being equalled or exceeded)
CBO	Community Based Organisations
Cfs	Cubic feet per second (cusecs) 1 cusec = 0.0283m^3/s)
CWC	Central Water Commission
CWPRS	Central Water & Power Research Station
DDMA	District Disaster Management Authority
DDMP	District Disaster Management Plan
DPR	Detailed Project Report
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EU	European Union
FSC	Flood Spill Channel
FWC	Flood Warning Centre
IFCK	Irrigation and Flood Control Department Kashmir
IMD	Indian Meteorological Department
J&K	Jammu and Kashmir
JAXA	Japan Aerospace Exploration Agency – Earth Observation Resource Centre
JKSDMA	Jammu and Kashmir State Disaster Management Authority
JTFRP	Jhelum and Tawi Flood Recovery Project
LAWDA	Lakes and Waterways Authority (J&K)
LEOS	Low earth orbit satellite
MAF	Million acre-ft (1 acre-ft is an area of one acre covered by water of depth 1 ft) 1 MAF = 1,234 Mm^3
Mm^3	Million cubic metres
m^3/s	cubic metres per second or cumecs (1 cumec = 35.3 cusecs)
PRI	Panchayati Raj Institutions
NASA	National Aeronautics and Space Administration (USA)
NIC	National Informatics Centre
NGO	Non-Government Organisation
NRSC	National Remote Sensing Centre
OFC	Outfall Channel
SCADA	Supervisory Control and Data Acqusition
SRTM	Shuttle Radar Topography Mission
TOR	Terms of Reference
UNESCO	United Nations Educational, Scientific and Cultural Organisation

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The Study Team also acknowledges the insight into Jhelum River flood management provided by the staff of the Chief Engineer of the Irrigation and Flood Control Department, Kashmir. In particular, thanks go to Mr. Shabeer Hussain, Mr. Mutayib Shah and Mr. Tasaduq Koul.

1 Introduction

1.1 Background

This project *Consultancy Services for preparing feasibility and detailed project report for flood mitigation and comprehensive river management measures for Jhelum basin*, is one element of the overall *Jhelum and Tawi Flood Recovery Project (*JTFRP).

EPTISA Servicios de Ingenieria SL (Eptisa) has been commissioned to undertake this Study on behalf of JTFRP. This report is the **Task 1 Report** for these Consultancy Services, and it comprises the work undertaken during the Inception Phase and Task 1 as per the TOR for Part A.

The Jhelum River Valley suffered record flooding in September 2014 as a result of abnormally high and widespread rainfall particularly in the southern part of the catchment. The rainfall across the southern catchment in the first week of September averaged 433mm (Romshoo et al 2018). This resulted in widespread flooding along the Jhelum River from the confluence of the southern tributaries near Sangam, through Srinagar City, and downstream to Baramulla. The peak flow in the Jhelum River at Sangam was estimated by the Irrigation and Flood Control Department (IFCK) to be 3,260 m^3/s (1,15,000 cusecs). The area flooded was approximately 850km^2. In Srinagar, the floodwaters were up to about 1.5m above the river embankments and large parts of the city were inundated at depths of up to 6m. Some areas of the city were flooded for up to 4 weeks. In addition to damage to people's homes and livelihoods, there was a great deal of damage to public infrastructure including roads, bridges and hospitals.

Many factors have influenced flooding in the Jhelum River valley including increasing encroachment by urbanisation and the reduction of the natural flood storage provided by Wular Lake and other lakes and wetlands due to sedimentation. There is over 100 years of flood mitigation history in Srinagar with the Flood Spill Channel constructed about 1903 being the first major flood mitigation infrastructure. There are a number of existing and proposed flood mitigation measures which together with the lakes, wetlands and natural floodplain storage present a complex problem for the mitigation of future floods.

This study is undertaken against the background of the recent flooding and recent and ongoing impacts of development as briefly outlined above.

1.2 Study Area

For hydrologic modelling purposes and for consideration of catchment management, the study area comprises the whole of the Jhelum River Catchment to the India-Pakistan border. For the hydrodynamic model, the study area comprises the Jhelum River valley and its floodplain from Khanabal Bridge to Salamabad Bridge.

Figure 1 shows the catchment area and the main sub-catchments within the Jhelum River basin.

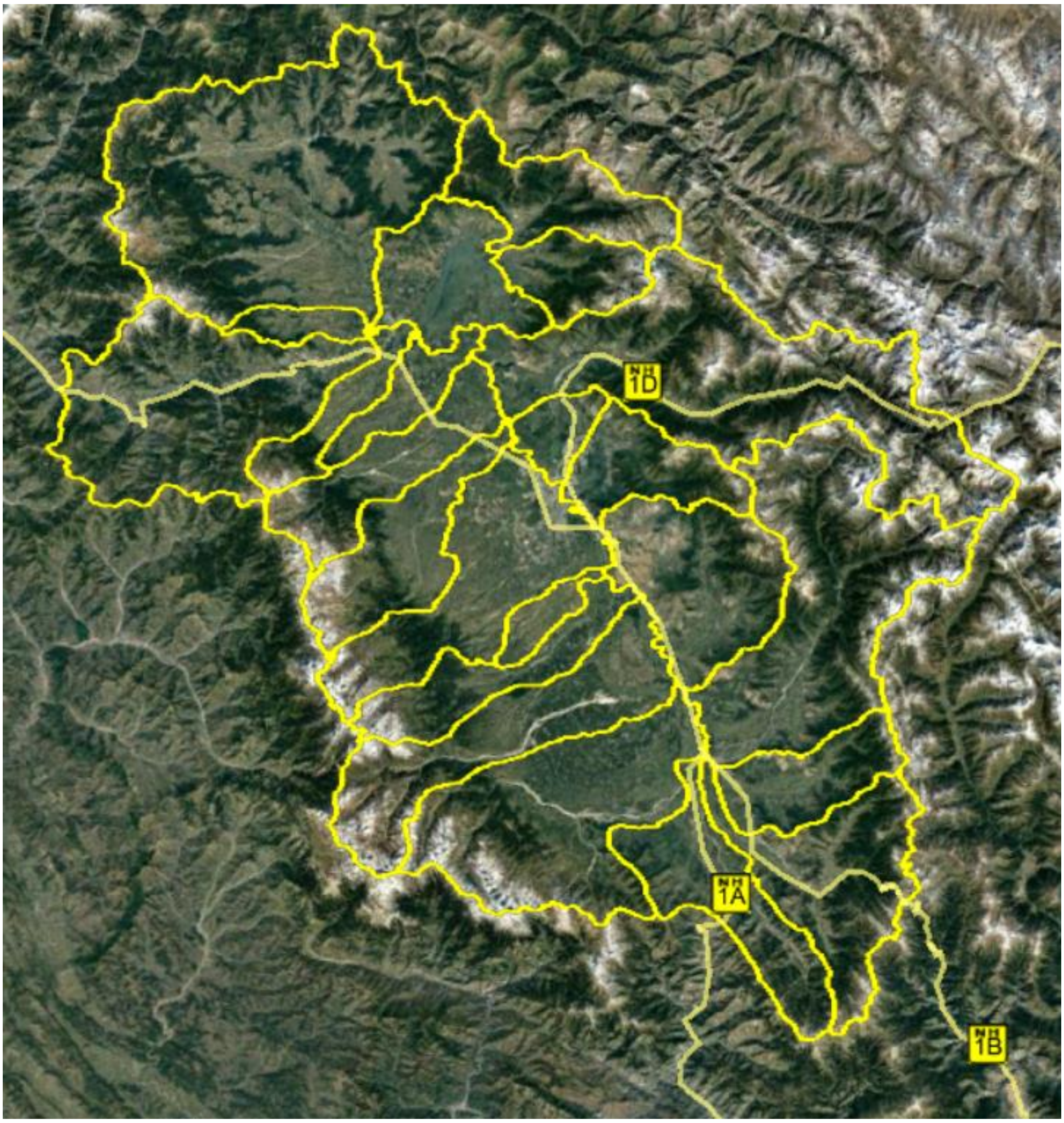

Figure 1 River Jhelum Catchment showing Major Sub-catchments

1.3 Objectives of the Study

The overarching objective of the study is to restore critical infrastructure, damaged primarily by 2014 floods, with upgraded resilient features including contingency planning for future disaster events.

This requires detailed flood inundation modelling in order to better understand the flooding processes occurring in the floodplain, and the interactions between its various components and also to investigate the effectiveness of a range of flood mitigation measures already under consideration and to identify and evaluate of potential measures such as tributary flood storage.

The various measures will be considered both individually and in various combinations to produce a resilient flood management plan, which will also include non-structural measures such as town planning/land use controls and catchment management to reduce sediment inflows into the river system.

The first stage of the Study (**Part A**) comprises the data collection, flood modelling, and concept design components leading to a feasibility study of options from which selected components will be selected for inclusion in the proposed Flood Management Plan. This plan will be a blueprint for flood management and mitigation in the Jhelum River catchment for several decades.

Once the elements of the Flood Management Plan have been finalised, the second stage of the Study (**Part B**) will comprise the development of a Detailed Project Report for the planned works including detailed design drawings and tender documents.

1.4 Comments on the Objectives

The objectives and scope of works as set out in the TOR are comprehensive and appropriate. As discussed further in **Sections 2.4** and **3** hereof, flood management in the study area is complex and will require a combination of structural and non-structural measures in its implementation.

We see the cross-section surveys of the River Jhelum and Flood Spill Channel and the bathymetric survey of Wular Lake, Anchar Lake and the other associated water bodies as a key element in providing adequate data to enable the development of the hydrodynamic model as a meaningful tool in evaluating a wide range of flood mitigation and management options. To this end, JTFRP has agreed to Eptisa's proposal to bring the start of these surveys forward to provide sufficient time for completion by the end of October. Whilst the data collection phase continues through to April 2019, the surveys are required by the end of October, in order that the hydrodynamic model can be developed to meet the Task 3 deadline in December 2018.

The development of a high resolution Digital Elevation Model (DEM) for the whole of the floodplain including the Srinagar City area is also critical in this regard. We have evaluated the ability of the available satellite imagery to provide the required accuracy, and have found this to be insufficient, and that LIDAR survey is required for the floodplain area. This approach has bene approved by JTFRP and at the time of writing, quotations for this work are in train.

Other primary and secondary data whilst important, and necessary, are not critical in this way.

1.5 Project Timing

Both **Part A** and **Part B** of the study are of 12 months duration, and with a starting date of 16th July 2018, the completion dates are 15th July 2019 for **Part A** and 15th July 2020 for **Part B**. The timing for the completion of **Part B** is provisional on there being no delay between the completion of **Part A** and the commencement of **Part B**.

1.6 Report Structure

This report is structured into 2 Volumes, namely:

- Volume 1 Main Report: and
- Volume 2 Preliminary Morphology Mapping (1:25,000) scale.

Within Volume 1, the report is structured as follows:

Section 2	Inception Report including project risks and challenges
Sections 3 to 5	Task 1 Report including Preliminary Hydrology and Preliminary Morphology Reports
Section 6	Methodology and Work Plan for the remainder of **Part A** and for **Part B**
Section 7	References
Appendices	
Appendix A	Study Team
Appendix B	Photographs from Site Inspections
Appendix C	List of Tributaries

2. Inception Phase

2.1 Mobilisation

The Contract between the Jhelum and Tawi Flood Recovery Project (JTFRP) and Eptisa was signed on 2nd July 2018 and several members of the Study Team were mobilised to Srinagar for the project "kick-off" meeting, which was held on 17th July 2018, by which time the project office had been established in accommodation provided by the Client in Hotel Ranchi. Team members present at the "kick-off" meeting are listed in **Appendix A.**

2.2 Site Inspections

Three one-day site inspections were organised for members of the Study Team by the Irrigation and Flood Control Department (IFCK) during the Inception period (16th July – 15th August). These took place in the southern, central and northern parts of the Jhelum River main stream respectively. These were very useful in familiarisation of the Study Team to the Jhelum River, Flood Spill Channel, Outfall Channel, Wular Lake, and Anchar Lake.

Photographs from these site inspections are given in **Appendix B** hereof.

Eptisa thanks the staff of the IFCK in organising and participation in these site inspections and conveying their knowledge of the river basin and its flood characteristics.

2.3 Preliminary Data Collection

During the Inception phase IFCK was the primary source of primary hydrologic and spatial data, and reports on flood management. Data collection from IMD was also initiated and is ongoing. Secondary spatial data were obtained from a variety of public domain sources together with various other data and reports. The collection of social and environmental data also commenced and is ongoing. A summary of the major data sources is given below:

2.3.1 Spatial Data

The following spatial data were obtained and entered in a GIS. (The GIS has been established using QGIS which is public domain software).

a) Data from IFCK
- Map of catchment and sub-catchment boundaries;
- Map of water bodies in the Jhelum River catchment;
- Map of rain gauges and snow gauges in Jhelum River catchment;
- Map showing river distances along Jhelum River main channel, gauging station locations and bridges; and
- Map of flood inundation extent in September 2014;
- Map showing preliminary alignment of possible Dogripora to Wular Lake Diversion Channel

b) Digital elevation models (DEM)
- Low resolution DEM from ALOS (JAXA 2009) (30m grid, vertical accuracy ~ +/- 5m)

- Low resolution DEM from SRTM (NASA 2000) (30m grid, vertical accuracy ~ +/- 15m)

2.3.2 Hydrological Data

The following hydrological data were received from IFCK:

- Annual maximum discharge and stage data for Jhelum River main stream stations at Khanbal, Sangam, Awantipora, Pampore, Padshahi Bagh, Munshi Bagh, Shadipora, Asham, Sopore and Baramulla for the period 1955-2017;
- Annual maximum discharge and stage data for the following Jhelum River tributaries: Aripal, Aripath, (2 stations) Aroo, Bringi (2), Dachigam (2), Dakil, Dangawari, Doodganga (2), Erin, Ferezpora (3), Gogaldara, Hamal (2), Kamil, Liddar (6),Lolab (2), Madhumati, Ningli, Pohru (3), Rambi Ara, Romshi Tail, Sandran (2), Shali, Sheshnag, Sindh (3), Sukhnag (4), Tailbag, Taller, Vethvethroo (2), Vij, Vishow and Watalara Nallahs for the period 1961-2017;
- Daily stage level at Sangam, Ram Munshi Bagh and Asham 2008 -2018;
- Daily water level at Wular Lake outlet 2000-2007
- Rating curves for Jhelum River sites Sangam, Munshi Bagh, Asham and Sopore;
- Bridge cross-sections: and
- Map showing locations of gauging sites, bridges and river distances.

2.3.3 Geomorphological Data

The following geomorphological data were received from IFCK:

- Jhelum River cross-sections used in CWPRS's HEC-RAS model – these are not georeferenced and are understood to be from 2010 survey

2.2.4 Meteorological Data

Meteorological data has to be sources from IMD's head office in Pune, for which fees are charged. This process has been initiated, in the meantime the following rainfall data has been accessed:

- Monthly rainfalls at Srinagar, Qazigund, Pahalgam and Kokernag for the period 1980 to 2017 provided by the Srinagar office of IMD; and
- Daily rainfall at Srinagar, Anantnag and Baramulla for the period 1901-1970 from the KNLI Climate Explorer website.

2.2.5 Flood Management Reports

S.No	Issues/Topics	Main Outcome
1	CWPRS (April 2018) Mathematical Model Studies for Routing of Flood in River Jhelum at Srinagar, Jammu And Kashmir, Technical Report 5593)	1D HEC-RAS model of Jhelum River used for design of Interim Flood Mitigation Scheme to the enable the Jhelum River to convey 1,700m^3/s (60,000 cusecs) at Sangam through the system without significant flooding. A number of options were considered. Main recommendations are: • Extending the channel of the Flood Spill Channel (FSC) through the Hokesar Lake effectively increasing the conveyance though the lake – sub options vary the width of this channel between 30m and 80m; and

		• Increasing the width of the Outfall Channel (OFC) from Sopore Bridge (RD 150.25km) to RD 173.2km by an additional 40m along the thalweg line.
2	Dept. of Ecology, Environment and Remote Sensing (2015) A satellite based rapid assessment on Floods in Jammu & Kashmir – September, 2014	flood inundation mapping throughout the flood will be useful in model calibration. Suggestions for further flood protection measures.
3	IFCK (Feb 2015) Kashmir Flood 2014	Observations on department of Ecology, Environment and Remote Sensing (J&K) report on sept 2014 flood; discussion on climate change; potential for a secondary flood relief channel; consideration of impact of new expressway to Jammu and railway on flooding; requirement for improved flood warning system; requirement for improved catchment management; removal of bottlenecks; need for flood zoning; potential of cascade of weirs in tributaries
4	Sphere India: Rapid Joint Needs Assessment Report - Phase 01- 28th September 2014	As of 16 September 2014, 190 people and 78 people have been reported dead in Jammu and Kashmir division respectively. As per the preliminary information of Government 9,814 residential houses were fully damaged and 23,763 partially damaged in Jammu region. The Govt. has started over 87 camps in Jammu and over 147 (excluding Srinagar, Banidipora and Kupwara) in Kashmir division. Water level was more than 3 feet in 62 villages and has entered into the houses in 87 villages. 86% of the wards were affected and major damages to shelter, water and sanitation facilities, crop/agriculture land and education. Tourism is one of the most important source of livelihoods (earnings) which is most affected. September is the peak season and had been stopped, thus leading to reduced incomes. Survey results focus on impacts and its main reason in various essential sectors such as education, shelter, agriculture, livestock, livelihood etc. and related mitigation measures (immediate, mid-term and long term)
5	International Research Journal of Engineering and Technology (IRJET)	This research paper gives an overview of all the major and minor changes during the evolution of Srinagar that have been causing floods in the past or are having a potential to do so in the future and also suggests guidelines to mitigate floods in existing as well as upcoming cities. The guidelines shall be in the form of planning criteria for different layouts, use of new materials and adaptive building construction techniques which have been derived from the vernacular planning and architectural vocabulary to ensure social acceptance along with environmental sustainability.

		Some of the main reasons for floods identified are a) high run off as a result incessant rains may induce melting of glaciers and add to ferocity of floods, barriers to water flow, weak embankments, siltation's etc. The floods in the valley apart from innumerable man made factors are a result of the climate change in a broader perspective. Adapting the construction styles according to the change in climate and rainfall patterns that are inevitable in future is also required to prevent the loss of lives in any such future hazards and protect the fragile heritage of the Paradise on Earth. The proposed scheme would be embraced by its prime stakeholders as it would promote the ancient cultural and social values that people have evolved with and adapted to over years rather than putting them in an alien setting. Thus, it would help to sustain the social traditions and cultural heritage in an absolutely new setup by holding on to the roots.
6	Consolidated report from Office of Divisional Commissioner, Kashmir,' Damages of flood' 2014	As per the report, the following were the main observations against damages of **Structures:** 1. fully damaged (kacha – 1052; pacca: 9747) 2. Severely damaged (kacha – 1629; pacca: 29069) 3. Partially damaged (kacha – 5425; pacca: 86929) 4. Huts damaged : 4447; 5. Cowshed damaged: 17199 **Total damage:155497** **Crops:** Total crop area affected:5555117 K3M Total Beneficiaries:906091 Compensation given: NIL **Cattle:** Total cattle loss: 92635 Amount sanctioned in Lacs: (83.12) Disbursed: 37.61 No. of beneficiaries: 11566
7	UPPAL HL (1955) Book on River Jhelum	Useful historic information on early flood management works

2.3 Project Risks

The perceived risks and challenges to the timely completion of the project are listed in the **Table 1** together with their level of risk, and proposed risk mitigation. These relate to river cross-section, bathymetric and floodplain surveys to be undertaken in Task 2: delays in these surveys will result in delay to the flood modelling and feasibility study tasks in particular.

Action has been taken to commence the field surveys earlier than originally planned which helps to address the potential delays but is also a practical move in order to complete these surveys before winter.

Table 1 Project Risks and Challenges

Risk	**Risk Level**	**Impact on project completion**	**Mitigation of risk**
Part A – Task 2 Delays to cross-section and bathymetric surveys due to rain and flooding	Low to Moderate	Delay in completion of Part A	The field work has been brought forward to start as soon as possible to reduce this risk. Client assistance in expediting any required survey clearances may be required. If this delay does eventuate, resulting in delays to field work, Eptisa will make its best endeavours to make up time.
Delays to floodplain survey: Preliminary analysis has shown that a DEM derived from stereo photogrammetry of satellite imagery is not of sufficient accuracy and that LIDAR survey is the preferred technology for data capture. There is a risk that aerial survey will not permitted due to security issues.	Moderate to High	Lack of accuracy in floodplain modelling if satellite imagery is inadequate but has to be used. Potential delay if LIDAR allowed but release of data delayed	Risk reduced by requiring survey only to Baramulla avoiding the area near the Line of Control. If aerial LIDAR is not possible, the fall-back option is to use ground based vehicle mounted LIDAR or DGPS survey for urban areas and along roads and tracks
Difficulties in obtaining site access for geotechnical, geomorphological and geological investigations	Low to moderate	Delay in completion of Study	Client assistance in expediting any required access clearances may be required.
Part B Difficulties in obtaining site access for additional geotechnical investigations	Low to moderate	Delay in completion of Study	Client assistance in expediting any required access clearances may be required.

2.4 Project Challenges

The principal challenge for this project is to develop a flood risk management plan for the Jhelum River that can deal with a flow at Sangam equivalent to that which occurred in September 2014, taking account of the fact that the current river capacity is only about 50% of that flow, and that existing flood management works which have developed over the last 100 years, and the ongoing sediment inputs together with largely uncontrolled development in the floodplain, have led to a very complex flood management situation.

The development of a sustainable plan will require a combination of structural and non-structural measures which are then implemented and enforced.

Whilst it is too soon in the course of the project to identify specific works, it is likely that the plan will contain both structural and non-structural elements, such as those outlined below.

2.4.1 Structural Measures

a) Upstream of Srinagar

As the channel capacity of the Jhelum River at Sangam is about 1,700 m^3/s (60,000 cusecs) and the September 2014 flow was estimated to be 3,260m^3/s (1,15,000 cusecs), clearly one objective is to reduce the peak flow in the river upstream of Srinagar. The design capacity of IFCK's interim scheme is 1,700 m^3/s (60,000 cusecs) at Sangam, so the flood management plan needs to deal with flows above 1,700m^3/s to a design flow of 3,260 m^3/s (1,15,000 cusecs), and also consider the consequences of flows in excess of that design flow.

Ideally the peak flow could be reduced by construction of flood control dams (detention storage) in a number of the southern tributaries. Unfortunately, because of the steep gradient of the tributaries, the storage to height ratio of any dams is likely to be poor. This may require a number of relatively small capacity dams. Identification of possible sites from the DEM will be an early priority.

Also, as many of the southern tributaries are of similar lengths and gradients, their peaks all reach the Jhelum at similar times, thereby adding to the peak flow. Storage, if suitable sites exist, would not only reduce the peak flow in the tributary but would delay the peak. If tributary inflows could be delayed by differing amounts, their peaks would enter the river over a longer period which would again aid in attenuating the peak flow.

However, it seems likely from our initial inspection of the catchment maps, from the low resolution DEMs currently available, that the scope for this is very limited, although it may be possible to extend the storage at existing water bodies on the Lidder and Kuthar Nallahs. The opportunities for flood control storage will be fully evaluated during the feasibility stage of the project.

Any such storages would also act as sediment basins and they would need to be designed so that accumulated sediment could be readily removed, and where suitable used for building sand or gravel.

The Jhelum River is embanked along virtually its whole length from Sangam to Srinagar and during major floods, the embankments overtop and are breached in several locations. It is not practical to increase the channel capacity by raising the banks as that would lead to worse problems when the banks did overflow. However, controlled overflow from the river into the floodplain will be considered. By having controlled overflow from spillways that are lower than the general top-of-bank level, allows the overflow to be directed into floodplain areas to be allocated for this purpose prior to general overtopping occurring.

The Jhelum River floodplain between Sangam and Srinagar is mainly on the left bank and has significant capacity for temporary flood storage. The new expressway appears to have significantly less cross-drainage provision than the railway further to the west, so this will impede and restrict the flow of water in the floodplain. The presence of the new road may also encourage uncontrolled development along its length which will further reduce the active floodplain capacity.

One the hydrodynamic model has been established it will be used to investigate the extent to which flood storage capacity may be enhanced possibly by the construction of polders to holder water above the natural flood level, with polders overflowing successively to the next downstream.

Previous considerations of controlled spill have identified that this would result in low sediment load water flowing into the floodplain and the water with higher sediment concentration remaining on the river. This could be obviated by the use of underflow gates (sluices) instead of overflow weirs if this approach is found to be otherwise useful.

Land acquisition issues will need to be addressed as part of this evaluation.

IFCK considers that the construction of a second flood relief channel, taking water from the Jhelum River near Dogripora to convey flood waters directly to Wular Lake, which was first advocated in the 1930s, has merit so this will also be considered and evaluated using the hydrodynamic model.

b) Srinagar

The Flood Spill Channel (FSC) was constructed in 1903 with a design capacity of about 500m^3/s (17,500 cusecs) but this is understood to have reduced considerably since its construction despite its extension downstream and other works carried out to increase its capacity. IFCK's Interim Scheme includes some works to increase its capacity by the construction of a pilot channel or cunnete through Hokesar Lake and Nowgham Zeel. A proposal to increase the capacity of the FSC to 623m3/s (22,000 cusecs) was never constructed.

CWPRS's recent modelling for the Interim Scheme shows a flow in the River Jhelum through Srinagar, downstream of the FSC of 1260m^3/s (44,500 cusecs) with about 350m^3/s (12,400 cusecs) entering the FSC. The gauge records for the 2014 floods show a peak upstream of the FSC of 2,300m^3/s (81,200 cusecs) and 2050m^3/s (72,600 cusecs) downstream of the FSC and, hence, approximately only 250m^3/s (8,800 cusecs) entering the FSC.

The surveys to be carried out in Task 2 will enable the capacity of the river through Srinagar and along the FSC to be updated and included in the hydrodynamic model, together with the evaluation of the effectiveness of widening the channel to increase its capacity.

The possibility of storage on the tributaries which flow directly into the FSC should also be considered but it is likely that these will be few opportunities for this as discussed in Section a) above in relation to the southern tributaries. Enhancing the use of Dal Lake for flood storage will be considered although this is unlikely to be major contributor to flood management.

As the river banks through the city are substantially above natural ground level, when the banks overtop significant areas are flooded at depths of up to 4 – 5m. This is exacerbated where breaches occur in the embankments.

The collective effect of the many bridges through the city reach also need to be evaluated in the model and any bridges which contribute significantly to the total afflux should be considered for reconstruction. Also, the recent renovation of the Chattabal Weir will be included in the model and its effect evaluated.

It is clear that the capacity of the River Jhelum through the city reach cannot practically be increased, so reduction in flow in this reach is critical given the consequences of flooding of the city. The principal options for reducing the flow in the river reach come down to upstream storage or further diversion, or a combination of both.

c) Srinagar to Wular Lake

Downstream of Srinagar, the Jhelum River flows to Wular Lake entering the lake near its northern end. In this reach a major right bank tributary, the Sindh Nallah enters the Jhelum. Part of the Sindh Nallah's flow passes through Anchar Lake which provides natural temporary flood storage, hence reducing the peak flow from Sindh Nallah into the Jhelum River. Survey of Anchar Lake is required to determine its capacity and also the extent of bund construction within it which may have affected its connectivity. Enhancing the flood control role of Anchar Lake is an option that will be assessed. A partial diversion from the Jhelum River at Gagazu into Anchar Lake returning to the Jhelum River at Shadipora was first suggested in 1915, and will also be evaluated.

Wular Lake is an extensive natural lake which swells in area up to about 175km^2 during flood but reduces to only about 20km^2 in dry periods. It is apparent from aerial photography that the volume of Wular Lake has reduced substantially over time as a result of sediment inflow. The bathymetric survey to be undertaken during the study will establish its current volume, and the utility of increasing this volume by large scale dredging will be evaluated with the hydrodynamic model. Dredging of Wular Lake may invoke an issue with the Indus Water Treaty regarding Jhelum River storage: the safe approach would be to limit the dredged capacity to that existing at the time the Treaty was passed (1960).

There is some concern that the water level in Wular Lake during flood exerts a backwater effect on the flood level in the Jhelum River as far upstream as Srinagar, which supports the dredging of Wular Lake to restore, or at least partially restore, its capacity. It is possible that this dredging could initiate a sequence of headwards erosion along the Jhelum which would, over time, increase its capacity, but this would be at the expense of generating more sediment flow into Wular Lake. It may be necessary, if dredging of Wular Lake is found to be beneficial, to construct a sill at the entrance to prevent the headwards erosion occurring.

The sediment in Wular Lake is finer than that in the Jhelum River upstream of Srinagar and is of no use as building sand. Large scale dredging would result in a large material disposal problem, which could possibly be met by the construction of artificial islands within the lake.

The outflow from the FSC also enters Wular Lake needs its southern end. There is a proposal to shorten the length of the channel from the FSC to Wular Lake by construction of a diversion channel. This option will also be investigated.

Currently the outlet from Wular Lake is constrained by a coffer dam which was constructed as part of a proposal to provide conservation storage within Wular Lake up to a certain level. However, as this would further reduce its flood mitigation capacity, this project has been on hold pending the outcome of the current study. It is also possible that the capacity of Wular Lake could be increased by bunding but increasing the maximum flood level would worsen any backwater effects, so this needs to be studied using the model, together with increasing the outlet capacity.

d) Downstream of Wular Lake

Downstream of Wular Lake to Salamabad, the Jhelum River is known as the Outfall Channel (OFC). Whilst this channel has a higher gradient than that above Wular Lake, the capacity is still restricted, and the Interim Scheme included provision for a 40m widening of the OFC from the outlet from Wular Lake (RD 168.11km) to the Lower Jhelum hydropower barrage (RD 173.5km).

Within this reach, the Pohru Nallah enters the Jhelum on its right bank. The Pohru Nallah with a catchment area of some 1850km^2 is the largest tributary of the Jhelum River within Kashmir and it produces a high sediment flow. Pohru River sediment, which is readily identified as it contains many seashells, extends along the Jhelum both upstream and downstream of the confluence for 3-4km. each successive flood brings more sediment which forms a constriction in the river channel.

One possible solution, if a suitable site can be found, is to construct a flood control storage within the Pohru Nallah which would also act as a sediment trap preventing much of its sediment load reaching the Outfall Channel.

These matters are further discussed in **Section 3.4** hereof.

2.4.2 Non-Structural Measures

Non-structural measures which need to be considered include the following, particularly in relation to Srinagar, where severe encroachment along the river and uncontrolled development within the floodplain has occurred:

- Development and enforcement of planning controls to exclude or severely restrict development in flood prone areas;
- Where development in floodplain areas is allowed, to specify minimum floor heights of buildings and where this is substantially above ground to require the building to be constructed on piles with no walls within the flood prone area to minimise the impact on floodplain flow;

- Acquisition and demolition of the worst affected buildings with adequate and appropriate compensation to owners – following demolition these areas should be preserved as open space such as parks;
- Improvement of flood forecasting and warning system by the installation of a SCADA based system;
- Upgrading of the provision of flood warning system to improve the dissemination of warnings to the public (possibly by SMS) and of interpretation of flood warnings (possibly by flood markers in streets);
- Use of floodplain mapping, to be developed by the study, to increase community awareness of flood issues and to enable meaningful interpretation of flood warnings;
- Control of the ongoing sand mining of the Jhelum main channel by a myriad of boats – whilst the sand mining is of benefit overall, there will be areas which are over-dredged which risks undermining of river banks and bridge piers – control by licencing, identification of areas in which sand mining is not permitted and enforcement could be undertaken either by IFCK or by a separate agency established for this purpose;and
- Catchment management measures – principally reforestation to reduce the sediment load from the upper catchment over time.

2.4.3 Climate Change

Climate change impacts are also an important challenge, which we will take into account in the hydrologic modelling on the basis of the research in this field, particularly that in respect of the Himalayan Region.

One important practical aspect of the adaptation to climate change, is that works planned now be designed to be robust and resilient to the possible changes considered likely to take place to the end of the current century. For example, there are indications that the frequency of very heavy rainfall events will increase (or conversely, the probability of a given rainfall event occurring will increase). To ensure resilience in this area, designs should go beyond the perceived change to consider the performance of the works in the case of a more extreme event, and that the works will survive without major damage in such an event.

3 Task 1 Review Flood and River Management Options

The Preliminary Hydrology Report and Preliminary Morphology Report required as part of Task 1 are the subject of **Sections 4** and **5** of this report respectively.

The remaining paragraphs in this section deal with the other components of Task 1.

3.1 Observations on the September 2014 Flood

3.1.1 Physical

The Jhelum River flood of September 2014 was the highest at and upstream of Srinagar since records began in 1955 with a peak flow at Sangam of some 3,250m^3/s (1,15,000 cusecs), which is about double the channel capacity at that point and almost double the previous maximum recorded of 1,850m^3/s (65,000 cusecs) in October 1992.

The flooding was extensive as shown in **Figure 2** covering a total of about 900km^2 including large parts of the city of Srinagar. The flood resulted in many deaths, damage to buildings, loss of crops and livestock and damage to infrastructure.

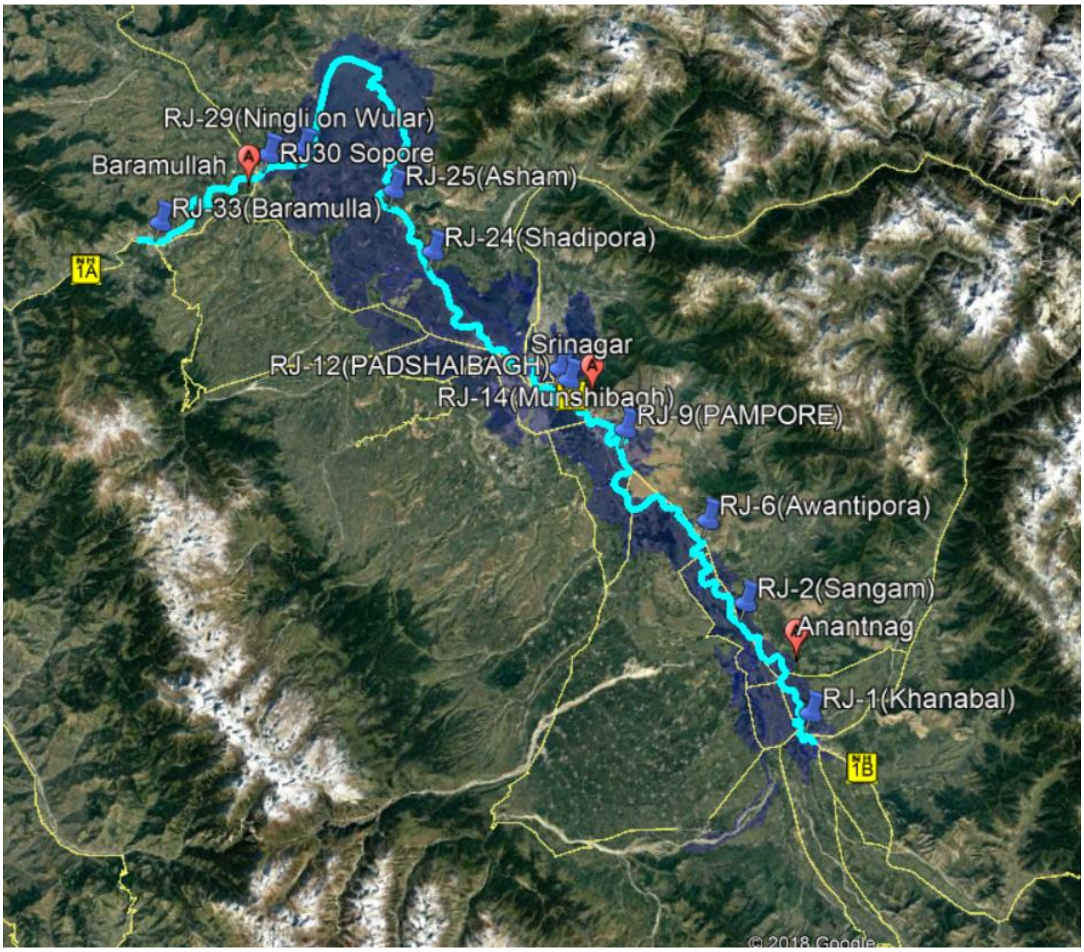

Figure 2 Flood Inundation Extent in September 2014 and Jhelum River Gauging Station Locations

The flood resulted from very high rainfalls, particularly in the upstream catchment (southern tributaries). Precipitation throughout the Jhelum basin in the first week of September 2014 is shown in **Figure 3** whilst **Figure 4** gives daily rainfalls for this period at Srinagar and other locations.

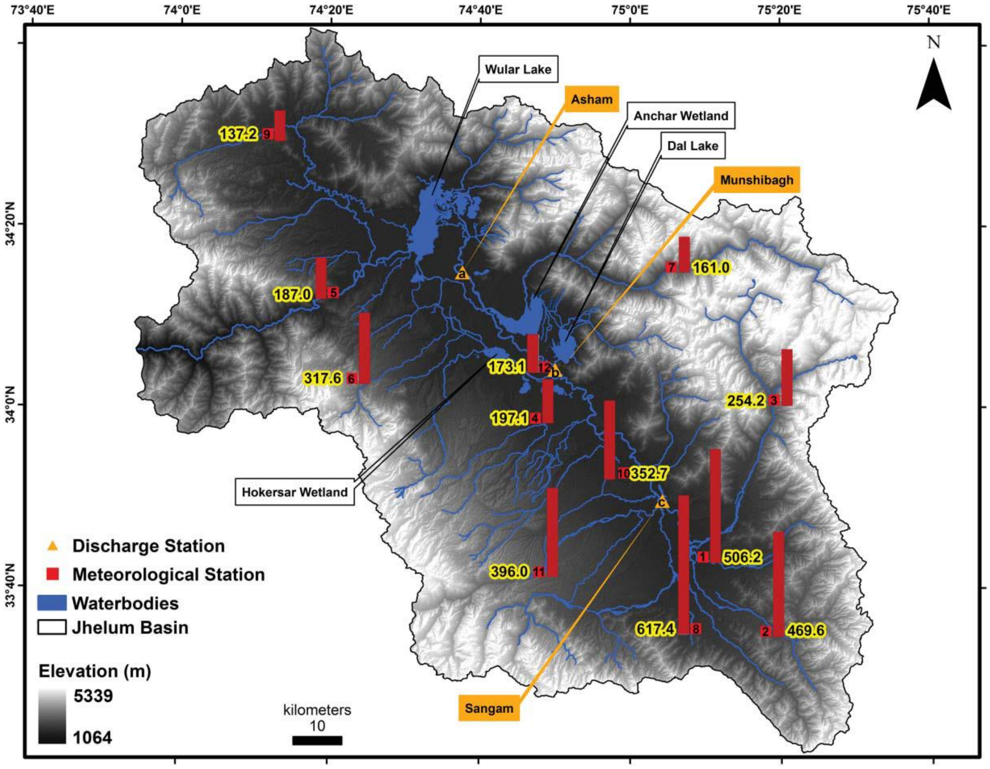

Figure 3   1-7 September Rainfall on Jhelum River Catchment (Source: Romshoo et al 2018)

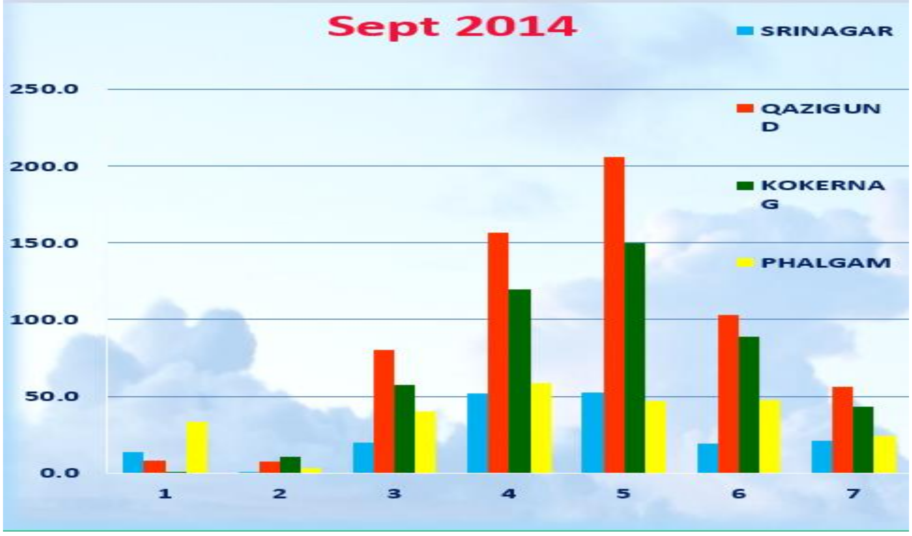

Figure 4   Daily Rainfall for 1-7 September 2014 (Source: IMD)

Ray et al (2015) opine that the rainstorm was caused by large scale disturbed atmospheric conditions as a consequence of the interaction between the westward-moving monsoon low and the eastward moving deep trough in the mid-latitude westerlies, causing extremely heavy rainfall over districts in the southwestern region of J&K.

Figure 5 shows flood hydrographs for Sangam and Asham for the September 2014 flood (these are the only stations with sub-daily data). The flood volume was estimated from these data to be approximately 1,700 MCM at Sangam and 1,000 MCM at Asham. The flow in the FSC would account for about 200 MCM of the difference between these figures, so the overflow would have been about 500 MCM. These are crude figures as they don't take account of inflows downstream of Sangam, so 500 MCM is likely to be an underestimate. Nonetheless this gives an indication of the flood overflow volume and also of the storage volume which would be required to control the overflow upstream of Srinagar.

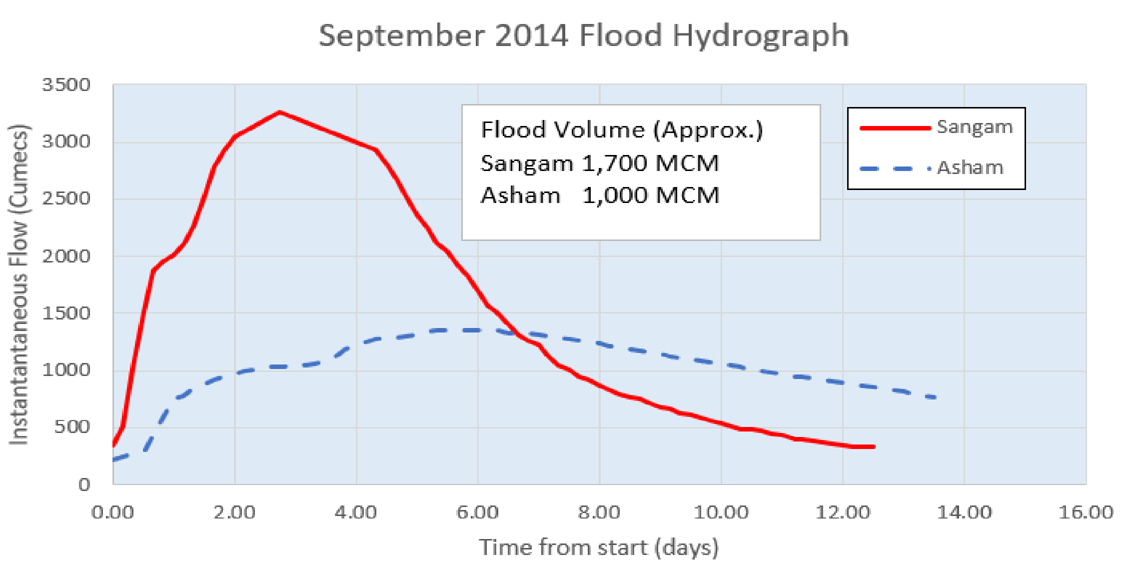

Figure 5 September 2014 Flood Hydrographs

Looking at the peak flows at the Jhelum River gauging stations in September 2014, compared to other years, and to each other is instructive. **Table 2** shows the peak flows from the Jhelum River and major tributary gauging stations from the 2014 flood together with their ranking in the 62 year flood record (extracted from the data supplied by IFCK).

Table 2 Selected Flow Statistics regarding 2014 Flood

River	Location	Reach	Peak flow 2014 m^3/s	Flood of record m^3/s	Year	Rank 2014 flood
Jhelum	Kandabal RD ~-1.5km	Upstream of Lidder, Vishav & Rembriana Nallahs	944	944	2014	1
	Sangam RD 17.1km	Sangam - Srinagar	3263	3263	2014	1
	Awantipora RD 32.33 km		1703	1844	1992	2
	Pampore RD 52.20 km		1796	1796	2014	1
	Padshahi Bagh 66.93 km		2299	2299	2014	1
	Munshi Bagh 71.70 km	Downstream of FSC	2055	2055	2014	1
	Shadipora 96.98 km	Srinagar - Wular Lake	1321	1385	1992	2
	Asham 106.10km		1384	1494	1996	4
	Sopore 150.20 km	Downstream of Wular Lake	921	1112	1996	6
	Baramulla 167.00km		984	1525	1987	12
Lidder	Akura		744	744	2014	1
Lidder	Kirkadal		108	164	1975	2
Vishow	Arwani		866	866	2014	1
Rambiari	Wachi-Nayina		280	356	1976	3
Romshi	Pahoo		110	121	1975	2
Sindh	Dodoaharma		311	434	1995	3
Sindh	Narayan Bagh		253	546	1995	3
Bringi	Dantar		506	506	2014	1
Sandran	Vwrinag		126	126	2014	1
Pohru	Seuloo		239	808	1965	12

Table 2 clearly shows the following:

- There was a very significant inflow from the major southern tributaries Lidder Nallah and Vishow Nallah in particular, which accounted for most of the difference in peak flow at Sangam and that upstream at Khanabal[3] -this is consistent with the rainfall distribution (refer **Figure 3**);
- This high flow from the south of the catchment resulted in the flow in the Jhelum River between Sangam and Srinagar being the highest recorded at 4 of the 5 gauging stations in this reach (the exception being at Awantipora where the flow was 8% lower than that in 1992);
- The flows in the major southern tributaries, Sandran, Bringi, Vishow and Lidder all had record floods in this event;
- The rapid reduction in peak flow downstream of Sangam, from 3,260m^3/s (1,15,000 cusecs) at Sangam, to 1,700m3/s (60,100 cusecs) at Awantipora is consistent with the major overflows into the floodplain in this reach;

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[3] This assumes that the peaks are coincident but as these are mean daily flows this is reasonable – analysis of the timing of the peaks based on hourly flows will be undertaken in Task 2, as will checking of flow data generally

- The increase in flow from Awantipora to Padshahi Bagh (2,300m^3/s (81,200 cusecs)) is probably due to inflows from Romshi Nallah and other minor left bank tributaries and direct local inflows;
- The difference in flows between those recorded at Munshi Bagh and Padshahi Bagh gives a measure of the flow into the Flood Spill Channel, which, on this basis was only 244m^3/s (8,600 cusecs) confirming the reduction in capacity of the FSC by about 50% from its original 500m^3/s (17,500 cusecs)[4];
- Downstream of Srinagar and upstream of Wular Lake, the 2014 flood is no longer the flood of record:
  - at Shadipora it is the 2nd ranked flood being marginally lower than that in 1992; and
  - at Asham it slips to the 4th ranked flood being lower than floods in 1996, 1995 and 1992;
- Although the capacity of Wular Lake has reduced significantly over the years, it still has a major peak attenuation effect, with the peak flow reducing from 1384m^3/s (47,000 cusecs) at Asham to 984m3/s (32,500 cusecs) at Sopore;
- The peak flow attenuation of Anchar Lake is considerably less, not only due to the relative sizes of the two waterbodies but because at Anchar Lake only part of the flow of the Sindh Nallah passes through the waterbody, the rest flowing directly to the Jhelum River – in the 2014 flood the peak flows upstream and downstream of Anchar Lake were 311m^3/s (11,000 cusecs) and 253m^3/s (8,900 cusecs) respectively; and
- Downstream of Wular Lake, the 2014 flood slips further down the flood ranking being:
  - The 6th highest flood at Sopore; and
  - The 12th highest flood at Baramulla.;
- The latter indicates the importance of floods in the Pohru Nallah, which is the largest of the tributary catchments to flooding in the Jhelum River downstream of Wular Lake i.e. along the Outfall Channel (OFC).

All of the above observations indicate that the worst of the flooding was upstream of and around Srinagar resulting from the extreme rainfalls in the upper catchment. These flows are unprecedented, at least within the 62 year period of record, with the flow at Sangam being twice the channel capacity.

It is clear that meaningful mitigation along the Sangam to Srinagar reach requires flood control storage either within the upper tributaries or by controlled flooding of the floodplain. Hence, this will be one of the focuses of the flood mitigation component of the study.

3.1.2 Social

Flood waters from Jhelum River breached embankments in many low-lying areas in Kashmir, including the capital Srinagar and Tawi River in Jammu forcing people to move to safer places. Heavy rainfall had caused:

- Flash flooding with localized damage across the state,

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[4] As this estimate is a relatively small difference between 2 larger numbers, any errors in the latter would be accentuated in the difference, so this estimate may be of low accuracy.

- Landslides, which impacted on communities and road connectivity and
- Widespread flooding in the Jammu & Kashmir Valley.

The statewide impacts are summarised in **Table 3** (note these include Jammu as well as Kashmir). More detailed data for Kashmir will be collected in Task 2 of the Study.

