Terms of Reference

DEVELOPMENT OF HIGH RESOLUTION DIGITAL ELEVATION MAP (MODEL (DEM) OF KOSHI BASIN) OF TERAI REGION

(Contract ID: PPCR/DHM/S/CQS-26)

September 2015

1. Introduction

This Terms of Reference (ToR) is for a consulting firm to prepare **High Resolution Digital Elevation Model (DEM) of Koshi basin** as a supporting activity in establishing people-centered functional "End-to-End" Flood Early Warning System (FEWS) to mitigate adverse impacts of flooding in the Koshi River Basin of Nepal, downstream of Chatara.

Building Resilience to Climate Hazards (BRCH) Project

Nepal is one of the nine countries participating in the global Pilot Program for Climate Resilience (PPCR) financed by the Climate Investment Funds. This program provides financing for least-developed countries to pursue a climate-resilient development path that reinforces poverty reduction goals. The Ministry of Science, Technology and Environment (MoSTE) is the Government of Nepal's focal ministry for the PPCR.

The multilateral development banks—the Asian Development Bank (ADB), the International Finance Corporation (IFC) and the World Bank—administer the funds on behalf of the Climate Investment Funds and supervise the projects in collaboration with MoSTE.

Nepal prepared the "Strategic Program for Climate Resilience" (SPCR) to outline its program to respond to priority climate risks. The SPCR complements the National Adaptation Program of Action (NAPA), National Climate Change Policy, Local Adaptation Plans of Action (LAPAs).

Among the five components identified under Nepal's SPCR, now the following four components are being implemented:

Component 1: Building Climate Resilience of Watersheds in Mountain Eco-Regions

Component 2: Building Resilience to Climate-Related Hazards

Component3: Mainstreaming Climate Change Risk Management in Development

Component 4: Building Climate Resilient Communities through Private Sector Participation

BRCH project falls under Component 2. The main objective of the BRCH project is to enhance government capacity to mitigate climate related hazards by improving accuracy and timeliness of weather and flood forecasts and warnings for climate vulnerable communities, as well as developing Agricultural Management Information System (AMIS) services to help farmers mitigate climate related production risks. The project comprises of four components:

A. Institutional strengthening, capacity building and implementation support of DHM;

B. Modernization of observation networks and forecasting;

C. Enhancement of the service delivery system of DHM; and

D. Development of an Agriculture Management Information System (AMIS).

Component A aims to develop and/or strengthen DHM's legal and regulatory framework, improve institutional performance as the main provider of weather, climate and hydrological

information for the nation, build capacity of personnel and management, ensure operability of the future networks, and support project implementation.

Component B aims to modernize DHM observation networks, communication and ICT systems, improve hydro-meteorological numerical prediction systems and refurbish DHM offices and facilities.

Component C aims to enhance the service delivery system of DHM by creating a public weather service that provides timely and accurate weatherobservations and forecasts, and information services for climate-vulnerable communities and the key weather dependent sectors.

Component D will provide critical and timely agro-climate and weather information as well as agro-advisories to farmers in order to increase productivity and reduce losses from meteorological and hydrological hazards.

For the implementation of the BRCH project, two Technical Committees have been established, one chaired by DG of DHM focusing on Components A, B and C, and the other chaired by MoAD focusing on Component D. The two committees coordinate as needed.

2. Rationale

The Koshi River is one of the largest rivers of Nepal. It originates in Tibet Autonomous Region of China and drains down south to Nepal. Flowing further south, the Koshi joins the River Ganga in India. The basin covers six geological and climatic belts varying in altitude from above 8,000 m to 59 m comprising the Tibetan plateau, the Himalayas, the Himalayan mid-hill belt, the Mahabharata Range, the Siwalik Hills and the Terai. The river is 720 km in length and drains an area of about 61,000 km^2 in Tibet, Nepal and Bihar.

The area considered in this study is the Koshi Basin downstream of Chatara Gorge in the Terai region of the Eastern Nepal (Figure 1). The catchment area up to Chatara is 57,760 sq. km which includes Tibetian Plateau, the Himalayan, Middle Mountain and Siwalik hills of Nepal. In Nepal, the basin consists of 7 major watersheds: Indrawati, Sunkoshi, Tamakoshi, Likhu, Dudhkoshi, Arun, and Tamor. After the confluence of three major rivers Sunkoshi, Arun and Tamor at Tribeni the River is known as Saptakoshi. Chatara lies at an elevation of 140 m. downstream of Tribeni. From Chatara, the river emerges into the plain area and causes devastating flood during monsoon. The Sunsari and Saptari are the worst flood hit districts. To save the enormous damage from the Koshi flood, it has become essential that a proper early warning system (EWS) be established to save the lives and properties of the area downstream of Chatara. For this purpose, High Resolution Digital Elevation Model (DEM). DEM is required that would help:

- Determine flood warning and danger levels;
- Prepare Flood inundation maps;
- Assess the vulnerability of population, buildings, infrastructures, agriculture and other assets.