*Table 3 **Impact of Flood Data at a glance (Flood 2014)***

S.no	Issues	Impacts
1	Population Affected: Communication, Accessibility, Availability of Supplies, Agriculture, Livestock, Assets Losses	10,136,063 out of which 8,186,273 indirectly affected and 1,949,790 directly affected (tangible and intangible)
2	Direct loss of household assets, livelihood, Psychosocial	659,737
3	Houses flooded	97,159+
4	Population shelter partially damaged	574,209+
5	Displaced by flooding and shelter damage	1,290,052+
6	Houses un-inhabitable	121,124+
7	Direct loss of household assets, livelihood, Psychosocial	659,737
8	Population shelter fully damaged	715,841+
9	Deaths	280+
10	Persons injured/ sick	53,082+
11	Evacuated	226,000+

Source: Sphere India: J&K Flood Affected Districts Jammu and Kashmir State, India (28th September 2014)

Impacts due to Flood

Sphere India (2014) prepared the Joint Rapid Needs Assessment (JRNA). During the assessment survey team has covered 108 villages from the worst affected districts of Jammu and Kashmir. Out of 108 villages assessed by the team, water level was more than 3 feet in 62 villages and had entered into the houses in 87 villages. The team reported that the 86% of the wards were affected and major damages to shelter, water and sanitation facilities, crop/agriculture land and education. However, the information related to existing situation before flood impact is yet to be collected to assess the status of impact.

Table 4 summarises impacts on social security schemes.

Table 4 Impacts of Flood on Social Security Schemes

S.no	Issues	Percent
1	Stocks severely destroyed	82.3%
2	No private places to breastfeed children and in risk of improper breastfeeding	68.3 %
3	Decrease of food consumption after floods in Kashmir	86%
4	Food consumption level decreased after the floods in 5 districts.	100%

5	Completely destroyed in the floods	139,413 kanals of land or 17,426 acres
6	Paddy to be one of the most important crops in 68 villages	57%
7	Cost of food has increased tremendously	62.7%
8	Markets functioning in the village and markets running out of stock	8.3% & 81.5 %
9	Loss of livestock	43% in Kashmir and 7% in Jammu
10	Availability of fodder adversely affected	74% in Kashmir and 55% in Jammu

Source: Sphere India: J&K Flood Affected Districts Jammu and Kashmir State, India (28th September 2014)

From the above table it is quite evident that:

- Paddy and fruit crops had suffered huge losses; there were also reports of severe damage to vegetable and maize crops, resulted in reduction in yield or loss of crops. However, the production of paddy, fruits crop and maize etc. in impacted areas prior to flood condition is not available and will need to be collected from concerned line department and during socio-economic survey;

- It is likely that land will be unfit for agricultural production for some time after the flood. However, the time for the land to return to productivity needs to be confirmed;

- Potential loss of seeds and tools;

- Supply routes and transportation networks were severely affected, which led to reduced availability of food stocks, increased prices and reduced access of households to food. Information related to rates of food items before flood condition is yet to be collected form the concerned department;

- Access issues also hampered the ICDS services and PDS but information related to number of impacted ICDS/PDS centre is not available and to be collected;

- Flooding is likely to have had a major impact on household level food stocks, with water logging causing damage to dry rations, and flash floods washing away household assets. It would be effective to understand the asset loss in Rupees;

- The poorest survive by buying and cooking food daily, maintaining limited storage of food supplies. Considering the disruption to supply or distribution, the flooding caused immediate shortages for these groups. The numbers of BPL families in impacted area (district-wise) are not available at present and need to be collected form concerned line agencies and during survey; and

- Many of the migrant workers, known as Biharis (irrespective of place of origin) were reported to leave the state during the flooding. The shortage of laborers had resulted in nearly 30 to 50 per cent hike in the daily wages of skilled and unskilled laborers. While skilled laborers had hiked their daily wage rates from Rs. 400 to Rs. 600, the unskilled laborers increased it from Rs. 330 per day to Rs. 420 per day. An estimated three lakh migrant laborers come to Kashmir to every year to earn a livelihood.

Table 5 summarises the main impacts in relation to sanitation and water supply.

Table 5 Impacts of Flood on Water Sanitation & Hygiene

S.no	Issues	Percentage
1	Water source damaged	53%
2	Before the flood, villages with piped water as the primary source of water	63%
3	After the flood the availability of water was	13% of villages use wells, 29% ponds, 30% tube-wells, and 12% other sources.
4	Damaged sanitation facilities	85%
5	Primarily practicing open defecation	59%

Source: Sphere India: J&K Flood Affected Districts Jammu and Kashmir State, India (28th September 2014)

From the above table it is quite evident that:

- Water sources were inundated and mostly contaminated;
- Water supply through tube-wells, pipe water, and open wells were adversely damaged in almost all affected villages. Current source of water supply were ponds and open water bodies and few tube wells. The army supplied the drinking water in most of the affected villages;
- Toilet facilities had been damaged in all villages;
- There was a potential threat of diseases in all the villages due to no proper disposal or debris and carcasses. The existing status on health conditions will be collected during public consultation with various stakeholders and socio-economic survey; and
- Overflow of pit latrines and sanitation practices continued to put communities at risk once the water started receding. The information related to status of ground water before and after flood condition is yet to be collected.

The main outcomes as the survey findings in relation to impacts on the health sector are shown in **Table 6**.

Table 6 Impacts of Flood on Health Sector

S.no	Issues	Percentage
1	Death of neonates before reaching to hospitals	20
2	District Hospital overloaded	From 10 delivery per day to 100 deliveries per day
3	Status of GB Pant Hospital, the flood waters, which stayed on for 10 days:	damaged key equipment, especially ventilators, radian warmers, incubators and oxygen concentrator. Disruption of electricity led to failure of most systems

Source: Sphere India: J&K Flood Affected Districts Jammu and Kashmir State, India (28th September 2014)

From the above table and other information in the survey, it is quite evident that:

- Water borne and vector borne diseases spread in most of the affected villages due to shortage of safe drinking water and water logging;
- Significant impact on access to Medical facilities and on operation of facilities;
- Affected people were suffering from Injuries including lacerations, broken limbs, water inhalation and ingestion;
- Overcrowding in displacement camps led to increased risk of transmission of communicable diseases. The information related to average person per camp against its capacity is yet not available. This needs to be collected form the concerned department;
- As the flood was unprecedented and worst flooding experienced by the region in many decades, the population was under a state of shock. Many were in need of psychosocial support;
- In Srinagar, most hospitals were inundated. Doctors were in urgently need for more medicines and equipment to cater to patients, who were even being treated on floor because of lack of enough beds. Data related to existing infrastructure facilities to hospitals, and clinics is yet to be collected; and
- Hospitals sustained major losses to machinery and diagnostics equipment as a result of the water logging.

In respect of the impacts of the flood on education:

- Many schools in the villages were partially or completely damaged and submerged in water. After receding of water from most of the schools and the ICDS centres, there were reports of silt deposition (a few schools reporting up to 100mm – 150mm);
- None of the affected schools were functioning - children had lost textbooks, there had been damage to the buildings, furniture & fixtures and there was a foul smell in all the affected areas;
- Some schools in the state had remained closed for an extended period.

The main outcome findings from the survey in respect of shelter are given in **Table 7.**

Table 7 Impact of Flood on Shelter:

S.no	Issues	Percentage
1	Number of Household severely damaged	Shopian: 1307 houses Baramulla: 1755 residential structures damaged Many villages are still completely submerged in water.
2	Temporary Shelter	Sambha (Jammu): fully damaged 627 houses and partially 2777
3	Required shelter support	Reasi, Poonch, Rajouri and Udhampur

Source: Sphere India: J&K Flood Affected Districts Jammu and Kashmir State, India (28th September 2014)

Other Impacts of the flood are summarised below:

- Incidents of breakdown of law and order reported in Bandipora and Baramulla villages, presence of non-state actors in some of the villages were seen;
- Forced return and relocation of communities in a few villages were reported;
- Gender violence erupted in some of the villages;
- Loss of legal documents reported in a few villages assessed in Baramulla and Bandipora;
- Displacement of vulnerable groups, women-headed households, elderly, persons with disability, was reported;
- Loss of agricultural livelihood for women-headed households were seen in most of the villages;
- Limited privacy for women and children in relief camps; and
- Migrant groups were left vulnerable -during the study assessment of type of vulnerability will be assessed.

3.2 Historic Development of Flood Management in the Jhelum Valley

The flood history of the Kashmir Valley goes back millennia and several rulers have undertaken flood control programs over many centuries.

The first major flood control works of recent times was the construction of the Flood Spill Channel (FSC) in 1903, following the major flood of 1893. The FSC was designed to carry about 500m^3/s (17,500 cusecs), but its current capacity is only about 50% of the original due to sedimentation and construction of low level crossings.

Since that time a number of reports have been prepared including a range of suggestions including:

- Purves (c 1915) reported in recommended:

  - Partial diversion from the Jhelum River at Gagazu into Anchar Lake returning to the Jhelum River at Shadipora; and
  - Diversion of the Pohru Nallah into Wular Lake.

- Dass (1928) Divisional Engineer, Irrigation, Kashmir (reported in CWPRS (2018) and Uppal (1955) suggested that:
  - The capacity of the existing FSC be increased to 623 m^3/s (22,000 cusecs) and construction of subsidiary flood spill channel;
  - The diversion of the Jhelum from Asham to Ningli;
  - The dredging and possible diversion of the Pohru Nallah;
  - Increasing the height of the river bunds through Srinagar;
  - Controlling the spill from the Jhelum River upstream of Srinagar by controlled openings in the bunds between Khanabal and Padshahi Bagh.

- Harris (c 1930) reported in CWPRS (2018), Uppal (1955) and Lone (1988) suggested:
  - Strengthen the embankments though Srinagar and raise them by 1m – 1.3m to above the level of the 1928 flood together with the provision of spillways to discharge up to 1,100m^3/s (44,000 cusecs) into the floodplain;
  - Replace 5 old bridges in Srinagar with newer ones at higher level;
  - Construction of a diversion channel with a capacity of 450m^3/s (16,000 cusecs) by a cut through the Dudhganga ridge upstream of Srinagar to Batmallu Nambal;
  - Construction of a new outfall channel of capacity 340m^3/s (12,000 cusecs) from Batmallu Nambal to the Jhelum River;
  - Constructing new bunds on the west and southwest sides of the Batmallu Nambal with spillways to discharge up to 225m^3/s (8,000 cusecs) to Hokesar Lake;
  - Construction of a diversion channel with a capacity of 565m^3/s (20,000 cusecs) from the Jhelum River at Gagazu into Anchar Lake returning to the Jhelum River at Shadipora;
  - Reopening of Shadipora Nullah; and
  - Ceasing dredging of the Outfall Channel.

- Uppal (1955) noted that the operation of the FSC is limited by backwater influence from its outfall at Parampura and that during the 1950 flood it carried little or no flow for 1.5 to 2 days;

- Uppal (1955) considered a range of possible flood mitigation measures including:
  - increasing the river's carrying capacity by widening of the channel, or by constructing an embankment parallel to the river but set some distance back from it;
  - Overflow weirs to discharge into the floodplain;
  - Upstream flood control storage; and
  - Reforestation of the upper catchment.
- After considering these alternatives, Uppal proposed the following in combination:
  - Strengthening and realignment of bunds but no further raising;

  - Meander cut-offs;
  - Construction of a supplementary diversion channel from Dogripora to Wular Lake;
  - Diversion of the Ningli Nallah into Wular Lake;
  - Complete diversion or diversion of sediment from the Pohru Nallah into Wular Lake;
  - Stabilising rapids below Wular Lake;
  - Removal of a footbridge at Baramulla;
  - Removal of the Ningli plantation above Sopore; and
  - Dredging of the outfall channel.

- The Central Water & Power Commission (now CWC) (c 1953) recommended:
  - Enlargement and excavation of the existing FSC from Padshahi Bagh to Wular Lake;
  - Diversion of the Ningli Nallah into the Haigum Jheel;
  - Removal of the bar in the OFC at the mouth of the Pohru;
  - Construction of a supplementary channel from Marval about 30km downstream of Dogripora to Padshahi Bagh; and
  - The question of partial or full diversion of the Pohru into the Wular Lake or into the OFC near Baramulla, to be examined further.

- The Master Plan for Flood Control and Drainage in the Kashmir Valley (1958) recommended that:
  - Two low lying areas on the left bank floodplain upstream of Padshahi Bagh be used as detention basins;
  - Increase the capacity of the FSC to 566m^3/s (20,000 cusecs);
  - Reopen the Shadipora Nallah opposite to the mouth of the Sindh Nallah and connect it to the FSC;
  - Divert the Doodh Ganga Nallah into the Narkura Nambal;
  - Widen and deepen the OFC from Wular Lake to Khadnyar;
  - Divert the Pohru Nallah into Wular Lake; and
  - Divert the Ningli Nallah into the Haigham Jheel.

Few, if any, of these various recommendations have been implemented.

3.3 Currently Proposed Flood Control Measures – the Interim Scheme

Following the 2014 flood, the IFCK has developed an Interim Scheme to be implemented pending the outcomes from the current study, the enable the Jhelum River to convey 1,700m^3/s (60,000 cusecs) at Sangam through the system without significant flooding. A Detailed Project Report (DPR) is currently being developed for the Interim Scheme.

CWPRS (2018) conducted hydraulic modelling studies of this Interim Scheme using an unsteady flow 1-D HEC-RAS model. The main components of the current Jhelum River system, as modelled, are shown in **Figure 6**.

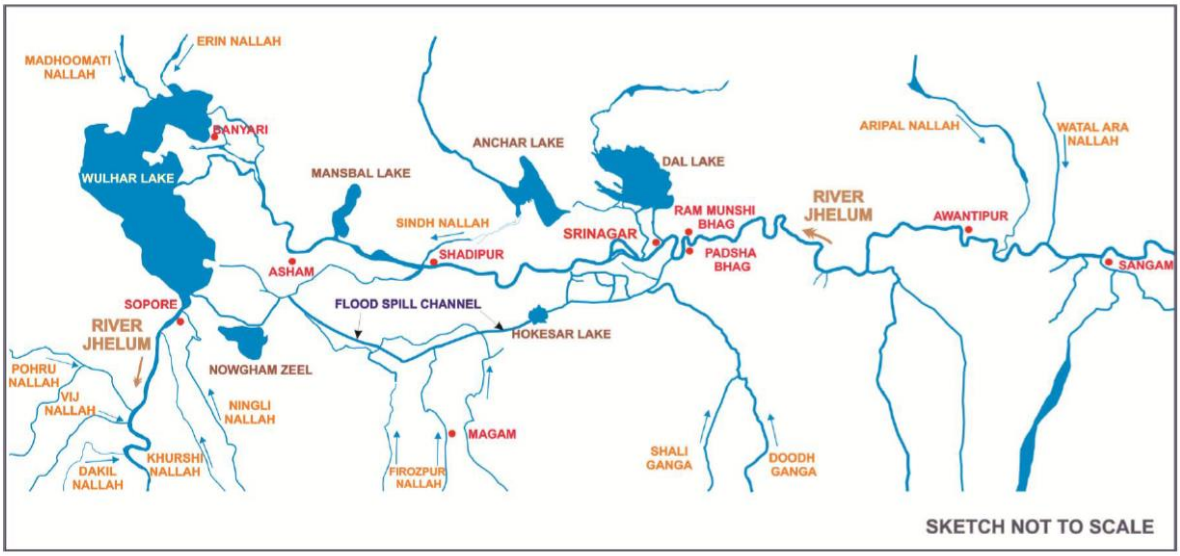

Figure 6 Main Elements of Jhelum River (source: CWPRS 2018)

The principal outcome of the CWPRS study was the endorsement of the interim scheme. As noted above, the interim scheme is not designed to convey the estimated design peak flow of 3760m^3/s (1,15,000 cusecs) based on the 2014 flood. Conveyance of the latter will require additional measures which are the subject of the current consultancy.

The interim scheme is, therefore, a starting point for the considerations of the current consultancy, and it is assumed that construction of the proposed measures will be implemented.

Whilst there are some minor differences between various options to be resolved during the development of the DPR, the interim scheme essentially comprises the following main components:

- Extending the channel of the Flood Spill Channel (FSC) through the Hokesar Lake effectively increasing the conveyance though the lake – sub options vary the width of this channel between 30m and 80m; and
- Increasing the width of the Outfall Channel (OFC) from Sopore Bridge (RD 150.25km) to RD 173.2km by an additional 40m along the thalweg line.

In addition to the works to be included in the interim scheme, CWPRS also recommended that further consideration be given to:

- Cessation of dredging of Jhelum River between Sangam and Asham;
- Dedication of low lying areas on the left bank of the Jhelum River near the start of the Flood Spill Channel to form detention basins of 49km^2 and 44km^2) – uncontrolled development in these areas will preclude their utility for flood retention in the future;
- Reconstruction of four bridges (at RD 151.25, 167.5, 182 and 201.1km) which interfere with flow flows; and

- Increasing the width of the outflow from Wular Lake.

However, these additional measures are not part of the interim scheme.

3.4 Review Flood Management Issues and Opportunities

As has been discussed in Section 2.4 above, the principal challenge for this project is to develop a flood risk management plan for the Jhelum River that can deal with a flow at Sangam equivalent to that which occurred in September 2014, taking account of the fact that the current river capacity is only about 50% of that flow, and that existing flood management works which have developed over the last 100 years, and the ongoing sediment inputs together with largely uncontrolled development in the floodplain, have led to a very complex flood management situation.

Upstream of Wular Lake, and particularly upstream of and through Srinagar, the lack of channel capacity is the main issue. Whilst it would be possible to construct a further diversion channel starting near Dogripora and continuing to Wular Lake, as shown in **Figure 7**, this channel would be some 80km in length and would be very expensive.

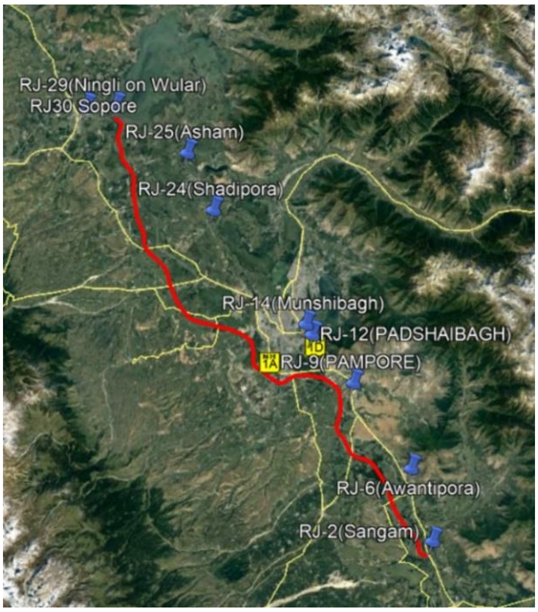

Figure 7 Possible Route of Diversion Channel from Dogripora to Wular Lake (Source: IFCK)

An alternative strategy would be to reduce peak flows in the river by the introduction of flood control storage in the southern tributaries. If sufficient flood control storage sites can be found and construction at those sites is feasible, it may be possible to reduce the peak flows to a sufficient extent that they are within the capacity of the Jhelum River. In the event that there are insufficient suitable sites, due to the steep gradients of the tributaries, a larger number of relatively small storages in cascade may be appropriate.

This alternative would also be very costly, but also has the benefit that the storages could be designed to trap sediment, in a way in which their capacity could be relatively easily maintained by the regular excavation of trapped sediment. Every effort will be made during the feasibility study phase to identify and evaluate potential flood storage sites.

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Off-channel floodplain storage along the Sangam – Dogripora reach will also be considered and its comparative advantages/ disadvantages compared to upstream tributary storage will be evaluated. The economics of such storage will be compared with that of the Dogripora to Wular Lake channel.

The possibility of storage on the tributaries which flow directly into the FSC should also be considered but it is likely that these will be few opportunities for this as discussed above in relation to the southern tributaries. Enhancing the use of Dal Lake for flood storage will be considered although this is unlikely to be major contributor to flood management.

The potential of the detention basins recommended by CWPRS (2018) will also be considered, although it is noted that unapproved developments in these areas has reduced their availability for this purpose. Land acquisition issues will need to be addressed as part of this evaluation.

Opportunities for increasing the capacity and storage along the FSC together with the possibility of storage on tributaries feeding directly into the FSC will also be considered. The possible construction of a new, considerably shorter outfall channel from the FSC to Wular Lake will also be investigated.

Enhancing the flood control role of Anchar Lake will also be investigated: this could involve diverting a larger proportion of flow from the Sindh Nallah into Anchar Lake; and revisiting the suggestion (from Purves 1915) of a partial diversion from the Jhelum River at Gagazu into Anchar Lake returning to the Jhelum River at Shadipora.

It is apparent from aerial photography that the volume of Wular Lake has reduced substantially over time as a result of sediment inflow. The bathymetric survey to be undertaken during the study will establish its current volume, and the utility of increasing this volume by large scale dredging will be evaluated with the hydrodynamic model. Dredging of Wular Lake may invoke an issue with the Indus Water Treaty regarding Jhelum River storage: the safe approach would be to limit the dredged capacity to that existing at the time the Treaty was passed (1960).

Currently the outlet from Wular Lake is constrained by a coffer dam which was constructed as part of a proposal to provide conservation storage within Wular Lake up to a certain level. However, as this would further reduce its flood mitigation capacity, this project has been on hold pending the outcome of the current study. It is also possible that the capacity of Wular Lake could be increased by bunding but increasing the maximum flood level would worsen any backwater effects, so this needs to be studied using the model, together with increasing the outlet capacity. Again, this would need to be limited by the bounds of the Indus Water Treaty.

Downstream of Wular Lake to Salamabad, the Jhelum River is known as the Outfall Channel (OFC). Whilst this channel has a higher gradient than that above Wular Lake, the capacity is still restricted, and the Interim Scheme included provision for a 40m widening of the OFC from the outlet from Wular Lake (RD 168.11km) to the Lower Jhelum hydropower barrage (RD 173.5km). The potential for further work on this reach may be limited but will be investigated.

Within this reach, the Pohru Nallah enters the Jhelum on its right bank. The Pohru Nallah with a catchment area of some 1850km^2 is the largest tributary of the Jhelum River within Kashmir and it produces a high sediment flow. Pohru River sediment, which is readily identified as it contains many seashells, extends along the Jhelum both upstream and downstream of the confluence for 3-4km. each successive flood brings more sediment which forms a constriction in the river channel.

Consideration will be given to the construction of flood control storage within the Pohru Nallah which would also act as a sediment trap preventing much of its sediment load reaching the Outfall Channel. This is, of course, dependant on being able to locate a suitable site or sites. This will certainly be investigated.

Section 2.4 also lists a number of opportunities in terms of non-structural measures which need to be addressed. These are repeated here for ease of reference:

- Development and enforcement of planning controls to exclude or severely restrict development in flood prone areas;
- Where development in floodplain areas is allowed, to specify minimum floor heights of buildings and where this is substantially above ground to require the building to be constructed on piles with no walls within the flood prone area to minimise the impact on floodplain flow;
- Acquisition and demolition of the worst affected buildings with adequate and appropriate compensation to owners – following demolition these areas should be preserved as open space such as parks;
- Improvement of flood forecasting and warning system by the installation of a SCADA based system;
- Upgrading of the provision of flood warning system to improve the dissemination of warnings to the public (possibly by SMS) and of interpretation of flood warnings (possibly by flood markers in streets);
- Use of floodplain mapping, to be developed by the study, to increase community awareness of flood issues and to enable meaningful interpretation of flood warnings;
- Control of the ongoing sand mining of the Jhelum main channel by a myriad of boats – whilst the sand mining is of benefit overall, there will be areas which are over-dredged which risks undermining of river banks and bridge piers – control by licencing, identification of areas in which sand mining is not permitted and enforcement could be undertaken either by IFCK or by a separate agency established for this purpose.; and
- Catchment management measures – principally reforestation to reduce the sediment load from the upper catchment over time (see also Section 3.7 hereof).

Figure 8 shows the locations of a number of possible sites for flood control storage together with the additional diversion channels which have been suggested.

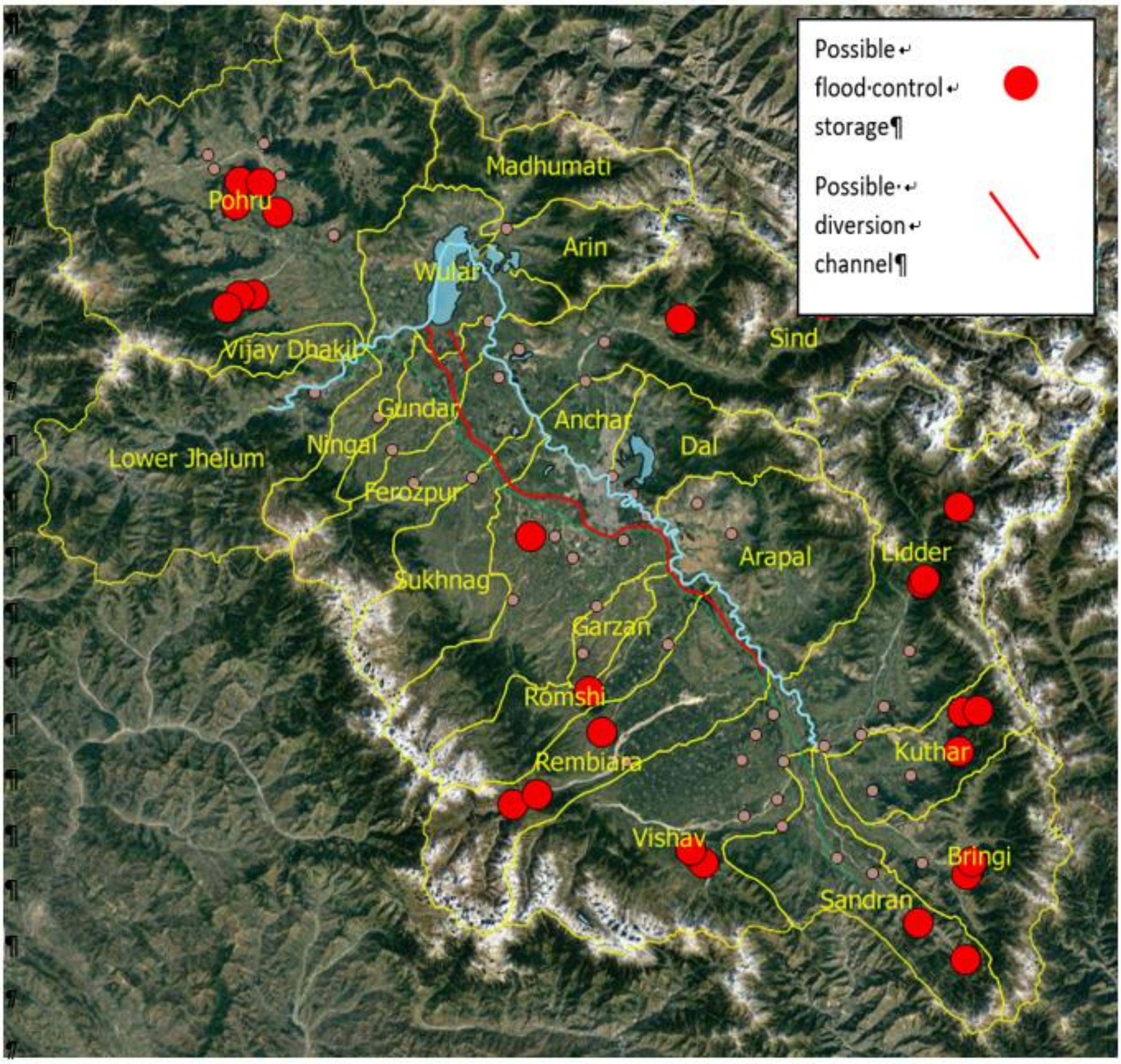


Figure 8 Possible Flood Control Storage Sites and Diversion Channels

3.5 Selection of Mathematical Models

We propose that the following mathematical models be used for the hydrologic and hydrodynamic modelling:

- Hydrologic model – HEC-HMS (current version 4.2.1); and
- Hydrodynamic model – HEC-RAS (current version 5.0.5).

These are both licence-free, public domain models developed by the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. The models are well respected and have both been widely used successfully across a wide range of environments. The relevant members of the Study Team have used these models and are fully familiar with their use.

HEC-HMS (Hydrologic modelling system) (HEC 2016a) is designed to simulate the precipitation-runoff processes of dendritic catchments and to be applicable in a wide range of geographic areas and a range of hydrologic issues. For example, it includes a detailed snowmelt component which is useful for the current study.

Outputs from the model will provide input hydrographs for the flood hydrodynamic model.

Hydrologic models are a numerical representation of the processes in the hydrological cycle thatseek to replicate these natural processes as far as is practicable. In simple terms, the model processes the input data (precipitation) and estimates the outputs, in this case in the form of streamflow hydrographs.

HEC-RAS (River Analysis System) (HEC 2016 b, c) was originally developed as a 1-D only hydrodynamic model and became an industry standard model. Version 5.0, first issued in 2015, introduced 2-D modelling to the software for the first time. Since that time, the 2-D version has become widely used. Not only is it public domain software, it has significant advantages over other, commercially available software, in that it is possible to incorporate several of its 1-D elements, such as modelling of bridges, and it also has complete hydraulic description of each grid element compared to most models which have only a single level for each grid element. This latter feature enables larger grid sizes to be used reducing computation time whilst maintaining accuracy. The model also includes dam-break modelling which is an extra to many commercial programs.

Like comparable commercial programs the model can be used as a pure 2-D, model, pure 1-D model or a combination of both. For example, the main river can be modelled in 1-D and the floodplain in 2-D.

In addition to its use for the main hydrodynamic modelling for flood management, the model can also be used for flood forecasting although a 1-D model is usually preferable for food forecasting due to the computation time required for the 2-D model.

Both of these models are recommended for use in the Jhelum River study. Further discussion of the models capabilities and data requirements are given in **Section 6.2** hereof.

3.6 Compliance with Indus Water Treaty

As the Jhelum River is a tributary of the Indus River, any development of water resources for conservation or flood control within the catchment is subject to compliance with the Indus Water Treaty (MEA 1960).

In summary terms, in relation to the Jhelum River, the Indus water Treaty contains the following provisions:

- Water used for flood control is regarded as a “non-consumptive” use providing the water is returned to the same river or its tributaries undiminished in volume;

- Annexure C- Agricultural Use by India from the Western Rivers restricts conservation storage in the Jhelum River system to 0.2 MAF (247Mm^3);
- Annexure E - India may construct on the Jhelum Main such works as it may consider necessary for flood control of the Jhelum Main provided that:
  - Any storage which may be affected by such works shall be confined to off-channel storage in side valleys, depressions or lakes and will not involve any storage in the Jhelum Main itself;
  - Except for the part held in lakes, borrow-pits or natural depressions, the stored waters shall be released as quickly as possible after the flood recedes and returned to the Jhelum Main lower;
- Annexure E - The design of any storage work shall conform to the following:
  - With respect to the flood storage provision above, the design of the works on the Jhelum Main shall be such that no water can spill from the Jhelum Main into the off-channel storage except when the water level in the Jhelum Main rises above the low flood stage.

The main points relevant to any recommendations to be made by this Study are:

- Any additional flood storage shall not be on the Jhelum Main stream which includes Wular Lake;
- Any proposal for dredging of Wular Lake, or building of embankments to increase conservation storage could be in contravention of the Treaty – restoration to its capacity as of the date of the Treaty would be expected to be acceptable;
- Additional storage for flood control only does not contribute to the allowable conservation storage for agricultural use of 0.2 MAF (247Mm^3), but any conservation storage component included in a multi-purpose project would be included;
- It is not clear if the storage within Wular Lake, Anchar Lake, Dal Lake, Mansbal Lake and Nowgham Zeel are considered to be conservation storage for agricultural use under these provisions – if this were so their volumes would contribute to the allowable 0.2 MAF (247Mm^3);
- Offtakes for off-channel storage on the Jhelum main stream should be above *low flood stage* which needs to be defined at any prospective offtake location.

3.7 Catchment Management

The REFORM project of the European Union has developed a framework for river restoration projects designed to improve their success and sustainability. This includes the development of procedures to monitor the biological response of changes in geomorphology and in restoration interventions to provide sustainable, ecologically effective management within the socio-economic setting. This framework is illustrated by **Figure 9.**

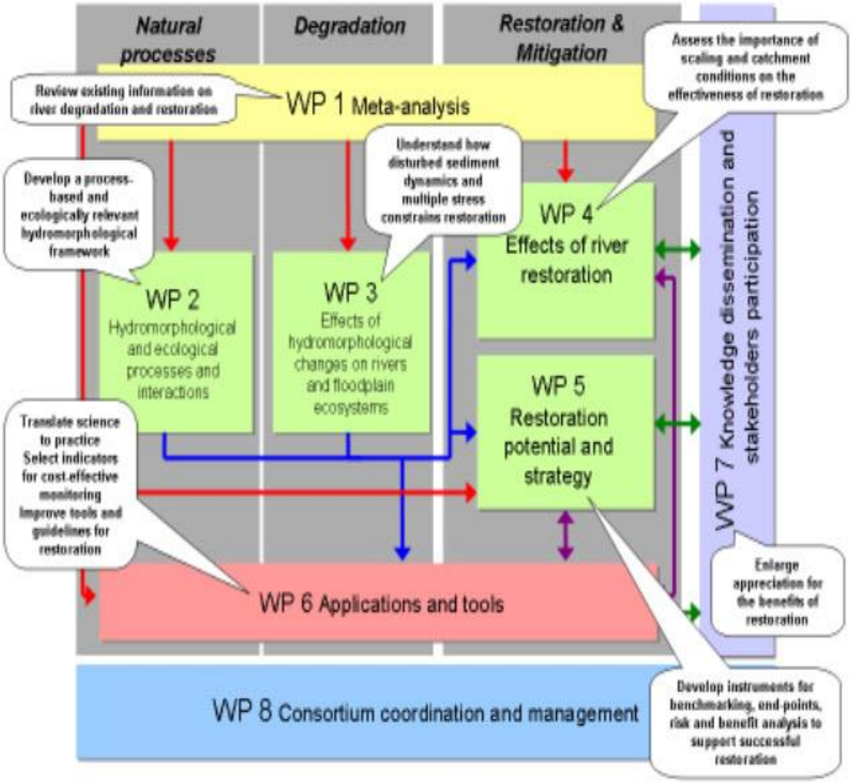


Figure 9 REFORM Process for River Restoration

The specific objectives of REFORM are:

- To select WFD compliant hydromorphological and biological indicators for cost effective monitoring that characterise the consequences of physical degradation and restoration in rivers and their services.
- To evaluate and improve practical tools and guidelines for the design restoration and mitigation measures.
- To review existing data and information on hydromorphological river degradation and restoration.
- To develop a process-based, multi-scaled hydromorphological framework on European rivers and floodplains and connected groundwaters.
- To understand how hydromorphological pressures interact with other pressures that may constrain successful restoration.
- To assess the significance of scaling effects on the effectiveness of different adaptation, mitigation and restoration measures to improve ecological status or potential of rivers, floodplains and connected groundwaters.
- To develop instruments to analyse risk and assess benefits of successful river restoration, including resilience to climate change and relations to other socioeconomic activities.
- To increase awareness and appreciation for the need, potential and benefits of river restoration.

There are river restoration centres or agencies in EU, USA, UK, Australia, Russia and a number of other countries and a number of publications regarding this topic, including the UNESCO report (Speed et al 2016). Little work appears to have been done in India in this regard, although there is a realisation that such work needs to be done.

In the context of the Jhelum River, this relates principally to catchment management initiatives to reduce sediment generation and transport into the Jhelum. This issue will be addressed more fully in Task 4. It is anticipated that this will relate principally to reforestation but may also include recommending changes to farming practices.

4 Preliminary Hydrology Report

4.1 Study Area

From a hydrology perspective, the study area comprises the whole of the Jhelum River catchment downstream to the Inia-Pakistan border. The Khadanyar gorge divides the catchment into two areas: the upper segment which is the subject of the current study, drains the whole of the Kashmir Valley and comprises a catchment area of some 12,750km^2

The Jhelum River catchment is bounded by high mountains all around: The Great Himalayas on the east, rising to 5,300m; and the Pir Panjal Range on the west rising to 5,000m. Erosion from these catchments has resulted in the formation of a very flat valley floor form by deposition of the eroded material, such that the Jhelum River has an average grade of only 1 in 10,000. Hence, there is a major contrast between the upper catchments of the and the Jhelum River Valley which is at an elevation ranging from about 1,400m to 1,650m.

There are a number of glaciers and glacial lakes at the higher altitudes and forests are dominant between about 1,650m and 3,500m. Due to the flat gradient of the valley floor, there are a number of lakes and wetlands the largest of which Wular Lake provides significant attenuation of flood flows. Wular Lake, Anchar Lake and other wetlands are major refuges for migrating water birds, (some of which are RAMSAR sites).

The Kashmir Valley which contains the Kashmiri capital Srinagar as well as a number of other towns and villages, is the economic heart of Kashmir. Srinagar is an ancient city built on the banks of the Jhelum River and whilst the old city is on higher ground, much of the modern city is within the Jhelum River Floodplain. The natural river banks have been raised at various times and are now of such a height that if overtopped, or breached, during flood extensive flooding occurs.

Precipitation generally increases with altitude and depending on the season, may fall as snow on the upper slopes. Whilst the catchment is sufficiently far north to miss most of the rainfall from the southwest monsoon, this does sometimes cause high rainfall in this region. The other major weather system is the westerly disturbance, a mid-latitude system which can bring rain systems from the west. The 2014 flood was the result of an unusual combination of both systems (Ray et al 2015).

Figure 10 shows the catchment boundary and that of the major sub-catchments, and **Figure 11** shows a contour map of the catchment (contours derived from ALOS DEM).

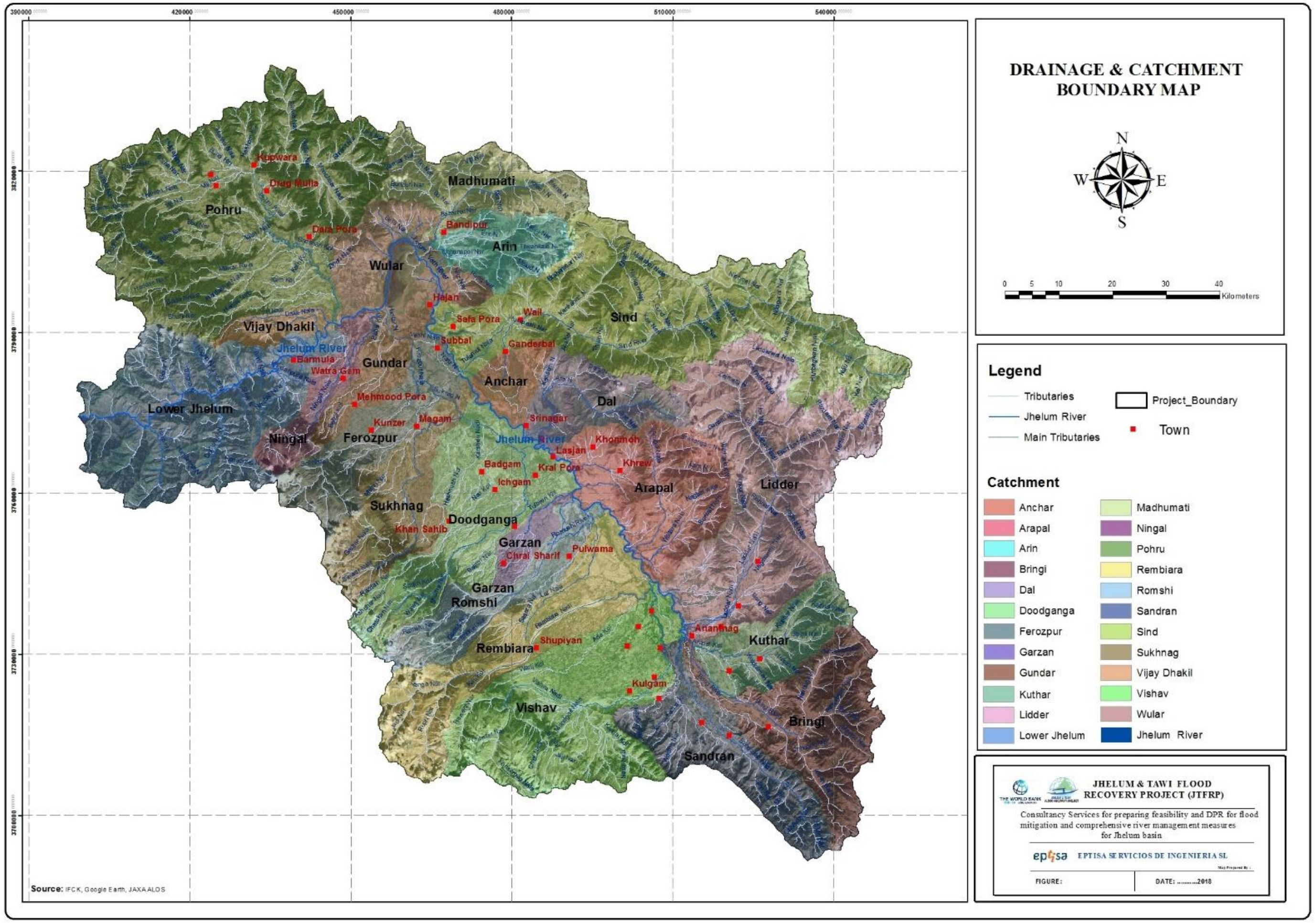


Figure 10 Jhelum River Catchment showing Major Sub-catchments

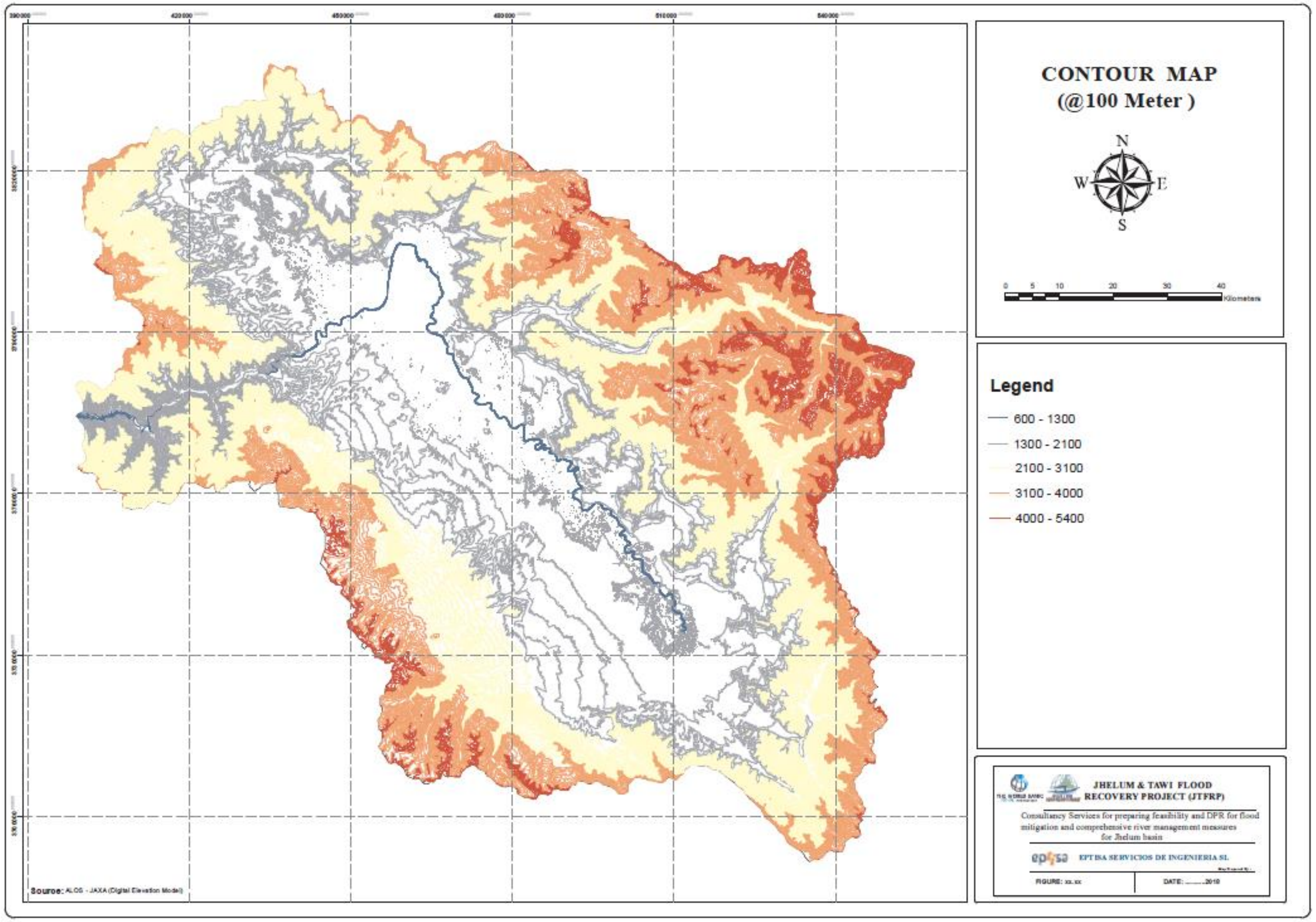


Figure 11 *Jhelum River Basin - Contour Map*

4.2 Climate of the Study Area

The Köppen climate classification for the Jhelum basin is *humid sub-tropical* (Cfa). Humid subtropical climates have a warm and wet flow from the tropics that creates warm and moist conditions in the summer months. **Figure 12** shows monthly mean precipitation and temperature for Srinagar. It can be seen from **Figure 12** that the bulk of the precipitation occurs in winter and spring, when precipitation may fall as snow on the higher ground. There is a secondary, but smaller rainfall peak in late summer associated with the southwest monsoon.

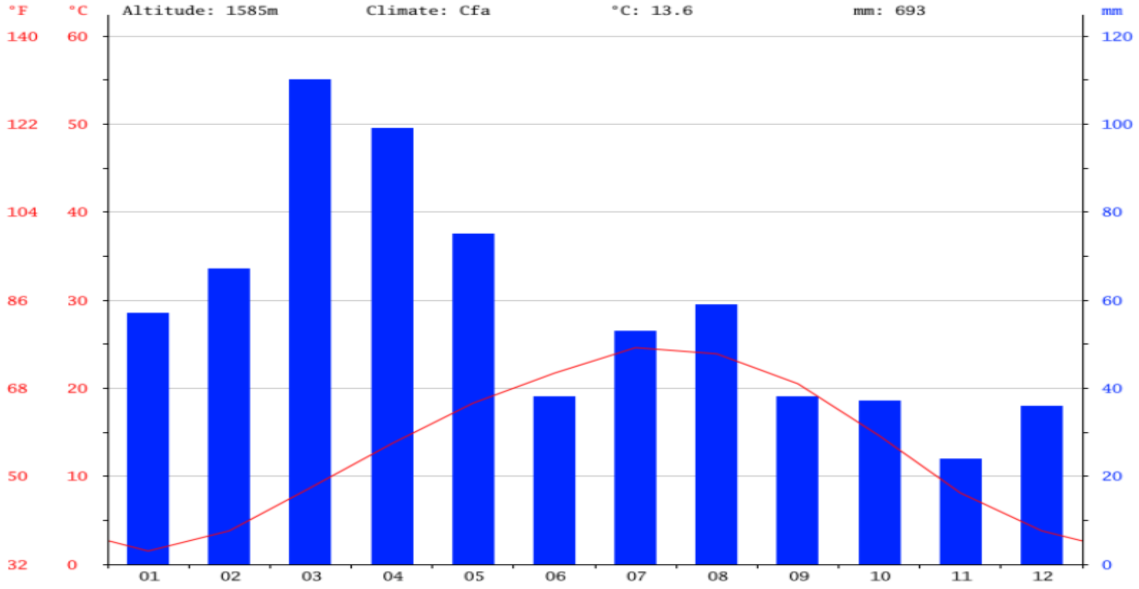


Figure 12 Monthly Mean Precipitation and Temperature for Srinagar (Source: IMD)

4.3 Precipitation Data and Analysis

The analysis if precipitation data during Task 1 has been limited as a result of the data acquisition procedure of IMD which requires official requests and payment for data. It has not been possible to obtain the long period data required for analysis until this data request has been finalised.

Figure 13 shows the location of rain and snow gauges in the Jhelum River catchment.

4.3.1 Precipitation Data

Until the long term data are obtained from IMD, the analysis has been based on the following:

- Monthly rainfalls at Srinagar, Qazigund, Pahalgam and Kokernag for the period 1980 to 2017 provided by the Srinagar office of IMD; and
- Daily rainfall at Srinagar, Anantnag and Baramulla for the period 1901-1970 from the KNLI Climate Explorer website.

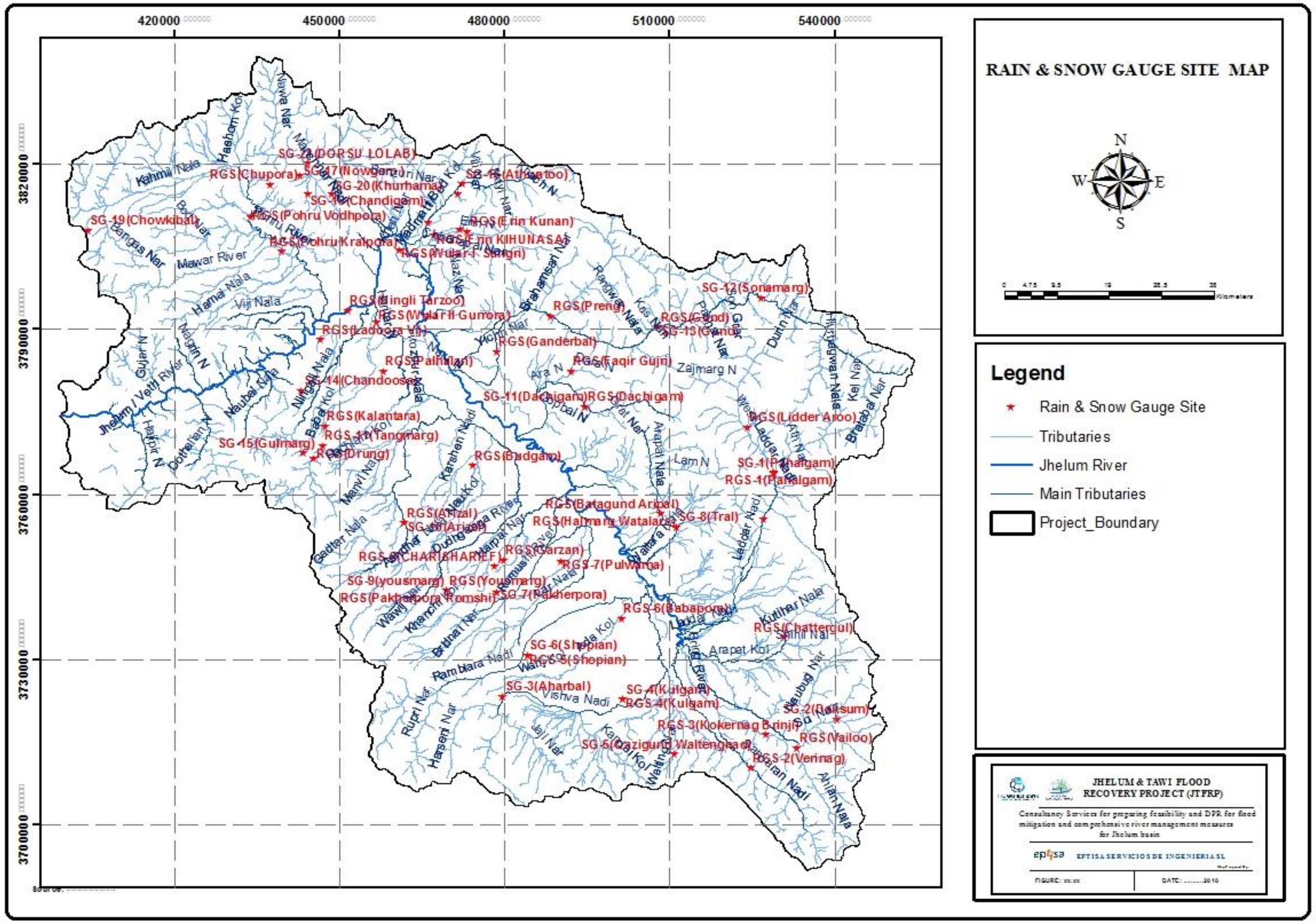


Figure 13 *Rain and Snow Gauges in Jhelum River Catchment*

4.3.2 Daily Rainfalls

Daily rainfall for Srinagar, Anantnag and Baramulla over the period 1901 to 1970 are shown in **Figure 14**. These show maximum 1-day rainfalls of 148mm at Srinagar (in 1930), 149mm at Anantnag (in 1928) and 148mm at Baramulla (in 1930).

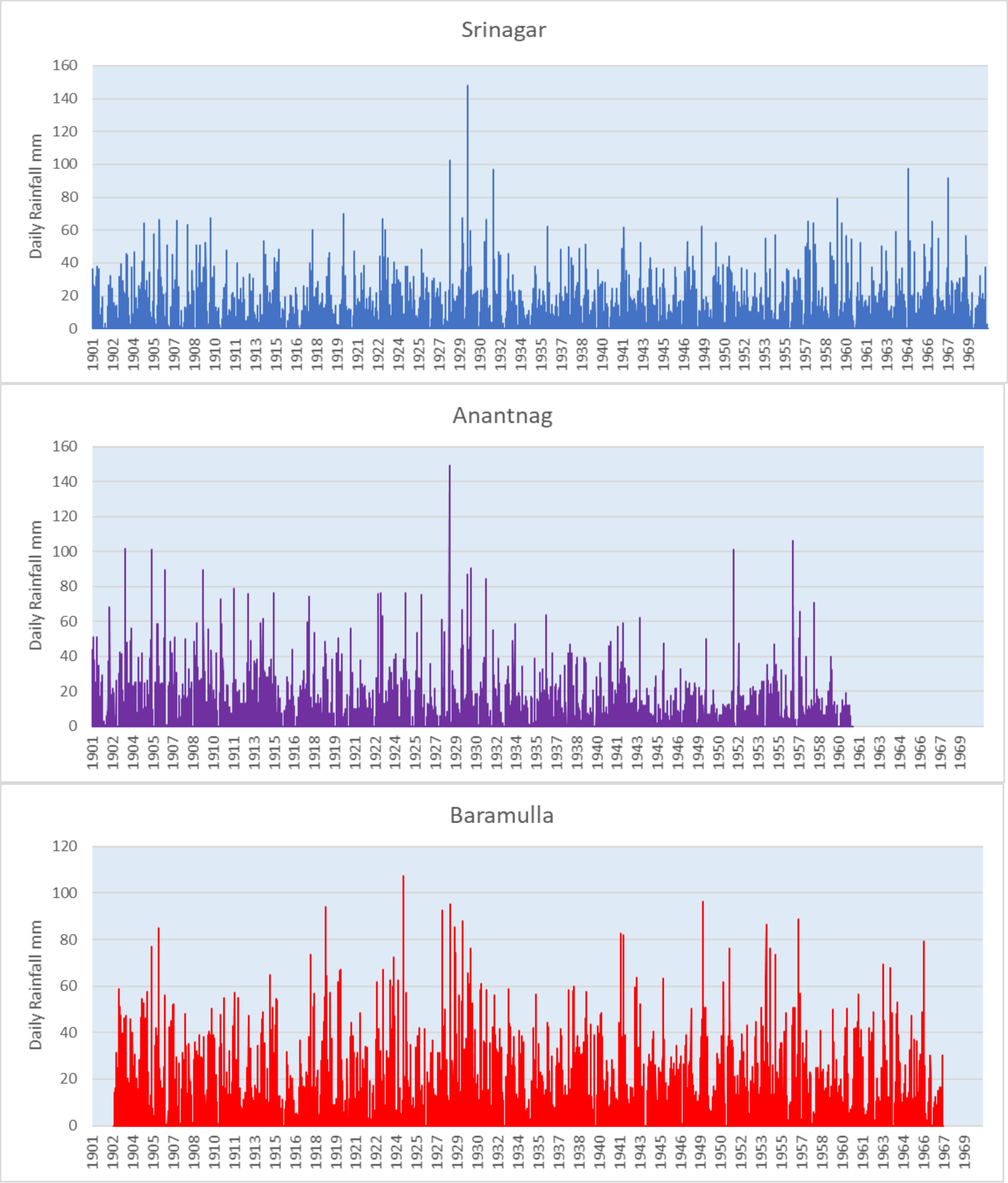


Figure 14 Daily Rainfalls 1901-1970

Figure 15 shows mass curves of these rainfall records: the mass curve is a graph of cumulative rainfall over time and should present as approximately straight apart from perturbances from very dry and very wet periods. Non-straightness or change in slope of the graph indicates time variance or trend in the data. It can be seen from **Figure 15** that whilst the graphs for Srinagar and Baramulla rainfalls are essentially straight, that for Anantnag shows a significant decrease in slope around 1914 and around 1942. This change could be real, although it is more likely to be due to changes in equipment, observer practice or exposure. For example, gradual change could suggest that trees growing near the gauge have shielded the gauge leading it to under-record, and that the under recording has worsened as the trees have grown. Also, as this trend is not apparent in the other data, it is unlikely to be real. Whatever the reason, these long-term records for Anantnag are not reliable.

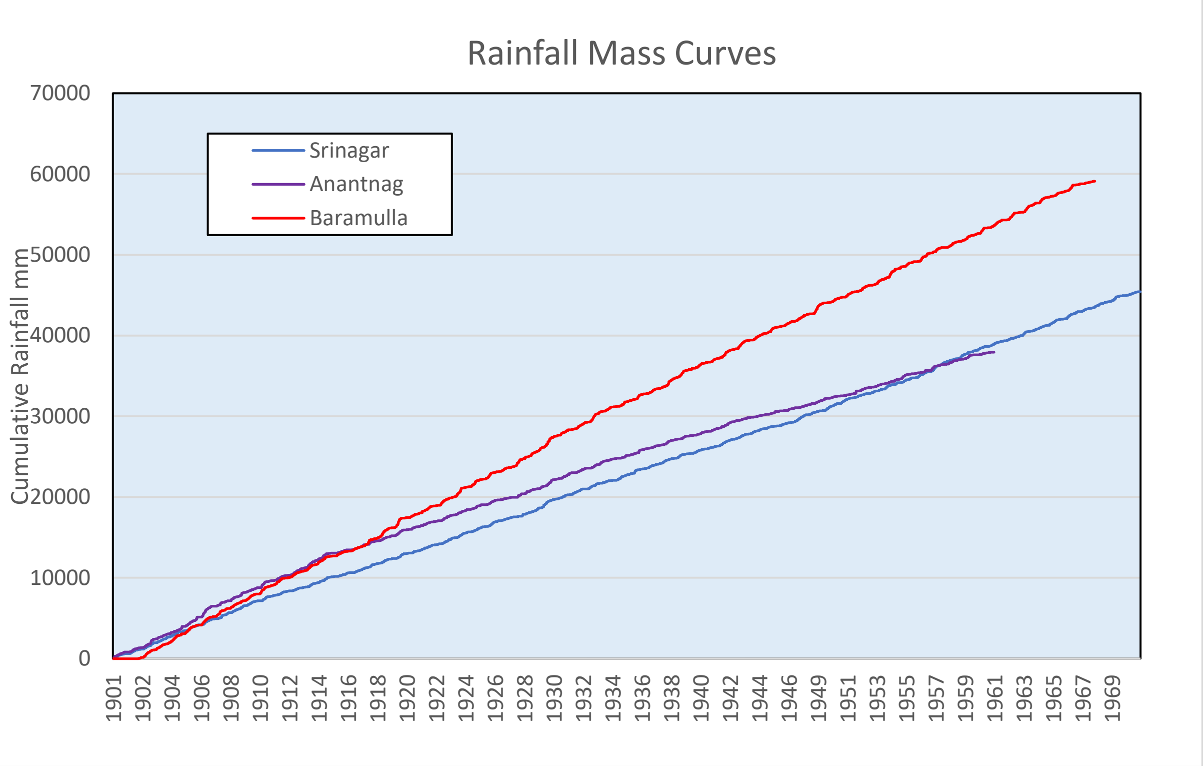


Figure 15 Rainfall Mass Curves

4.3.3 Rainfall Frequency Analysis

Frequency analysis was carried out for the 1-day and 5-day annual maxima for the long term records for Srinagar, Anantnag and Baramulla. As the *Log-Pearson Type 3* (LP3) distribution was used for the streamflow analysis (**Section 4.4.3** refers), this was also adopted for the rainfall frequency analysis.

The 1-day and 5-day frequency curves for these rainfalls are given in **Figures 16** to **18**.

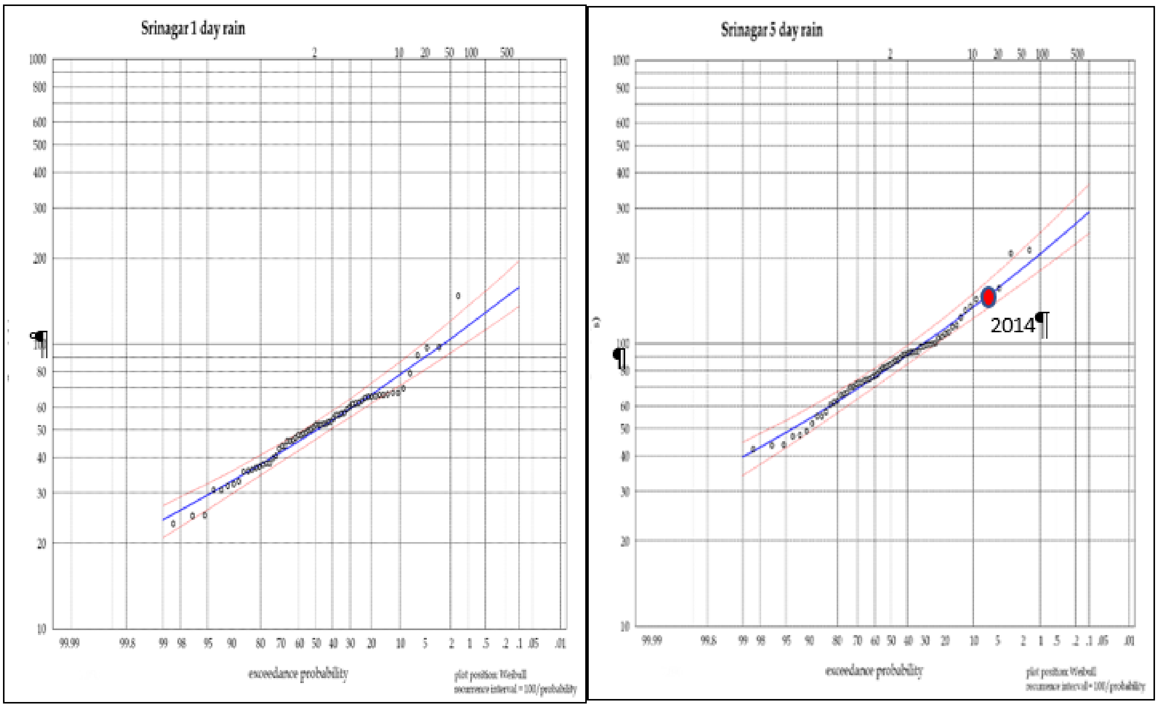


Figure 16 Frequency Curves for 1-day and 5-day Annual Maximum Rainfall – Srinagar

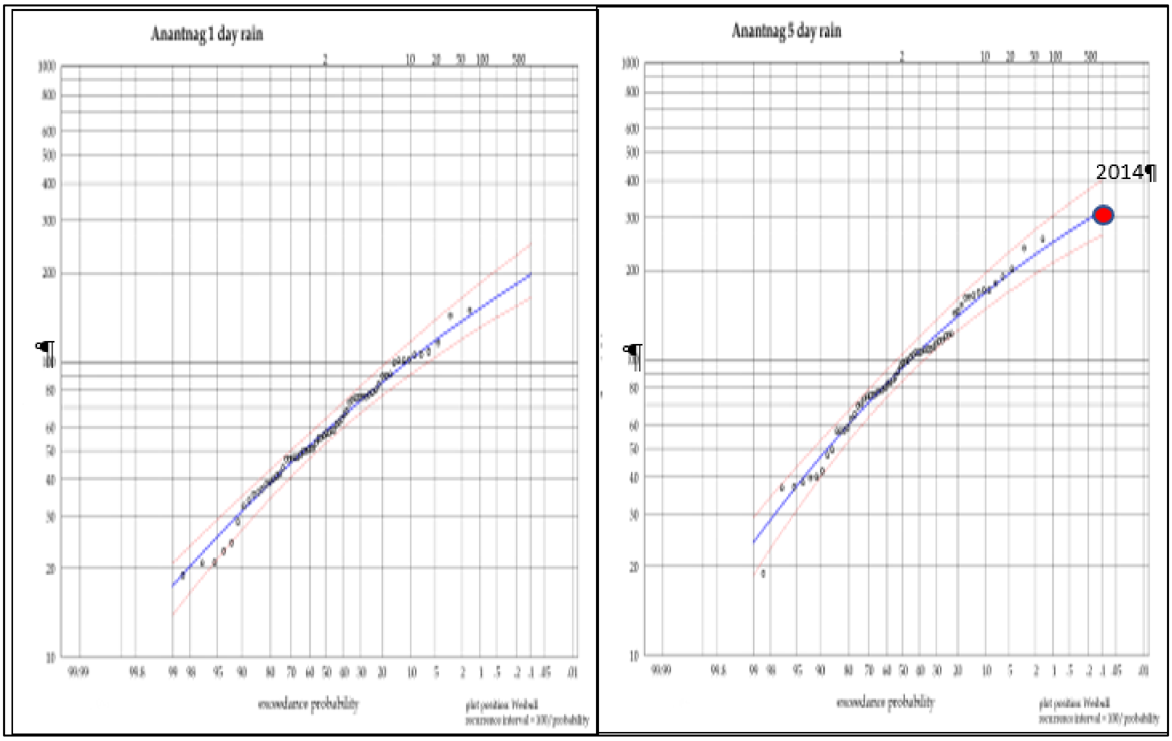


Figure 17 Frequency Curves for 1-day and 5-day Annual Maximum Rainfall - Anantnag

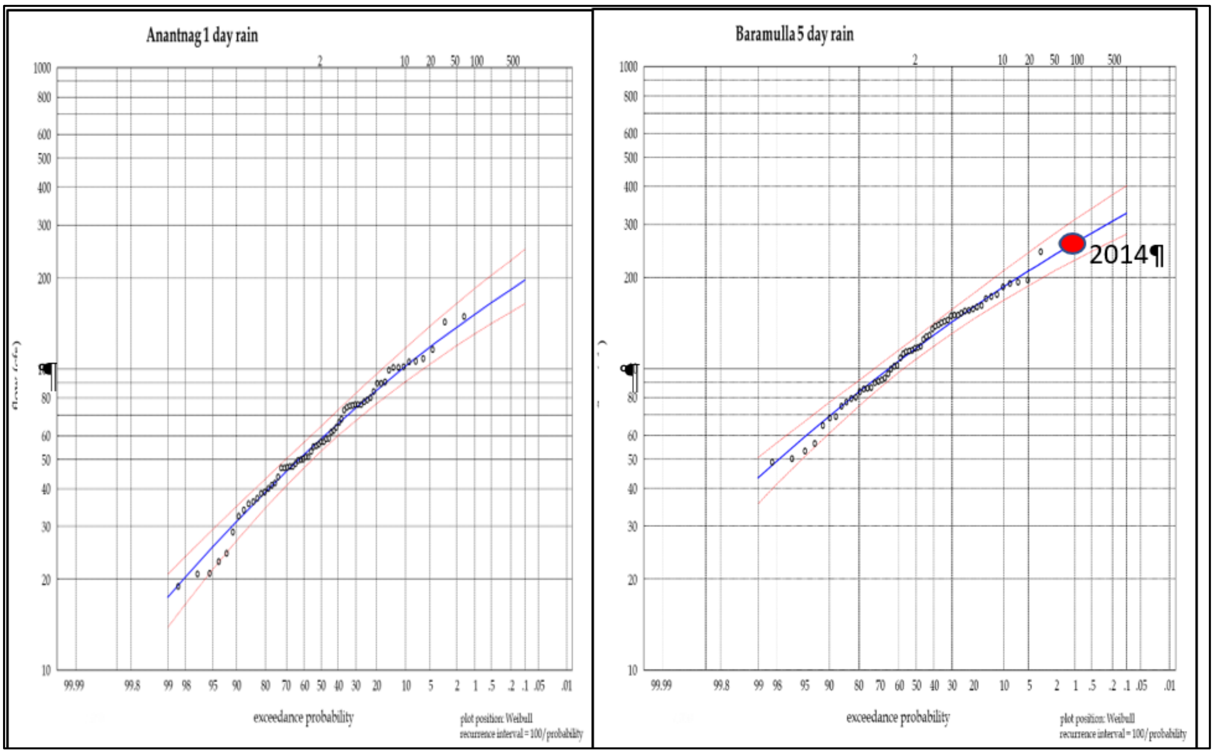


Figure 18 Frequency Curves for 1-day and 5-day Annual Maximum Rainfall – Baramulla

Table 8 summarises the outcome of the rainfall frequency analysis and also shows the approximate probability of the 5-day rainfalls for 2014 at the various locations from the fitted distribution. On this basis, the 2014 event was about 6.6% AEP (15 year ARI) at Srinagar, 1.25% AEP (80 year ARI) at Baramulla and 0.14% (700 year ARI) at Anantnag. As discussed in **Section 4.3.2**, the Anantnag daily rainfall data are unreliable, but even so this points to a rare rainfall total around Anantnag.

Table 8 Summary of 1-day and 3-day rainfall frequencies

Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI) Years	Srinagar		Anantnag		Baramulla	
		1 day max (mm)	5 day max (mm)	1 day max (mm)	5 day max (mm)	1 day max (mm)	5 day max (mm)
0.1	1000	159	291	197	317	197	327
0.2	500	145	264	184	297	184	308
0.5	200	128	231	166	270	166	281
1	100	116	207	152	249	152	261
2	50	105	184	138	226	138	240
4	25	93	162	123	202	123	217
5	20	89	155	118	194	118	210
10	10	78	134	102	168	102	186
2014			148		309		256
			15yr		700 yr		80yr
			6.60%		0.14%		1.25%

4.4 Streamflow Data and Analysis

4.4.1 Streamflow Data

IFCK has a well established network of river level and discharge measurement gauges on the Jhelum River and its tributaries, as shown in **Figure 19.**

IFCK has provided the following streamflow data**:**

- Annual maximum discharge and stage data for Jhelum River main stream stations at Khanbal, Sangam, Awantipora, Pampore, Padshahi Bagh, Munshi Bagh, Shadipora, Asham, Sopore and Baramulla for the period 1955-2017;
- Annual maximum discharge and stage data for the following Jhelum River tributaries: Aripal, Aripath, (2 stations) Aroo, Bringi (2), Dachigam (2), Dakil, Dangawari, Doodganga (2), Erin, Ferezpora (3), Gogaldara, Hamal (2), Kamil, Liddar (6),Lolab (2), Madhumati, Ningli, Pohru (3), Rambi Ara, Romshi Tail, Sandran (2), Shali, Sheshnag, Sindh (3), Sukhnag (4), Tailbag, Taller, Vethvethroo (2), Vij, Vishow and Watalara Nallahs for the period 1961-2017;
- Daily stage level at Sangam, Ram Munshi Bagh and Asham 2008 -2018;
- Daily water level at Wular Lake outlet 2000-2007
- Rating curves for Jhelum River sites Sangam, Munshi Bagh, Asham and Sopore;
- Bridge cross-sections: and
- Map showing locations of gauging sites, bridges and river distances.

This preliminary report is based on analysis of the above data only. Long term daily flow data are required for further analysis, such as trend analysis and data consistency analysis and these will be conducted during Tasks 3 and 4 of **Part A** if such data are available.

Although stage-discharge rating curves have been provided, these have not yet been reviewed as the individual gauging records have not yet been made available. We understand that until 2015 gaugings were made by float measurement, and that since 2015 when two *acoustic doppler current profilers* (ACDPs) this new equipment has bene used at two sites only. Float measurements of discharge require adjustment from surface velocity to average velocity and knowledge of the channel cross-section. As the latter has been measured infrequently, detailed review of the flow estimation needs to be made to establish the reliability of the discharge calculations. This will be done as part of Task 2.

As the daily records have been provided in stage form only, there has not been time in Task 1 to convert these into discharge records, and hence to conduct any form of trend and consistency analysis. This will be undertaken as part of Task 2.

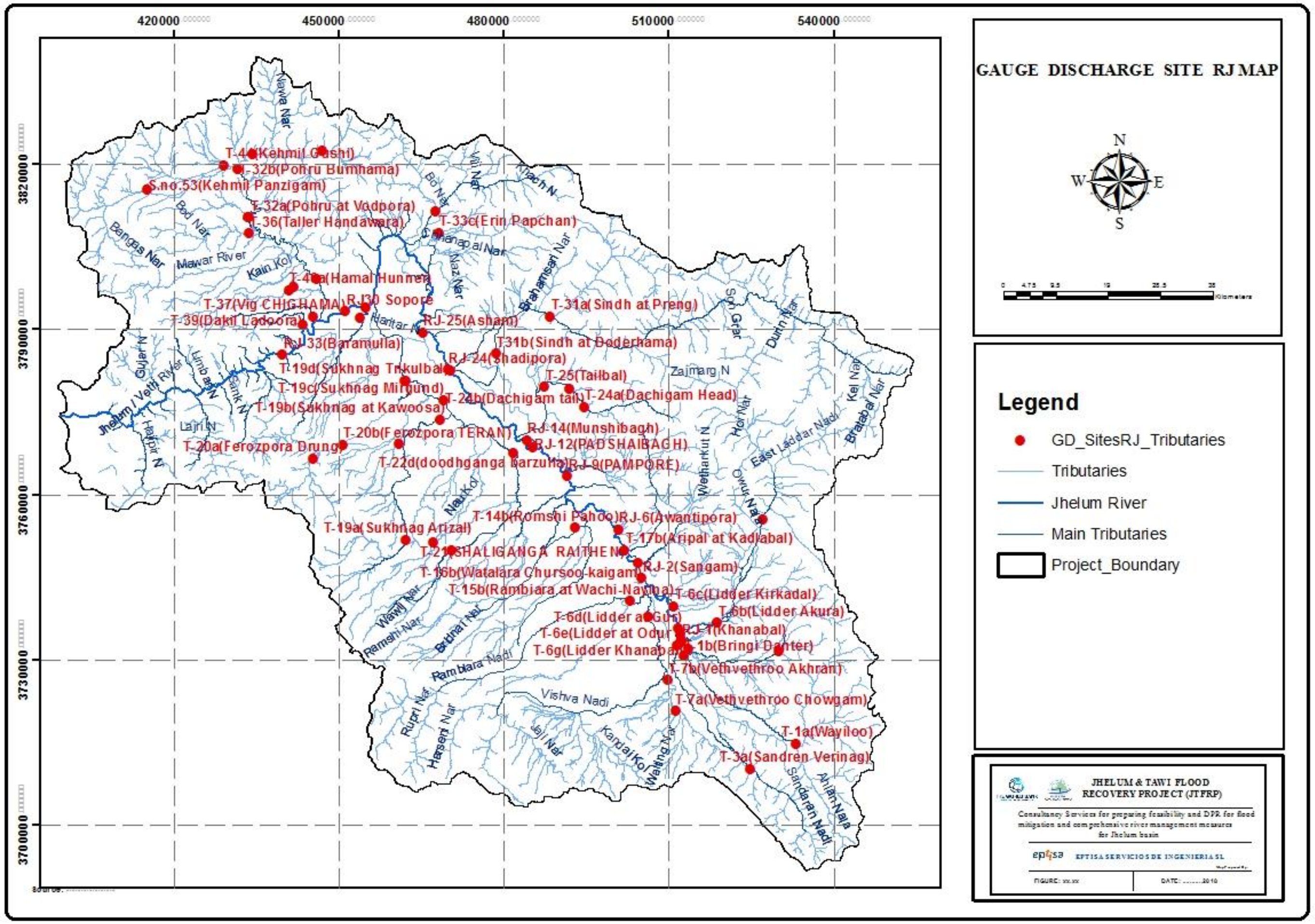


Figure 19 Flow Measuring Stations Jhelum River and Tributaries

4.4.2 Daily Water Level Records

As stated in **Section 4.4.1**, daily data have been provided only in terms of mean daily stage, and conversion of these records to flows will be undertaken in Task 2 once the stage-discharge relationships have been reviewed.

Figure 20 shows daily stage from January 2008 to July 2018 at Sangam, Munshi Bagh and Asham. It can be seen from **Figure 20** that the minimum stage at Sangam reduced significantly between 2009 and 2014, and then more slowly since 2014. At Munshi Bagh, there has been a slight increase in minimum level over this period and none at Asham. This indicates that the river bed at Sangam was being eroded quite rapidly over 2009-2014, at an average rate of approximately 1m per annum, and about 0.25m per annum since 2014.

This could be a result of the sand mining which occurs along the river, but this high rate suggests that this may be due to a head cut moving upstream, which could have been initiated by the sand mining further downstream. The reduction in erosion rate since 2014 could be due to the head cut having passed upstream of Sangam, or the result of the large sediment inflow during the 2014 flood, or a combination of the two.

4.4.3 Flood Frequency Analysis

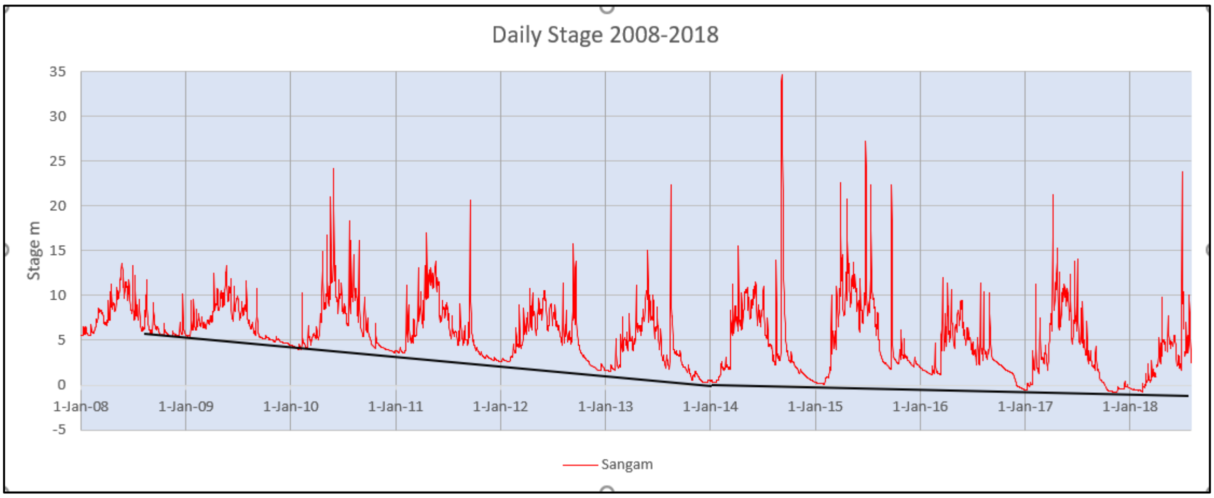
The preliminary analysis has concentrated on flood frequency analysis (FFA) of the annual maximum series of daily flows for the Jhelum River and major tributaries, which is important in developing the relative contributions of the major tributaries to flood flows, in a statistical sense.

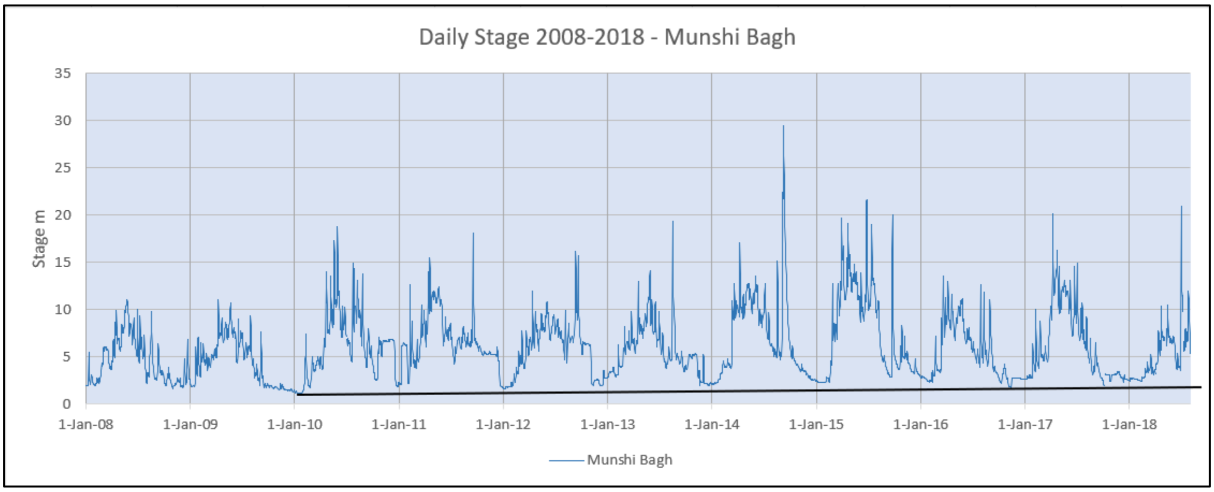
It should be noted that this analysis is based on peak daily flows and not peak instantaneous flows which will be higher, particularly in the tributaries.

a) Jhelum River

Annual maximum series were extracted from the spreadsheets provided by IFCK for Jhelum River stations. These records are generally for the period 1956 to 2017, a total of 62 years. These are shown in **Figure 21** and **Figure 22** for locations upstream and downstream of Srinagar respectively.

There is clear difference in the annual maximum series of the Jhelum River flow measurement stations upstream of Srinagar and those downstream: upstream of Srinagar the 2014 flood is the highest on record (with the exception of Awantipora where the 1992 flood was higher); but downstream of Srinagar, this is not the case; and downstream of Wular Lake, there are several floods larger than that of 2014. As noted in **Sections 2.4** and **3.4**, this demonstrates that the major problem is upstream of Srinagar.





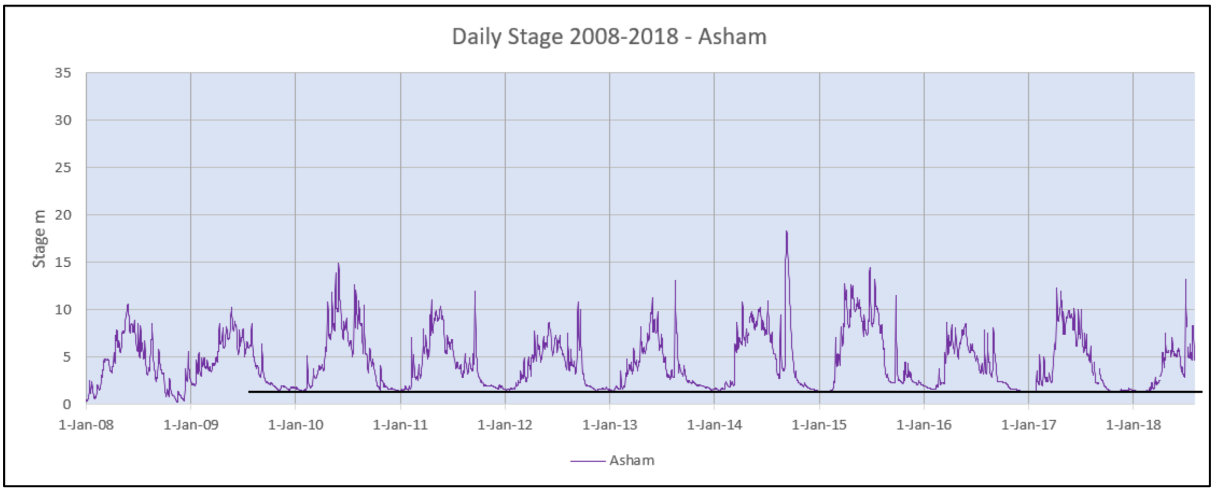


Figure 20 Daily Stage 2008-2018 – Jhelum River at Selected Gauging Stations

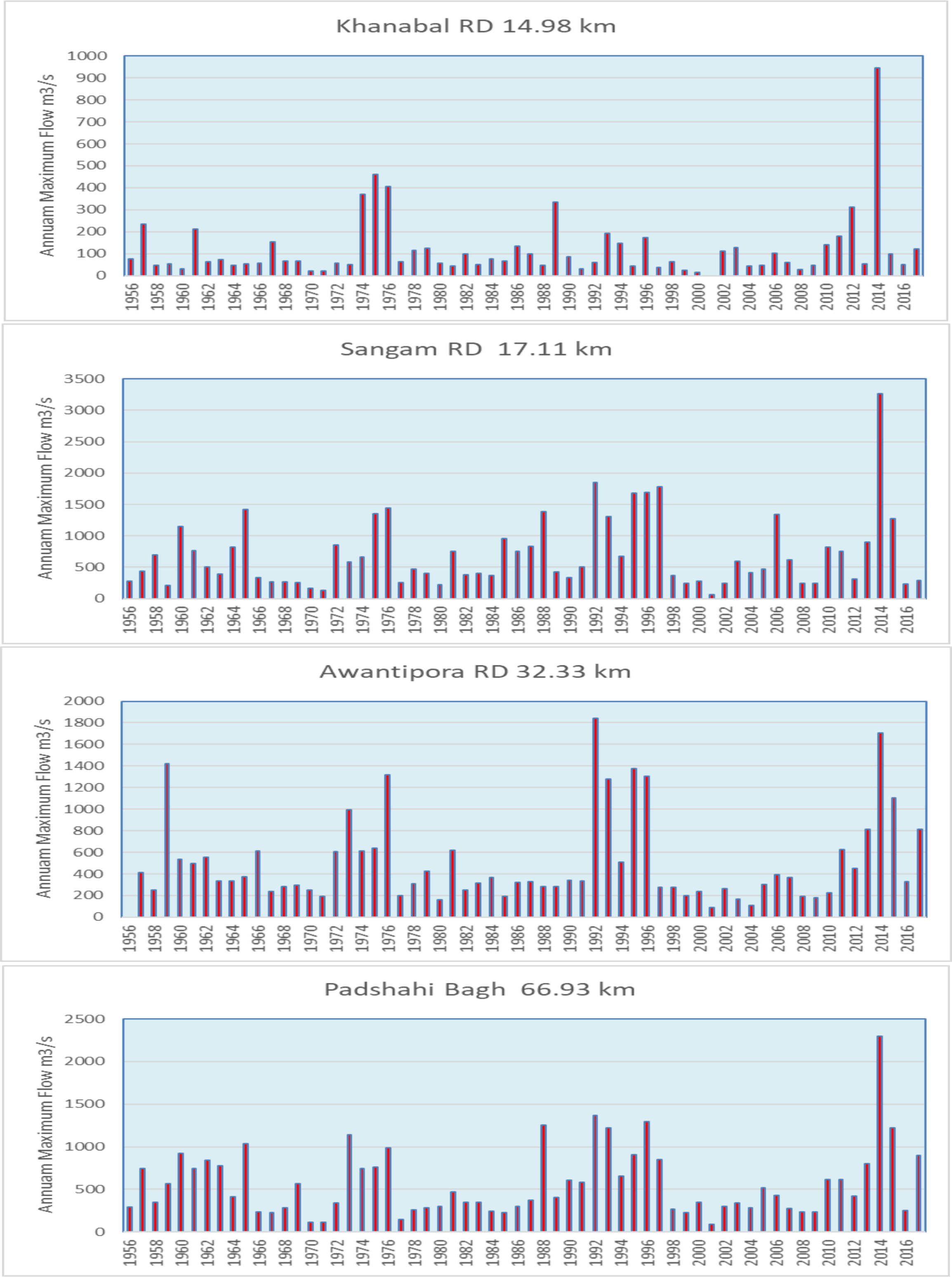


Figure 21 Annual Maximum Series of Daily Flows - Jhelum River upstream of Srinagar

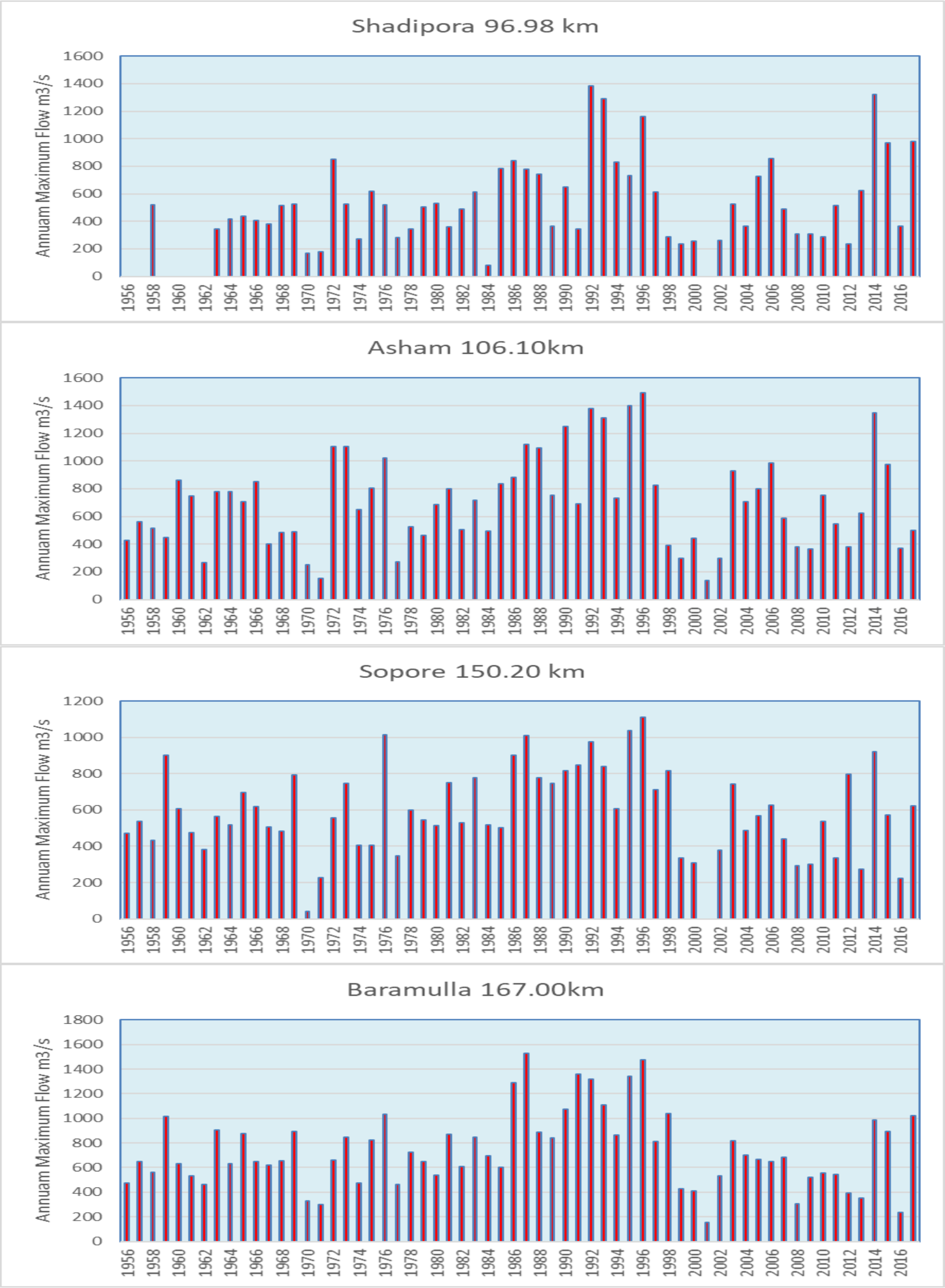


Figure 22 Annual Maximum Series of Daily Flows - Jhelum River downstream of Srinagar

Flood frequency analysis was carried out on these series. **Figure 23** shows the outcome of an L-moment (linear moments) analysis (Hosking & Wallis 2005). This is a relatively new statistical technique which provides improved distribution fitting and also indicates the most appropriate distribution for analysis. The L-Moment diagram (L-skewness vs L-kurtosis) for the Jhelum River gauging stations is given in **Figure 23.**

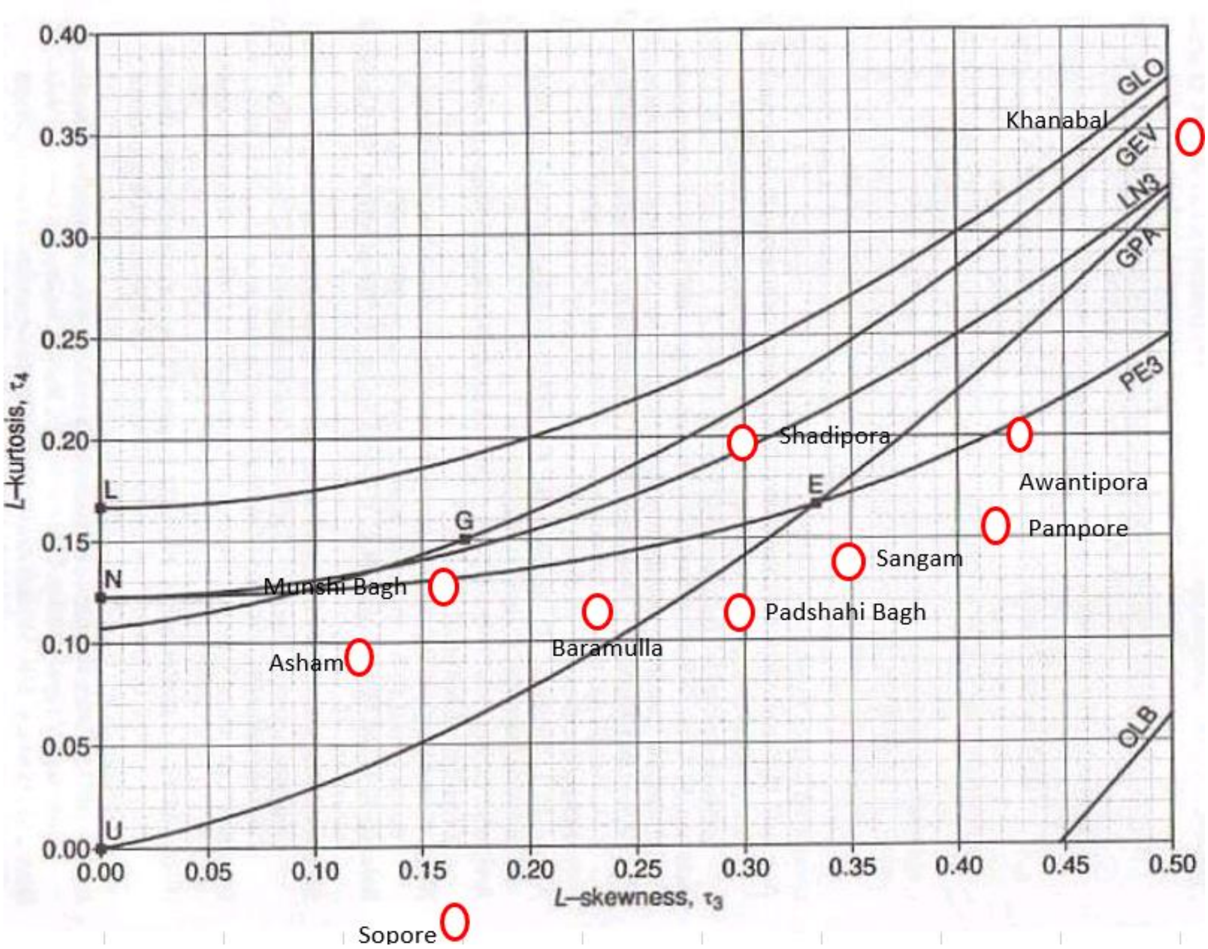


Figure 23 L-Moment Diagram

Although there is considerable scatter, most of these points are clustered around the PE3 line indicating that the *Log-Pearson Type 3* (LP3) distribution is expected to give the best fit.

Individual flood frequency curves for the Jhelum River gauging stations are given in **Figure 24** and **Figure 25**.