In Nepal, digital contour line maps are available with 10 - 40 m contour spacing from which DEM can be produced. Agencies such as NASA's Shuttle Radar Topographic Mission and ASTER (Advanced Space-borne Thermal Emission and Reflection) and others freely provide DEM, but none of these products are suitable to model floods and prepare inundation maps in the relatively flat terrain. Hence it has become necessary that DEM be prepared to suit the needs of EWS for this particular area.

The area requiring DEM is shown in the following figure:

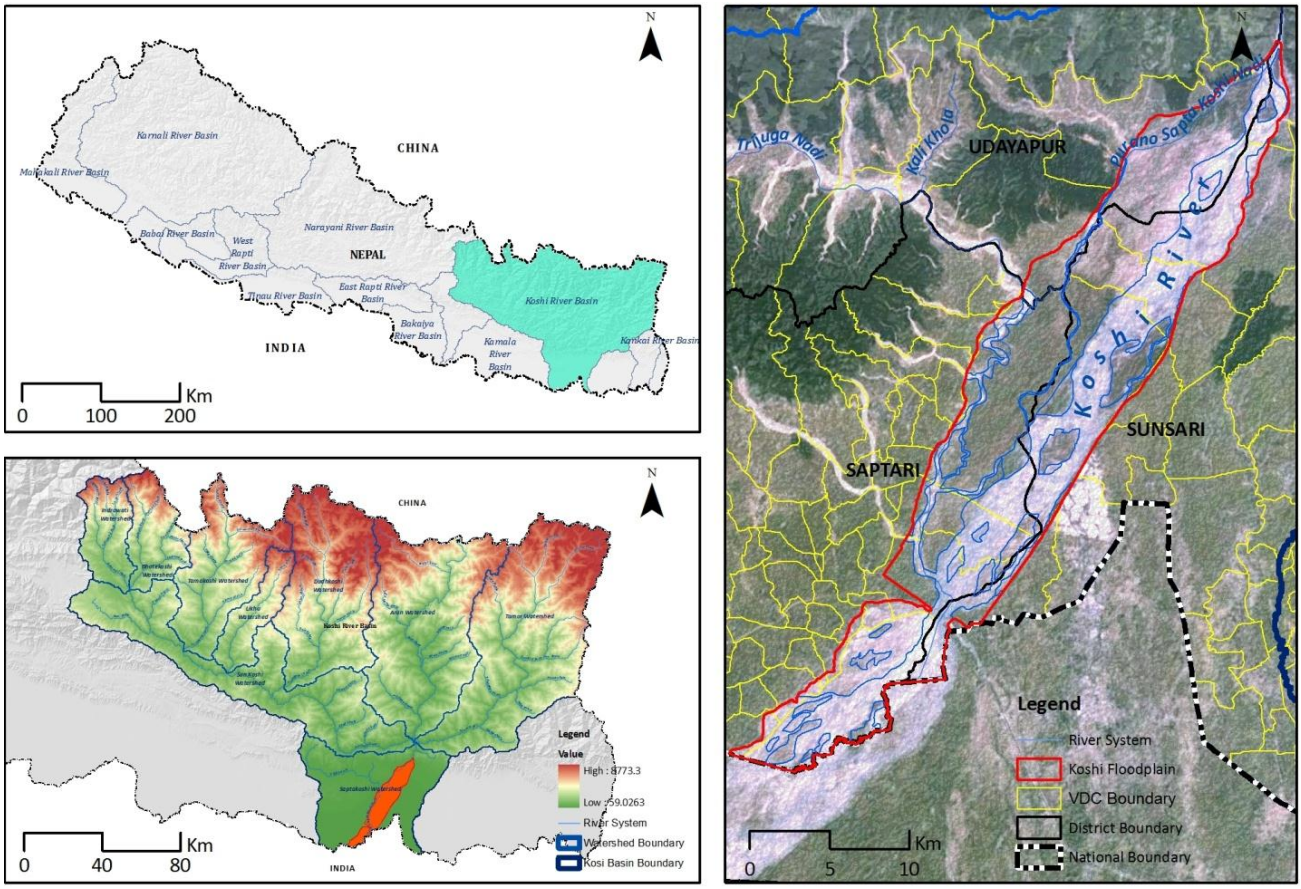

Figure 1 Location Map of study Area

3. Objective

The main objective of this study is to create a high resolution digital elevation model of the Koshi Basin downstream of Chatara tosupporti the activities required to establish people-centered functional "End-to-End" Flood Early Warning System (FEWS) to mitigate adverse impacts of flooding in the Koshi River Basin of Nepal, downstream of Chatara 3.

4. Scope of Work

The overall scope of work is to prepare a high resolution DEM covering the Koshi flood plain area (downstream of Chatara) to provide support in establishing a robust people-centered functional "End-to-End" Flood Early Warning System (FEWS).

Specifically, the scope of work covers the following activities:

- Explore the availability of high resolution stereo images of the study area;
- Develop a most suitable method of DEM creation tools using available stereo data, field data and spot heights from the topographic maps**;**
- Create a high resolution Digital Elevation Model of the Koshi basin, downstream of Chatara;
- Provide training on ortho-image rectification, DGPS survey and post processing, and DEM creation using stereo images to the DHM staff;

5. Tasks of the Consulting Firm

Task 1: Environment setup and necessary data collection

- Collate and evaluate the source, quality and coverage of the available data. If needed, find out the gaps where existing or available high resolution satellite stereo images are inadequate. If gaps found, recommend and suggest the same resolution or quality of the data to purchase.
- Set up an environment or make a plan to ensure a smooth operation including field activities.