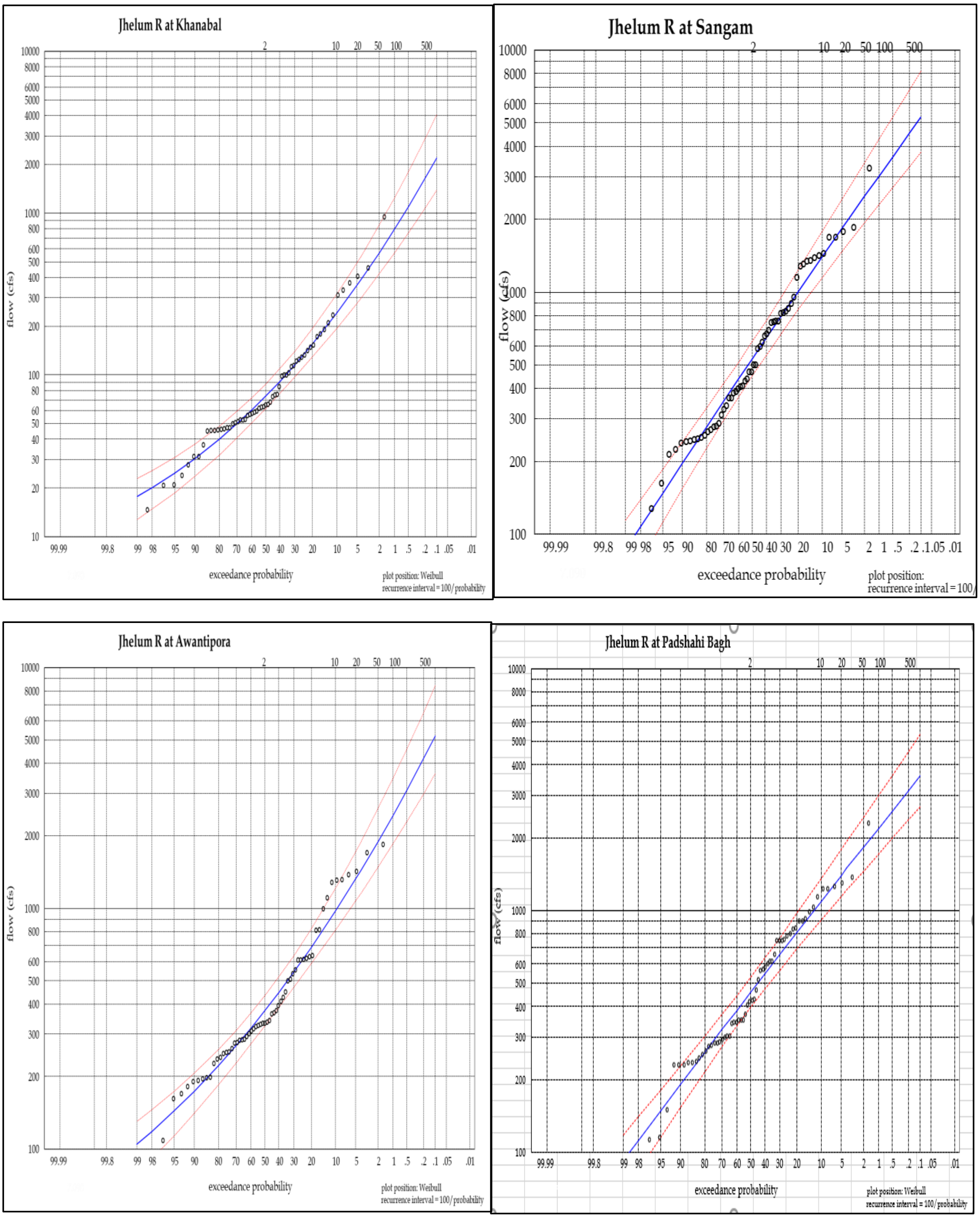


Figure 24 *Flood Frequency Curves for Jhelum River Stations upstream of Srinagar*

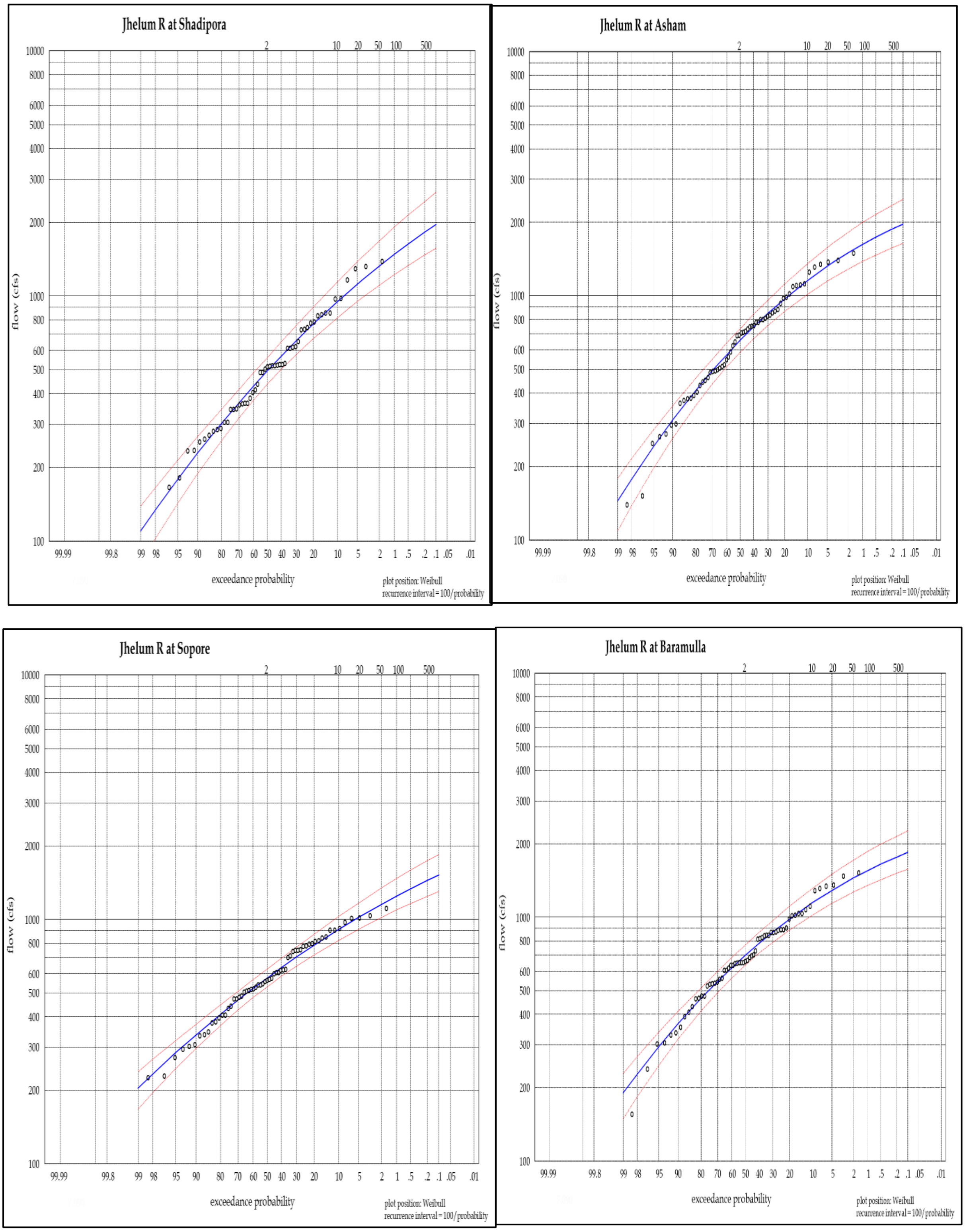


Figure 25 *Flood Frequency Curves for Jhelum River Stations downstream of Srinagar*

Again, there is a clear distinction in the frequency curves for gauging stations upstream and downstream of Srinagar. The curves for locations upstream of Srinagar show a positive or near zero skewness which is shown in the frequency curves (in log-probability space) as being concave upwards or straight respectively – indicating that there is no upper bound. In contrast, the curves for locations downstream all have strongly negative skewness, showing as being convex upwards, indicating that the distribution has an upper bound.

Figure 24 and **Figure 25** also show the 5% and 95% confidence limits of the fitted distribution, (90% chance that the true value lines between these lines). With the exception of Awantipora, the 2014 value for the locations upstream of Srinagar lies within, but close, to the upper confidence line, indicating it is unusually high.

Table 9 summarises the fitted probability relationships for the Jhelum River gauging stations.

Table 9 Estimated Flood Probabilities - Jhelum River

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years	Maximum 1 day flow (m^3/s)								
		Khanabal	Samgam	Awantipora	Padsashi Bagh	Munshi Bagh	Shadipora	Asham	Sopore	Baramulla
0.1	1000	2,191	5,273	5,195	3,607	2,170	1,964	1,967	1,519	1,847
0.2	500	1,633	4,525	4,180	3,139	2,049	1,824	1,875	1,441	1,768
0.5	200	1,092	3,634	3,097	2,573	1,876	1,633	1,741	1,331	1,653
1	100	795	3,030	2,438	2,183	1,734	1,484	1,629	1,244	1,556
2	50	570	2,481	1,894	1,823	1,581	1,330	1,505	1,151	1,450
4	25	400	1,984	1,446	1,490	1,414	1,171	1,367	1,053	1,331
5	20	356	1,835	1,319	1,389	1,357	1,119	1,320	1,019	1,289
10	10	241	1,401	973	1,090	1,169	950	1,159	908	1,149

Table 10 shows the probability of the 2014 flood at the various locations from the fitted distribution. Apart from Awantipora and Munshi Bagh, which appear to give an anomalous value, this table clearly shows the reducing probability of the 2014 flood in a downstream direction.

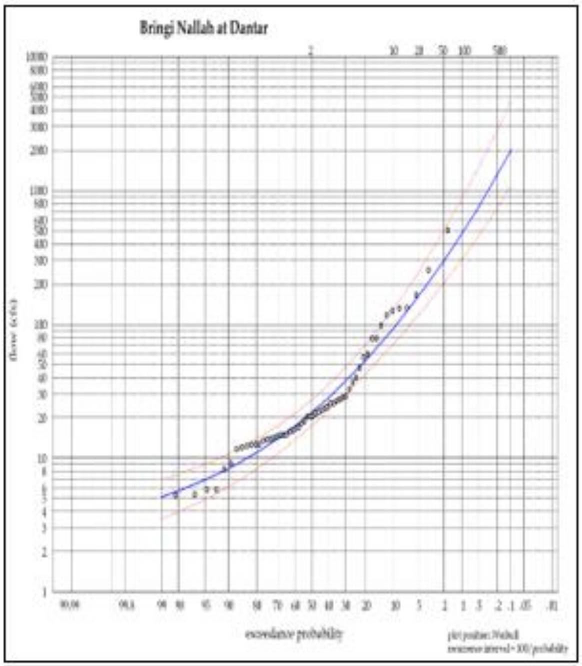
Table 10 Indicated Probability of 2014 Flood – Jhelum River

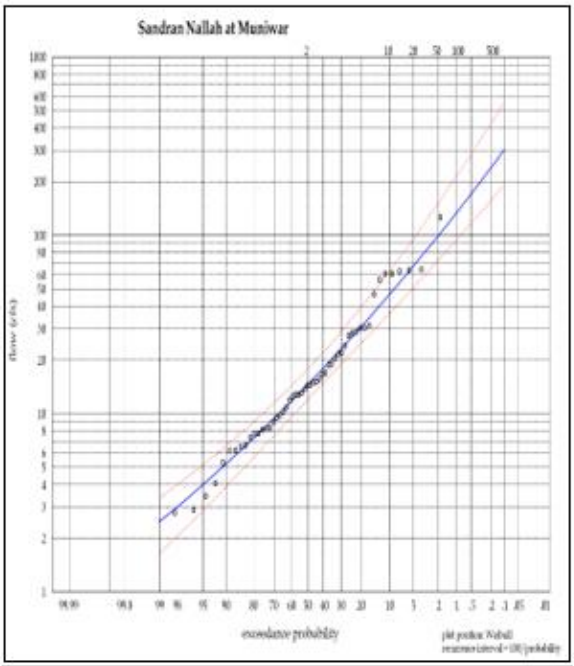
Location	Peak flow (m_3/s)	Estimated Average Recurrence Interval (ARI) (Years)	Estimated Annual Exceedance Probability (AEP) %
Khanabal	944	137	0.8
Sangam	3263	125	0.73
Awantipora	1703	37	2.7
Padshahi Bagh	2299	120	0.83
Munshi Bagh	2055	500	0.2
Shadipora	1321	48	2.08
Asham	1348	23	2.35
Sopore	921	10	10
Baramulla	984	5	20

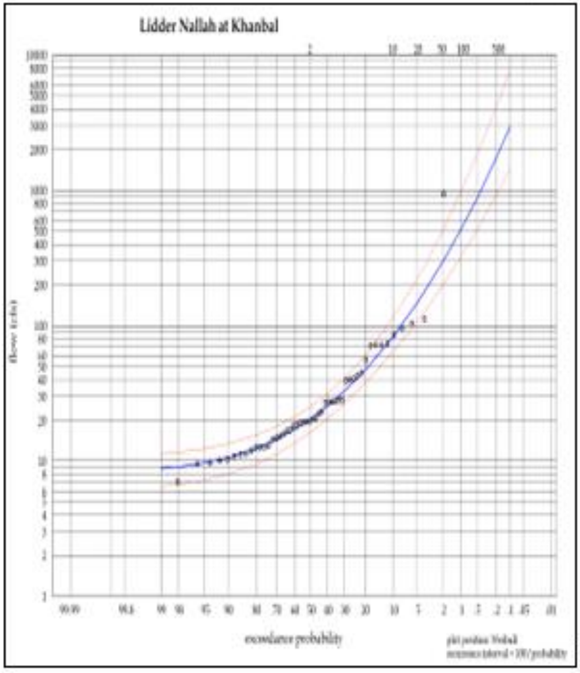
On all of the above measures, it is clear that the flood was a rare, but not extreme, event in the Jhelum River upstream of Srinagar, but an increasing frequent flood further downstream.

b) Tributaries

A similar flood frequency analysis was undertaken for the annual maxima series of the major tributaries. The resulting flood frequency curves are given in







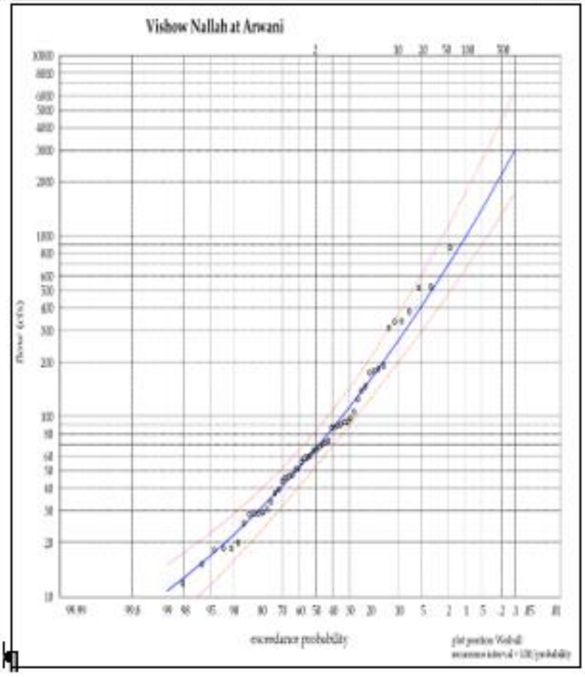
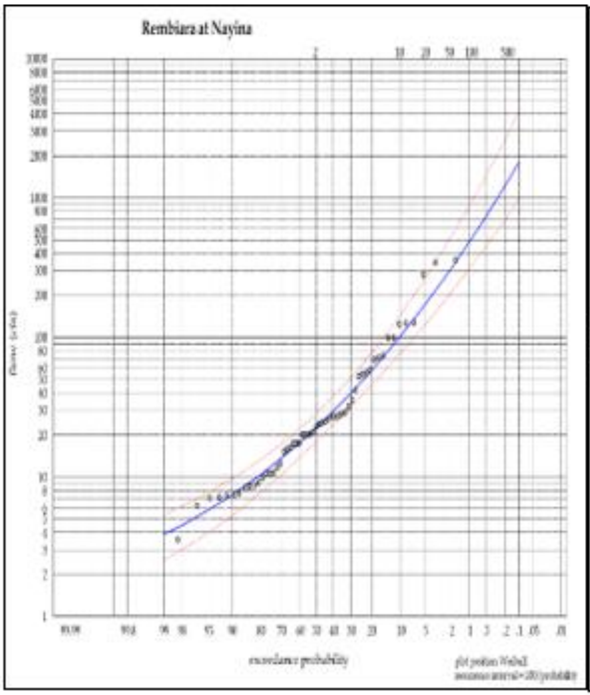
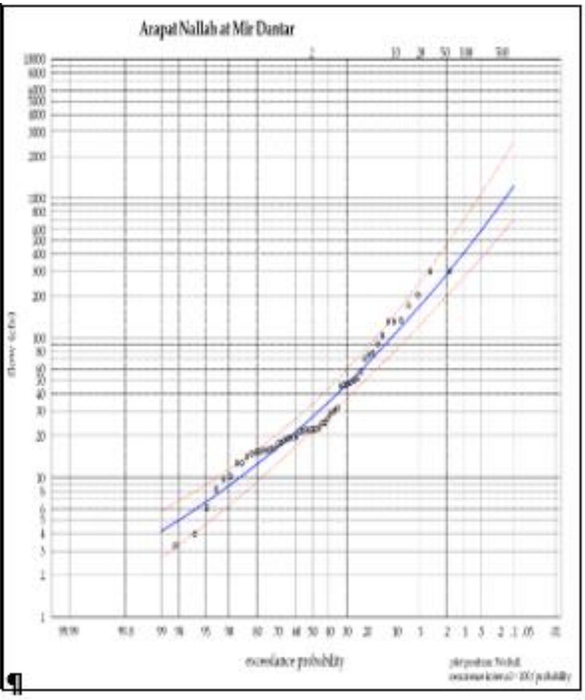
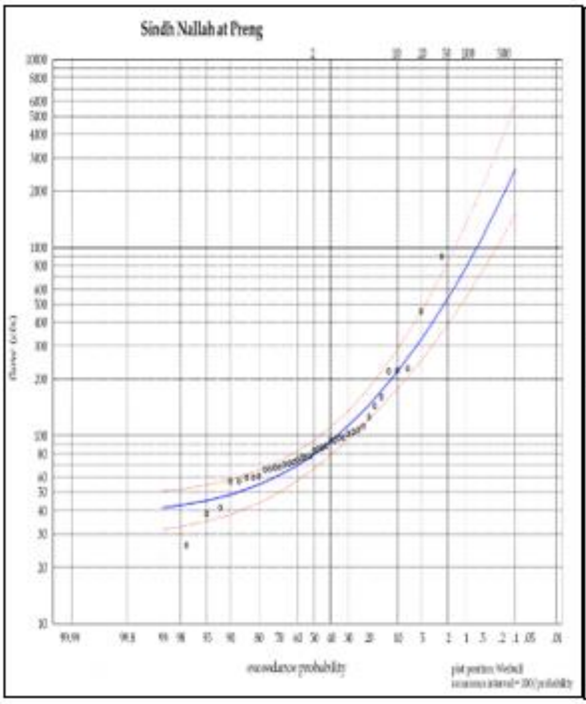


Figure 26 and







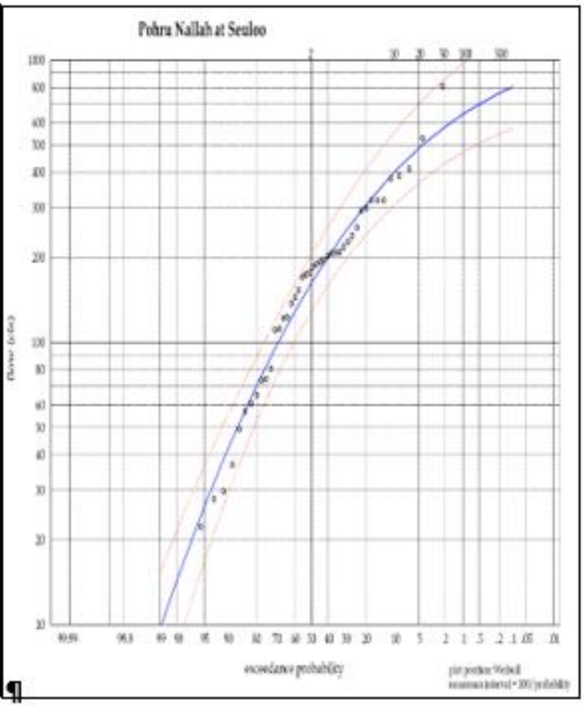


Figure 27, and results are summarised in

Table 11.

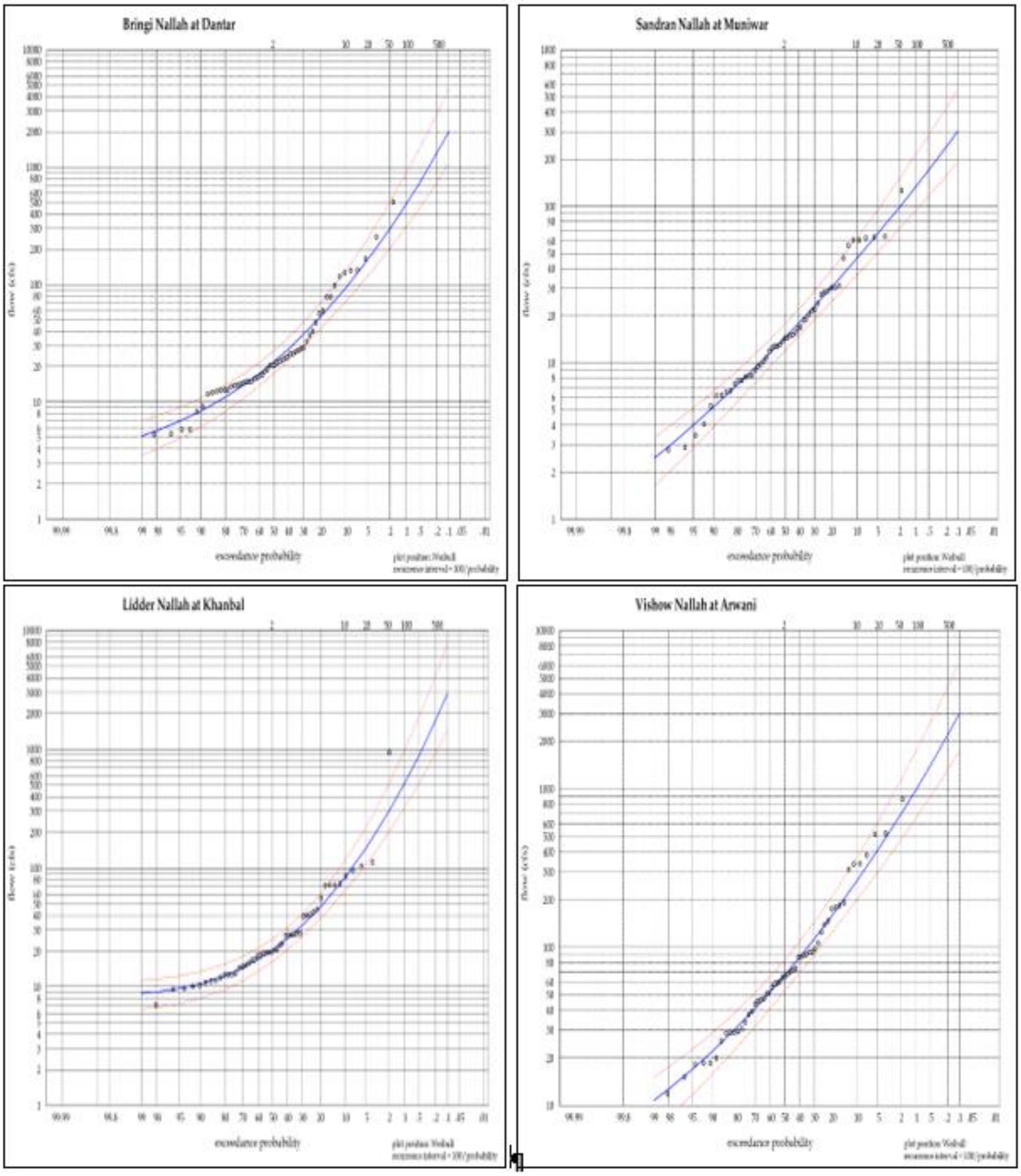


Figure 26 Flood Frequency Curves for Major Tributaries -1

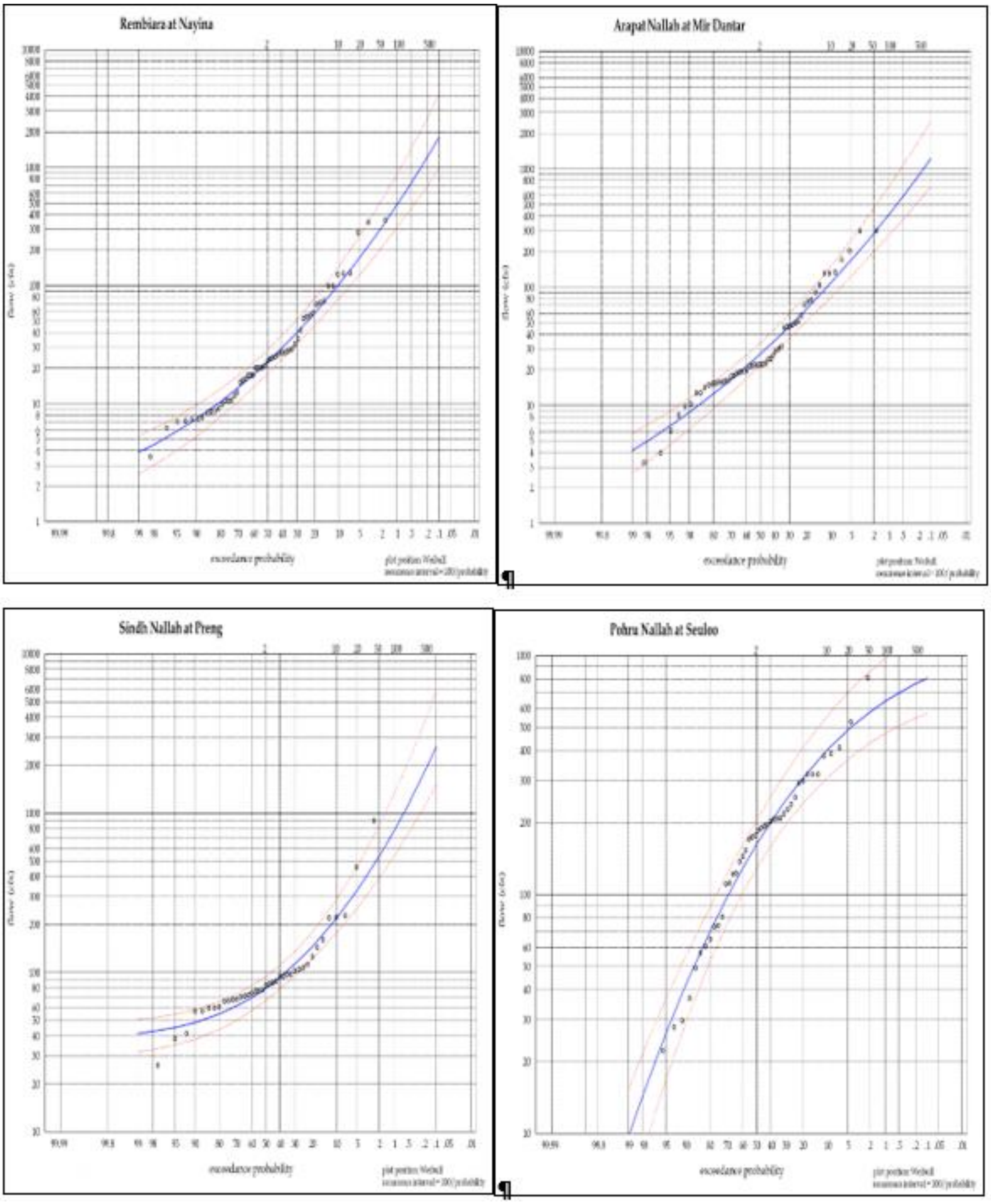


Figure 27 Flood Frequency Curves for Major Tributaries -2

Table 11 Summary of Flood Frequency Curves for Major Tributaries

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years	Maximum 1 day flow (m^3/s)							
		Bringi at Dantar	Lidder at Khanbal	Sandran at Muniwar	Vishow at Arwani	Rambiari at Nayina	Arapat at Dantar	Sindh at Preng	Pohru at Seuloo
0.1	1000	2,025	2,623	302	1,831	1,831	1,226	2,623	803
0.2	500	1,328	1,827	239	1,244	1,244	896	1,827	762
0.5	200	750	1,128	172	734	734	581	1,128	699
1	100	480	780	132	484	484	411	780	644
2	50	303	536	100	313	313	285	536	582
4	25	188	366	73	198	198	193	366	511
5	20	160	323	66	170	170	169	323	486
10	10	95	218	46	102	102	109	218	403
2014		506	944	298	866	356	300	896	239
ARI Years		106	200	900	70	60	50	120	3
AEP %		0.90%	0.50%	0.10%	1.40%	1.70%	2.00%	0.80%	32%

Table 11 also shows the estimated probability of the September 2014 peak flow in the major tributaries. In terms of actual flows the largest flows were from the Lidder Nallah and Vishow Nallah, but in terms of probabilities, the most extreme was the Sandran Nallah in which the flow was approaching the 0.1% (1,000 year) event. The Lidder, Bringi and Sindh Nallahs all had flows in excess of the 1% AEP (100 year ARI) with the Lidder being at 0.5% (200 year ARI).

These results are consistent with those from the rainfall frequency analysis and the frequency analysis for the Jhelum River flows, all of which indicate that the most extreme events occurred in the southern tributaries all of which feed into the Jhelum in its upstream reaches around Sangam.

5 Preliminary Morphology Report

The 1:25,000 scale preliminary morphology maps of the Jhelum river floodplain have been prepared at A2 size (40 sheets) and have been printed separately, as **Volume 2** of this report.

5.1 Spatial Geomorphologic and Geologic Data

The Jhelum River lies within the Kashmir Valley; which consists of a large open valley between the Great Himalayan and Pir Panjal Mountain Ranges and was a former lake in previous geologic times. The Valley geomorphology consists of a deep, wide alluvial valley, confined by mountain Ranges on all sides, with a single outlet through a rift in the mountain range bordering the north-west end of the Kashmir Valley; where the Jhelum River exits the Kashmir Valley. The upper catchment areas in the south-eastern, eastern and north-eastern portions of the Kashmir Valley are characterized by steep slopes with highly erodible features in some sub-catchment areas. The western and north-western portions of the Kashmir Valley have more gradual slopes in the upper catchment areas, although are still highly erodible in some sub-catchment areas. The geomorphologic and geologic features of the Kashmir Valley are described in more detail in the next sections. **Figure 28** and **29** shows the surface geology of the Kashmir Valley, as well as a geologic cross-section through the Great Himalayan Range, the Kashmir Valley and the Pir Panjal Range.

5.1.1 Topography

The specific mountain Ranges that enclose the Kashmir Valley (**Figure 29**) are the Zanskar Range, North Kashmir Range and the Lesser Himalayas (Pir Panjal Range). The Zanskar Range runs on a southeast to northwest axis all along the northeast side of the valley. It is part of the Great Himalayan Range and before ending at Nanga Parbat, encloses the Kashmir Valley on its north, north-west, north-east and eastern sides. The North Kashmir Range forms the watershed between the Jhelum River and Kishanganga River and originates at the Zoji-La Pass, in a division of the Great Himalayan Range. The Lesser Himalaya Mountains around the northeast side of Wular Lake consist primarily of Pir Panjal and Ratan Pir Ranges.

5.1.2 Alignment of mountain Ranges:

The north-eastern, eastern and south-eastern portions of the Jhelum River Valley are bounded by high mountains of the Great Himalayan and Pir Panjal Ranges, with steep upper slopes, only decreasing as they intersect the Jhelum River Valley floor. The northern side of the Pir Panjal Range is characterized by gentle slopes along with the presence of erodible Karewa sediments, while the southern slopes are steep with lesser quantities of Karewa sediments.

Figure 28 is a geomorphologic depiction of the spatial geologic formations that exist throughout the Jhelum River Valley. The Jhelum River Valley largely consists of geologic formations from fluvial and lacustrine formations (alluvial material), due to glacial activity and floods in the past. **Figure 29** is a basic geologic cross-section of the Great Himalaya Range and the Pir Panjal Range that bound the Kashmir Valley. The Carboniferous-Triassic formation underlies the Kashmir Valley alluvial valley and outcrops of the Older Palaeozoic, Archean, Eocene and Cretaceous formations are also exposed on the north-east and eastern sides of the Kashmir Valley.

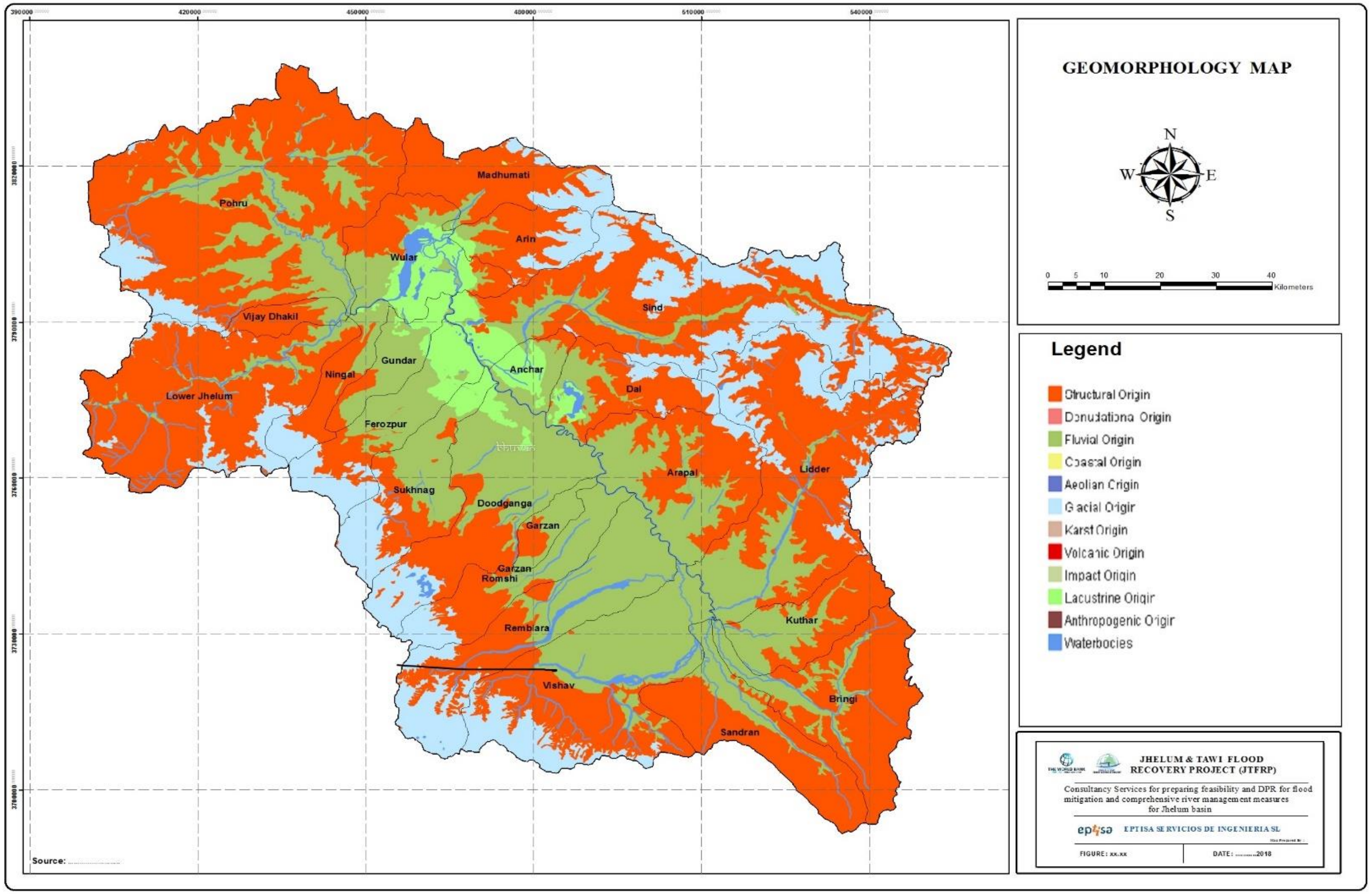


Figure 28 Geomorphologic Map of the Kashmir Valley

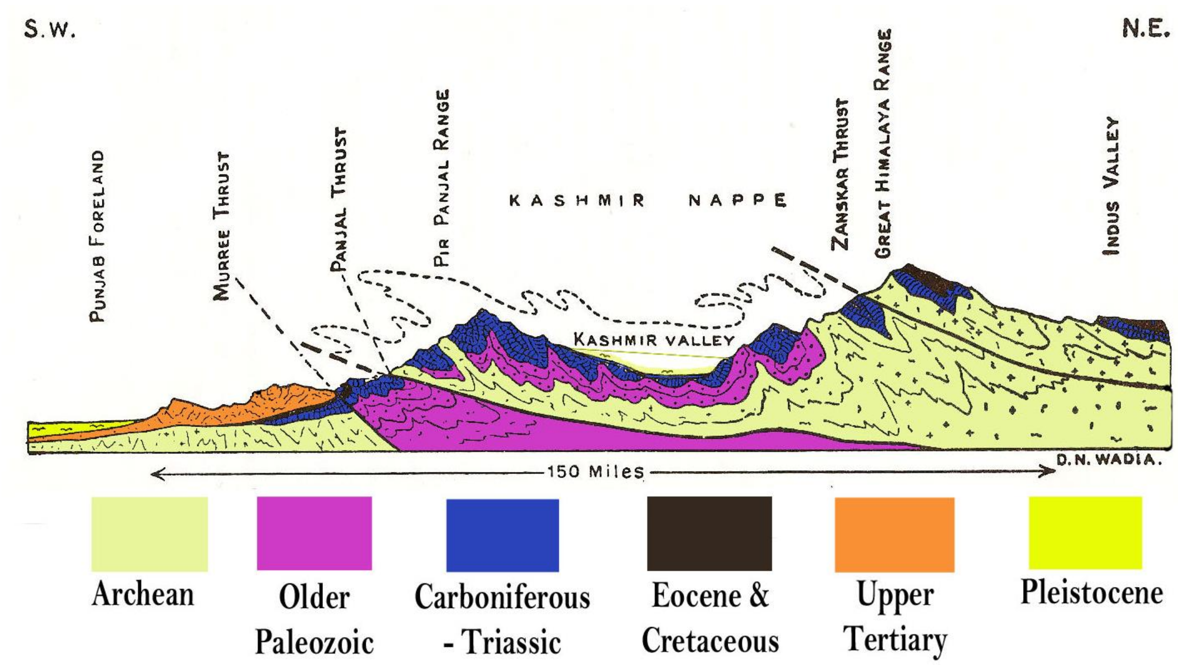


Figure 29 Geologic Cross-Section of the Kashmir Valley

The Great Himalayan Range on the north-eastern and northern side of the Kashmir Valley consists of a continuous chain of high mountains with steep slopes toward the Jhelum River Valley and more gentle slopes towards Ladakh. The upper catchment tributaries of the Jhelum River Valley have steep slopes in the higher elevations, although the channel gradients gradually decrease as they enter the Jhelum River Valley floor and their confluence with the Jhelum River. **Table 12** lists the Geological Formations of the Kashmir Valley, including localities in the Jhelum River Basin where they occur.

5.1.3 Alignment of the Jhelum River Valley and Khadanyar Gorge

Geological records and marine deposits have shown the Kashmir Valley was a huge palaeo-lake during the Pleistocene period; which drained through a rift in the mountain range downstream of Baramulla, forming the existing Outlet Channel of the Jhelum River. After the lake drained, a series of lakes, smaller water bodies and wetlands within the Kashmir Valley remained along the wide valley floor, including the largest water body, Wular Lake.

The Jhelum River Channel formed in the lower levels of the Kashmir Valley and became the main river channel conveying river discharge through the length of the Kashmir Valley. It is a part of the overall Indus River system, which flows through India and Pakistan before merging with the Chenab River and subsequently into the Indus River before discharging into Arabian Sea.

Table 12 Geological Formations of the Kashmir Valley

Era	Period	Age	Formations	Localities
Cenozoic	Quaternary	Recent Pleistocene	Recent alluvium, Older alluvium Karewa deposits, River terraces	Jhelum River Valley, Karewa uplands bordering the valley, river terraces in the upland valleys
	Tertiary	Eocene	Nummulitics, ranicot series	South-western flank of the Pir-Panjal range
Mesozoic		Cretaceous	Shales, agglomerates, agglomeratic conglomerates and volcanic series	Astor, Burzil, Dras, Ladakh
		Jurassic	Spiti shales, kioto limestones	Banihal
		Triassic	Pir panjal trap, Triassic shales with limestone dolomies	Sind Valley, Lidder Valley and Northern slopes of Pir Panjal Range
Palaeozoic		Permian	Zewan beds, productus shales, dark arenacious shales and limestones	Pir Panjal, Upper Sind and Liddar Valley
		Carboniferous	Panjal trap, agglomerates, limestones and shales	Pir Panjal Range
		Devonian	Muth quartzites	Zanskar Range, Banihal
		Silurian	Sandy shales, shaley sandstone and yellow limestones	Liddar Valley, Pir Panjal, Southern Flank
		Ordivician	Quartzite, limestones,	Liddar Valley, (Anantanag)
		Cambrian	Greywackes,soft quartzites, massive clays, limestones	Sind and Liddar Valley, Baramulla and Anantanag, Pir Panjal, Banihal Valley
Archaean		Pre-Cambrian	Fundamental gneisses, intruded granites	Great Himalayan Range, Pir Panjal

The Jhelum River's origin is from a deep spring at Verinag, located in the south-eastern end of the Kashmir Valley, at the foot of the Pir Panjal Mountain Range. The Jhelum River has widened and formed meander bends where the channel gradient is very low, as much as 1:10,000 to 1:12,000 gradient in the reach passing through Srinagar and continues to meander as it flows to Wular Lake, although the meander bends are not as close as they are in the reach passing through Srinagar. The Jhelum River channel also becomes more constricted and the channel gradient slightly increases from Srinagar to the channel outlet in Wular Lake.

The Jhelum River channel emerges from the west end of Wular Lake upstream of Baramulla to form what is known as the Outfall Channel (OFC). The Jhelum River Outfall Channel continues in a westerly direction from Wular Lake to Pakistan. Downstream of Wular Lake the Ningi Nallah joins the OFC from the south and further downstream the Pohru Nallah joins the OFC from the north near Dobgah. Downstream of the Pohru Nallah confluence, the Mundri Nallah joins the OFC from the south and the Dakil and Vij Nallahs join the OFC from the north.

Downstream of Baramulla, the OFC becomes more confined and the channel gradient increases significantly to the Lower Jhelum (Hydel Power Plant) Barrage, through the Khadanyar Gorge to Salamabad, approximately 43km downstream of the Hydel Power Plant Barrage.

5.2 Earthquake-Prone Seismic Zones

The Kashmir Valley lies in an earthquake-prone seismic zone, ranging from Zone V in the southern half of the Valley to Zone IV in the northern half of the valley. **Figure 30** shows the approximate coverage of the seismic zones in the Valley.

With reference to the Seismic Zone Map (**Figure 30**), the highest risk zone, Zone V, for seismic activity and potential earthquakes is in the south-eastern centre portion of the Jhelum River Basin. The western and northern portions of the Basin are somewhat less susceptible, classified as Zone IV, although still have a high potential for seismic activity.

5.3 Soils and Slopes

5.3.1 Soils Spatial Coverage and Depths

The soil depths within the Jhelum River Basin range from very shallow (10-15cm) in the upper sub-basins to deep (>50cm) in the Jhelum River alluvial valley. **Figure 31 and Figure 32** show the spatial distribution of soil texture types and soil depths throughout the Jhelum River Basin respectively. The soil textures within most of the Jhelum River Basin are silty and sandy loam, which are susceptible to erosion. There are isolated areas where clay soils are prominent, but those areas are much less in area, compared to the silty and sandy loam areas. With reference to the soil depth map, the deepest soils lie within the lower elevation portion of the Jhelum River valley and shallower soil depths occur nearer to the hydrologic divides and upper mountain areas where the slopes are very steep, up to 30% or more.

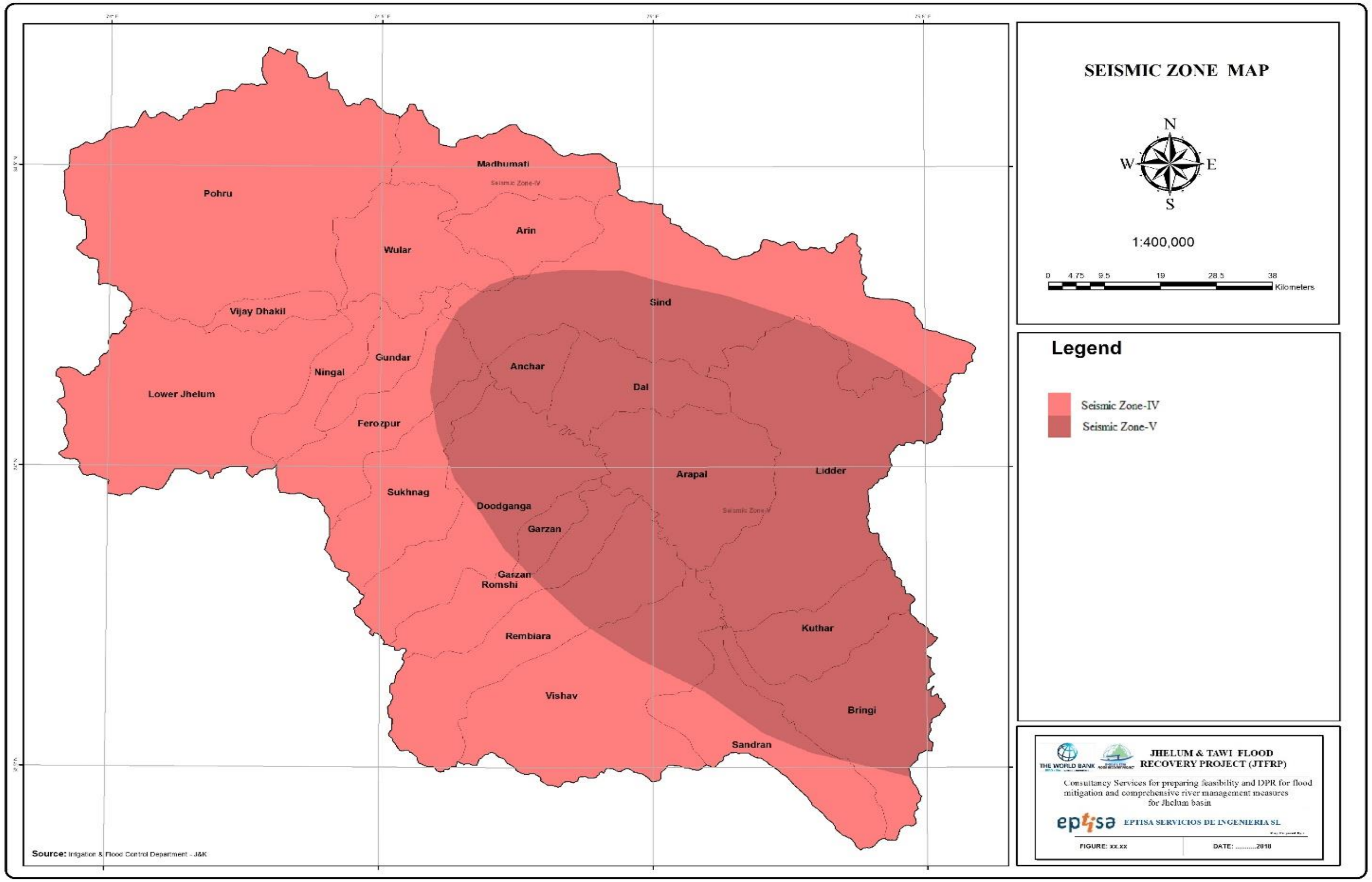
5.3.2 River Basin Slopes

The Great Himalayan and Pir Panjal Mountain Ranges bordering the Jhelum River Basin have steep slopes leading to the intersection with the Jhelum River alluvial valley and floodplain area. Much of the soils within the Jhelum River sub-basins are highly erodible and subject to displacement and suspension in tributary flows during high-intensity rainfall events.

Some of the tributaries in the southern and western portions of the Jhelum River Basin tend to carry high sediment loads into the Jhelum River during significant storm events. Much of these sediments remain in suspension and are deposited downstream in the Jhelum River channel, as the channel gradient decreases and the flow velocities necessarily decrease.

Figure 33 shows the ground slope from which it is apparent (as expected) that the steepest slopes occur in the upper portions of the Jhelum River Basin, becoming steeper from the valley floor to the mountain divides. In the lower portion of the Jhelum River valley, the slopes are much more gradual, less than 15% and may be as little as 3% in some areas within the Jhelum River floodplain. Based on the spatial distribution of erosive soil areas within the Jhelum River Basin, shown in **Figure 34**, the upper portions of the River Basin where the slopes are the highest also have the areas that are the most prone to soil erosion. As a result, the sub-basins with catchment areas is higher, steeper areas are the most erosive and likely contribute more to sediment transport to the Jhelum River during high intensity storm and runoff events.

Generally speaking, slopes of greater than 15% are sediment source areas, slopes between about 3-5% and 15% are sediment transport zones, and slopes below 3% are sediment deposition zones.



Source: Irrigation & Flood Control Department - J&K

Figure 30 Seismic Zones in the Kashmir Valley

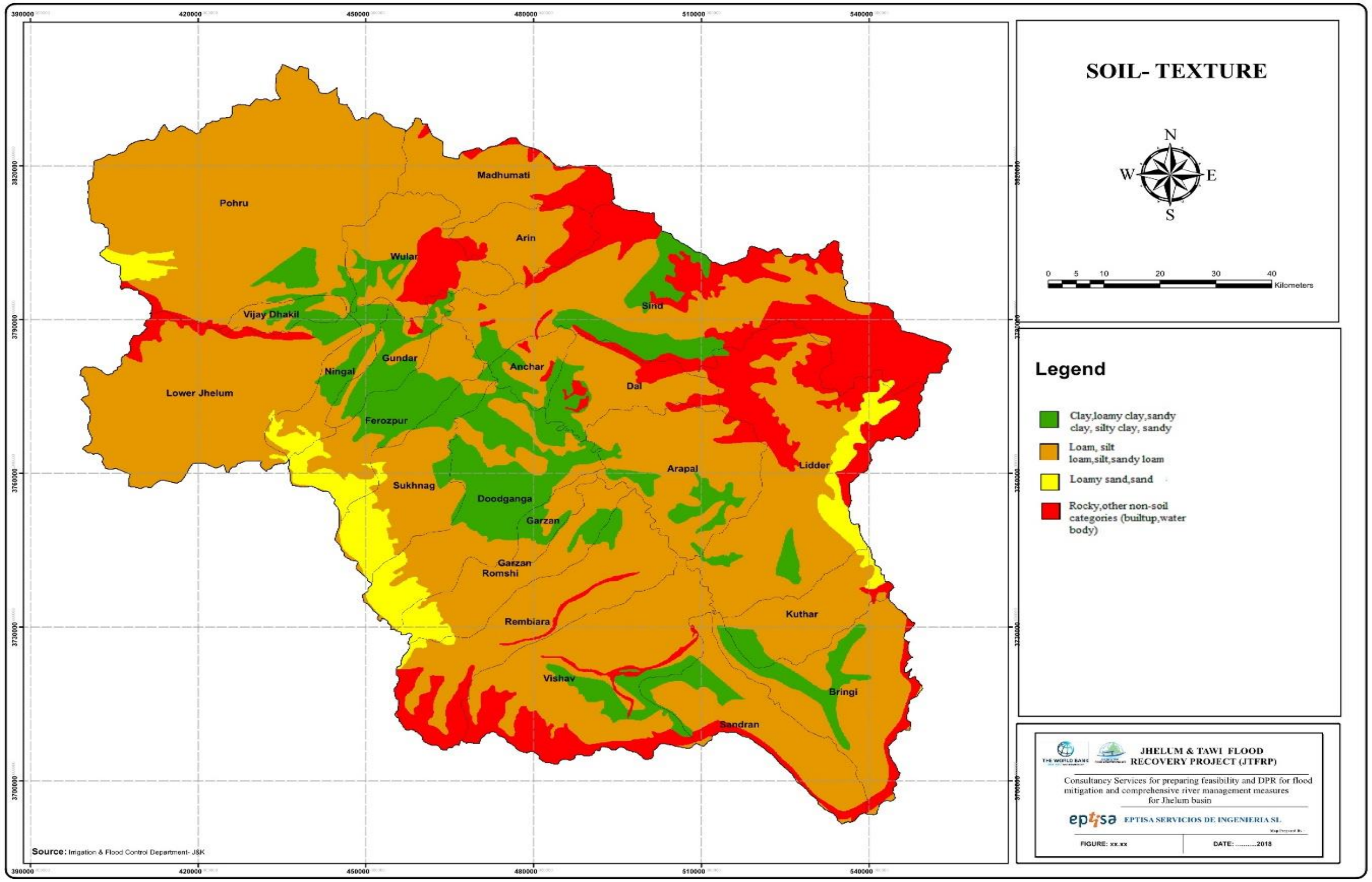


Figure 31 Soil Texture in the Jhelum River Basin

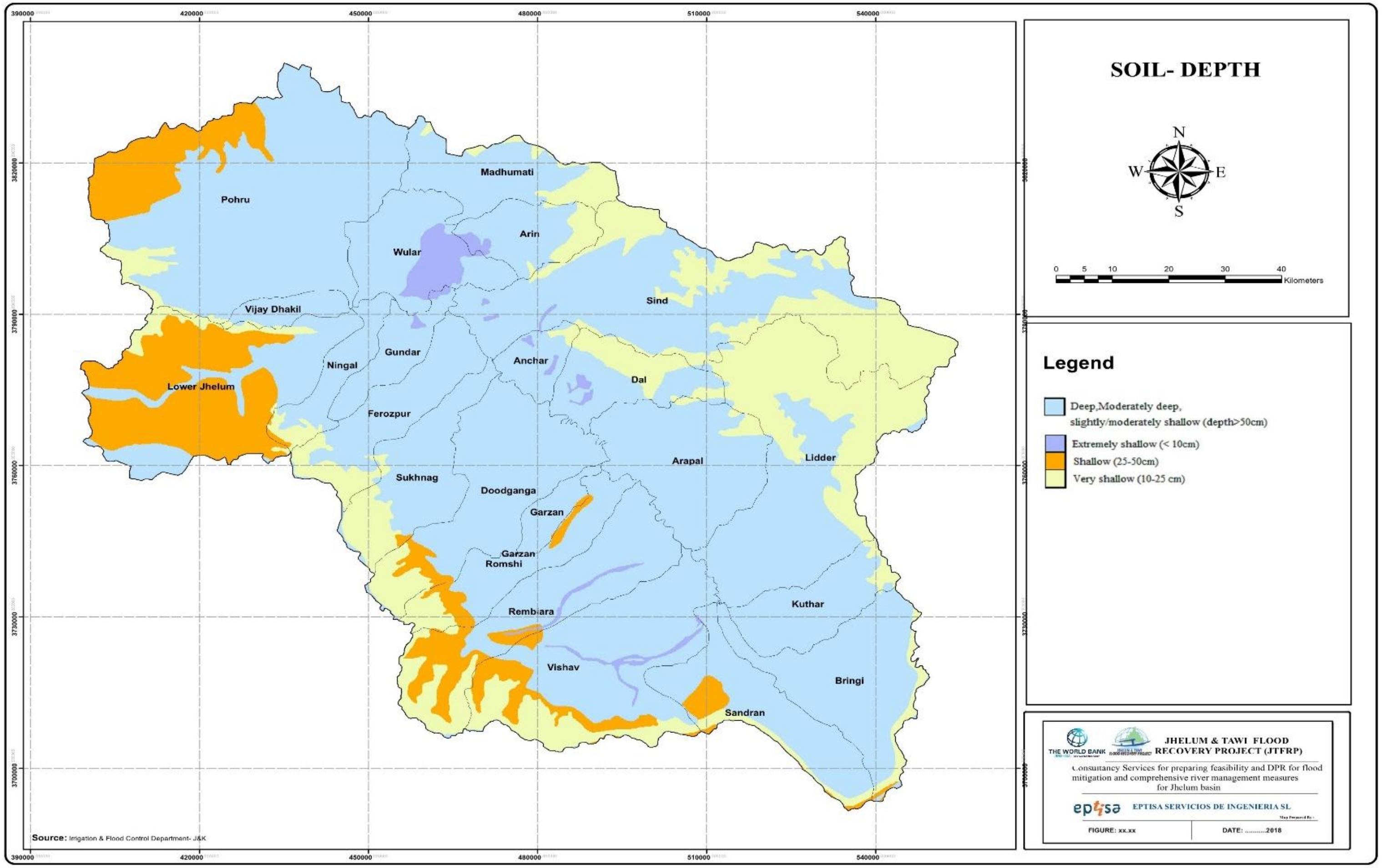
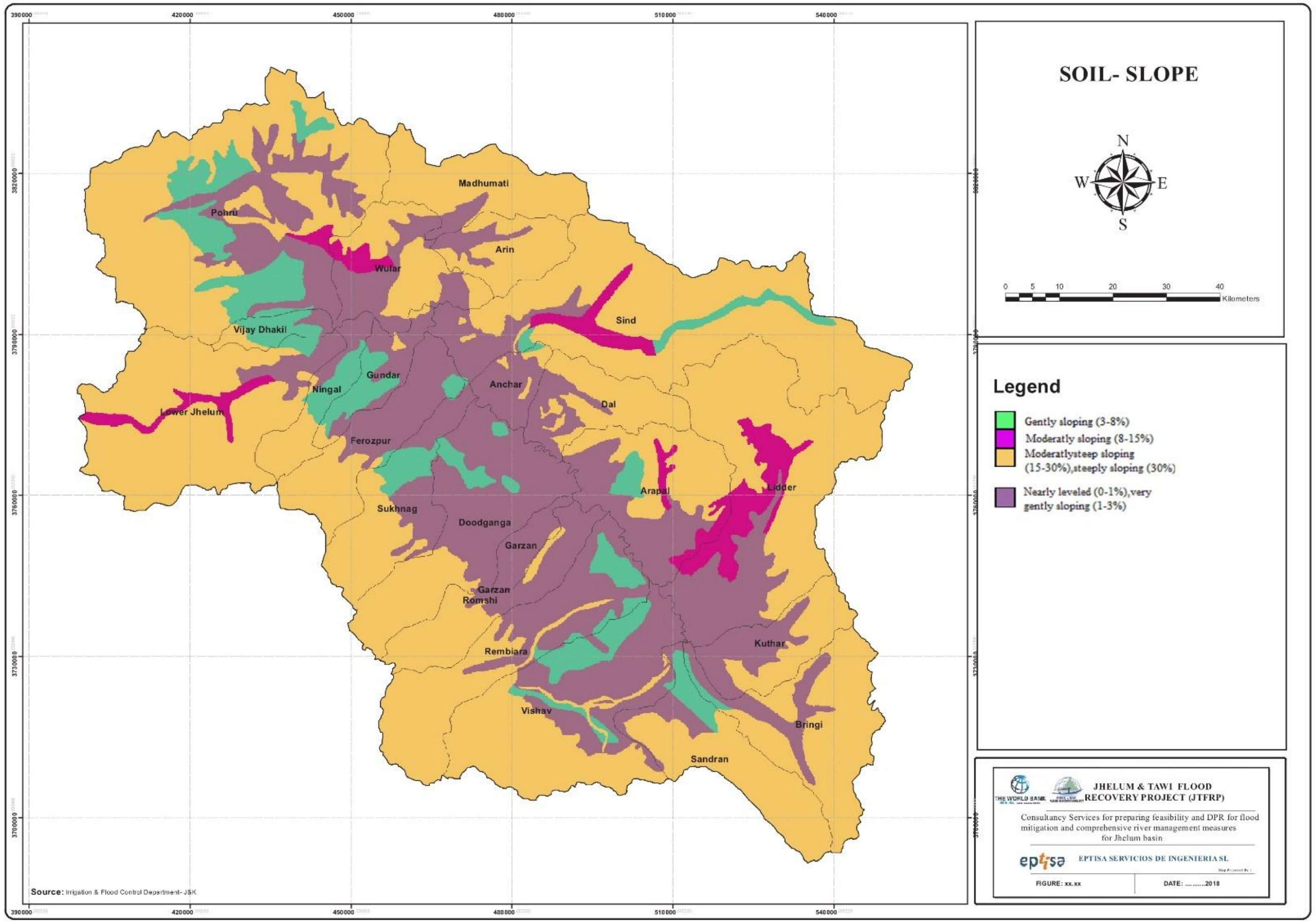


Figure 32 Soil Depths in the Jhelum River Basin



Source: Irrigation & Flood Control Department- J&K

Figure 33 Soil Slopes in the Jhelum River Basin

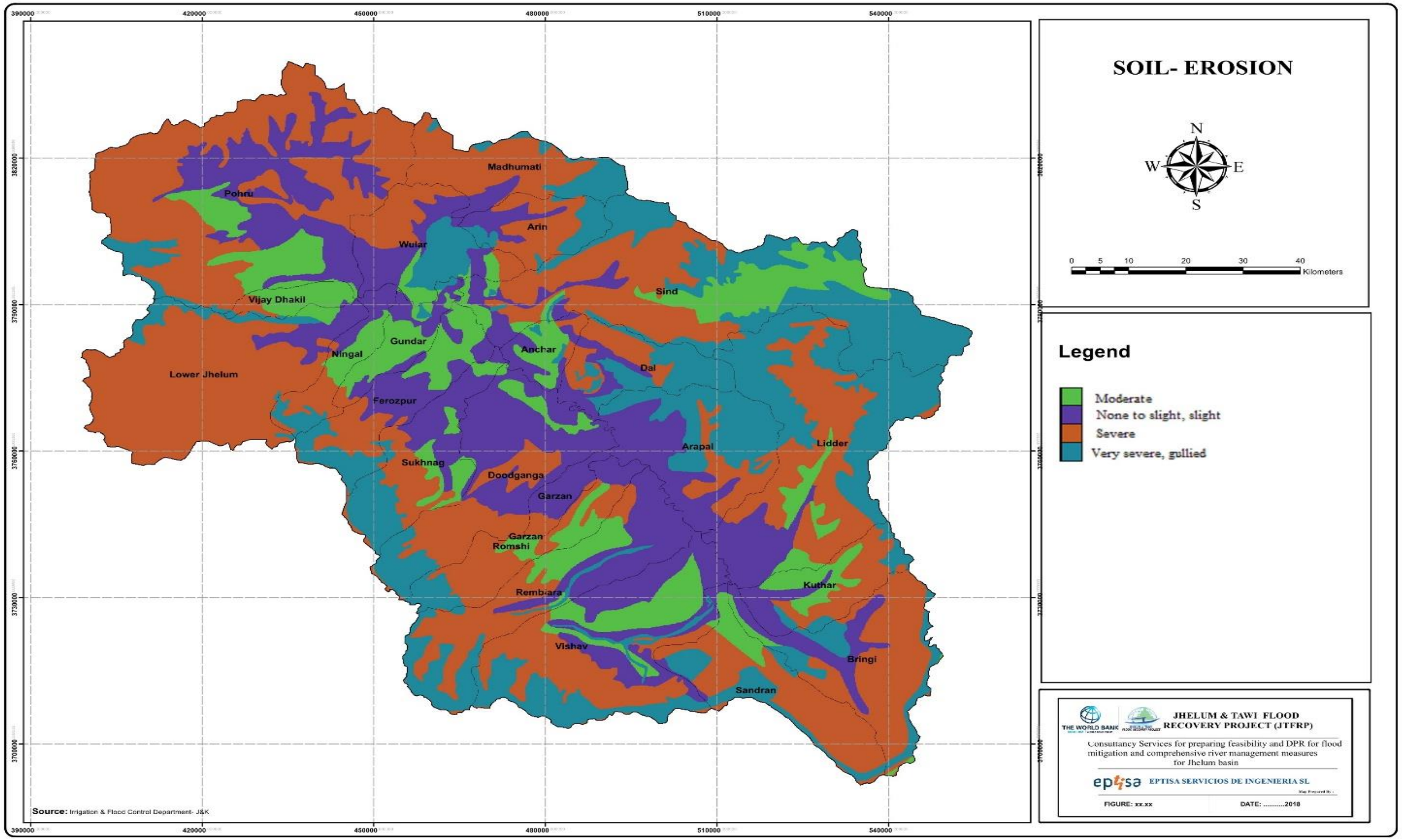


Figure 34 Soil Erosion in the Jhelum River Basin

5.4 River Basin Rainfall Catchment Area

The Jhelum River Basin drainage and catchment boundary is shown on **Figure 10.** The estimated area of the Jhelum River Basin is 12,750 km^2, with an estimated total distance of 186km from the south-east to the north-west ends of the catchment area and a maximum of 123km in width between major drainage divides. There are many significant tributaries that join the Jhelum River, from the Jhelum River origin near the south-east end of the Jhelum River Basin to Salamabad in the Khadanyar Gorge.

5.5 Main River Channel Geomorphologic Characteristics

5.5.1 Main River Channel Physiography

The Jhelum River Study Area originates approximately 2km upstream of the Khanabal Highway Bridge at the Sandran Nallah confluence. The Jhelum River channel continues from that point in a north-westerly direction through Srinagar to Wular Lake, for an estimated channel distance of 131km. The Jhelum River Channel passing through Wular Lake from the Lake inlet to the Lake outlet is about 24km. The Outflow Channel distance from the Wular Lake outlet to the Lower Jhelum Barrage downstream of Baramulla is an estimated 32km and the channel distance to Salamabad the downstream end of the Study Area is a further 43km,. Therefore, the estimated total Jhelum River Main Channel Length from upstream of the Khanabal Bridge to Salamabad, including Wular Lake, is 225km Wular Lake. **Figure 35** shows the Jhelum River Channel alignment as a red line through the Jhelum River Valley, exiting to the west toward Salamabad, the downstream end of the Study Area.

Figure 35 Image of Jhelum River Channel Alignment in the Kashmir Valley from Khanabal to Salamabad

5.5.2 Channel Meandering, Bifurcation and Natural Migration

The Jhelum River Channel from the Sandran Nallah confluence has a relatively gradual slope all the way to Wular Lake, due to the wide river valley and former lakebed area. As a result, the Jhelum River Channel to Wular Lake is a meandering channel that has changed alignment by natural migration in the past in the wide, alluvial floodplain, primarily due to flood flows in the main river channel, influence of the larger tributaries joining the main channel and possible tectonic activity during the long geologic period when the valley was being formed.

The channel reach passing through the dense urban area of Srinagar is a highly meandering reach with a very gradual bed slope of 1:12,000 in some reaches. This is also the case with other smaller urban areas along the Jhelum River Channel from Khanabal to Wular Lake, where the river bed slope may range from 1:8,000 to 1:10,000. There are some short reaches where the channel splits forming islands and again joins to form a single channel downstream in more confined reaches. These bifurcated channel reaches are primarily located upstream and downstream of Srinagar, where the channel widths are wider and less confined.

Figure 36 clearly shows how close the meander bends occur in the south end of Srinagar and shows the congested urban and commercial development that has occurred adjacent to the Jhelum River active channel. The Flood Spill Channel (FSC) inlet is shown in the lower left side of the highly sinuous, meandering Jhelum River Channel and does have some capacity to divert flood flow from the Jhelum River Channel during high flood events, although the conveyance capacity of the FSC has been significantly reduced due to sediment deposition and obstructions within its downstream reaches.

Figure 36 Image of Jhelum River Meander Reach in the Srinagar Area

5.5.3 Active Channel Banks and Artificial Bunds/Berms

The Jhelum River channel is essentially confined through Srinagar and other urban areas, due to urban encroachment and placement of earth bunds and berms along river channel banks to raise the river banks to better confine the river flows, particularly during flood events. This has significantly reduced the capacity of the Jhelum River channel to convey flood water and has reduced the capacity of adjacent overbank floodplain areas to store flood water when major flood events occur. It has also increased the potential for earth berm and bund breaches during high flood events, causing floodwater to enter the urban areas that have been developed in the Jhelum River natural floodplain areas.

(Note: Quarry/Landslide area in the background on mountain slope.)

Photograph of Jhelum River Channel – Temporary Repair of River Left Bank Near Sangam – Sep. 2014 Flood Breach Location

5.5.4. Channel Bed and Bank Material

The channel bed and bank material Ranges from rocks, cobbles and gravel in the upper reaches of the Jhelum River Channel and Main Tributaries to silty and sandy material in the relatively flat, alluvial areas from Khanabal to Wular Lake. Previous studies (Uppal 1955) have shown that the bed material is fine sand of about 1mm in diameter.

Table 13 summarizes sediment sample results that were collected in four locations along the Jhelum River in 2011. The sample sites were located at Marwal, Aramwari, Qumarwari and Tengpora. The following is a description of the sample locations regarding sediment collection and origin. Site I

(Marwal Pampore) had an average water depth of about 1.6m and the area was characterized by rural settlements along the banks, agricultural land and dense trees of different species, particularly Populous and Salix. Site II (Aramwari near Zero Bridge Srinagar) had an average water depth of about 2m and the area was characterized by dense urban and commercial development along both banks and domestic wastes were being discharged into the Jhelum River in some reaches in that area. Site III (Qamarwari Srinagar) had an average water depth of about 1.2m and the area was characterized by residential and commercial developments along both banks, releasing wastes into the river without treatment in that area. Site IV (Tengpora Srinagar) had similar features along both river banks as in Site I, where the residential development is much less than was present in Site II and III locations. Sampling was conducted monthly from June to November 2011 using an Ekman's Dredge (15cm × 15cm sample area).

Table 13 Summary of Sediment Particle Size Distribution - Jhelum River - 2011

SEDIMENT PARTICLE SIZE IN THE JHELUM RIVER - 2011					
SEDIMENT PARTICLE SIZE IN THE JHELUM RIVER - 2011					
Soil Texture	**SITE I (Marwal)**	**SITE II (Aramwari)**	**SITE III (Qamarwari)**	**SITE IV (Tengpora)**	**MEAN**
Sand (%) *(0.075 to 2.0mm)*	66	62	55	60	61
Silt (%) *(0.002 to 0.02mm)*	22	22	28	21	23
Clay (%) *(<0.002mm)*	12	16	17	19	16
Textural Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
Latitude	33° 58' 45" N	34° 04' 9" N	34 ° 05' 35" N	34 ° 07' 47" N	
Longitude	74° 54' 16" E	74° 50' 20" E	74 ° 46' 45" E	74 ° 43' 11" E	
Source: *1: P. G. Department of Environmental Science, University of Kashmir, Srinagar-190006, J&K, India. 2: P. G. Department of Environmental Science and Centre of Research for Development (CORD), University of Kashmir, Srinagar-190006, J&K, India. (24 January 2013 by Modern Scientific Press Company, Florida, USA) - (Soil Particle Size in Parentheses – clay to medium sand)*					

The sediment sample results indicate the textural class of channel bed sediment remained sandy loam from Site I to IV, although the silt and clay fractions tended to increase slightly in downstream Sites III and IV nearer to Wular Lake.

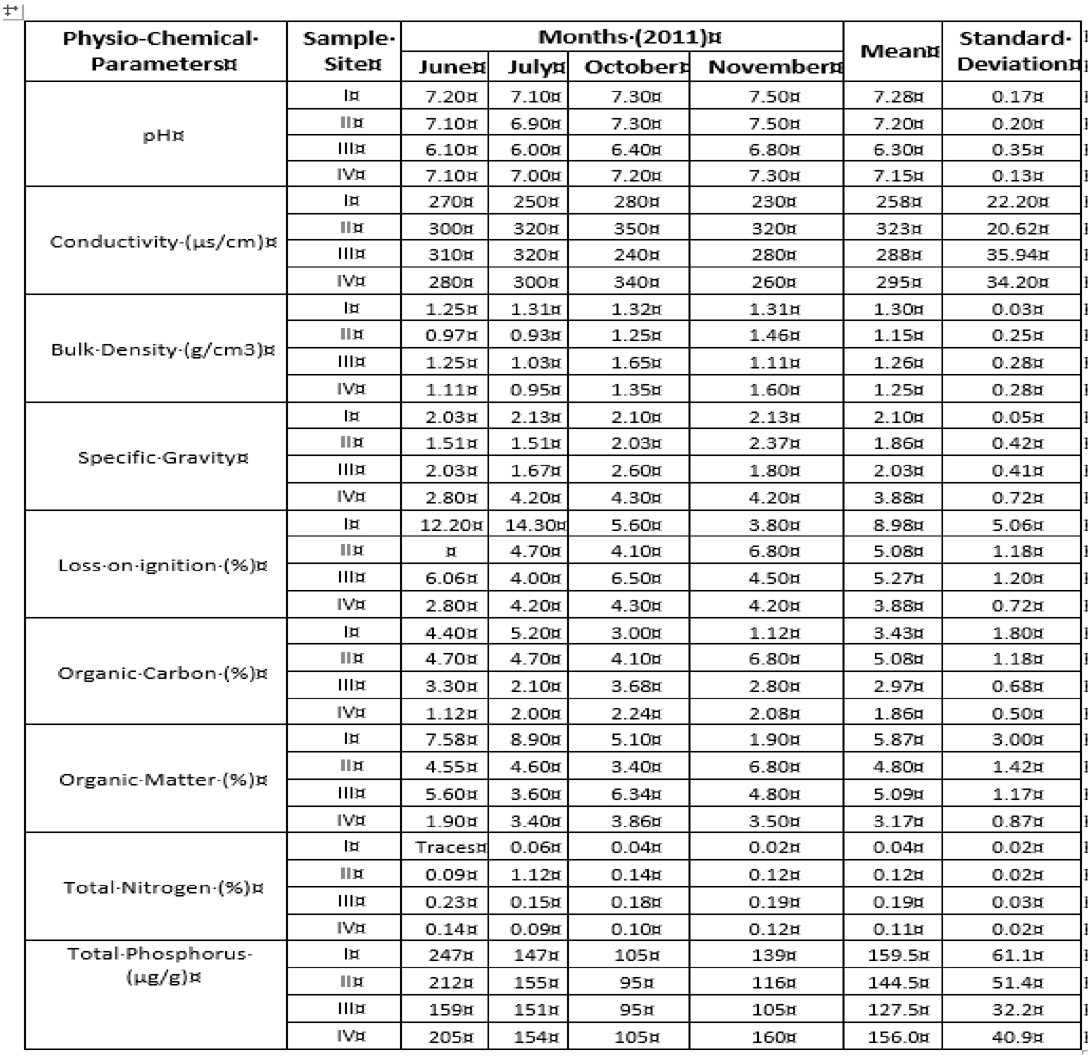
5.5.5 Water Quality

Water quality samples were also taken from the Jhelum River by the same researchers in Site I to IV locations, during the same period as when the sediment samples were also taken. **Table 14** is a summary of physio-chemical and ionic parameters from water samples taken at each of the four sample sites. During the research study it was found that the sediments of Jhelum River Jhelum are slightly alkaline. The sample analysis results revealed that physical and chemical weathering of minerals and anthropogenic activities played an important role in physio-chemical properties of the sediments.

Table 15 is a summary of ionic parameters. The ionic analyses of the water samples indicated cations calcium and potassium were found to be dominant in comparison to magnesium and Sodium. In the anion analyses, chloride dominated the Bicarbonates. The high organic matter content from the sample taken at Site I was likely due to abundant vegetation in that reach of the river, which was also responsible for high phosphates, since both are closely correlated.

Among the different soil textural classes in bed material sediment samples, sand was found to be dominant, the percent fraction of sand decreased moving downstream and the percent fractions of silt and clay increased moving downstream. The statistical analysis of the data showed there was a positive correlation between the parameters and samples taken from the four sites, and the analysis results were not significantly different from each other. In comparing sample analyses from the four sample sites, it is apparent that Jhelum River water at Sites II and III located in the urban areas is more affected by pollution than Jhelum River water at Sites I and IV, located in the more rural areas.

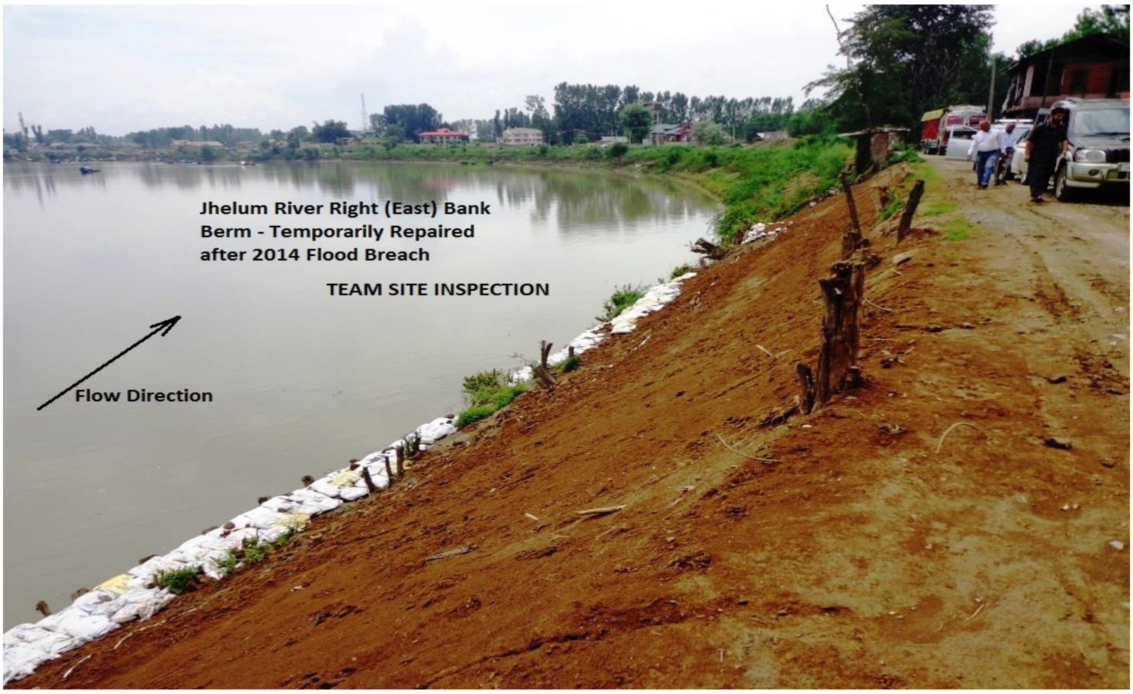
Table 14 Variation of Physio-Chemical Parameters from Jhelum River Water Sample Sites



Physio-Chemical Parameters	Sample Site	Months (2011)				Mean	Standard Deviation
		June	July	October	November		
pH	I	7.20	7.10	7.30	7.50	7.28	0.17
	II	7.10	6.90	7.30	7.50	7.20	0.20
	III	6.10	6.00	6.40	6.80	6.30	0.35
	IV	7.10	7.00	7.20	7.30	7.15	0.13
Conductivity (µs/cm)	I	270	250	280	230	258	22.20
	II	300	320	350	320	323	20.62
	III	310	320	240	280	288	35.94
	IV	280	300	340	260	295	34.20
Bulk Density (g/cm3)	I	1.25	1.31	1.32	1.31	1.30	0.03
	II	0.97	0.93	1.25	1.46	1.15	0.25
	III	1.25	1.03	1.65	1.11	1.26	0.28
	IV	1.11	0.95	1.35	1.60	1.25	0.28
Specific Gravity	I	2.03	2.13	2.10	2.13	2.10	0.05
	II	1.51	1.51	2.03	2.37	1.86	0.42
	III	2.03	1.67	2.60	1.80	2.03	0.41
	IV	2.80	4.20	4.30	4.20	3.88	0.72
Loss on ignition (%)	I	12.20	14.30	5.60	3.80	8.98	5.06
	II		4.70	4.10	6.80	5.08	1.18
	III	6.06	4.00	6.50	4.50	5.27	1.20
	IV	2.80	4.20	4.30	4.20	3.88	0.72
Organic Carbon (%)	I	4.40	5.20	3.00	1.12	3.43	1.80
	II	4.70	4.70	4.10	6.80	5.08	1.18
	III	3.30	2.10	3.68	2.80	2.97	0.68
	IV	1.12	2.00	2.24	2.08	1.86	0.50
Organic Matter (%)	I	7.58	8.90	5.10	1.90	5.87	3.00
	II	4.55	4.60	3.40	6.80	4.80	1.42
	III	5.60	3.60	6.34	4.80	5.09	1.17
	IV	1.90	3.40	3.86	3.50	3.17	0.87
Total Nitrogen (%)	I	Traces	0.06	0.04	0.02	0.04	0.02
	II	0.09	1.12	0.14	0.12	0.12	0.02
	III	0.23	0.15	0.18	0.19	0.19	0.03
	IV	0.14	0.09	0.10	0.12	0.11	0.02
Total Phosphorus (µg/g)	I	247	147	105	139	159.5	61.1
	II	212	155	95	116	144.5	51.4
	III	159	151	95	105	127.5	32.2
	IV	205	154	105	160	156.0	40.9

Table 15 Ionic Composition from Jhelum River Water Samples

Ionic Parameters	**Sample Site**	**Months (2011)**				**Mean**	**Standard Deviation**
		June	**July**	**October**	**November**		
Chloride (meq/100g)	I	0.90	1.00	0.80	1.10	0.95	0.13
	II	1.90	2.30	1.00	1.50	1.68	0.56
	III	1.60	1.90	1.00	2.10	1.65	0.48
	IV	0.90	1.00	0.90	1.10	0.98	0.10
Alkalinity (meq/100g)	I	0.80	1.00	1.20	1.10	1.03	0.17
	II	0.50	1.00	0.90	1.20	0.90	0.29
	III	1.20	1.40	1.30	1.20	1.28	0.10
	IV	0.40	0.90	0.80	0.90	0.75	0.24
Calcium (meq/100g)	I	4.00	4.52	4.32	2.27	3.78	1.00
	II	4.80	8.64	3.36	3.20	5.00	2.53
	III	4.72	6.60	3.32	3.04	4.42	1.63
	IV	4.32	5.04	3.60	2.48	3.86	1.00
Magnesium (meq/100g)	I	2.00	3.90	0.96	1.20	2.02	1.30
	II	3.20	4.16	3.04	1.60	3.00	1.06
	III	2.48	3.80	2.36	1.80	2.61	0.85
	IV	2.08	3.04	2.80	1.50	2.36	0.70
Extractable Na (mg/kg)	I	28	67	84	59	60	23.4
	II	62	72	64	56	63	6.7
	III	90	84	94	38	77	26.1
	IV	72	63	70	20	56	24.6
Soluble Na (mg/kg)	I	1.6	1.3	1.9	0.0	1.0	0.8
	II	36.3	4.6	0.7	17.5	15.0	16.0
	III	35.9	14.2	3.8	12.0	16.0	13.7
	IV	38.0	60.0	70.0	20.0	47.0	22.4
Exchangeable Na (mg/kg)	I	26	66	82	59	58	23.4
	II	26	67	63	38	49	20.0
	III	54	70	90	26	60	27.1
	IV	38	60	70	20	47	22.4
Extractable K (mg/kg)	I	37	36	154	110	84	58.0
	II	49	49	156	120	93	53.5
	III	62	34	89	138	81	44.2
	IV	52	54	108	112	81	32.8
Soluble K (mg/kg)	I	2	1	75	26	26	34.6
	II	10	5	63	34	28	26.5
	III	26	8	64	34	33	23.1
	IV	8	5	65	22	25	27.9
Exchangeable K (mg/kg)	I	35	34	79	84	58	27.2
	II	39	44	93	86	65	28.1
	III	36	26	25	104	48	37.8
	IV	44	49	42	90	56	22.5



Photograph of Jhelum River Channel – Temporary Repair of River Right Bank Outside Bend – Sep. 2014 Flood Breach Location

5.5.6 Channel Bed and Bank Erosion and Stability

The alluvial material in the river banks and river bed from Khanabal to Wular Lake is highly erodible and the river banks are relatively unstable where bank slopes are steep and unprotected. As a result, flood flows exacerbate river bank erosion, particularly on the outside (apexes) of river bends, where the velocity profile is more concentrated, increasing bank erosion and bank failures and breaches to occur at those points.

During low flow periods, the river bed is stable and uniform, consisting of sand and silt material. During flood flow events, the increased flow velocities tend to scour the channel bed, suspending and moving silt and sand downstream on the rising limb of the flood hydrograph and depositing sand and silt downstream on the receding limb of the flood hydrograph.

5.5.7 River Floodplain Areas

The Jhelum River Valley is a wide, gently sloping valley that was a large lakebed area in the past. The floodplain areas outside the active Jhelum River channel are extensive and contain marshy, wetland areas, as well as lakes and small water bodies. Before development along the river channel and within the floodplain areas occurred, the floodplain areas and lowland wetland areas served as flood storage areas during major flood events when overbank flows occurred.

The increase in urban development and shifting of population from rural farm areas to urban areas has resulted in significant residential and commercial development within the Jhelum River floodplain area. This has dramatically decreased flood storage areas with building and road developments, has necessitated the construction of earth berms and bunds along the active channel river banks, to confine flood flows and protect urban and commercial developments in the former floodplain areas. This has dramatically decreased flood storage areas with building and road developments, has necessitated the construction of earth berms and bunds along the active channel river banks, to confine flood flows and protect urban and commercial developments in the former floodplain areas.

Figure 37 shows a Landsat Image that was taken of the Jhelum River in September 2014 during the peak flood inundation period in the Srinagar meander reaches of the Jhelum River, where much of the overbank urban and commercial area was flooded, causing significant damage, economic loss and some loss of lives. The Jhelum River channel is shown as the red line on the image.

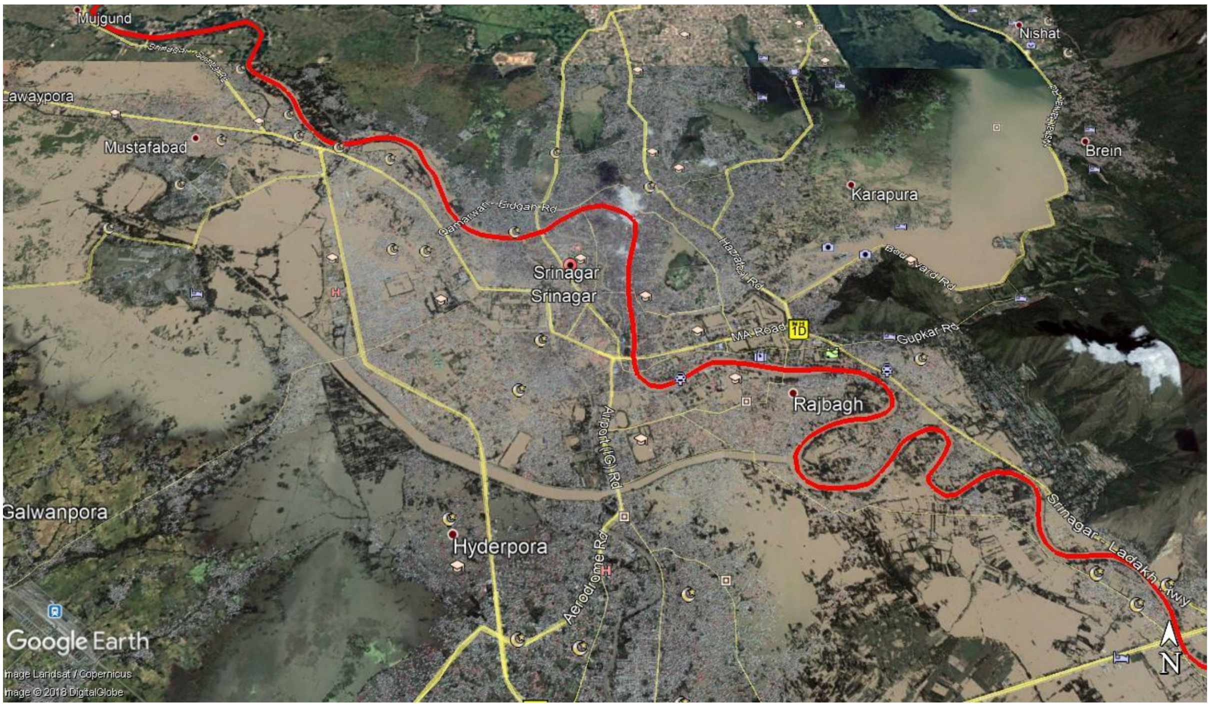


Figure 37 Landsat Image of Flood Inundated Area in Srinagar – Sept. 2014

5.5.8 Sediment Transport and Deposition

Some of the main tributaries draining into the Jhelum River near the southern upper parts of the river basin contribute significantly to the sediment load in the Jhelum River, as well as the subsequent sediment deposition in the channel in downstream reaches. Development along the main tributaries and deforestation will have increased the areas in the sub-basins that are susceptible to soil erosion and subsequent sediment transport to river tributaries during high-intensity rainfall events.

A comparison was made between Landsat images from 1984 to 2016 to determine if significant deforestation was apparent in the upper sub-basins of the southern part of the Jhelum River Basin, that may increase the potential for slope erosion and sediment transport to the Jhelum River. In comparing the upper sub-basin areas south of Khanabal (Sandran, Bringi and Liddar Nallahs), in **Figure 38** from 1984 to **Figure 39** from 2016, there does not appear to be a significant change in forest cover in that part of the basin, even though some of the highest sediment loads may originate from those sub-basins. In reviewing Landsat images along the mountain fronts in the eastern, north-eastern, western and north-western areas of the Jhelum River Valley from 1984 to 2018, the areas most affected by deforestation appear to be within the lower tributary valleys and not in the higher, steeper sloped areas of the sub-basins. This means that reforestation will not result in a significant reduction in sediment load, at least from the southern tributaries.

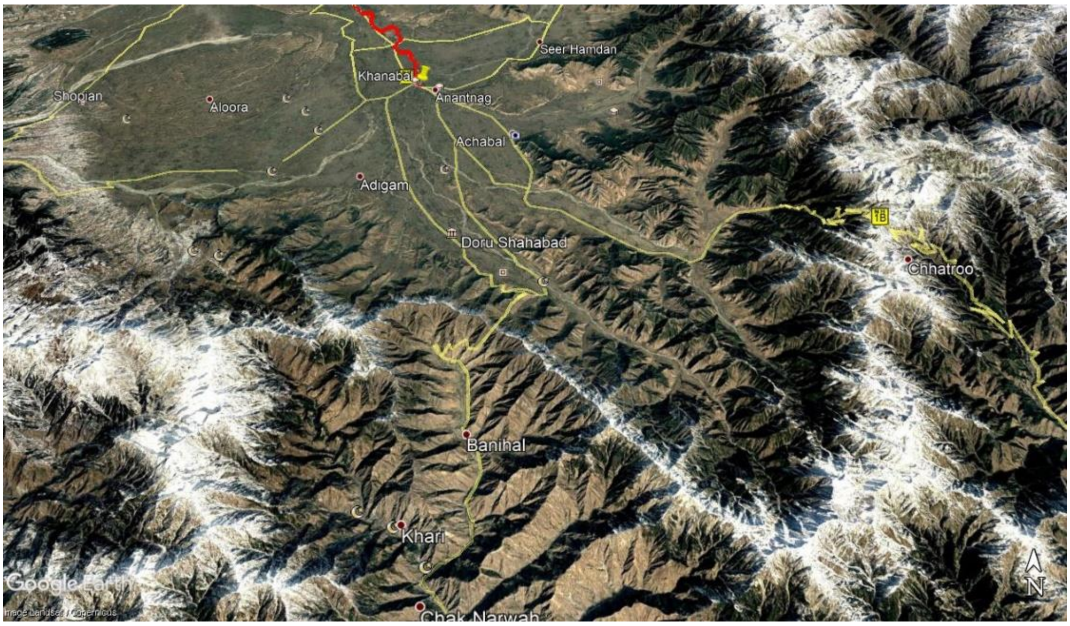


Figure 38 Southern Jhelum River Basin – Upper Sub-Basin Area -1984

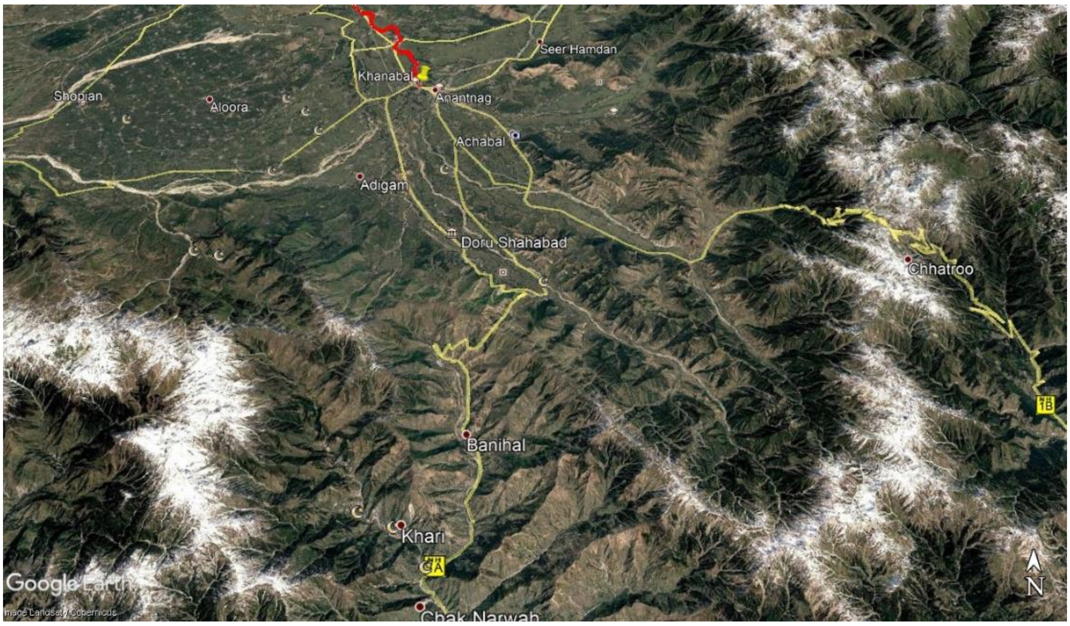
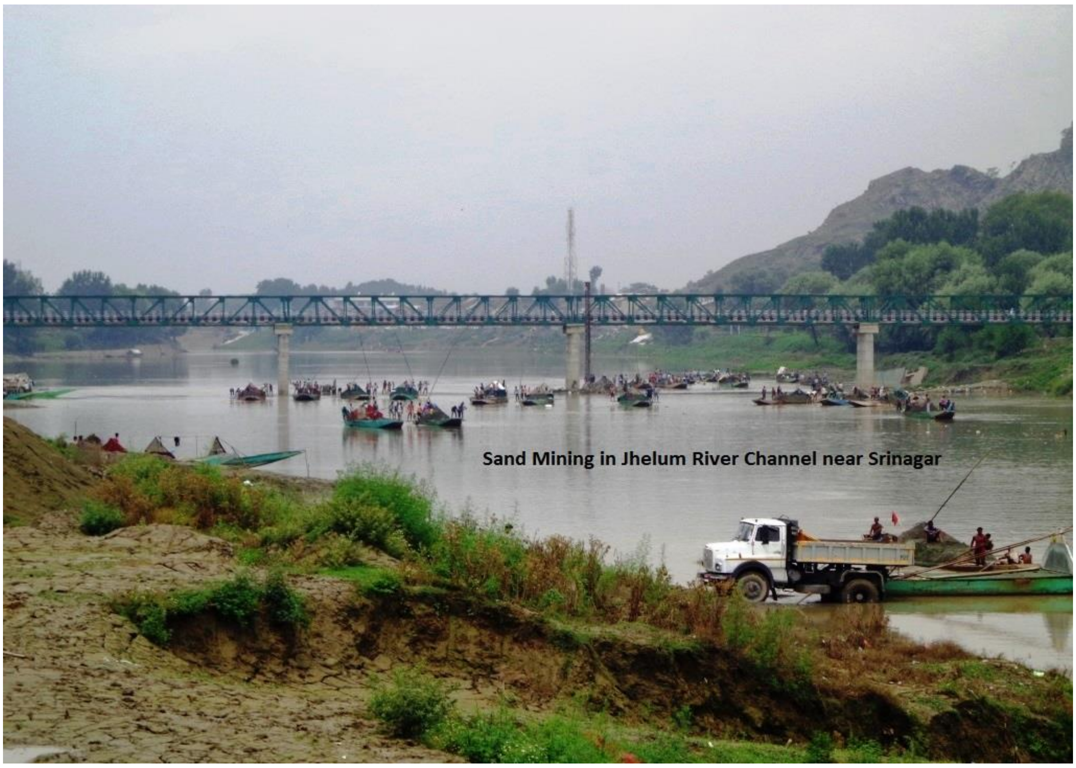


Figure 39 Southern Jhelum River Basin – Upper Sub-Basin Area -2016

5.5.9 Channel Dredging and Sediment Removal

There is substantial channel dredging taking place in the Jhelum River channel, particularly in the Srinagar area for economic purposes. This is in the form of sand mining by man small boats. The dredged sediment which is high in sand content, is being dredged from the channel using boats for transport to banks and is sold for construction material. The sediment dredging effort is largely unmanaged and does change the channel bed configuration, as well as endangers the toes of river banks and berms when it is carried out along bank and berm areas.

The mined sand is transferred from boats to dump trucks to be transported to construction sites to be used in building construction, because the sand percentage is high, and the material is suitable for some construction purposes.



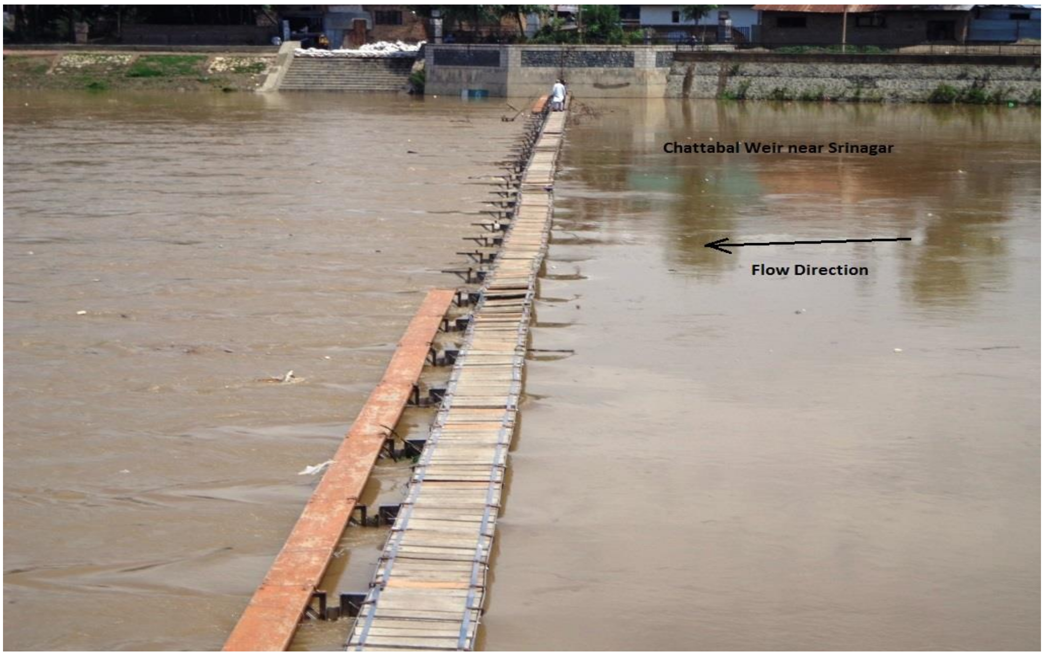
Photograph of Sediment Mining Activities in the Jhelum River Channel near Srinagar

5.5.10 Channel Constrictions

There are a significant number of bridges crossing the Jhelum River channel throughout the channel reach from Khanabal to Wular Lake and some bridges create restrictions to flow during flood events, primarily due to channel width reductions between bridge abutments. Wide bridge piers and low bridge soffits (underside of bridge decks) also reduce the area for conveyance of river discharge under the bridge structures during high flood events.

There are also other artificial barriers, such as the Chattabal Weir in Srinagar, that creates a barrier to river flow in a highly urbanized area, resulting in higher flood levels in the river reach upstream of the weir. Irrigation canal diversion and pump station structures may also create channel constrictions and cause flood levels to increase in the short reaches of the river channel that are directly affected by the structures.

The Jhelum River channel width in some reaches passing through Srinagar has been reduced due to development encroachment along the river channel, which has reduced the channel conveyance capacity and has caused increased flow velocities and river levels during flood events. Where channel banks are not adequately protected, flood events will cause bank erosion and breaches to occur in banks and berms during high flood events, such as was experienced in September 2014. The outsides of river bends are particularly susceptible to erosive effects of flood flows due to velocity profiles being more concentrated along the banks around the apex of the bends, rather than be more concentrated in the centre of the river channel in straighter channel reaches.



Photograph of Chattabal Weir across the Jhelum River Channel

Photograph of Badapora Bridge with Restricted Bridge Deck (Soffit) Height and Width

Photograph of the Jhelum River Channel in North End of Srinagar – Restricted Channel

Figure 40 to **43** show the progression of the urban development in the Srinagar area from 1984 to 2018, with increasing encroachment within the Jhelum River floodplain area. Previous **Figure 34** showed most of the Srinagar urban area was flooded in 2014.

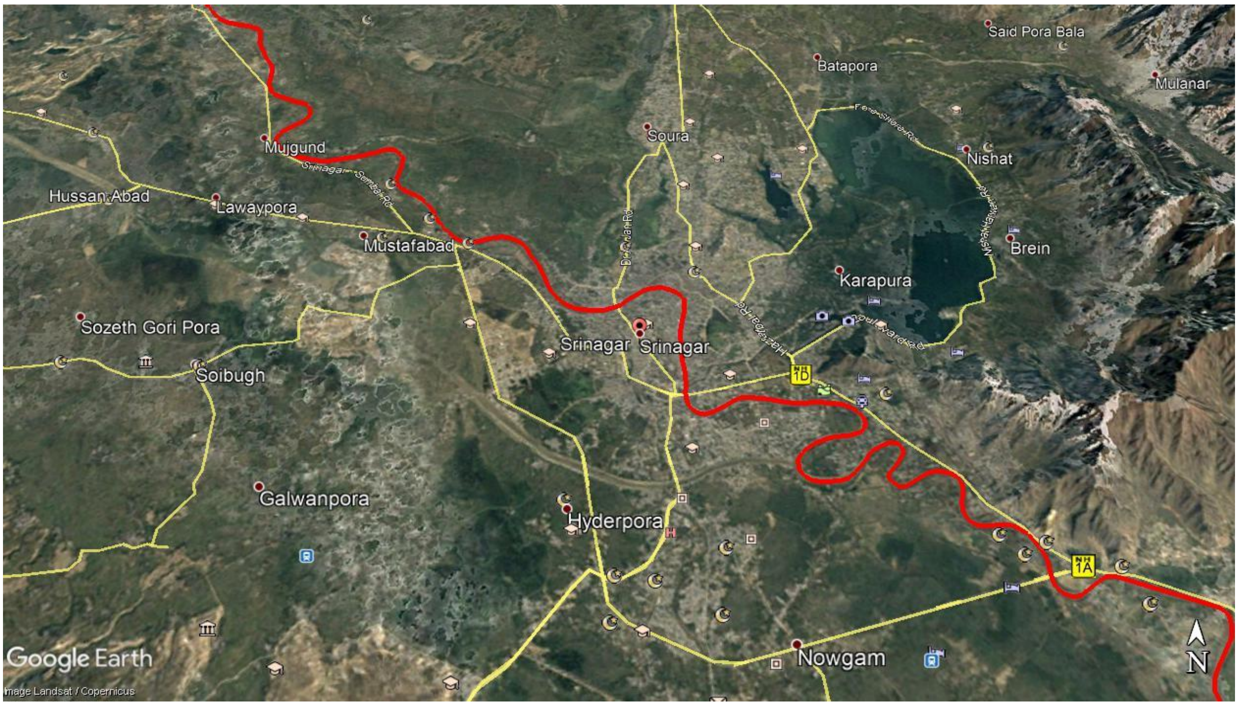


Figure 40 Landsat Image of Srinagar Urban Area in 1984

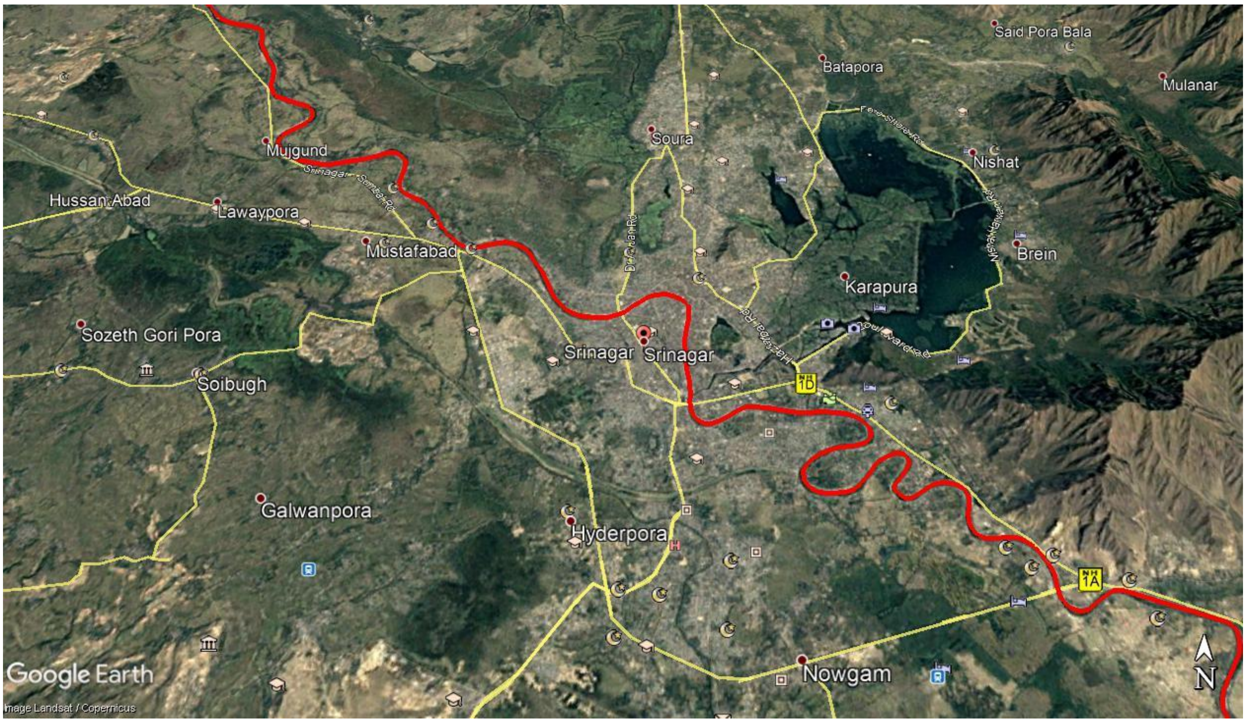


Figure 41 Landsat Image of Srinagar Urban Area in 2000

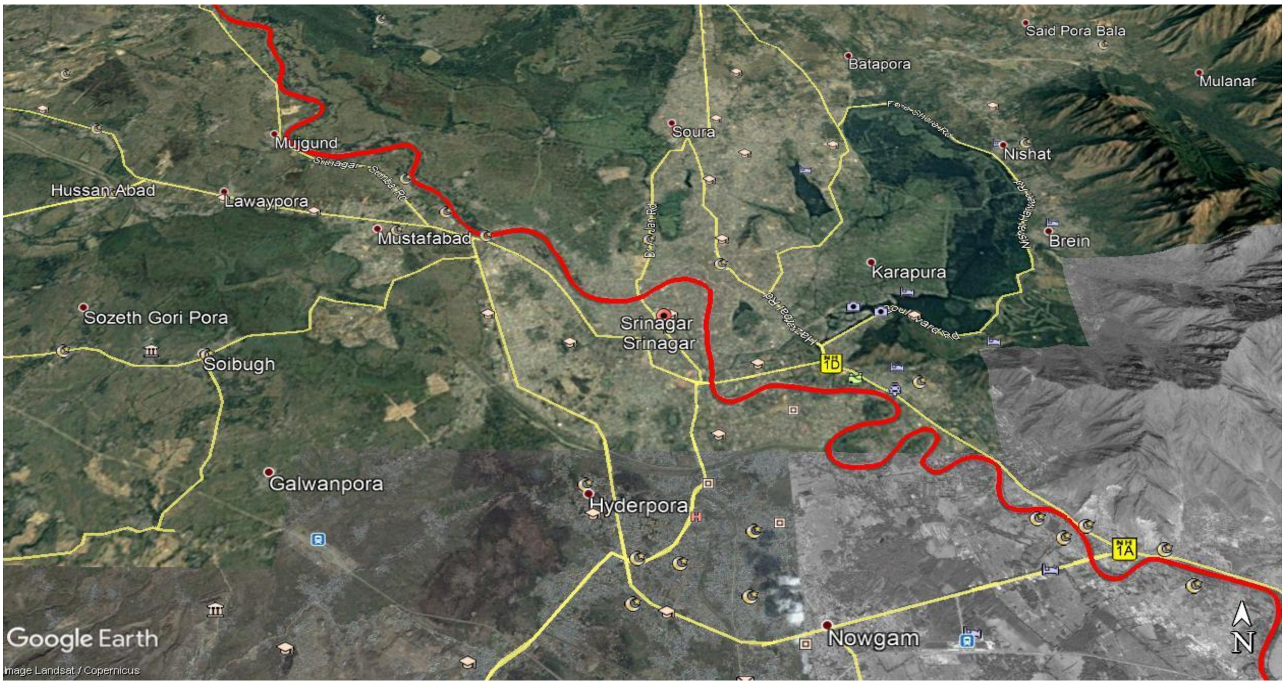
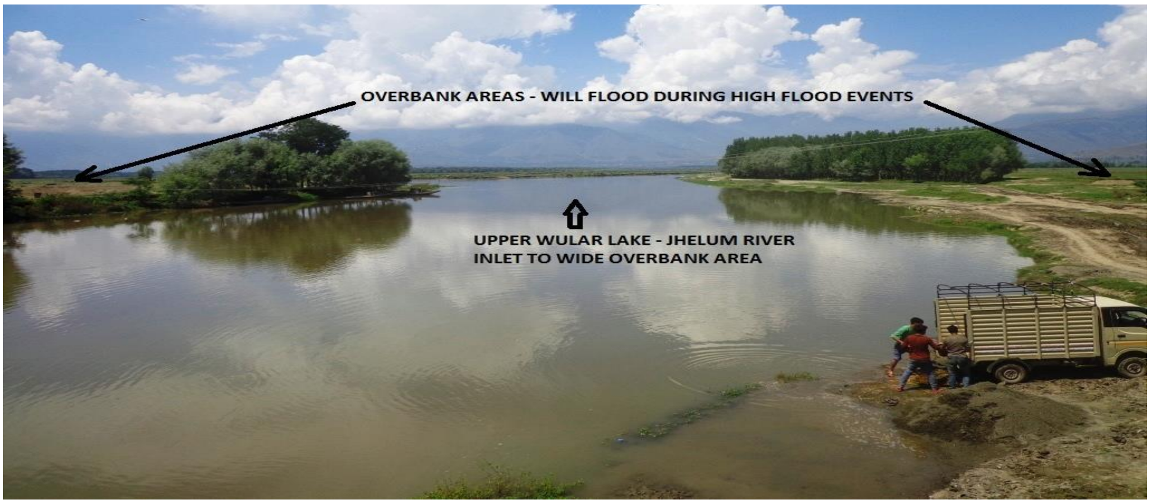


Figure 42 Landsat Image of Srinagar Urban Area in 2010

Figure 43 Landsat Image of Srinagar Urban Area in 2018

Downstream of Srinagar in the river reach leading to Wular Lake, the Jhelum River channel narrows in some reaches. The overbank floodplain areas in those reaches are largely agricultural areas that do become temporary flood storage areas during high flood events, when the Jhelum River channel banks are overtopped. Since most of these areas have not experienced significant urban development in the floodplain areas, the damage due to floods overtopping the river channel banks is not as significant as it would be in Srinagar and other upstream urban developments along the Jhelum River channel.



Photograph of the Jhelum River Channel at the Wular Lake Inlet

In the Jhelum River Outflow Channel downstream of Wular Lake, some of the bridges across the river channel do cause constrictions to flood flows, due to narrow widths between bridge abutments, wide bridge piers and remnants of old weirs under some bridge structures. As a result, during high flood flows, backwater conditions occur upstream of the bridge structures, raising flood levels enough to overtop river banks and allowing flood flow to pass into adjacent urban and commercial areas.

Photograph of a Bridge Structure near Baramulla Creating a Restriction to Flow during High Flood Events

Downstream of Wular Lake, there are remnants of former weirs under bridge crossings over the Jhelum River that also create barriers to flood flows, increasing backwater conditions and higher flood levels upstream of bridge structures that are affected. The old weirs were originally constructed to retain river flows during low flow periods for water supply and irrigation purposes, without much consideration for flood levels during high flood events.

5.6 Flood Spill Channel Geomorphologic Characteristics

5.6.1 Flood Spill Channel Physiography

The Flood Spill Channel (FSC) alignment in **Figure 44** is shown as the red line west of the Jhelum River Channel. The Jhelum River FSC inlet is located at Padshahi Bagh in the south of Srinagar and the inlet on the Jhelum River left bank (west bank) is essentially uncontrolled. The FSC was constructed in 1903 to divert a portion of flood flows in the Jhelum River around the developing urban area of Srinagar. Flows enter the FSC when its bed level at the inlet is exceeded by the water level in the Jhelum River and continues until the level falls below this sill level.

The FSC length is about 47.4km from the inlet from the Jhelum River to the outlet into Wular Lake. The FSC alignment roughly parallels the Jhelum River channel at an estimated distance of 3 to 7km through the west floodplain area and consists of two non-continuous reaches that have been widened and straightened and a reach north of Srinagar that essentially remains a natural, unimproved channel.

The widened and improved reaches of the FSC are located from the FSC inlet to about 11.3km downstream, where the channel becomes restricted with a more natural channel configuration for about 23.5km, leading to the lower channel reach that has been widened and improved and is about 12.6km in length, eventually discharging to Wular Lake upstream of its outlet at Ningli.

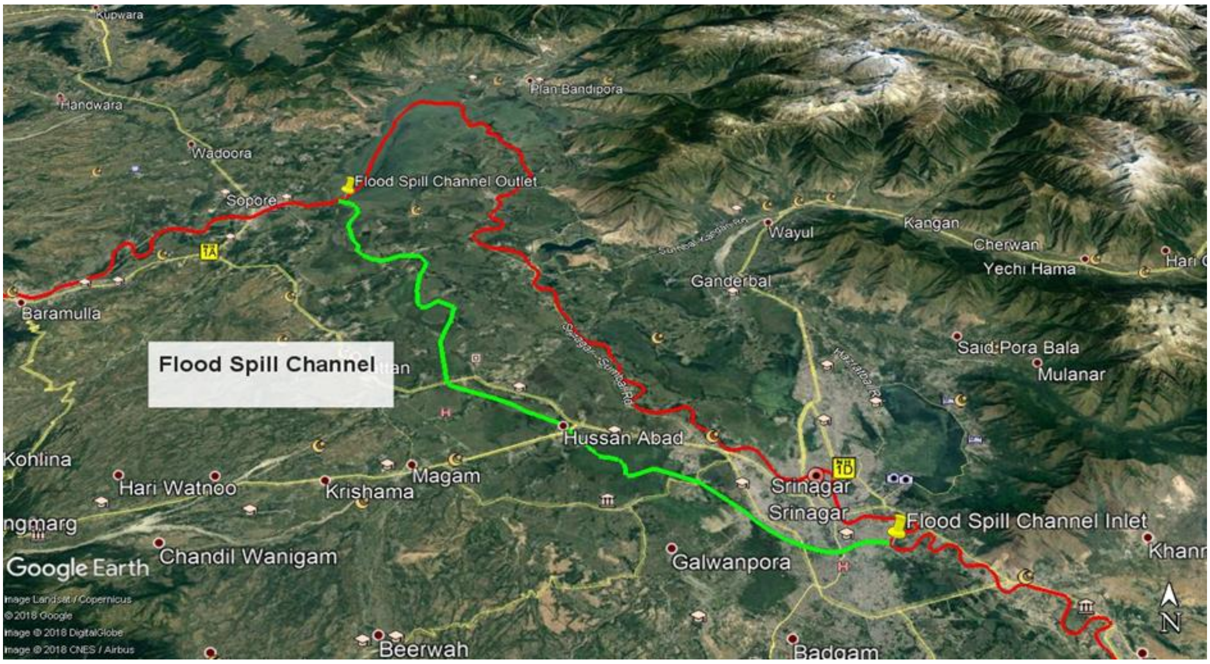


Figure 44 Image of Flood Spill Channel Alignment

Photograph of Flood Spill Channel Inlet from the Jhelum River

Photograph of Flood Spill Channel Inlet – Remnants of Concrete Control Weir Remains

As can be seen in the photograph above, there are remnants of an old concrete control structure across the channel and no other control exists at the channel inlet. As a result, flood flow from the Jhelum River is free to flow into the Flood Spill Channel, once the river level is high enough to flow over the old control structure. Flood flow will pass into the Flood Spill Channel until backwater conditions from downstream obstructions prevent flow to pass freely though the channel.

Most of the FSC does not have built-up berms to raise the bank levels and in the more narrow, unimproved channel reach, the channel and banks are essentially natural. The bed slope of the FSC is very gradual throughout most of the channel length, particularly in the widened and straightened reaches. As a result, in the wider channel reaches sediment deposition occurs as the flow velocities decrease.

The channel and bank materials are alluvial material and are subject to erosion during high flow conditions. The banks tend to be unstable if the slopes are too steep and are not protected by vegetation or artificial protection measures. The bed material is silty-sand for most of the channel length and is subject to scour and fill during high flow periods when the FSC is actively conveying flood discharge from the Jhelum River and small tributaries draining into the FSC from the west side of the Jhelum River Basin.

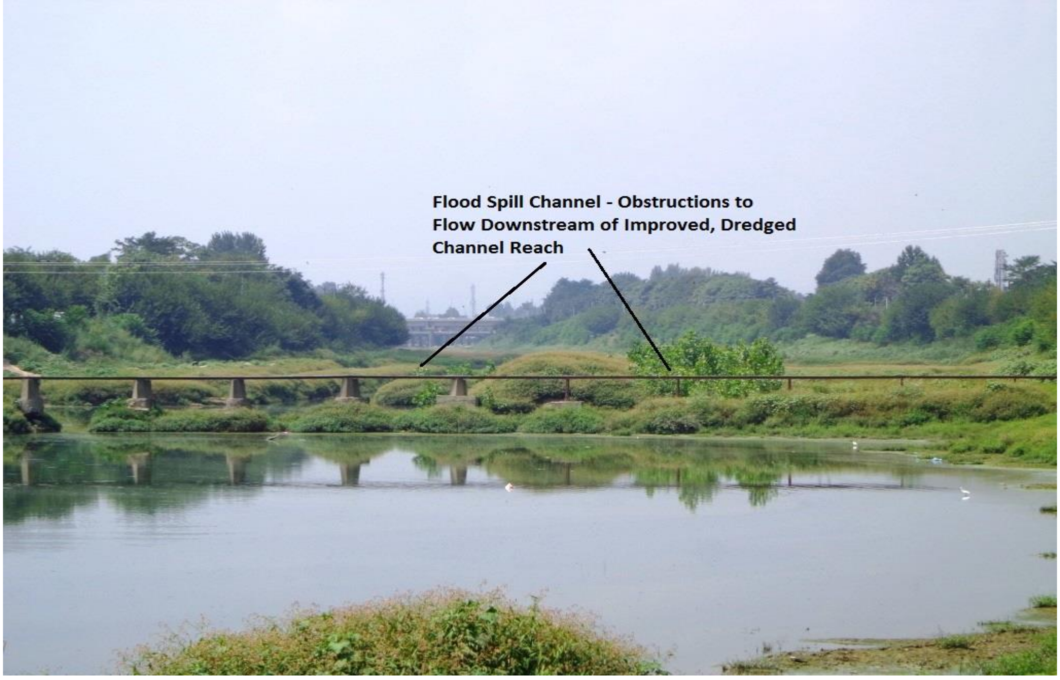
Photograph of Improved Flood Spill Channel Reach – Near inlet

Photograph of Flood Spill Channel Reach –Near Channel Outlet to the Jhelum River – View upstream

5.6.2 Channel Inlet, Constrictions and Obstacles

Several bridges cross the FSC as well as the remnants of old bridges that had been previously removed. The foundations of some of the old bridges remain in the FSC and some non-functional road crossings also remain in the widened reaches of the FSC, forming significant barriers to flow. Earth berm polders have also been constructed in the FSC, particularly in the widened reaches; which also form significant barriers to flow. Trees and other vegetation are growing in most of the FSC and form barriers to flow, as well as trap flood debris, further restricting flood flows.

Photograph of Flood Spill Channel Obstacles to Flow – Low, Narrow Bridge, Vegetation and Berms



Photograph of Flood Spill Channel Obstacles to Flow – Low Bridge, Upstream Berms and Vegetation

5.7 Jhelum River Main Tributaries

There are 24 main tributaries and sub-basins that contribute discharge to the Jhelum River Channel throughout the length of the Jhelum River Basin. **Figure 45** shows the sub-basin catchment delineations and the tributaries leading to the Jhelum River Channel.

A comprehensive list of the major and minor tributaries (nallahs) in the Jhelum River Basin; which includes 103 nallahs and tributaries, as well as estimated channel lengths and confluence junction points throughout the Jhelum River Basin is given in **Appendix C** hereof. The estimated total length of the listed first and second order nallahs is 1876km. The longest nallahs with channel lengths of 30km and over are: Bringi Nallah (30km), Aripath Nallah (44km), Vishow Nallah (62km), Riamb Ara Nallah (50km), Sandran Nallah (44km), Sasara Nallah (38km), Aripal Nallah (32km), Romshi Nallah (40km), Main Lidder Nallah (52km), Sindh Nallah (70km), Doodganga Nallah (42km), Sukhnag Nallah (54km), Ningli Nallah (45km) and Pohru Nallah (58km).

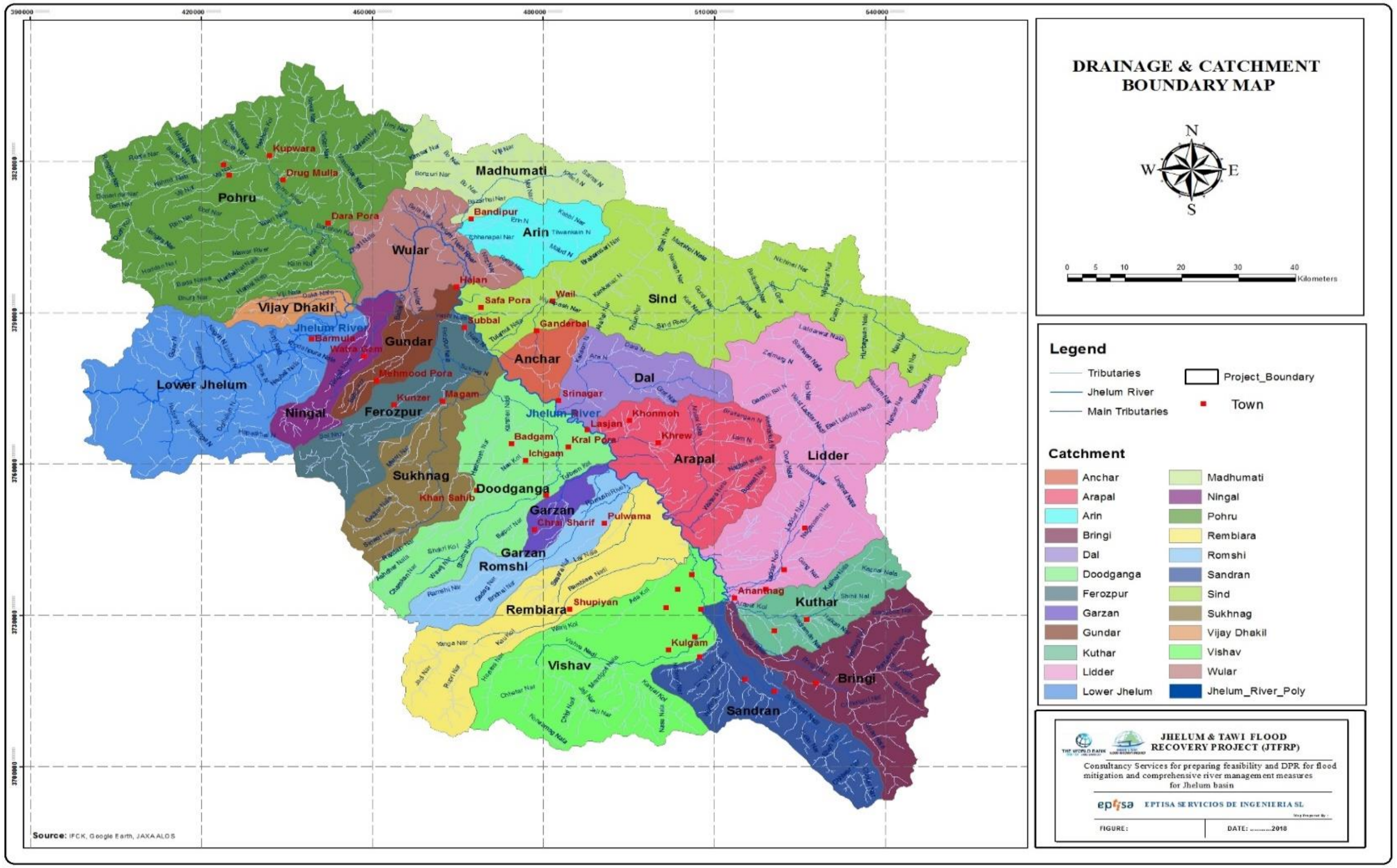
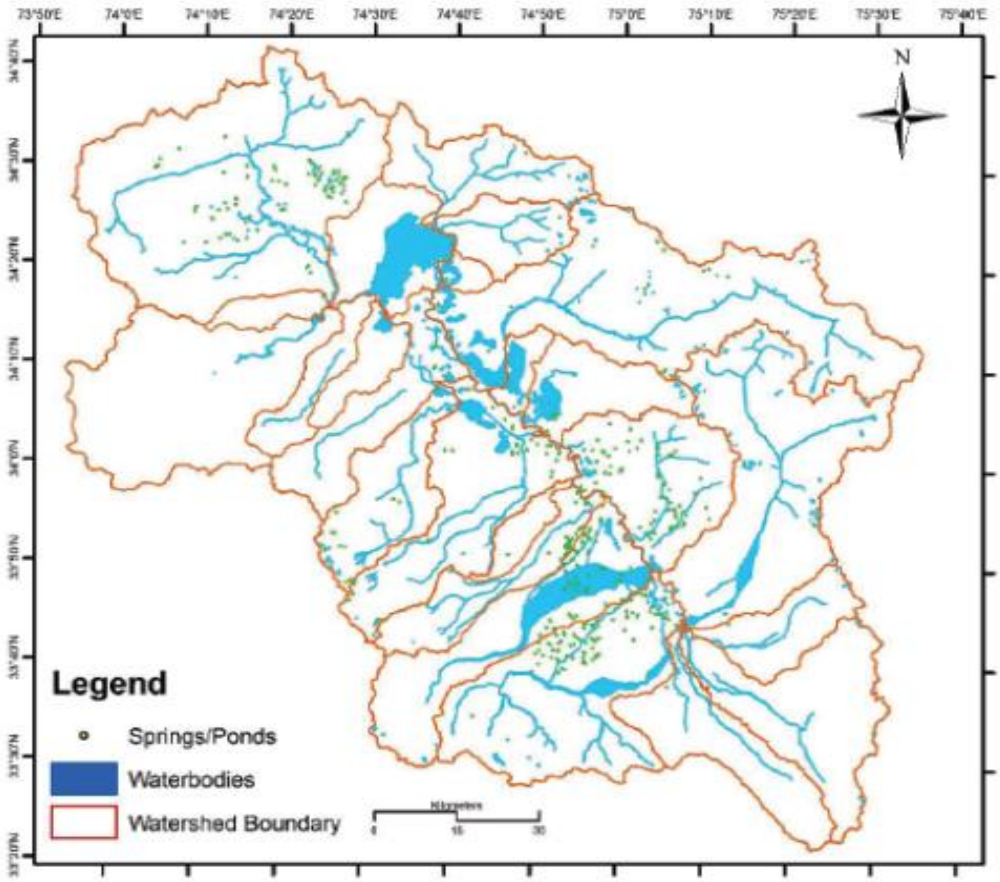


Figure 45 Map of Jhelum River Basin, Major Sub-basins, Tributaries and Jhelum River Channel

5.8 Jhelum River Lakes and Water Bodies

The Jhelum River Basin has many lakes, water bodies and lowland, swampy areas, most located outside the Jhelum River Channel in the floodplain area. Wular Lake, the largest lake in the Jhelum River Basin, has the Jhelum River Channel passing through the centre of the lake, from the south inlet to the west outlet.

The second lake in the Jhelum River Valley with a significant surface area is Dal Lake, located in Srinagar. Most of the remaining lakes and water bodies have individual surface areas less than 3 km^2. **Figure 46** is a general map of lakes and water bodies located in the Jhelum River Valley and Wular Lake is in the northern end of the Valley. **Table 16** lists the most significant lakes, jheels (smaller water bodies) and wetlands in the Jhelum River Basin.



Map showing the main drainage, lakes, wetlands and Waterbodies in the Jhelum basin

(Source: National Wetland Atlas: Jammu and Kashmir, 2010)

Figure 46 Map of Lakes and Water Bodies in Jhelum river Valley

Table 16 List of the Most Significant Lakes, Jheels and Wetlands in the Jhelum River Valley

No.	Names of Lakes, Jheels and Wetlands	Area during flood (km^2)	Low level area (km^2)
1	Wular Lake	175	18-24
2	Haigam Jheel (part of Wular Lake)	7.3	2-3
3	Malgam Wetland (part of Wular Lake)	4.5	1-2
4	Nankara Wetland	3.3	0.75-1
5	Hokersar Wetland	13.2	2-3
6	Nowgam Jheel	9.3	2-3
7	Mirgund Jheel	4.0	1-1.7
8	Anchar Sar/Shallebugh	30	2.5-3.5
9	Khushalsar and Gilsar	1.0	0.5
10	Dal Lake	22	18
11	Manasbal Lake	2.8	2

5.8.1 Wular Lake

Wular Lake is the largest lake in the Jhelum River Basin and is also the only lake that the Jhelum River passes through. The Lake is located near the north-west end of the Jhelum River Basin and much of the Wular Lake area remains exposed and unsubmerged during the drier portions of the year, when Jhelum River flows into the Lake are the lowest. The total area of Wular Lake is an estimated 175km^2 at full capacity and the maximum depth is an estimated 14m when the Lake is full.

During the dry, Summer months, the Wular Lake water area reduces to 18km^2 or less. The elevation of Wular Lake water level ranges from 1574m to 1580m. The maximum length of the Lake is about 16km and the maximum width is about 9.6km. The water-covered lake area varies by season and varies from year to year, based on amounts of rainfall and snowmelt runoff that occur in the Jhelum River Basin upstream of Wular Lake.

Figure 47 is a map of Wular Lake showing the inundated area boundary when the lake is full. The dark blue area shows the area covered by water when the lake level is low, such as in 2017 and 2018.

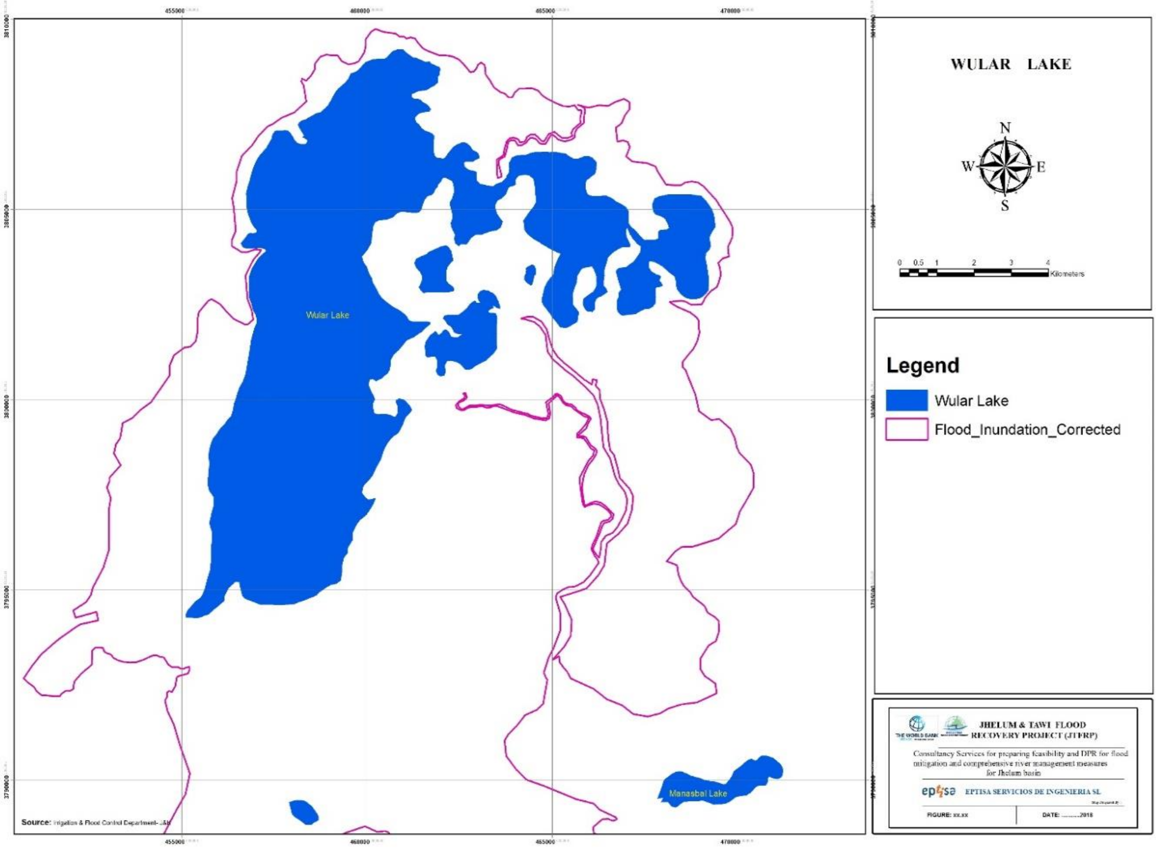


Figure 47 Map of Wular Lake – Flood Inundation Area and Low-Level Area

Figure 48 to **51** show Landsat images of Wular Lake taken in December 1984, December 1991, September 2014 and May 2018, respectively. The red line shows the Jhelum River Channel passing through the Wular Lake area. Note the large difference in submerged area between 1984 and 1991 during the same month of the year. Wular Lake was near full capacity in December 1991. The 2014 Landsat image of Wular Lake in **Figure 50** was taken prior to the mid-September flood period.

In the most recent Landsat image of Wular Lake taken in May 2018 in **Figure 51,** the light green area representing the area of impounded lake water indicates a relatively low submerged lake area, due to relatively low snowfall and precipitation in the previous winter and spring period.

During the dry, summer months, the Wular Lake water area reduces to 18km^2 or less. The elevation of Wular Lake water level ranges from 1574m to 1580m. The maximum length of the Lake is about 16km and the maximum width is about 9.6km. The Jhelum River discharges into the Lake near Bandipora and the Lake outlet is constricted by a temporary earth berm surrounded polder on the west end of the Lake near Ningli, with two outflow channels, one on each side of the earth-rimmed polder.

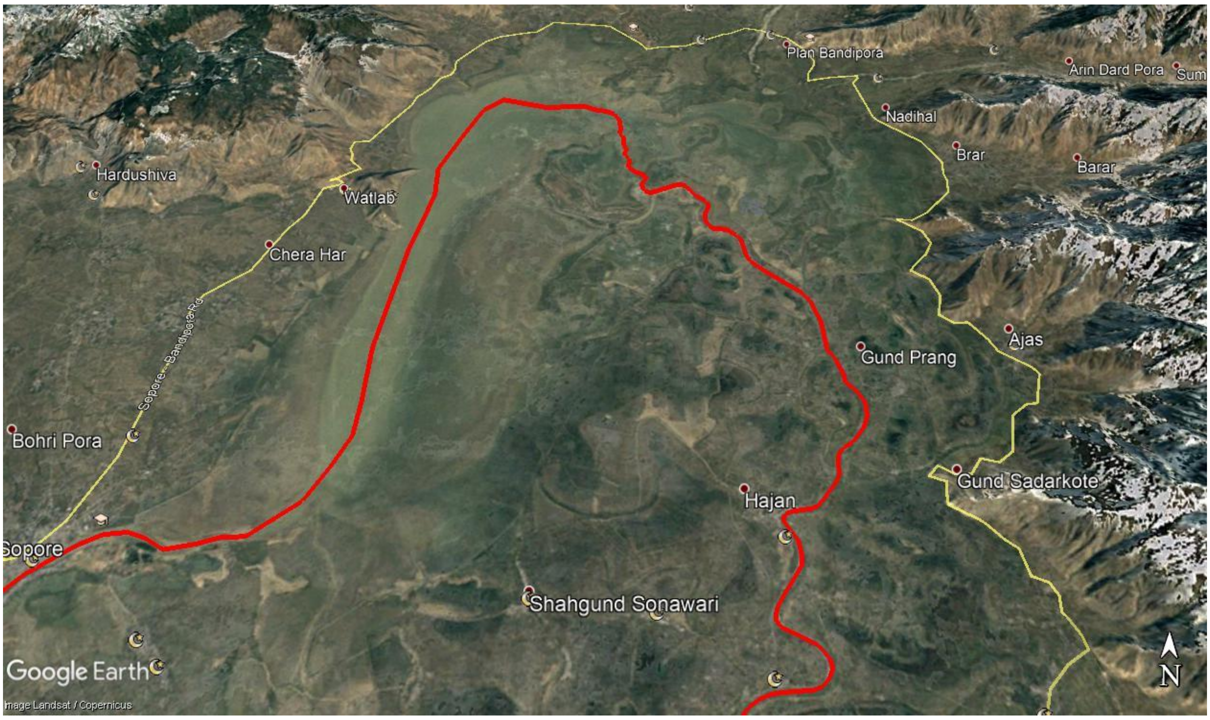


Figure 48 December 1984 Landsat Image of Wular Lake

Figure 49 December 1991 Landsat Image of Wular Lake

Figure 50 September 2014 Landsat Image of Wular Lake

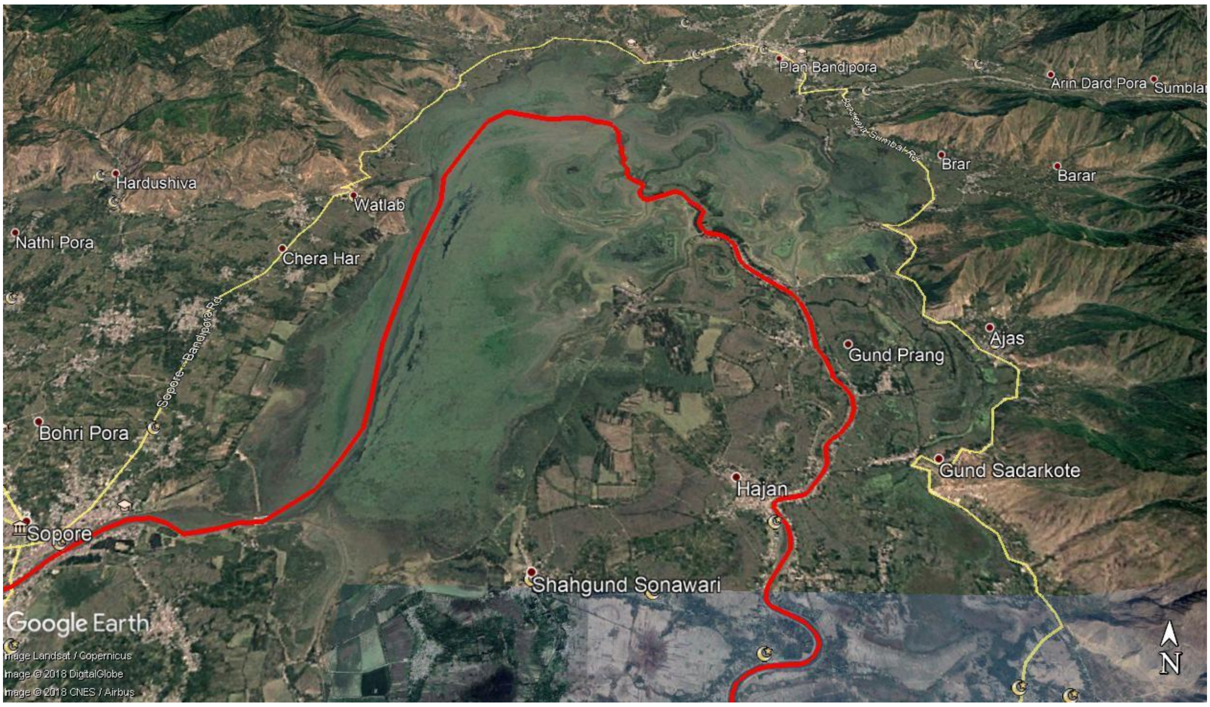


Figure 51 May 2018 Landsat Image of Wular Lake

The temporary polder was constructed to as part of a project to raise the Wular Lake level during the drier summer period, to increase the summer storage, as well as benefit the fishermen who gain their income from fish they harvest from the Lake.   That project is now on hold pending the outcomes of the current study.

Due to the temporary structural polder at the west end of the Lake, the left outlet channel is highly constricted, and the channel velocities are high enough during low flow periods to cause erosion of the polder berm, as well as the left bank of the outlet channel. A bridge has also been constructed across the left channel to link the polder with the left bank and has further constricted the channel width at that point.

IFCK has indicated that this to restrict the outflow is currently on hold and if current Study shows it would be more beneficial for flood control purposes to remove the earth berm polder and connecting bridge at the outlet to promote more unrestricted flow, IFCK may be receptive to such a recommendation.

Figure 52 shows Wular Lake levels recorded between January 2000 and August 2018 was in September 2014, when it was 1580m, approximately 6m higher than the lowest water levels recorded in 2017 and 2018.

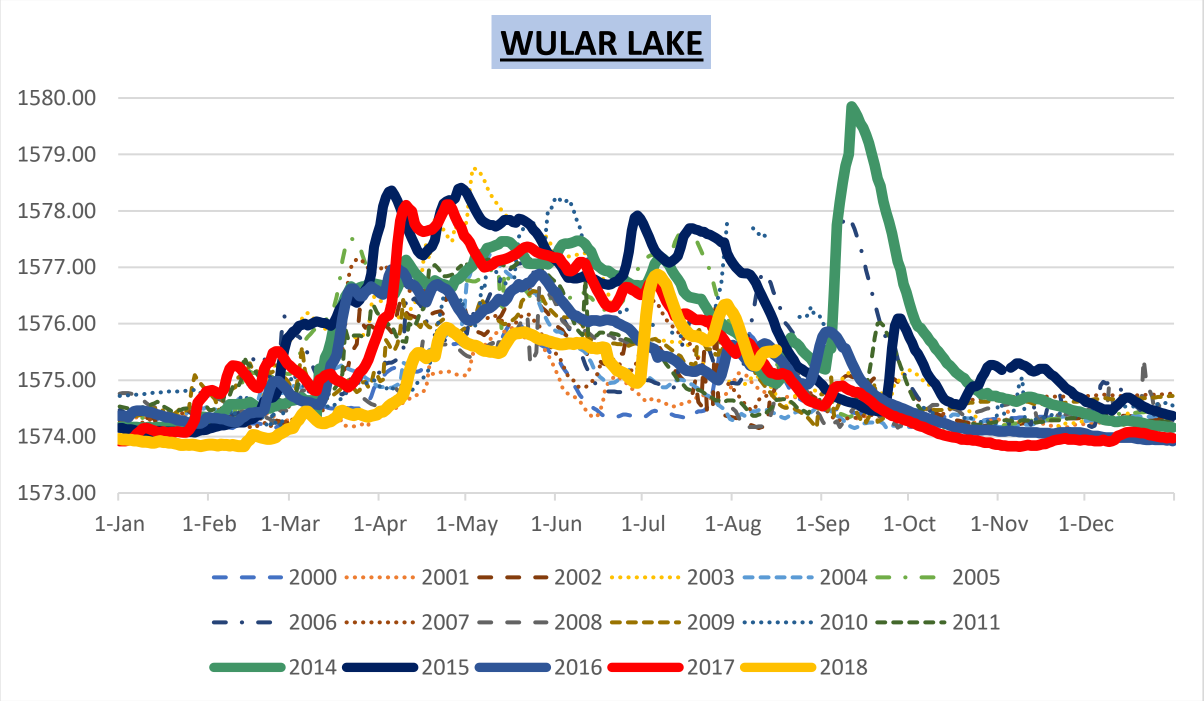
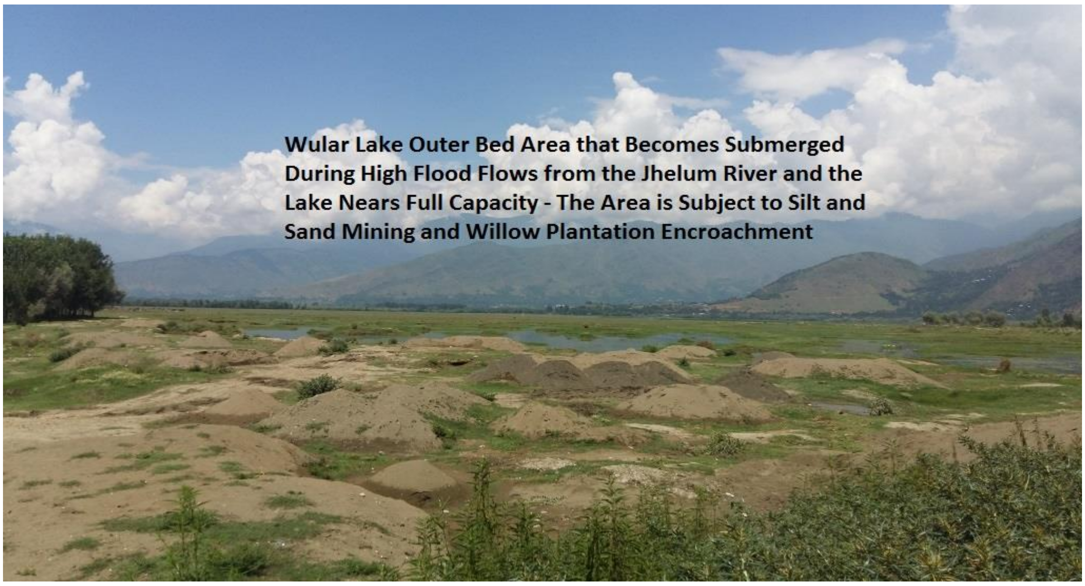


Figure 52 Levels in Wular Lake 2000-2018



Photograph of Exposed Lakebed of Wular Lake on South End Near Jhelum River Inlet

Photograph of Wular Lake Near Outlet to Jhelum River Outfall Channel

Photograph of Wular Lake Right Channel Outlet

Photograph of Wular Lake Left Channel Outlet

5.8.2 Dal Lake

Dal Lake is the second most significant lake in the Jhelum River Valley, particularly since it is closely entwined with the highly urbanized area of Srinagar. The lake is currently connected to the Jhelum River Channel by a controlled cross-channel to help regulate flow between Dal Lake and the Jhelum River. Inflow to Dal Lake comes from Marsar Lake through Telbal Nallah. Outflows are regulated by Dal Gate and Amir Nallah.

Figure 53 shows a 2018 image of Dal Lake. The darker area is the deepest area in the lake and the western side is shallower west and north of Karapura. The smaller lake to the left above Karapura is the Nigeen Lake, which is interconnected with Dal Lake and also with Anchar Lake.

There is significant urban and commercial development along the periphery of the lake, which has led to a deterioration in the lake water quality.

Figure 53 2018 Image of Dal Lake

Dal Lake is a major tourist attraction in Srinagar based on the large number of houseboats along its western shore and internal waterways.

5.8.3 Anchar Lake

Anchar Lake is located north-west of Dal Lake, as shown in **Figure 54** below.

Figure 54 Anchar Lake and Dal Lake

Anchar Lake, shown on the centre of the image in a light green colour on **Figure 55**, and Dal Lake in the lower right corner of the image, are connected by the Amir Nallah, although the Amir Nallah channel is not consistently open to allow clear water passage between the two lakes. As with Dal Lake, the water quality in Anchar Lake has deteriorated significantly from organic pollution and sediment inflows.

Figure 55 2018 Landsat Image of Anchar Lake

Amir Nallah is a distributary channel of the Sindh Nallah's inland delta. **Figure 56** shows the alignment of the Amir Nallah channel centre-line in light blue through which passes through Anchar Lake, Nigeen Lake and Dal Lake to two controlled outflow channels from Dal Lake, leading to the Jhelum River. The channel between Anchar Lake and Dal Lake is blocked at times, not allowing free flow between the two lakes to occur.

The Amir Nallah also has outflow channels from Anchar Lake to a wetlands area to the north-west, to allow passage of flow from the Amir Nallah to the Jhelum River without passing through Dal Lake. The orange-coloured lines show the Sindh Nallah/Amir Nallah branch channels leading to the west and ultimately to the Jhelum River, without passing through Nigeen Lake and Dal Lake. The Jhelum River Channel is shown as a red line in **Figure 56.**

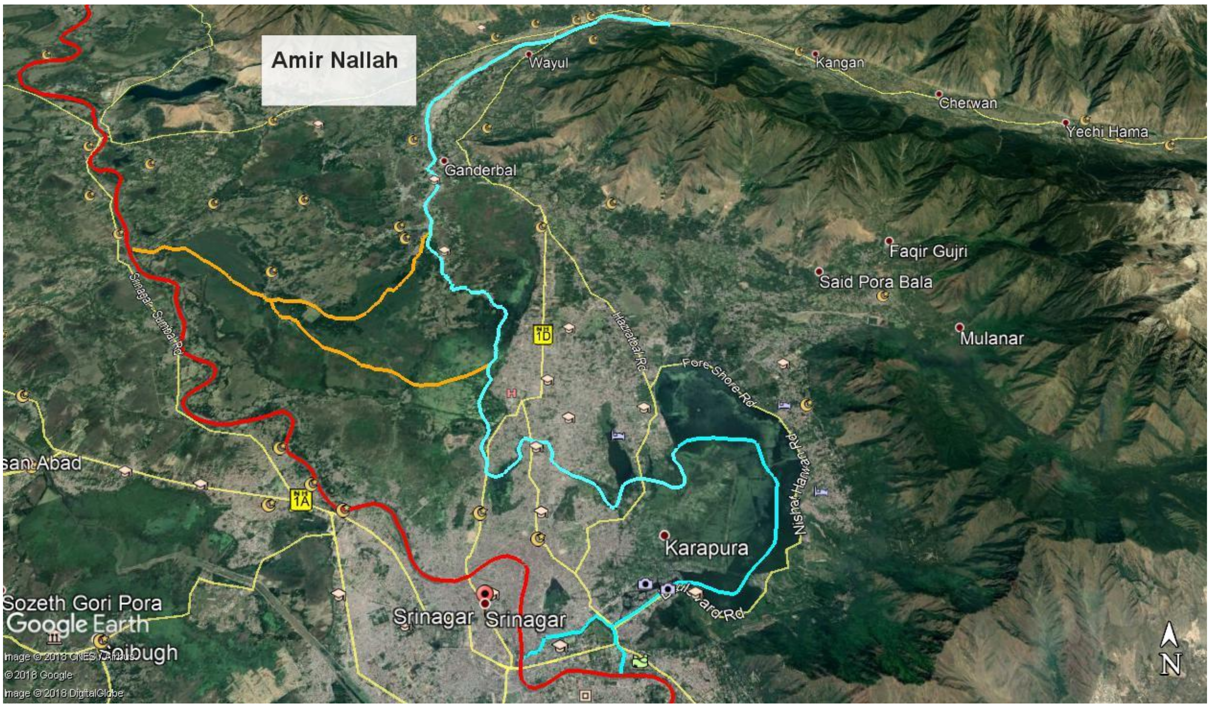


Figure 56 2018 Landsat Image of the Amir Nallah Main Channel and Branch Channels leading to the Jhelum River

5.9 Geomorphologic Models

Due to the large Study Area of the Jhelum River Basin, it is recommended that QGIS and HEC-RAS; which are open domain models, be used for hydrodynamic and geomorphologic modelling. QGIS is the GIS platform that will be used, and HEC-RAS is the hydrodynamic model that will be used for two-dimensional hydraulic modelling of the Jhelum River, Tributaries and Cross-Channels. QGIS will be used to develop a Digital Terrain Model (DTM) of the Jhelum River Basin, and the DTM will be linked to HEC-RAS Mapper for two-dimension presentation of HEC-RAS modelling results. HEC-RAS has the capability to perform inundation mapping of water surface profile results directly from HEC-RAS. Using the HEC-RAS geometry and computed water surface profiles, inundation depth and floodplain boundary datasets are created through the HEC-RAS Mapper. Additional geospatial data will be generated for analysis of flow velocity, shear stress, stream-power and floodway encroachment data.

5.10 Summary

The principal findings in regard to the fluvial geomorphology of the Jhelum River basin are:

- The main channel of the Jhelum River is generally stable having been fixed in place by the construction of high river banks along its whole length to Wular Lake, with minor instabilities on the outside of bends exacerbated by uncontrolled sand mining;
- There is no large-scale evidence of recent instability in the tributary channels, although these are inherently less stable than the Jhelum due to their steeper gradients, significant sediment loads and the absence of constructed banks;
- Sediment generation occurs generally at slopes greater than 15%, particularly above the tree line, with slopes between about 5% and 15% being essentially transport zones, and areas where slope is less than 5% are deposition zones;
- Due to its low gradient the Jhelum River has a meandering course, further development of which is constrained by the constructed river banks – the sinuosity of the meanders is highest on the south side of Srinagar;
- The FSC does not, in the main have increased banks but it does have a number of bed and bank constrictions – the capacity of the FSC is now only about 50% of its original design capacity as the result of sedimentation – it is possible that meander development could start in the future;
- The capacity of Wular Lake has also reduced significantly over recent decades reducing the flood attenuation capacity of the Jhelum River;
- Downstream of Wular Lake, significant sediment inflows from Pohru Nallah impact on the capacity of the Jhelum River and are being controlled by dredging;
- Catchment management, principally by reforestation needs to be expanded in order to reduce sediment generation; and
- Climate change over the remainder of the 21st century and beyond is expected to result in more intense rainfalls, which will exacerbate sediment generation.

6 Methodology and Work Plan

This section sets out the proposed methodology for Tasks 2 to 5 of Part A and of Part B.

6.1 Part A Task 2 – Data Collection

6.1.1 Collectionof Existing Data

As can be seen from the list in **Section 2.2** much of the available spatial, hydrological, meteorological, geomorphological and has already been acquired from IFCK and public domain sources and has been used in the preparation of **Sections 4** and **5** hereof.

Data has also been collected in respect of regional geology, soils and land use from public domain sources.

Considerable data has been collected in the social assessment area which will be supplemented by a significant survey of flood affected communities as outlined in **Section 6.1.8** hereof.

6.1.2 Identification of Data Gaps

The primary data gaps relate to topographic and bathymetric surveys which have already been identified as critical elements of this study. These are discussed further in the paragraphs **6.1.3** and **6.1.4.**

In relation to the social assessment components of the study, the following data gaps have been identified:

- Information related to existing situation before flood impact is yet to be collected to assess the status of impact on livelihood, agriculture production, water quality, health problems, education, shelter, etc.;
- Different proposals, projects, and initiatives undertaken by concerned line department after flood are yet to be collected;
- Existing status of affected persons, post flood conditions and benefits, compensation provided to rehabilitated families, etc.;
- Preliminary social assessment of families likely to be impacted living along the flood improvement proposed intervention alignment or affected areas;
- Awareness programs, community engagement initiatives, skill development training programs to affected persons, etc. information to be collected;
- List of agencies/NGOs/volunteers working in the field of flood management in affected areas in general and project area in particular;
- Any community level initiative undertaken to safeguard interest of flood affected persons to showcase humanity in suffering; and
- Role of media in showcasing actual field conditions and awareness generation to reduce panic condition in case of emergencies (print and electronic).

6.1.3 Bathymetric and River Cross-Section Surveys

The bathymetric surveys and Phase 1 of the river cross-section surveys are already in hand, their commencement being brought forward at Eptisa's request in order that they be completed in time to allow the hydrologic and hydrodynamic model to be developed according to the timing in the works plan. However, even bringing this forward to obtain quotations in August will not allow sufficient time for the development of the hydrodynamic model and completion of the morphology report (Tasks 3 and 4) by their current deadlines of mid-December 2018 and mid-January 2019 respectively. Consequently, the timing of Tasks 3 and 4 will be delayed, as discussed further in **Section 6.7** hereof.

This bathymetric and river-cross section survey is being conducted in 3 components, namely:

a) High accuracy ground control survey
b) River cross-section surveys of the Jhelum River and some tributaries from 2km upstream of the Khanabal Bridge to the Line of Control (LOC)
c) Bathymetric survey of Wular Lake and other waterbodies in the Jhelum River system.

The separate ground control survey is required to ensure high accuracy and consistency between the other survey components and the floodplain survey which is also required for the development of the DEM (refer Section 6.1.9). This is particularly important given the flat gradient of the Jhelum River valley.

Quotations have been sought and received from a number of land survey firms based in Kashmir. At the time of writing, the evaluation of the quotations has not been completed. It is anticipated that contracts will be awarded soon with work starting later in September.

These surveys are being undertaken with high level technology to ensure the highest possible accuracy. The ground control survey has been awarded separately to ensure its independence from the bathymetric and cross-section surveys for which it will provide essential cross-checking. Eptisa will also undertake spot checks on the ground survey components as part of its Quality Assurance procedures.

Phase 2 of the cross-section surveys for the 1900km of tributaries as listed in the TOR is not required for the development of the hydrodynamic models and will be undertaken during the period April-September 2019.

6.1.4 Preparation of Digital Elevation Model

The preparation of the Digital Elevation Model (DEM) is also a critical component for this project. The TOR calls for the development of DEMs at two different resolutions, namely: about 5m for hilly areas and 1m to 2m for floodplain areas. The TOR suggests exploring the SRTM data at 30m grid for the former and high resolution satellite imagery for the latter.

Eptisa has explored the use of the SRTM data (NASA) and the alternative ALOS DEM (JAXA) for the lower resolution DEM both of which are available in the public domain. Both of these DEMs are based on a 30m x 30m grid but the ALOS data is both more recent (2009 as opposed to 2000 for the SRTM) and has better vertical accuracy which has a standard error of 5m for ALOS and 15m for

SRTM. This means that 90% of individual elevation values will be within +/- 10m for ALOS and +/- 30m for SRTM. Carto SAT DEM is also available on a 30m grid and is understood to have similar vertical accuracy to the ALOS DEM.

These are clearly large potential errors, although the errors in adjacent values would normally be much less than this. Although these DEMs can be re-sampled at, say 5m intervals as suggested, this will provide no additional data but will simply interpolate between adjacent points.

Nonetheless we believe that the ALOS data is sufficient for the low resolution DEM which will be used only for the steeper parts of the catchment and primarily for the delineation of sub-catchment boundaries for the hydrologic model, and possibly for peripheral, non-critical regions of the hydrodynamic model.

In respect of the use of satellite imagery Digital Globe (2018) demonstrates that the best possible vertical accuracy is a standard error of about 0.3m resulting in 90% of individual errors being in the range +/- 0.6m. This assumes good ground control which may not be available. This is still insufficiently accurate for the floodplain area of the Jhelum Valley. We understand that RMSI will be pursuing the development of a DEM for the whole of Kashmir at this accuracy for the all Hazards mitigation project that they are undertaking for the JTFRP, so this product will be available on that basis.

In the light of this, Eptisa has developed a brief and, at the time of writing is in the process of seeking quotations in respect of aerial LIDAR survey be undertaken over at least the area inundated in the 2014 flood, an area of about 900km^2 and preferably over a wider area of 1800km^2.

Data from aerial LIDAR would then be used to generate a DEM at 1m x 1m grid with a standard error of about

6.1.5 Review of Hydrologic Network

The hydrologic network is already quite extensive along the Jhelum mainstream and the tributaries. We will review the network paying particular attention to the flood forecasting and warning aspect which would benefit from the placement of stations further upstream on the tributaries. The construction of hydrologic stations higher in the catchment may be restricted due to access, but that will be part of the evaluation.

One clear limitation of the current network is that there are no measuring stations along the FSC or on the channel downstream leading to Wular Lake or on some of the tributaries feeding directly into the FSC. Measurements on all of these waterways is required to fully quantify the water balance for the Jhelum system. Preferably, there should also be station at the inflow to Wular Lake as well as its outflow. Additional stations may also required on the Sindh Nallah sufficient to quantify the flows into and out of Anchar Lake including those on the channels between Anchar Lake and Dal Lake.

It may also be advisable to add stations at the offtake of the possible additional diversion channel near Dogripora in the main flood breakout channels.

Radar sensors for water level recorders will be preferred located on bridges where practical to do so.

The need for water quality and sediment sampling stations will also be reviewed and appropriate recommendations made. In the Jhelum River mainstream, sediment samples from sand mining operations will provide the bulk of the information. Sampling of suspended load and bed load is only worthwhile during high flows when access is difficult – the value of instigating a sample collection program will be evaluated and appropriate recommendations made.

In addition to reviewing the hydrologic data network, we will also review the accuracy of the flow data. This will be done in the following ways:

- Comparison by means of mass curves and double-mass curves of rainfall and streamflow to determine consistency over time;
- Volume comparison of flows at various locations;
- I&FC has already provided stage-discharge rating curves for the principal stations which will be reviewed
- The actual discharge measurements (prior to 2015) are understood to be based on float measurement of water surface velocity – these will be reviewed for estimation of mean channel velocity and the means of cross-section estimation used (e.g. from former surveys), enabling an estimation of the accuracy of individual gaugings.
- The float gaugings will also be compared with post-2015 gaugings using Acoustic Doppler Current Profilers (ADCP) of which we understand IFCK has two.

6.1.6 Additional Hydrometeorological Stations

Based on the above review, recommendations will be made for procurement of equipment to enhance the hydro-meteorological network including rain gauges, water level recorders and ADCPs. This will include recommendations for telemetry whether this be via radio (RF) or satellite technology (such as Galileo).

Construction of new stations under this process is programmed to take place in April/May 2019, so any data from the new sites will not be available until after the completion of Part A of the Study. As well as their use for routine monitoring, flood forecasting and warning in the future, early data from these stations may enable the hydrologic and hydrodynamic modelling to be refined during **Part B** of the Study.

Specifications for equipment procurement, site construction and commissioning will be prepared as part of this task.

We understand that IFCK has recently established a Flood Warning Centre (FWC) and Eptisa will review the current arrangements in order to assist in establishing an FWC in a flood free location with standby electrical power generation, incoming telemetry, data processing telecoms and radio communication equipment.

6.1.7 Conduct geotechnical, geomorphological and geological investigations

It is currently envisaged that the investigations under this task will primarily be geotechnical investigation of potential sites for structural works such a new flood control storage and/or diversion channels. The will require geotechnical investigations of both foundation materials and materials available for construction (borrow pits). Local geological mapping will be required around these sites, but no large scale geological mapping is envisaged.

Depending on the scale of proposed structures, foundations will be logged from boreholes and/or test pits and soil samples collected from these excavations will be tested for a range of parameters as a minimum, the following:

- **Gradings**: both mechanical sieving and hydrometer tests to determine the particle size distribution, identify the predominant soil type and the likely permeability of the material;
- **Atterberg limits**: measure the plastic limit and liquid limit of soil to enable the material to be classified and its suitability as a fill material assessed;
- **Proctor test**: to determine the maximum dry density and the optimum moisture content for use in compaction control during construction. Soils compacted to the maximum dry density are then at their maximum strength;
- **Crumb test**: to determine the disposition of the soil to disperse.

The numbers of tests required will be determined once the type and scale of possible structures has been identified. The geotechnical investigations will be undertaken during the feasibility study phase once potential options with merit have been identified – this is expected to commence in February 2019.

In respect of morphological data, bed samples from the Jhelum River Channel will be taken from different locations and reaches along the Jhelum River from Khanabal to Wular Lake and downstream. These will be analysed to determine the particle size distribution and clay fraction. This is particularly important downstream of main tributary confluence points with the Jhelum River and in lower reaches of the main tributaries, to help determine the primary origins of the sediment loads in the Jhelum River

Water samples will be taken from the Jhelum River, Dal Lake, Manasbal Lake, Anchar Lake and Wular Lake for water quality analyses. We also propose to conduct field water quality analyses for pH, turbidity, EC, temperature, etc. in selected locations.

6.1.8 Conduct Community Surveys

The overall objective of the assignment will be to:

a) To compile perception, needs and priorities, problems faced, feedback, and suggestion of various stakeholders including general community, affected persons, migrant labours, officials from concerned line departments, etc. to improve upon flood management systems.

b) Identify prioroty areas for planning awareness and skill develoment initiatves to improve economic status of local community including affected persons and overcome flood risks in future

c) To plan employment interventions in recovery and reconstruction need through institutional capacity building and programme design.

d) To undertake social assessment and compile information related to socio-economic status, social impact, status of land acquisitions, land transfers, donations etc. if any due to proposed interventions.

e) To plan community awareness and capacity building program to overcome flood risks in future.

The proposed approach is outlined in **Figure 57**. Appropriate components of this approach will include a community survey. This will be based on a target sample of about 5% of affected households. Appropriate survey forms/questionaires will be developed and a team of about 10 employed to undertake these surveys under the direction of the appropriate Study Team Members.

Survey results will be analysed and used to inform design of structural and non-structural works. Economic data produced from the survey will be used to inform the economic analysis to be undertaken in the feasibility study phase.

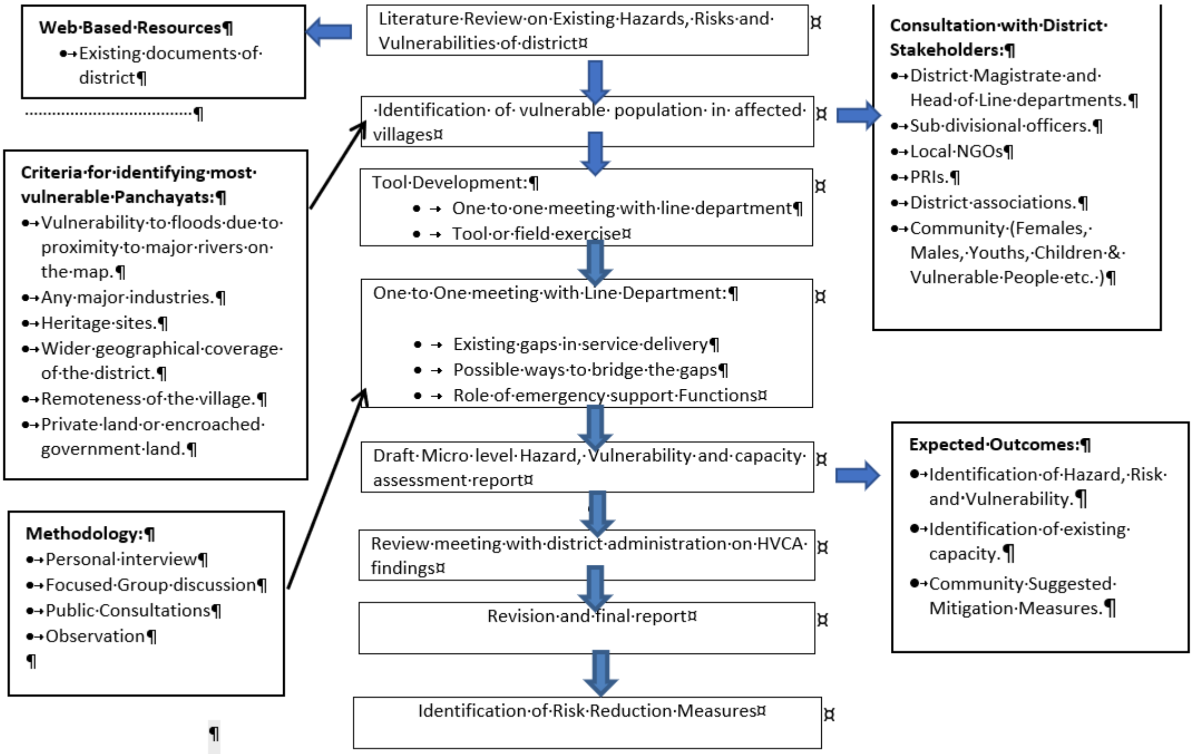


Figure 57 Proposed Risk Assessment Process

The proposed approach and methodology is summarised as follows:

Literature review and identification of stakeholders including vulnerables: The approach towards the entire exercise will include secondary data collection from different line agencies on issues related to existing status of state initiatives to take mitigation measures for flood affected persons, social, economic, health etc. status. The checklist for information required will be prepared for collection of information directly from concerned line department and/or through official websites. In addition to this, stakeholder identification and analysis or stakeholder mapping, will be done for undertaking public and stakeholders consultations, interviews, focus group discussions etc. The required information required and related approach are:

- Meeting with IFCK, JKSDMA, District Magistrate, Line Department officials, to know their perspective on social safeguard aspects. The existing data in the district will be collected from the different line department of the respective districts. The NIC of the respective districts will be involved in the data compilation.
- Meetings with PRI members and local NGOs to familiarise with the local issues and potential risk at district level. The participatory risk assessment exercise will be planned in detail with the help of local Panchayats.
- Secondary data from various sources for hazard, vulnerability and capacity analysis will be collected. The data will be collected from all the sources available in the districts such as line department, university and also from different NGOs.

The proposed stakeholders' and their roles in this process as listed in **Table 17.**

Preparation of survey tool and selection of survey team: This will be inclusive of development of questionnaire, checklist and draft template, training of local survey teams, primary data collection and use of GIS for hazard mapping, resource mapping and vulnerability mapping.

It is proposed to identify atleast 10-15 young boys and girls from college, university, or other locals from affected/project area districts interested to undertake survey. The identified survey team will be trained prior to sending them in field. The information collected will be crosschecked, reviewed by the Study Team and compiled for preparation of the assessment report.

The outputs will be directed to the district level Advisory Committee of each district together with detail timeline from district authorities to adopt the process and methodologies of Social Safeguards and community engagement plan.

Undertaking Social Assessment and preparation of report: The identified survey team will conduct social assessment survey and fill approximately 5 or 10% of the sample size from identified affected districts. The sample size to be collected during the survey will be finalised in consultation with IFCK. The detailed districtwise sampling will be done on the basis of total households, number of affected person etc. In addtion to this, 1-2 focus group discussion and public consultation will be organised amongst identified stakeholders. The preparation of the Assessment Report will be based on the outcome of the survey finding and focus group discussions.

The Assessment Report will be inclusive of proposed strategy for community awareness and engagement for flood risk management together with a related action plan with measurable indicators.

Table 17 Proposed Stakeholders and their Roles

Sr. No.	Name of Partner Agency	Role
1	Eptisa	Facilitating Agency (Lead Agency): Coordinate the entire initiative: • Engaging with state level agencies and DDMA • Coordinate with state and district governments • Jointly organise district level consultation with respective DDMA and state authority in each district • Prepare training module • Conduct survey • Data Collection
2	JKSDMA	• State Level Guidance and Approvals • Facilitate district authorities • Presence and guidance during state consultation
3	DDMAs	• District Level Guidance and Approvals • Line department coordination • Communication • Logistic arrangement • Coordination with panchayat • Support and linkage to Flagship schemes • Commitment to link JTFRP with Panchayat plans
4	PRIs and municipalities/ municipal corporation and Grass root Organisations	• Grass root level support and guidance to design outline of Social Safeguard Plan • Commitment to capture voices of vulnerable groups in DDMP • Coordinate with government agencies and get the plans of district consultations implemented
5	Flood and Irrigation Department (IFCK)	• Coordinate with JKSDMA; • Coordinate with other agencies doing social assessments in other flood districts of the state; • Guidance to organise consultations on Social Safeguards aspects in DDMP Framework

District level consultation will be organised in each proposed project district during the project for sharing of draft survey findings and to incorporate the social safeguard aspects in the District Disaster Management Plans (DDMP). This will be mainly with District Disaster Management Authority (DDMA) and other line departments, PRIs, municipalities/municipal corporations, grassroots organisations/CBOs and communities. This will be facilitated by Eptisa along with DDMA of the respective districts.

Social Safeguard aspects in DDMP: Preparation Planning and Reporting Mechanism for Ensuring involvement and ownership of DDMAs

District level consultation will be organised in the project . This will be mainly done with District Disaster Management Authority and other line departments, PRIs, municipalities/ municipal corporations, grassroots organisations/CBOs and communities. This will be facilitated by Eptisa and other NGOs active in the local area. The outputs will be directed to the district level Advisory Committee of each district and seek commitment from district authorities to adopt the process and methodologies of Social Safeguards. In each and every step the district level flood recovery department and DDMA will be involved so that they are aware about the entire process. The agency will also orient the entire district team so that the DDMA take take the lead in future updates of the DDMP.

6.1.9 Development of Geomorphological Database

All of the geomorphologic, hydrologic and spatial data obtained and analysed during this phase of the Study will be recorded into a well structured computer database.

User friendly tools will be developed in order to provide access for viewing, search and reporting from the database. Whilst the broad database can be made available for public access, access for updating and editing will be limited to appropriate personnel. The database will be a live document which can be readily updated as further data become available.

It is anticipated that the database will include the following:

- **Spatial data** – satellite imagery, aerial photography, mapping – topographic, geomorphologic, geologic, soils, land use and other relevant mapping;
- **Flood data**– inundation mapping, location of breaches, flood damage data, debris surveys, infrastructure damage;
- **River morphology and hydraulics** – river cross-sections, bathymetry, bank material, channel modifications, river bed and bank erosion and deposition, avulsions, head cuts;
- **Geotechnical & geological data** – regional geology, data from field investigations;
- **River Management** – bank protection works, river training works;
- **Hydrometric data** – water level records, discharge records, flow gauging records, rating curves, sediment data (suspended load and bed load), water quality data;
- **Precipitation data**: long term daily rainfall and snowfall data, sub-daily data for storm events, rainfall intensity-frequency-duration (IFD) curves, rainfall depth-area-duration (DAD) curves, isohyetal maps, flood producing storms, monthly, annual;
- **Other natural hazards** – earthquakes, landslides, glacial lake outflow floods

- **Environmental and Ecological data –** forest cover, land use, environmental degradation, loss of habit and diversity, RAMSAR data;
- **Socio-economic data** – demography, economic data, flood damages, loss of livelihood, health impacts;
- **Other relevant data**.

6.1.10 D2 - Data Collection Report

A comprehensive Data Collection Report (Deliverable 2) will be compiled which will describe the work undertaken in Task 2 under the sub-headings outlined above. The data collected in each sub-task will be included in Appendices to the report and will form the basis of the database.

It is not practical to include the tributary surveys, installation of additional hydrometric stations, or the geotechnical investigations required for the feasibility study within the timeframe of Task 2. These items have been left in Task 2 but will need to be reported upon later. In all other respects, the updated work plan complies with the timing of deliverables as stated in the Contract.

6.2 Part A Task 3 – Establishment of Hydrologic and Hydrodynamic Models

The timing of Task 3 is totally dependant on the timely completion of the river cross-section, bathymetry and LIDAR surveys for the development of the hydrodynamic model. Any delay in completion of these surveys will inevitably delay tasks 3 and 4 and the submission dates of their deliverables.

6.2.1 Data Requirements

The data required for the establishment and development of the hydrologic and hydrodynamic models comprises:

a) *For the Hydrologic Model*

- Sub-daily rainfall and daily rainfall data for all rain recorders and rain gauges in the catchment over the catchment for the September 2014 calibration event and for the 1992 validation event;
- Hourly (or at least 3 times per day) stage and discharge levels at all Jhelum River and tributary flow gauging stations for the September 2014 calibration event and for the 1992 validation event;
- Map of catchment and tributary sub-catchments;
- Soils maps;
- Land use maps;
- Low resolution DEM.

b) *for the Hydrodynamic Model*

- high resolution DEM compiled from ground survey, river cross-section survey and bathymetric survey;
- historical records of flood extent and floodplain flood depth for the September 2014 calibration event and for the 1992 validation event;

- historical records of river embankment breaches for the September 2014 calibration event and for the 1992 validation event;
- historic records of major erosion or deposition for the September 2014 calibration event and for the 1992 validation event;
- aerial photography (Google Earth);
- map of hydraulic roughness to be developed from aerial photography and land use mapping;
- details of all hydraulic structures including bridges, weirs, gates;
- hydrograph inputs to model (from hydrologic model);
- downstream model boundary condition.

6.2.2 Model Development, Calibration and Validation

a) Hydrologic Model

The purpose of the hydrologic model is to be able to replicate the flow hydrographs from each of the tributaries which then form the main input to the hydrodynamic model. By calibrating and validating the hydrologic model with the historic data, it can then be used with "design" data representing rainfalls for a number of synthetic events such as the 1% Annual Exceedance Probability (AEP) (also known as the 100 year Average Recurrence Interval) or events of other probabilities.

The first requirement in the setup of the hydrologic model is to define the catchment and the delineation of sub-catchments. Given the size of the tributary catchments, these will also be subdivided according to the drainage structure. This will be done to give roughly equal sub-catchment areas with a total number of not more than 100.

In addition to catchment areas, flow path length in each sub-catchment and gradient will be derived from the DEM to complete the physical structure components of the model.

The model is then subject to the input from the rainfall records for the main calibration event (September 2014). Each sub-catchment can have a different rainfall input, so the distribution of the historic rainfall across the catchment will be evaluated either using the Thiessen Polygon or by curve fitting.

HEC-HMS contains a number of sub models which must then be selected and calibrated. These include a canopy model (for interception loss), a surface model (for interception loss), a rainfall-runoff transform model, a baseflow generation model and a flow routing model. For each of these component models there are a number of options, each of which contains a number of parameters. Component models and parameters can be varied between sub-catchments. Where calibration data area available for each sub-catchment, the model can be complex. In this instance, there are flow data available at the downstream end of most (but not all) tributary catchments but generally not within the tributaries. Given this, a model of moderate complexity is anticipated.

The hydrologic model will be established for the whole of the Jhelum River basin within Kashmir. Sub-model component types and parameters will be varied so as to replicate the recorded tributary flow hydrographs as well as possible. It is expected that sub-models and parameters will vary between tributaries according to variations in their physical characteristics and geology. Tributaries with no flow records will use assumed values from adjacent tributaries.

Once a satisfactory calibration is achieved, the fitted model will be run with the rainfall inputs from the validation event, and the outputs compared to the recorded flows. Good agreement serves to validate the model and give confidence that it can be used with other events such as “design” events. If the validation run produces poor results, further work on calibration will be undertaken until satisfactory results are achieved from the validation event.

In this instance, good calibration to the 2014 flood is paramount as this is essentially the design flood.

The flow hydrographs from the hydrologic model are then used as the input boundary conditions for the hydrodynamic model.

b) Hydrodynamic Model

The first action required in the establishment of the hydrodynamic model is to input the high resolution DEM. This DEM should cover the area inundated in the 2014 flood plus a buffer. HEC-RAS has internal routines that allow the combination of DEMs if this has not been done externally. The model will not be established to cover the whole catchment as this would result in excessive computation times and is not necessary given the tributary inputs are defined near their entry into the Jhelum River. These entry points will be on, or close to, the model boundary.

Initially, a single 2-D model area will be used to cover the whole of the Jhelum River floodplain. Depending on the complexity as model elements are added, it may be necessary to separate the 2-D model into a number of smaller flow areas but his will be kept to a minimum commensurate with the requirements of the model. Hydraulic structures such as bridges, weirs and gates will be added as appropriate. The attenuation of the flood by passage though Wular Lake and the other waterbodies will occur directly as result of the DEM.

Model hydraulic roughness (Manning’s n) for the river channels, FSC, waterbodies, road, floodplains, urban areas will be mapped and given initial values based on normal values and experience. Modification of hydraulic roughness is one of the main tools in model calibration.

Once the model is set up, it will be run under 2014 conditions for the 2014 flood inputs. For example, the new expressway which was constructed after the 2014 flood will be removed form the model. Any other known adjustments of this type will also be made.

The performance of the model will be scrutinised in detail and compared to the actual flood behaviour in reality. The ability of the model to map the flood extent (and other parameters such as velocity, depth, shear stress etc) at selected time interval during the flood is extremely useful in this regard, so that considerations such as the timing at the point of overtopping of banks at various locations and the duration of flooding at various locations, can be taken into account in the calibration rather than just the flood peak.

The calibration will be developed to firstly replicate the levels along the Jhelum River and through Wular Lake, the OFC and the FSC to the extent possible, then fine tuned to replicate floodplain levels.

The model will be calibrated using the 2018 river cross-sections and bathymetry, as these are not available for 2014 conditions. This will introduce an unknown error into the modelling which is unavoidable. It may be possible to approximately georeference the 2010 cross-section used in the CWPRS's 1-D model to provide an alternative below water DEM. As there was no major flood between 2010 and 2014 this may be a better representation. This will be investigated during the modelling process.

Once the model has been satisfactorily calibrated it will be run with the 1992 flood and its performance evaluated. As for the hydrologic mode, good agreement serves to validate the model and give confidence that it can be used with other events such as "design" events. If the validation run produces poor results, further work on calibration will be undertaken until satisfactory results are achieved from the validation event.

The "on the fly" mapping referred to above may be used to produce an "animation" video showing the spread and subsequent retreat of the floodwaters, which has proven to be a valuable visual tool in community and stakeholder consultation.

The model calibration will be undertaken in close consultation with the IFCK as they have the best knowledge in this regard.

6.2.3 D3 - Report on Establishment of Hydrologic and Hydrodynamic Models

Deliverable 3, the report on the establishment of the hydrologic and hydrodynamic modelling of the calibration and validation floods will be prepared and submitted according to the revised Work Plan. This will provide a full description of the model development, data used, calibration and validation performance.

As stated above, the timing of this component is totally dependant on the timely completion of the river cross-section, bathymetry and LIDAR surveys for the development of the hydrodynamic model. Any delay in completion of these surveys will inevitably delay tasks 3 and 4 and the submission dates of their deliverables.

6.3 Part A Task 4 – Preparation of River Hydrology and Morphological Report

Primarily, Task 4 will comprise updating of the preliminary hydrology and morphology reports prepared under Task 1 based on the outcomes of Tasks 2 and 3. In addition the following form part of Task 4.

6.3.1 Review National Guidelines and Global Experience

A review of national and international guidelines on flood modelling and reporting on the hydrology and geomorphology of floods will be undertaken to ensure that the reports prepared by this study represent current best practice in this regard.

This will include national guidelines from the Central Water Commission (CWC), and the National Disaster Management Authority, and international guidelines from World Meteorological Organisation (WMA) the US Federal Emergency Management Agency (FEMA), European Union Flood Directives, best practice guide United Kingdom and Australia.

This sub-task will also include stakeholder consultation and a stakeholder workshop.

6.3.2 D4 - Prepare Updated Hydrology and Morphology Report

Following receipt of comments from the draft report and from the stakeholder consultation and any ideas from the guideline review, we will prepare the Final (Revised) Hydrology and Morphology Report.

As stated above, the timing of this component is totally dependant on the timely completion of the river cross-section, bathymetry and LIDAR surveys for the development of the hydrodynamic model. Any delay in completion of these surveys will inevitably delay tasks 3 and 4 and the submission dates of their deliverables.

6.3.3 Training in Models and Database

We will prepare user manuals for the hydrologic and hydrodynamic models and for the morphologic database and provide training in their use. The training will be tailored to the needs of JTFRP and IFCK in particular.

6.4 Part A Task 5 – Feasibility Study

The feasibility study phase will include the identification and evaluation of a range of potentially effective flood mitigation options. These will be initially evaluated individually and short listed when the remaining options may be considered in combination.

6.4.1 Identify and Evaluate Options

All of the modelling to this point will have been in regard to conditions as existing at the time of the 2014 flood. From this point the model will be modified to include a range of potential structural flood mitigation measures including the following:

- Proposals for dredging of Wular Lake and other waterbodies;
- Proposals for a new diversion channel creating a shorter route from the FSC to Wular Lake;
- The effectiveness of current proposal to widen the OFC;
- The possible additional diversion channel from Dogripora to Wular Lake;
- Development of detention basins within the floodplain;
- Potential for meander cutoffs and other river management measures;
- Possible development of flood control storage on southern catchments;
- Possible development of flood control storage on Pohru Nallah and Sindh Nallah;
- Various operational strategies to increase the use of Dal Lake and Nagin Lake;
- Other, not yet identified.

6.4.2 Feasibility Study

Initially, these and any other identified measures will be modelled individually and their effectiveness in flood mitigation evaluated. In addition to their flood control benefit this will include consideration of their environmental and socio-economic impacts, cost and constructability risk. Short-listing of these measures will be undertaken based on the above considerations and those potential measures with little or no merit, or with significant negative impacts will be discounted from further consideration. A stakeholder workshop will be held to short list the options.

The short-listed options will then be subject to further investigation including concept design, further geotechnical investigation (if required), EIA and EMP.

In addition to considering the individual proposals individually, at this point various, appropriate combinations will also be considered and evaluated.

The outcomes from these investigations will be used to prepare the Draft Feasibility Report (D5). A further stakeholder workshop will be held to discuss the findings of the draft feasibility report. The Final Feasibility Report (D6) will then be prepared taking account of the discussions and outcomes of the stakeholder workshop, reporting from which will be included in an Appendix to the report.

The feasibility study will also include the consideration of a range of non-structural measures including:

- Development and enforcement of planning controls to exclude or severely restrict development in flood prone areas;
- Where development in floodplain areas is allowed, to specify minimum floor heights of buildings and where this is substantially above ground to require the building to be constructed on piles with no walls within the flood prone area to minimise the impact on floodplain flow;
- Acquisition and demolition of the worst affected buildings with adequate and appropriate compensation to owners – following demolition these areas should be preserved as open space such as parks;
- Improvement of flood forecasting and warning system by the installation of a SCADA based system;
- Upgrading of the provision of flood warning system to improve the dissemination of warnings to the public (possibly by SMS) and of interpretation of flood warnings (possibly by flood markers in streets);
- Use of floodplain mapping, to be developed by the study, to increase community awareness of flood issues and to enable meaningful interpretation of flood warnings;
- Control of the ongoing sand mining of the Jhelum main channel by a myriad of boats – whilst the sand mining is of benefit overall, there will be areas which are over-dredged which risks undermining of river banks and bridge piers – control by licencing, identification of areas in which sand mining is not permitted and enforcement could be undertaken either by IFCK or by a separate agency established for this purpose.

The Final Feasibility Report will form the basis for the work to be undertaken in **Part B** of the study.

6.4.2 Propose SCADA System

The TOR refers to the proposed SCADA system in the context of monitoring and controlling flow for flood regulation in relation to flow regulators such as gates and other structures. The only gates of which Eptisa is currently aware are those linking the outflow from Dal Lake to the Jhelum River, which are operated infrequently. It is possible that additional gate or other control structures will be recommended by the study.

It is likely that telemetry systems will be recommended in respect of the flood warning system and this also requires SCADA systems for sending messages of warning levels to a control centre, even if no direct control system is required in this case. Where flood waring lead times are short, the telemetry system can be used to trigger the dissemination of flood warnings, for example, via SMS messages.

The requirements for the SCADA system will be evaluated so that appropriate technology can be applied. Except at gates or other control structures which require significant power input, upstream detection equipment requires only solar cell with battery storage. Nonetheless access issues may be important in remote, upstream locations.

The choice of communication system also needs consideration, - this can be via the telephone system, UHF or VHF radio and by satellite. If some telemetry stations are at high elevation, there may be no cell phone signal, and line-of-sight radio will not be an option, meaning that satellite communication can be the only possible option. The perceived risks and challenges to the timely completion of the project are listed in the **Table 1** together with their level of risk, and proposed risk mitigation. These relate to river cross-section, bathymetric and floodplain surveys to be undertaken in Task 2: delays in these surveys will result in delay to the flood modelling and feasibility study tasks in particular.

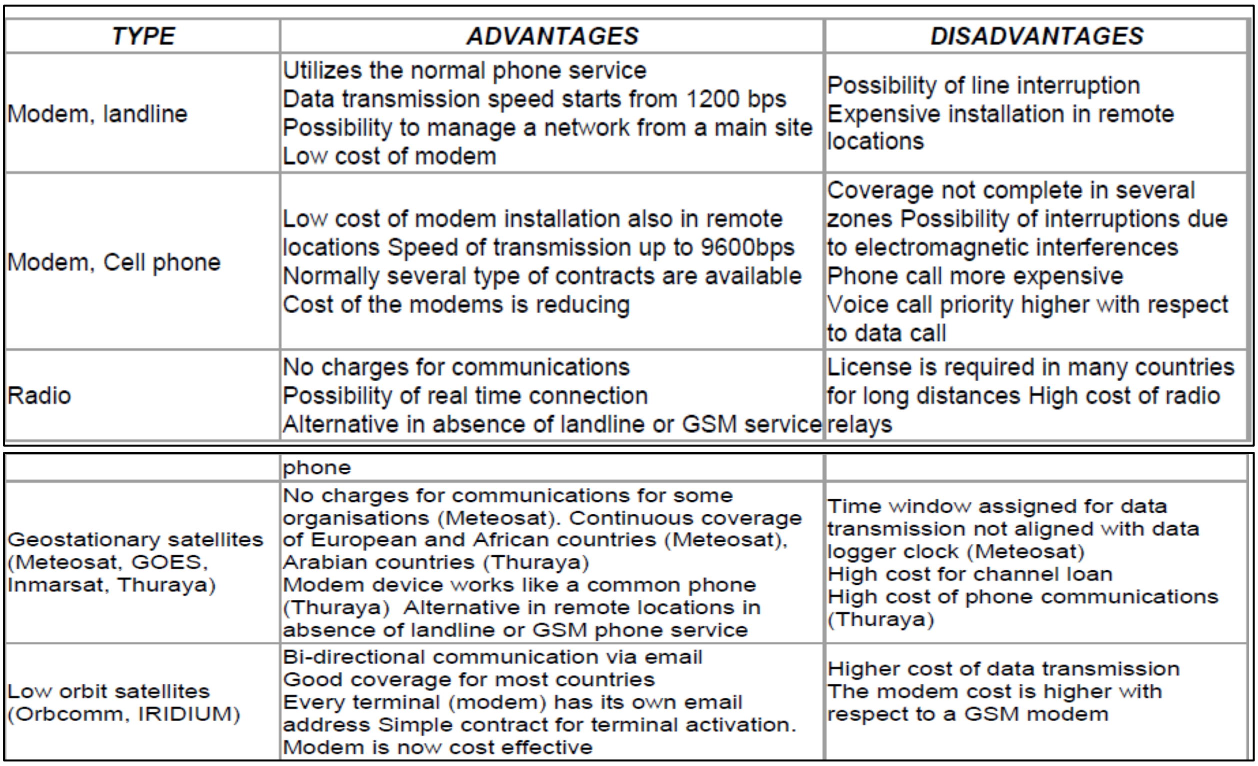
Action has been taken to commence the field surveys earlier than originally planned which helps to address the potential delays but is also a practical move in order to complete these surveys before winter.

*Table 1***Table 18** shows the advantages and disadvantages of the various options for data communication.

For early warning stations located in the upper mountain areas, the Low Earth Orbit Satellite (LEOS) are likely to be the most practical, whereas for valley locations with mobile phone coverage, this technology is likely to be the most appropriate.

The control centre hardware and software requirements will also be addressed and appropriate technology recommended.

Table 18 Advantages and Disadvantages of available Communication Systems



TYPE	ADVANTAGES	DISADVANTAGES
Modem, landline	Utilizes the normal phone service Data transmission speed starts from 1200 bps Possibility to manage a network from a main site Low cost of modem	Possibility of line interruption Expensive installation in remote locations
Modem, Cell phone	Low cost of modem installation also in remote locations Speed of transmission up to 9600bps Normally several type of contracts are available Cost of the modems is reducing	Coverage not complete in several zones Possibility of interruptions due to electromagnetic interferences Phone call more expensive Voice call priority higher with respect to data call
Radio	No charges for communications Possibility of real time connection Alternative in absence of landline or GSM service phone	License is required in many countries for long distances High cost of radio relays
Geostationary satellites (Meteosat, GOES, Inmarsat, Thuraya)	No charges for communications for some organisations (Meteosat). Continuous coverage of European and African countries (Meteosat), Arabian countries (Thuraya) Modem device works like a common phone (Thuraya) Alternative in remote locations in absence of landline or GSM phone service	Time window assigned for data transmission not aligned with data logger clock (Meteosat) High cost for channel loan High cost of phone communications (Thuraya)
Low orbit satellites (Orbcomm, IRIDIUM)	Bi-directional communication via email Good coverage for most countries Every terminal (modem) has its own email address Simple contract for terminal activation. Modem is now cost effective	Higher cost of data transmission The modem cost is higher with respect to a GSM modem

6.5 Part B

Part B of the project comprises the preparation of the Detailed Project Report (DPR) for the structural works recommended as the outcome of the Flood Management Plan developed under **Part A**.

The DPR will be prepared to comply with the requirements of the CWC's *Guidelines for Preparation of DPR for Flood Management Works* (CWC 2018). If necessary additional topographic survey, geological, geotechnical and geomorphological site investigations will be undertaken in **Part B**.

The DPR will include the required chapters on hydrology, morphology, design, financial and economic analysis, construction planning and drawings, and environmental impact assessment.

Social assessment will be included in the assessment of positive and negative impacts of the proposed schemes including: thier likely benefits to community, livelihood opportunities, ways of community engagement, mitigation measures (social and envirionment), impact on private land if any, etc. for each sub-projects identified under the project. The social component will also be inclusive of proposed mitigation measures to ensure compliance of social safeguard and its impact on local community.

The DPR will take account of, and refer to, the works being undertaken within the DPR for the Interim Scheme and any other works proposed by the IFCK.

The DPR will also be prepared in compliance with CWC's requirements for submission, appraisal and acceptance of flood control projects. The main components of this will be:

- Concept report including the preliminary design, drawings and cost components of the final scheme; and
- Draft Detailed Project Report which will include the detailed design, detailed drawings, detailed cost estimate and unit rate analysis;
- Final Detailed Project Report after incorporating stakeholder comments on the Draft Report;
- Tender documents for proposed scheme.

CWC is currently implementing a web-based system (e-PAMS) which is expected to be fully functional by the time **Part B** is being undertaken. This system is designed to simplify and expedite the approval process.

Part B will include the provision of clarifications to queries raised during the DPR process by CWC or other agencies and will provide require technical support. The complete clearance of the Dpr should be achieved by the end of the project.

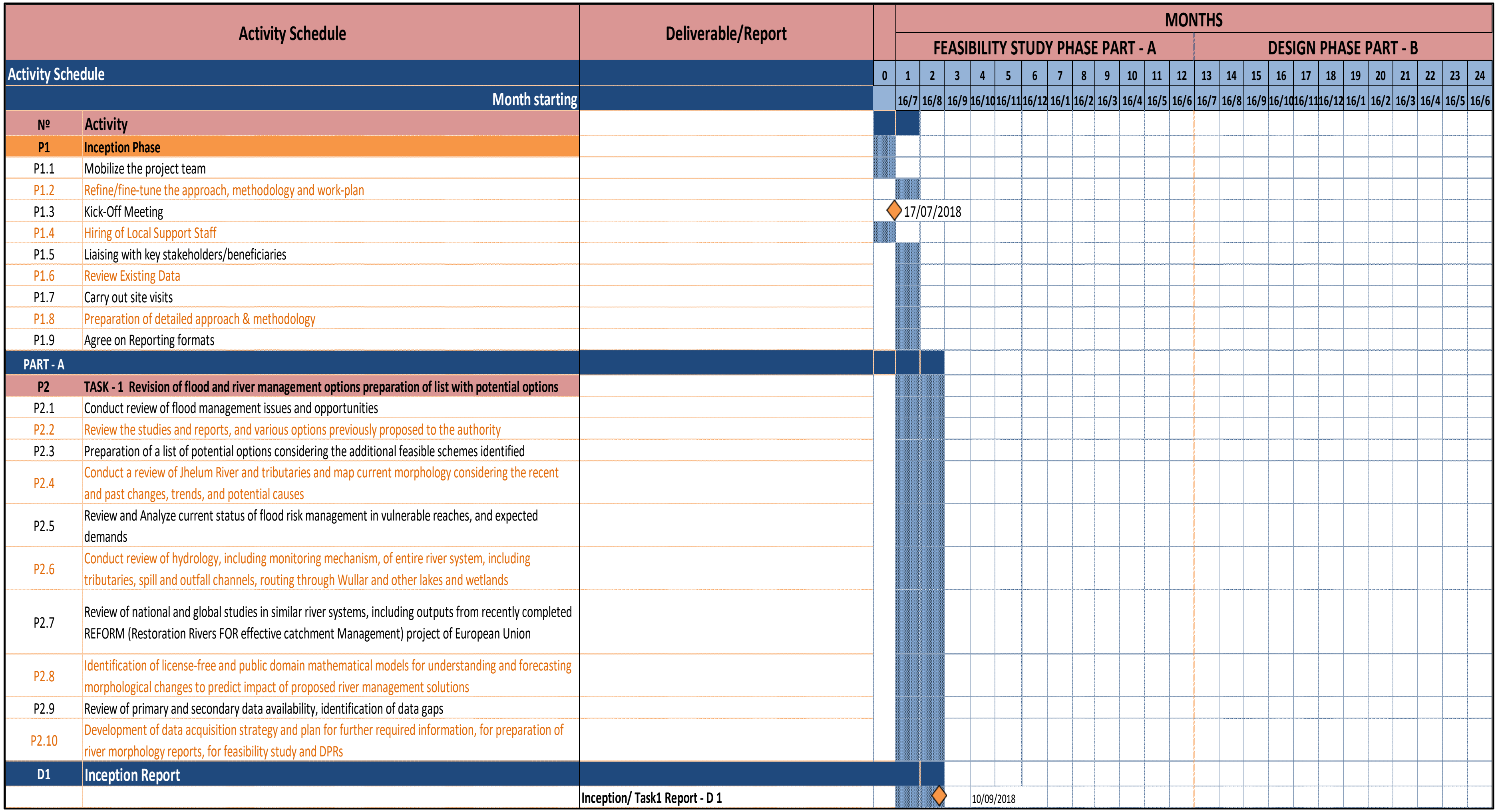
Following the approval of the DPR, tender documents for construction will be prepared including Specifications and Bills of Quantities.

6.6 Work Plan

The Work Plan has been updated to reflect these timing issues and the Methodology outlined above. The revised Work Plan is given in **Figure 58.**

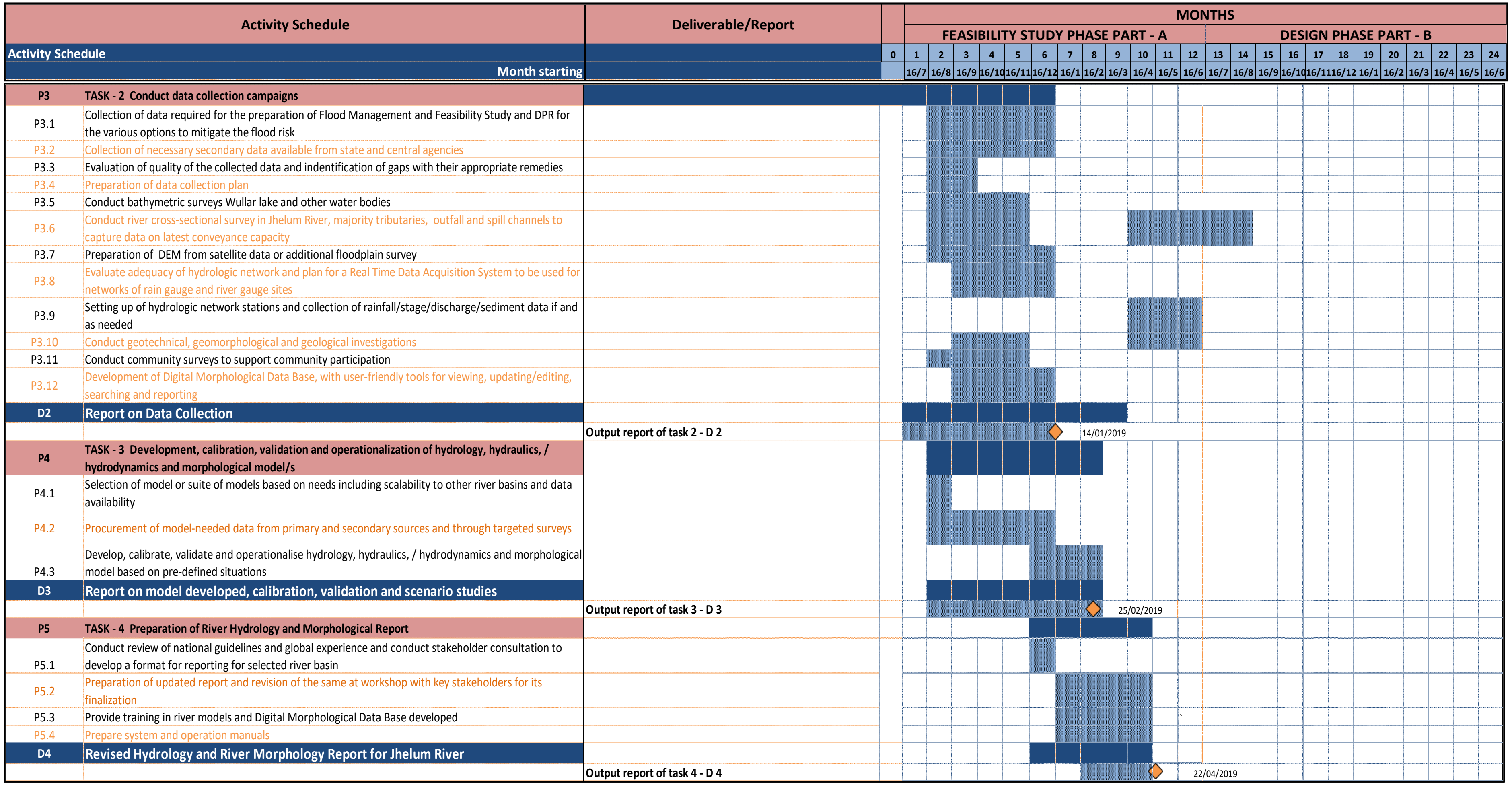
It is not practical to include the tributary surveys, installation of additional hydrometric stations, or the geotechnical investigations required for the feasibility study within the timeframe of Task 2. These items have been left in Task 2 but will need to be reported upon later. In all other respects, the updated work plan complies with the timing of deliverables as stated in the Contract.

The total months of the individual experts has not been varied in Staffing Schedule given in **Figure 59,** although there are changes to the timing of their various contributions. However, it is evident that the time allocated in **Part A** for the Team Leader/Flood Modeller and the Fluvial Geomorphologist are insufficient and it may be necessary to bring forward some of their time allocated in **Part B** to **Part A**. Eptisa proposes to leave the resolution of this to a later date, as it has contract implications.



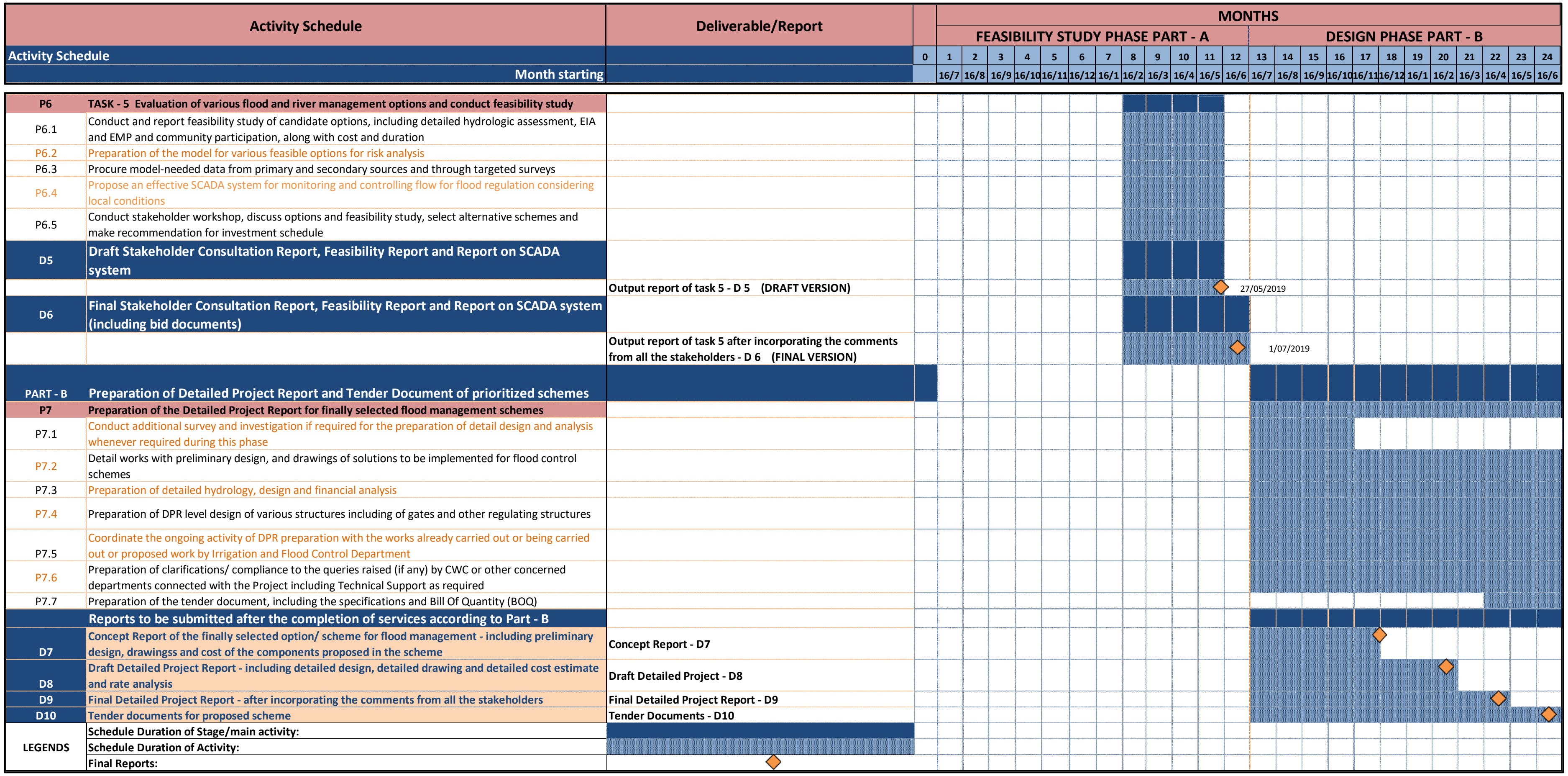
Activity Schedule		Deliverable/Report		MONTHS																							
				FEASIBILITY STUDY PHASE PART - A												DESIGN PHASE PART - B											
Activity Schedule			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Month starting			16/7	16/8	16/9	16/10	16/11	16/12	16/1	16/2	16/3	16/4	16/5	16/6	16/7	16/8	16/9	16/10	16/11	16/12	16/1	16/2	16/3	16/4	16/5	16/6
Nº	Activity		█	█																							
P1	**Inception Phase**		▨																								
P1.1	Mobilize the project team		▨																								
P1.2	Refine/fine-tune the approach, methodology and work-plan			▨																							
P1.3	Kick-Off Meeting		◆	17/07/2018																							
P1.4	Hiring of Local Support Staff		▨																								
P1.5	Liaising with key stakeholders/beneficiaries			▨																							
P1.6	Review Existing Data			▨																							
P1.7	Carry out site visits			▨																							
P1.8	Preparation of detailed approach & methodology			▨																							
P1.9	Agree on Reporting formats			▨																							
PART - A			█	█	█																						
P2	**TASK - 1 Revision of flood and river management options preparation of list with potential options**			▨	▨																						
P2.1	Conduct review of flood management issues and opportunities			▨	▨																						
P2.2	Review the studies and reports, and various options previously proposed to the authority			▨	▨																						
P2.3	Preparation of a list of potential options considering the additional feasible schemes identified			▨	▨																						
P2.4	Conduct a review of Jhelum River and tributaries and map current morphology considering the recent and past changes, trends, and potential causes			▨	▨																						
P2.5	Review and Analyze current status of flood risk management in vulnerable reaches, and expected demands			▨	▨																						
P2.6	Conduct review of hydrology, including monitoring mechanism, of entire river system, including tributaries, spill and outfall channels, routing through Wullar and other lakes and wetlands			▨	▨																						
P2.7	Review of national and global studies in similar river systems, including outputs from recently completed REFORM (Restoration Rivers FOR effective catchment Management) project of European Union			▨	▨																						
P2.8	Identification of license-free and public domain mathematical models for understanding and forecasting morphological changes to predict impact of proposed river management solutions			▨	▨																						
P2.9	Review of primary and secondary data availability, identification of data gaps			▨	▨																						
P2.10	Development of data acquisition strategy and plan for further required information, for preparation of river morphology reports, for feasibility study and DPRs			▨	▨																						
D1	Inception Report		█	█	█																						
		Inception/ Task1 Report - D 1		▨	▨ ◆		10/09/2018																				

Figure 58 Work Plan - 1



Activity Schedule		Deliverable/Report
Activity Schedule		
	Month starting	
P3	**TASK - 2 Conduct data collection campaigns**	
P3.1	Collection of data required for the preparation of Flood Management and Feasibility Study and DPR for the various options to mitigate the flood risk	
P3.2	Collection of necessary secondary data available from state and central agencies	
P3.3	Evaluation of quality of the collected data and indentification of gaps with their appropriate remedies	
P3.4	Preparation of data collection plan	
P3.5	Conduct bathymetric surveys Wullar lake and other water bodies	
P3.6	Conduct river cross-sectional survey in Jhelum River, majority tributaries, outfall and spill channels to capture data on latest conveyance capacity	
P3.7	Preparation of DEM from satellite data or additional floodplain survey	
P3.8	Evaluate adequacy of hydrologic network and plan for a Real Time Data Acquisition System to be used for networks of rain gauge and river gauge sites	
P3.9	Setting up of hydrologic network stations and collection of rainfall/stage/discharge/sediment data if and as needed	
P3.10	Conduct geotechnical, geomorphological and geological investigations	
P3.11	Conduct community surveys to support community participation	
P3.12	Development of Digital Morphological Data Base, with user-friendly tools for viewing, updating/editing, searching and reporting	
D2	**Report on Data Collection**	
		Output report of task 2 - D 2
P4	**TASK - 3 Development, calibration, validation and operationalization of hydrology, hydraulics, / hydrodynamics and morphological model/s**	
P4.1	Selection of model or suite of models based on needs including scalability to other river basins and data availability	
P4.2	Procurement of model-needed data from primary and secondary sources and through targeted surveys	
P4.3	Develop, calibrate, validate and operationalise hydrology, hydraulics, / hydrodynamics and morphological model based on pre-defined situations	
D3	**Report on model developed, calibration, validation and scenario studies**	
		Output report of task 3 - D 3
P5	**TASK - 4 Preparation of River Hydrology and Morphological Report**	
P5.1	Conduct review of national guidelines and global experience and conduct stakeholder consultation to develop a format for reporting for selected river basin	
P5.2	Preparation of updated report and revision of the same at workshop with key stakeholders for its finalization	
P5.3	Provide training in river models and Digital Morphological Data Base developed	
P5.4	Prepare system and operation manuals	
D4	**Revised Hydrology and River Morphology Report for Jhelum River**	
		Output report of task 4 - D 4

Figure 58 Work Plan – 2



	Activity Schedule	Deliverable/Report		MONTHS																						
				FEASIBILITY STUDY PHASE PART - A												DESIGN PHASE PART - B										
Activity Schedule			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Month starting			16/7	16/8	16/9	16/10	16/11	16/12	16/1	16/2	16/3	16/4	16/5	16/6	16/7	16/8	16/9	16/10	16/11	16/12	16/1	16/2	16/3	16/4	16/5	16/6
P6	TASK - 5 Evaluation of various flood and river management options and conduct feasibility study										■	■	■	■													
P6.1	Conduct and report feasibility study of candidate options, including detailed hydrologic assessment, EIA and EMP and community participation, along with cost and duration										▨	▨	▨	▨													
P6.2	Preparation of the model for various feasible options for risk analysis										▨	▨	▨	▨													
P6.3	Procure model-needed data from primary and secondary sources and through targeted surveys										▨	▨	▨	▨													
P6.4	Propose an effective SCADA system for monitoring and controlling flow for flood regulation considering local conditions										▨	▨	▨	▨													
P6.5	Conduct stakeholder workshop, discuss options and feasibility study, select alternative schemes and make recommendation for investment schedule										▨	▨	▨	▨													
D5	Draft Stakeholder Consultation Report, Feasibility Report and Report on SCADA system										■	■	■	■													
		Output report of task 5 - D 5 (DRAFT VERSION)									▨	▨	▨	◆		27/05/2019											
D6	Final Stakeholder Consultation Report, Feasibility Report and Report on SCADA system (including bid documents)										■	■	■	■	■												
		Output report of task 5 after incorporating the comments from all the stakeholders - D 6 (FINAL VERSION)									▨	▨	▨	▨	◆		1/07/2019										
PART - B	Preparation of Detailed Project Report and Tender Document of prioritized schemes		■													■	■	■	■	■	■	■	■	■	■	■	■
P7	Preparation of the Detailed Project Report for finally selected flood management schemes															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
P7.1	Conduct additional survey and investigation if required for the preparation of detail design and analysis whenever required during this phase															▨	▨	▨	▨								
P7.2	Detail works with preliminary design, and drawings of solutions to be implemented for flood control schemes															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
P7.3	Preparation of detailed hydrology, design and financial analysis															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
P7.4	Preparation of DPR level design of various structures including of gates and other regulating structures															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
P7.5	Coordinate the ongoing activity of DPR preparation with the works already carried out or being carried out or proposed work by Irrigation and Flood Control Department															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
P7.6	Preparation of clarifications/ compliance to the queries raised (if any) by CWC or other concerned departments connected with the Project including Technical Support as required															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
P7.7	Preparation of the tender document, including the specifications and Bill Of Quantity (BOQ)																								▨	▨	▨
	Reports to be submitted after the completion of services according to Part - B															■	■	■	■	■	■	■	■	■	■	■	■
D7	Concept Report of the finally selected option/ scheme for flood management - including preliminary design, drawingss and cost of the components proposed in the scheme	Concept Report - D7														▨	▨	▨	▨	◆							
D8	Draft Detailed Project Report - including detailed design, detailed drawing and detailed cost estimate and rate analysis	Draft Detailed Project - D8														▨	▨	▨	▨	▨	▨	◆					
D9	Final Detailed Project Report - after incorporating the comments from all the stakeholders	Final Detailed Project Report - D9														▨	▨	▨	▨	▨	▨	▨	▨	▨	◆		
D10	Tender documents for proposed scheme	Tender Documents - D10														▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	◆
LEGENDS	Schedule Duration of Stage/main activity:	■																									
	Schedule Duration of Activity:	▨																									
	Final Reports:	◆																									

Figure 58 Work Plan - 3

No	Name	Position	Expert's Input (in person/month)														PART-A			PART-B			TOTAL		
			Month	1	2	3	4	5	6	7	8	9	10	11	12		Home	Field	Total	Home	Field	Total	Home	Field	Total
			month start	16/7	16/8	16/9	16/10	16/11	16/12	16/1	16/2	16/3	16/4	16/5	16/6										
			Deliverables	D-1 ■	■																				
				D-2 ■	■	■	■	■	■	■	■	■													
				D-3 ■	■	■	■	■																	
				D-4 ■	■	■	■	■	■																
				D-5 ■	■	■	■	■	■	■	■	■	■												
				D-6 ■	■	■	■	■	■	■	■	■	■	■	■	■									
			Location	FEASIBILITY STUDY PHASE PART - A																					
KEY EXPERTS																									
																Total Part A									
K-1	David Sargent	Project Team Leader/ Flood Forecast and early warning system/Inundation mapping modeler	Home		0.25	0.25		0.25	0.25		0.25	0.25	0.25	0.25		2	3		6	5		10	8		16
			Field	1.0	0.75		0.5			1	0.75					4		3			5			8	
K-2	Ravindra Oak	Deputy Team Leader-River Engineering Specialist	Home		0.25	0.25			0.25	0.25	0.25	0.25	0.25	0.25		2	2		4	4		8	6		12
			Field	0.5				0.5				0.5	0.5			2		2			4			6	
K-3	Amaresh Sen	Hydrologist	Home		0.25	0.25			0.50	0.25		0.25	0.25	0.25		2	2		4	4		8	6		12
			Field	0.25			0.50	0.5			0.50	0.25				2		2			4			6	
K-4	Kiron Mazumdar	Geological/Geotechnical Specialist	Home		0.25			0.25	0.25		0.50	0.50		0.25		2	2		4	4		8	6		12
			Field	0.25						0.75			0.5	0.5		2		2			4			6	
K-5	Wayne Curry	Fluvial Morphology Specialist	Home					0.25			0.5	0.25	0.25			1.25	2		4	4		8	6		12
			Field	1.0	0.75					0.5	0.5					2.75		2			4			6	
K-6	Perwez Alam	Civil Design Engineer	Home						0.5	0.75	0.25			1	1	3.5	3.5		7	6.5		13	10		20
			Field	0.25							0.75	1.0	1.0	0.5		3.5		3.5			6.5			10	
K-7	Akhter Rasool Bhatt	Environmental Specialist	Home		0.25			0.25	0.25		0.25	0.25	0.25			1.5	1.5		3	3		6	4.5		9
			Field	0.25			0.5			0.25	0.25		0.25			1.5		1.5			3			4.5	
K-8	Dr. Barun Kumar Sarkar	Economist	Home										0.5			0.5	0.5		1	1.5		3	2		4
			Field									0.5				0.5		0.5			1.5			2	
K-9	Ashish Kumar	Social Scientist	Home			0.25	0.25		0.25			0.25				1	1		2	2		4	3		6
			Field	0.25		0.25	0.25				0.25					1		1			2			3	
K-10	Meera Mathur	Community Specialist	Home			0.25			0.25			0.25	0.25			1	1		2	2		4	3		6
			Field	0.25	0.25	0.25	0.25									1		1			2			3	
																	SubTotal		37	SubTotal		72	SubTotal		109
OTHER EXPERTS																									
NK-1	Santosh Singh	RS/GIS Specialist	Home		0.25	0.25			0.25	0.25		0.25	0.25			1.5	1.5		3	3		6	4.5		9
			Field	0.25	0.25			0.5			0.25		0.25			1.5		1.5			3			4.5	
NK-2	Ambrish Kumar Srivastava	Database Specialist	Home							0.25	0.25	0.25	0.25			1	1		2	2		4	3		6
			Field							0.5	0.5					1		1			2			3	
NK-3	Frinto Antony	Watershed Management Specialist	Home								0.25	0.25				0.5	0.5		1	1.5		3	2		4
			Field								0.5					0.5		0.5			1.5			2	
NK-4	Maroof Ahmad Shah	Surveyor	Home		0.5	0.5		0.5	0.5	0.5		0.5		0.5	0.5	4	4		8	2		4	6		12
			Field	0.25	0.5	0.5	0.5	0.5	0.5	0.5			0.75			4		4			2			6	
NK-5	Shankha Subhra Ghosh	Software Engineer	Home							0.25	0.25	0.25	0.25			1	1		2	2		4	3		6
			Field							0.5	0.5					1		1			2			3	
																	SubTotal		16	SubTotal		21	SubTotal		37
																							Total		146

Figure 59 Staffing Schedule

6.6 Summary of Deliverables

A summary of Deliverables under this project is given in **Table 19,** taking account of the changes to the Work Plan discussed above. This table supersedes that provided at the commencement of the Study.

Table 19 Summary of Deliverables

No.	Title	Submission Date
1	**Part A** Task 1 Report	10th September 2018
2	Data Collection Report	14th January 2019
3	Report on model developed, calibration, validation and scenario studies	25th February 2019
4	Revised Hydrology and River Morphology Report for Jhelum River	22nd April 2019
5	Draft Feasibility Report	27th May 2019
6	Final Feasibility Report	1st July 2019
	Part B Detailed Project Report & Tender Document (Dates are provisional based on estimated date of approval of **Part A**)	
7	Concept Report	16th December 2019
8	Draft Detailed Project Report	9th March 2020
9	Final Detailed Project Report	4th May 2020
10	Tender Document	29th June 2020

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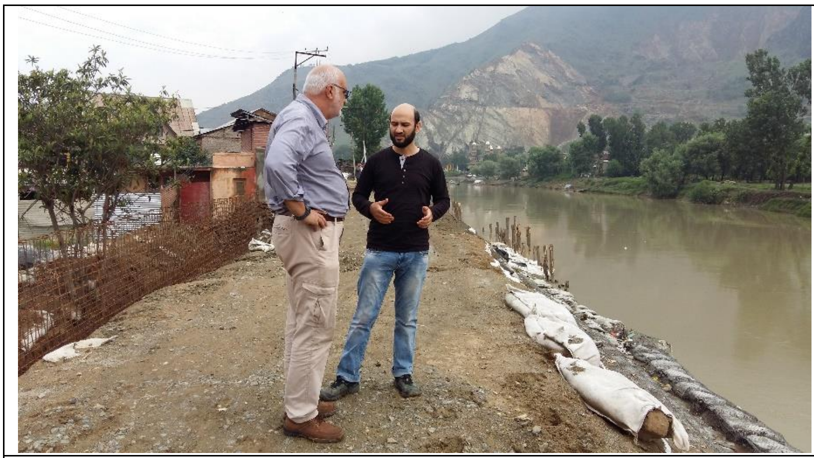
Appendices

Appendix AStudy Team

No	Name	Position	at "Kick-off" Meeting
KEY EXPERTS			
K-1	**David Sargent**	**Project Team Leader/ Flood Forecast and early warning system/Inundation mapping modeler**	**Yes**
K-2	**Ravindra Oak**	**Deputy Team Leader-River Engineering Specialist**	**Yes**
K-3	**Amaresh Sen**	**Hydrologist**	**Yes**
K-4	**Kiron Mazumdar**	**Geological/Geotechnical Specialist**	**Yes**
K-5	**Wayne Curry**	**Fluvial Morphology Specialist**	**Yes**
K-6	**Perwez Alam**	**Civil Design Engineer**	**Yes**
K-7	**Akhter Rasool Bhatt**	**Environmental Specialist**	**Yes**
K-8	**Dr. Barun Kumar Sarkar**	**Economist**	**No**
K-9	**Ashish Kumar**	**Social Scientist**	**Yes**
K-10	**Meera Mathur**	**Community Specialist**	**Yes**
OTHER EXPERTS			
NK-1	**Santosh Singh**	**RS/GIS Specialist**	**No**
NK-2	**Ambrish Kumar Srivastava**	**Database Specialist**	**No**
NK-3	**Frinto Antony**	**Watershed Management Specialist**	**No**
NK-4	**Zulkernain Ali Khan**	**Surveyor**	**Yes**
NK-5	**Shankha Subhra Ghosh**	**Software Engineer**	**No**

Appendix BPhotographs from Site Inspections

a) Southern Region Field Trip 23rd July 2018



Left: Repair of breach in river bank – upstream of Srinagar

Right: Inclined staff gauge – Jhelum River at Sangam

Below: 2014 flood level on building at Sangam gauging station

Left: Jhelum river upstream of Srinagar

Left: Exposed bridge piers on new Expressway Bridge at Khanabal Note also low clearance of bridge above pile cap

Right: Lidder Nallah upstream of Jhelum River confluence

Left: Footbridge over Lidder Nallah

b) Central Region Field Trip 25th July 2018

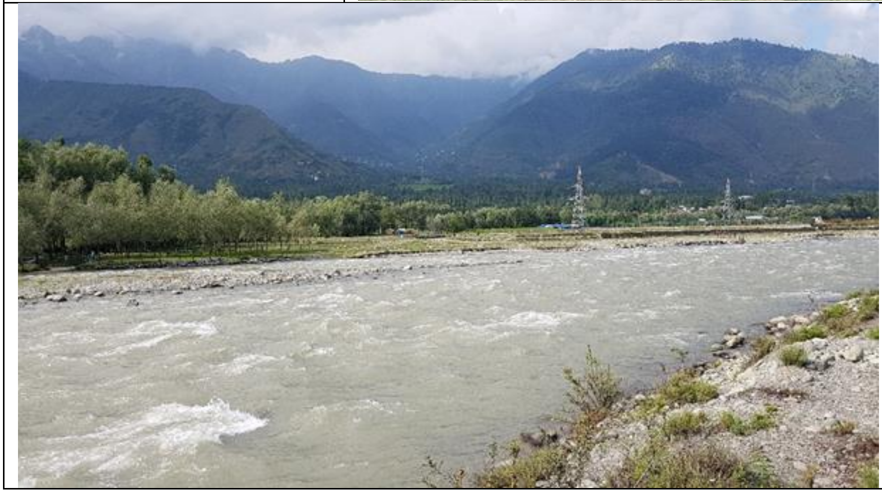
Left: Urban encroachment – Jhelum river relief channel Srinagar

Right: Urban encroachment – Jhelum river relief channel Srinagar

Left: Jhelum River Srinagar
Chattabal Weir
Which has been recently reconstructed

Left: Flood Spill Channel, near inlet

Right: Jhelum River: Asham Bridge



Left: Sindh Nallah upstream of Jhelum River confluence

Left: Sindh Nallah at Anchar Lake

Right: Anchar Lake outlet to Sindh Nallah

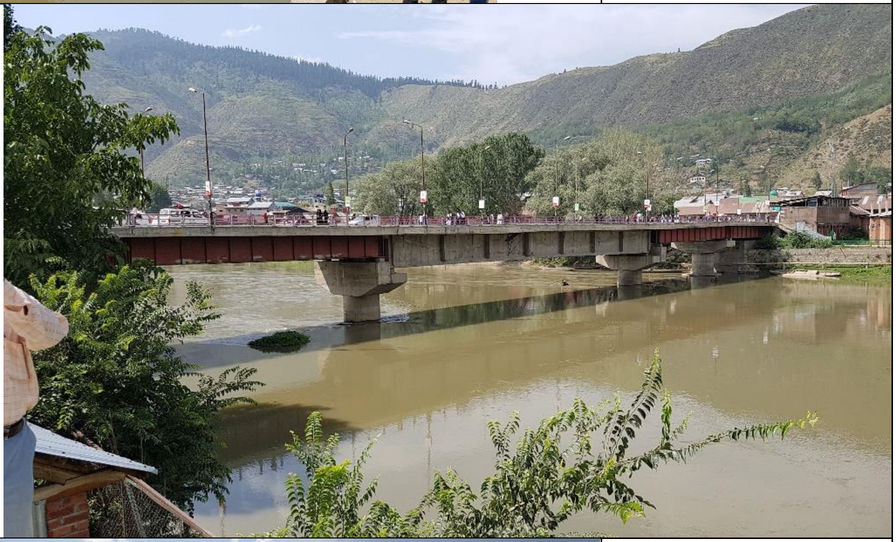
Left: Jhelum River just upstream of Wular Lake

c) Northern Region Field Trip 31st July 2018

	**Left: Left bank exit from Wular Lake**
Right: Right bank exit from Wular Lake	
	**Left: Outfall Channel downstream of Wular Lake looking across at Pohru Nallah confluence**

Left: Bridge on Outfall Channel at Baramulla
Note: afflux due to constriction and old weir/bridge piers which have not been removed.

Right: Bridge on Outfall Channel at Baramulla



Left: Outfall channel looking upstream from Lower Jhelum Barrage

Appendix CList of Major Tributaries

LIST OF JHELUM RIVER BASIN NALLAHS

No.	River Serial Number	Name of Nallah	*Length in km	Upper Nallahs and Villages	Jhelum River or Nallah Confluence Junction Points
1	1	Bringi Nallah	30.0	Wayilo, Divalgam, Adigam, Suhuf ,Kandiwari, Khalhar, Hillar, Dehrana, Zaldara, Larkipora, Fetehpora, Schen, Lalan, Danter	Jhelum River at Danter
2	1a	Gawran/ Daksum Nallah	24.0	Higher Reaches of Gawran , Gurdaman, Naboogh , Larnoo, Bidhal, Wayilo	Bringi at Wayiloo
3	1b	Gadol Nallah	12.5	Higher Reaches of Gadol, Drugmulla, Ahlan, Wayilo	Bringi at Wayiloo
4	1c	Hakura Nallah	17.5	Syphon Khartar, Budsgom, Palepora, Dailgam, Ashji Pora	Confluence with Aripath
5	1d	Magam Nallah	9.5	Magam, Sunbari, Wangam, Devalgam	Bringi Nallah at Goihard Wandewalgam
6	1e	Khalshi Nallah	16.5	Watnard, Narowpora, Hayatpora, Sagam, Buchoo, Peertakia, Bahie, Bamdoora, Dahrena	Bringi Nallah at Dahrana
7	1f	Koril Nallah	10.0	Panzgam, Kherpora, Zagimarg and Soaf	Main Bringi at Soaf Downstream of Bridge
8	1g	Kokernag Nallah	8.8	Bidder, Hangulgund, Danwatpora, Hayatpora, Buchoo Sagam and Bahie	Khalsi Nallah at Bahie
9	1h	Saldoo Nallah	7.0	Flows from Aripat Nallah at Ultersoo, Khanpora, Ultrasoo, Noge Gund, Ashjaji Pora, Anantnag	Confluence with Bringi Nallah at Ultersoo
10	1i	Brigi Nallah	5.0	Branch of Bringi Nallah. Dailgam, Chechrepora, Asjajipora Papaibal	Confluence with Bringi Nallah at Nathpora
11	1j	Haune Khul	15.0	Branch of Bringi Nallah. Nagigund, Bonidagam, Movenabad Havan Colony, Ashjajipora	Confluence with Bringi Nallah at Nathpora
11	1j	Haune Khul	15.0	Branch of Bringi Nallah. Nagigund, Bonidagam, Movenabad Havan Colony, Ashjajipora	Confluence with Bringi Nallah at Danter
12	K1	Aripath Nallah	44.0	Dardpora,Telwari, Poshnari, Mategund, Cheripora, Brakepora, Asjipora, Zadipora, Pushwara, Dagipora, Khanabal	Bringi at Danter and Jhelum River near Kanabal

LIST OF JHELUM RIVER BASIN NALLAHS

No.	River Serial Number	Name of Nallah or Tributary	*Length in km	Upper Tributaries and Villages	Jhelum River or Tributary Confluence Junction Points
13	K2	Dethu Nallah	20.0	Ohpusan, Matigund, Brisnoo, Mategund, Krad, Wangam, Issoo	Aripath at Issoo
14	K3	Methmoo Nallah	7.0	Methmoo Hills, Sangloo, Cheripora	Aripath at Cheripora
15	K4	Bariagan Nallah	6.0	Bariagan Hills, Ultersoo	Aripath at Ulterso
16	K5	Goriwan Nallah	5.0	Goriwan Shangus Hills, Rayakapora.	Aripath at Rayikpora
17	K6	Pushroo Nallah	16.0	Audoo Hills,Pushroo, Qatihar, Nowgam, Check Khundroo	Aripath at Khundroo
18	K7	Gamdoo Nallah	14.0	Verinag springs, Khaighall	Aripath at Khaighall
19	K8	Thrpoo Nallah	8.0	Thrpoo Springs, Samsua, Haji Mohallah, Thijiware	Aripath at Thijiwara.
20	K9	Achibal Nallah	4.0	Achebal Springs, SamsuaThijiwan	Aripath at Thijiwara
21	K10	Rakhi Brah Nallah	6.0	Rakh Hills, Ranipora, Krad	Aripath at Ranipora.
22	K11	Sheerbagh Nallah	3.0	Sheerbagh Springs, Wazirbagh	Confluence with Aripath Nallah at Wazir Bagh
23	2	Veshow Nallah	62.0	Aehrabal, Manzgam, Ardgen, Arigtnoo, Khudwani, Wanpoh,Laktipora, Sangam	Jhelum River at Sangam
24	2a	Khandia Nallah	23.0	Dandward, Kutmarg, Batigehallan, Chimmar, Lagopora, D.K.Margh	Veshow near Adijan Damhal Hanjipora (DH Pora)
25	2b	Bush's Nallah	7.0	Balsern, Boh, Dragdan, Dadav, Kandi, Margh, (D.K. Margh)	Kandie Nallah at Danew near Bridge
26	2c	Zumsthal Nallah	15.0	Balsern, Dandward,Chek, Kounserbal, Damhal, Hanjipora, D.K. Margh	Veshow at Damhal Hajipora Upstream of Degree College
27	2d	Khurbatpora Nallah	21.0	K.B.Pora, Vedigam, Mandguri, Yaru, Gandwani	Veshow Downstream of Nehama Bridge
28	2e	Avil Nallah	18.0	Sungura,Yaru,Lassarpora, Avil	Veshow Downstream of Nehama Bridge
29	2f	Malvan/Banimullah Nallah	17.0	Chinddergee, Banimullah, Malwan,K hiloora. Lankar Pombay, Devsar Balla	Veshow at Devsar

LIST OF JHELUM RIVER BASIN NALLAHS					
No.	**River Serial Number**	**Name of Nallah**	***Length in km**	**Upper Nallahs and Villages**	**Jhelum River or Nallah Confluence Junction Points**
30	2g	Hardmanguri Nallah	15.0	Dandward, Check, Dadren, H.M.Guri, Damhal, Hjipora	Veshow at Adijan - Damhal Hanjipora.
31	2h	Vethvathroo Nallah	29.0	Khagund, Hillard, Qazigund, Khushipora, Mandhol, Chowgam, Amanpora, Palepora	Veshow Nallah at Palepora/Ahkran
32	2i	Ardekaj Nallah	4.0	Badermuna via Lower Munda, Budermuna, Changoo	Confluence at Changoo/Badermuna with Vethvathroo
33	2j	Arshi Nallah	4.0	Hillard, Praynigam, Tol Post	Confluence at Hillard with Vethvathroo
34	2k	Tunjloo Nallah	4.5	Tunjloo, Check	Confluence at Jammu- Sgr N.H.W at Wangam with Vethvathroo
35	2L	Ganiard Nallah	6.0	Adre Malik, Kewa	Confluence near Upper Bazar Qazi Gund with Vethvathroo
36	2m	Khader Nallah	12.0	Kund Valley to Pajgam, Real, Thout, Nigeenpora, R. Ozolla	Confluence at Khushipora Nethepora with Vethvathroo
37	2n	Lammer Nallah	6.0	Brinail, Lamard, Chowgam	Confluence at Nova with Vethvathroo
38	2o	Papahari Nallah	8.0	Dardegund, Vethvathroo via Devsar	Confluence at Manigam/Kelam with Vethvathroo.
39	2p	Tongri Nallah	25.0	D.K.Pora, Narwani, Munand Guphan, Chitragan, Ribbon, Hydergund, Zampora, Safa Nagri, Darbagh, Zahid Bagh	Veshow Nallah at Naina Ghat Upstream of Kawani, TD 15.20km
40	2q	Raimb Ara Nallah	50.0	Herpora, Shopian, Nazneen Pora, Tukwagam, Panjran,S ugan,H eff, Achan, Litter, Wachi, Naina Ghat, Meloora	Ramb Ara at Village Zahid Bagh
41	2r	Vedji Nallah	25.0	Sedow, Saidpora, Vehil Kachdoora, Hamshipora, Ray Kapran, Sehpora, Pariwan, Wangam	Grimtoo at Pariwaran with Veshow at Waripora

LIST OF JHELUM RIVER BASIN NALLAHS

No.	River Serial Number	Name of Nallah	*Length in km	Upper Nallahs and Villages	Jhelum River or Nallah Confluence Junction Points
42	3	Sandran Nallah	43.5	Hangipora, Kapran, Thamenkote, Reyan, Chowgund, Nowgam, Gurnar, Panzoo, Bonu Gund, Chenigund, Duru, Mehmood Abad, Shankerpora, Vessu, Sadoora, Bumthan, Mulward,Takie Behram Shah at Khanabal	Jhelum River at Takie Behram Shah Khanabal
43	3a	Dangi Nallah	12.0	Zalpora, Checkpat, Laketpora, Shupora	Sandran Nallah at Shupora
44	3b	Saud wara Nallah	6.5	Branch of Sandran Nallah offtake at Muneward	Confluence at Housing Colony - Khanabal
45	3c	Hakhran Nallah	5.0	Umoh, Verinag, Bungund	Confuence with Sandran at Bunagund
46	4	Rather Khul	12.0	Mathan Springs, Dangerpora, Rather Mohallah	Confuence with River Right Bank at Batipora Khanabal.
47	5	Wankran Nallah	19.0	Arihal , Tahab, Chandgam, Nownagri, Palpora, Wasoora, Wahipora, Chako Ora, Kulpora, Bandina, Kawani	Left bank of Jhelum River at Village Kawani
48	6	Sasara Nallah	38.0	Mulpathri, Kuthuhallan, Gatipora, Borthipora, Butmurran, Kelampora, Rajpora, Sonsamiloo, Bendzoo, Chatripora,Trichal, Tengpuna, Koil	Lara Nallah at Village Talangam
49	7	Romshi Nallah	40.0	Sangerwani, Kellar, Yachgoos, Drabgam, Rohmu, Goose, Chewa Kallan, Karimabad, Inder, Guder, Hassan Wani, Pohu, Mohanvij, Kakapora	Left Bank of Jhelum River at Village Lelhar Kakpora
50	8	Watal Ara Nallah	30.0	Machhama, Nagbal, Khalil, Poner, Mandura, Tral, Rathsuna, Saimoh, Laryar, Buchoo, Hariparigam, Charsoo	Right Bank Jhelum River at Kethpora Chursoo RD 23km
51	9	Aripal Nallah	32.0	Naristan, Satura, Lam, Aripal, Pastuna, Wagad, Seer,B atgund, Gulbagh, Nowdal, Chandrigam, Sail, Charsoo	Right Bank Jhelum River at Charligund, RD 25km
52	9	Lar Nallah	11.0	Koil, Narawa, Ratnipora, Gulbugh, Reshipora,Wandakpora, Baderpora	Left Bank of Jhelum River at Village Lelhar Kakpora, RD 42 Km

LIST OF JHELUM RIVER BASIN NALLAHS					
No.	**River Serial Number**	**Name of Nallah**	***Length in km**	**Upper Nallahs and Villages**	**Jhelum River or Nallah Confluence Junction Points**
53	10	Main Lidder Nallah, Guree Branch	52.0	Langanbal, Batkoot, Saller Batepora, Yanir, Dachigam, Amadzoo, Watalfoher, Trail, Shamshipora, Amirpora Numbal, Seepan, Akura, Aung, Oudar	Jhelum River at Khanabal
54	10a	Lidder -Khanabal	12.0	From Khanwardi Bumzoo	Jhelum River at Khanabal
55	10b	Lidder -Odur Branch	13.0	From Amirpora Numbal /Ahkura	Jhelum River at Khanabal
56	10c	Kirkadal Branch	20.0	From Kanzduri Kathsoo to Kirkadal	Jhelum River at Khanabal
57	10d	Sarbal Nallah	5.0	Sarbal Hills	Confluence with Lidder at Sarbal
58	10e	Langnai Nallah	6.0	Langnai Hills	Confluence wth lidder at Batkoot Upstream
59	10f	Overa Nallah	6.0	Overa Hills	Confluence wth lidder at Movera
60	10g	Lehan dajam Nallah	10.0	Lahan Dajam Hills	Confluence wth Lidder at Saller Batapora
61	10h	Trout Nallah	13.0	Offtake at Jaibal	Confluence at Ahdigol with Lidder
62	10i	Aru Nallah	12.0	Source from Tarsar	Confuence with Lidder at Phalgam
63	10j	Shesh Nagh Nallah	12.0	Source from Sheshnag Lake	Confulenece with Lidder at Phalgam
64	10k	Zal khul	8.0	Flows from Khayar	Confluence at Hutmara
65	10L	Hapatnard Nallah	13.0	Offtake at Hapatnard Hills	Confluence at Ahidigole Banderbal Seer
66	10m	Ishnard Nallah.	10.0	Ainow Hills	Confluence at Tulnard with Trout Nallah
67	10n	Saller Nallah	6.0	Shiehpora saller	Confluence at Kattsoo with Ardwani Nallah
68	11	Flood Spill Channel	47.0	Padshaibagh, Srinagar, Bemina, Hokersar , Narbal, Singhpora, Nowgam Jheel, Zalpora, Naidkhai, Ningli in Wular	Wular at Ningli

LIST OF JHELUM RIVER BASIN NALLAHS					
No.	**River Serial Number**	**Name of Nallah**	***Length in km**	**Upper Nallahs and Villages**	**Jhelum River or Nallah Confluence Junction Points**
69	11a	Doodhganga	42.0	Offtake Point of Batewader Khul, Branwar, Suersyar, Daompora, Nowhar, Hanjura, Kralewari, Sgam.Badipora, Chudura, Wathrora, Krelepore, Barzala	Flood Spill Channel at Dubal Bemina
70	11b	Shaliganga	21.0	Basantwader, Watrud, Raithan, Darigam, Arigam, Kaner, Khusroo, Panzan, Bagh Bacroo	Doodganga at Batepora
71	11C	Tulbran Nallah	22.0	Malepora, Hayatpora, Kasermulla, Tangnar, Nowbugh, Kuzwara, Khanda, Nehema, Khadermoh	Jhelum River Left Bank at Khadermoh
72	11d	Sukhnag Nallah	54.0	Arizal, Zanigam, Beerwah, Ratsun, Peth, Makaham, Kawoosa, Narbal, Daslipora, Trikulebal, Palhalan Ghat, Nowgam Jheel	Flood Spill Channel at Nowgam Jheel Zalpora
73	11e	Gogaldara Nallah	18.0	Duderpora, Khag, Labran, Busharun, Allapora, Gamboora, Kandhama, Badran, Adina, Peth Makhama	Sukhnag at Peth Makahma
74	11f	Ferozpora Nallah Kunzer Branch	26.0	Drung, Sharie, Kunzer,Lalepora, Babegund, Khoor,GundekhgajaQasim, Gunde ibrahim, Trikulebal, Nowgam Jheel	Sukhnag at Trikulebal
75	11g	Ferozpora Nallah Magam Branch	29.0	Tumber Hama, Bongam, Karhama, Goigam, Magam, Nowpora. Flood Spill Channel at Chanebal	Flood Spill Channel at Chenebal
76	12	Ninghli Nallah	45.0	Shranz, Dandmoo, Wagoora, Tarzoo and Ningli	Wullar at Tazoo / Ningli
77	13	Gundyari/ Prashar /Balla, Khul Nallah	39.6	Shoom, Ganderpora, Wanigam Payeen/Allapathri, Shiekhpora, Freshar/Freshar, Hyderbeigh, Andergam, Loolipora	Jhelum River at Loolipora
78	14	Erin Nallah	13.0	Surinder, Sumlar, T.A. Shah, Erin , Papchan, Zalwan	Wullar at Zalwan
79	15	Mudhmati Nallah	16.8	Pannar, Athwathoo, Sunnerwani, Waterna, Kaloosa, Ayatmulla	Wullat at Ayatmulla

LIST OF JHELUM RIVER BASIN NALLAHS					
No.	**River Serial Number**	**Name of Nallah**	***Length in km**	**Upper Nallahs and Villages**	**Jhelum River or Nallah Confluence Junction Points**
80	16	Khurshi Nallah	29.0	Chandoosa,Takie Wagoora, Nowpora Kroe, Potkhal	Sopore with Jhelum River
81	17	Puhroo Nallah	58.0	Mughalpora, Bumehama, Check, Drugmulla, Lagarpora, Kulangam, Baripora, Drugmulla, Jagarpora, Kulangam, Baripora, Sail, Wahipora, Unisoo Bridge, Sopore Nowpora and Daobgah	Jhelum Jhelum River Right Bank at Daobgah
82	17a	Vernaw Nallah	15.0	Khurhama, Shale Gund, Vernow, Affan, Malegund, Kulegam, Maidanpora, Badibera, Vowoora	Lolab Nallah
83	17b	Kalaroos Nallah	9.0	Karkote Lada, Nagshri, Narizab, thyan, Kanipora, Kalaroos, Madhavmov, Tulewari, Khumeryal, Shale Guphian	Lolab Nallah
84	17c	Lolab Nallah	15.0	Vowoora, Putshai, Kanthipora, Shumeryal, Gunde Jhengir, Khumerayal, Goose, Girhatti, Galzai, Kupwara	Puhroo Nallah at Kupwara Offtake Point
85	17d	Haihama Nallah	13.0	Balepora, Gonipora, munegab, Glass Daji, Sangipeer,, Chalegund,zadipora, Gundesana, Manzhar, Shalipora, Sehipora,Sanokote, Dodwan, Regipora/Kupwara	Lolab Nallah
86	17e	Gunde Mancher	13.0	Tekipora,, Khanchek,Rakhi Gunde Mancher,Gunde mancher, Margi,Tang Chek, Gangebugh, Badibera	Lolab Nallah
87	17f	Dardpora kralepora Nallah	8.0	Mir Mohallah dardpora,Katri Mohallah, Lone Mohallah, Dardpora Kashmiri, Vaser kutoo,/Kralepora	Hudi Furkian Nallah
88	17g	Hudipora Farkian Nallah	12.7	Furkian Meelyal, Kachehama, Sonerpora, HuleLone Harie, Kralepora, Shimnag, Shulura, Gophbal	Kahmil Nallah
89	17h	Awoora Nallah	9.0	Manvan - Awoora , Aladin Zeb, Gulgam, Batergam	Kahmil Nallah

LIST OF JHELUM RIVER BASIN NALLAHS					
No.	**River Serial Number**	**Name of Nallah**	***Length in km**	**Upper Nallahs and Villages**	**Jhelum River or Nallah Confluence Junction Points**
90	17i	Zurhama Nallah	10.0	Marhama/Zurhama, Kaba Marg, Hundi, Kheri, Batergam/ Buhipora, Kheri, Batergam/ Buhipora	Kahmil Nallah
91	17j	Vij Nallah	20.0	Haffdara, Taratpora, Bavilgam, Panzwa, Pazipora, Dadikote, Gotungu, Gashi, Karihama	Kahmil Nallah
92	17k	Doomari Badnambal N.	8.0	Doomari Badnambal Balla, Doomari Payeen,	Kahmil Nallah
93	17L	Kahmil Nallah	30.0	Rangwar, Zumreshi, Mavseri, Chokibal, Radi, Panzgam, Manzgam, Babepora, Kalmuna, Shulura, Gophbal,P adar Gund,Trihgam, Narampora, Gunde Mumin, Bagund Gund, Khurs, Poshipora, Pushwari, Gotengu, Kunan, Gushi, Bajipora, Mugal Gund, Headworks of Lal Khul.	Jhelum River
94	17m	Mawar Nallah	30.0	Putwari, Tuligind, Urjoo, Babegund , Unisoo	Puhroo Nallah at Unisoo
95	17n	Talri Nallah	25.0	Wader Balla, Gurihaker, Totigund, Wuderpora	Puhroo Nallah at Unisoo
96	17o	Hardi khari Nallah	15.0	Haril Forests, Bategund	Mawar Nallah.
97	17p	Latir Nallah	8.0	Durashpora, Baripora	Puhroo Nallah
98	17 q	Hamal Nallah	30.0	Kiterdagi, Watergam, Nowpora, Rebbon	Puhroo Nallah
99	18	Dakil Nallah	28.0	Khamoa forests, Ruhama, Ladoora	Jhelum River at Ladoora
100	19	Binner Nallah	13.0	Door/ Kaninar Forests, Binner, Janbazpora	Jhelum River at Janbazpora
101	20	Gratenar Nallah	4.0	Hapet Dub	Jhelum River at Drangbal
102	21	Mundryari Nallah	5.0	Nambla Forests, Baramulla old town,Baghi Islam, Sheeripora	Jhelum River at Sheeri.
103	22	Vij Nallah Baramulla	8.0	Downstream Huma Dub Forests	Jhelum River at Vijbal near Puhroo
Total Length in Km:			**1876.3**	***Note: The lengths of Nallahs/Tributaries may vary +/- 5 to 10%, based on actual surveys (From I&FCD).***	