Task 2: Prepare high resolution Digital Elevation Model (DEM)

- High resolution(≈ 1 m) Digital Elevation Model (DEM) using suitable spatial resolution (with required vertical accuracy of <0.25m) shall be prepared using very high resolution stereo/tri-stereo satellite imageries.
- The DEM can be made from bought satellite images (eg. Pleiades,CARTOSAT) or can be made from the available data provided that the spatial resolution falls within the aforementioned range.
- The DEM shall be georectified using at least 20 spot heights per square kilometer measured onsite using Differential GPS (DGPS) along with the sectional data of the Koshi River, canals as well as other drainage in that flood prone areas.
- The DEM shall have at least 1 control point per square kilometer taken using Differential GPS to ensure the required vertical accuracy.

- The horizontal accuracy is generally believed less than 2 meter or so as a basic cartographic limitation.
- The tools and algorithm used for the Geo-rectification shall be described in detail in the documentation.
- The output format for the elevation (X, Y, Z) shall be in Vector and Raster format (DEM) compatible to general RS and GIS software.
- Along with the DEM, the consulting firm should provide ortho-rectified satellite images suitable to print in the scale of 1:5000 or larger. The consulting firm should provide both the horizontal and vertical accuracy assessment with some verification.

Task 3: Cross-Sectional Survey of the Koshi River

Cross-sectional survey shall be carried out as following:

1. 300m upstream of Chatara Hydrological station
2. At the hydrological station
3. 300m downstream of Chatara and after that
4. At every 2 km interval up to Koshi Barrage

- Depending on the nature of the river course, additional cross section shall be taken at critical and vulnerable areas such as canals, upstream/downstream of settlements, excessive bank cutting areas, meandering areas among others . The cross section survey measurements shall be taken up to 500 m above the highest flood level but not be limited to stipulated distance if field scenario permits to survey beyond 500 m. The cross-sectional survey shall be done by establishing high accuracy controls stations at appropriate locations using DGPS along the banks of the river. Tachymetric survey shall be carried using Total Stations/Auto Level for cross section readings. Eco-sounder shall be used to measure the cross-sectional depth wherever necessary and applicable.
- The horizontal cross-sectional survey measurement shall be taken in every 2 m horizontal interval up to normal water level, in every 10 m interval up to high flood level and in every 20 m above high flood level (i.e., up to 500 m in both sides). Additional point shall be taken at every major change within horizontal interval as stipulated above. Intensive cross section survey shall be done at every 100 m interval at settlement area taking adequate points per cross-section or near to settlement area from the river.

Task 4: Documentation of the work including horizontal and vertical accuracy and data storage

- Consulting firm should provide a complete documentation of the work incorporating DEM generating method in detail including horizontal and vertical accuracy.
- Establish an acceptable correlation between values of DEM and value of cross section survey and justify the accuracy.
- The DEM data are to be stored in DHM data base and are to be formatted:

Vector Data format

Vector format will include collection of xyz points (location and elevation) as cloud points. These cloud points should be made available in Geodatabase and SHP formats. The data formats allows user to generate the DEM either in TIN Model or Raster Model.

Raster Data Format

The raster format will include the continuous elevation values which can be expressed with decimal places appropriate for the accuracy of the data. The DEM should be stored as floating point values. The consultant should provide DEM in the commonly encountered raster elevation formats: namely, GeoTIFF, IMG, ESRI Grid.

Task 5: Knowledge transfer and training to the DHM staff

- The consulting firm should provide training to the assigned DHM staff on the ortho-rectification of satellite imagery, field data collection and DEM creation.

6. Consultant's Qualification and Experience

A. General Qualification of the Consulting Firm

- At least 5 Years of experience in handling geospatial data. More than 5years preferred
- At least 5 years of experience in providing consulting services in the area of satellite data processing including ortho-rectification, satellite image processing
- At least one task to process the stereo image in order to derive the DEM
- At least two tasks of DGPS surveying for satellite image ortho-rectification.

B. Key professionals:

- Team Leader/ GIS/Remote Sensing /Geo-informatics Expert (4 man-months)
- Senior Field Surveyor (4 man-months)
- GIS/Remote Sensing Expert 1 no. (3 man-months)
- Hydro-meteorology Expert 1 no. (1 man-month)

C. Required qualification of Experts/Personnel

Following key and supporting personnel is required for undertaking the assignment:

SN	Personnel	Requirements	Inputs (Man months)
1	Team Leader/ GIS/ Remote Sensing/Geo-informatics Expert	MSc or M.Tech in Geo-information and Earth Observation/GIS or other relevant subject with 10 year of progressive experience in topographical mapping, digital photogrammetry and satellite image analysis, and GIS analysis.	4
2	Senior Field Surveyor	BE/BSc in Survey Engineering or Senior Survey Training from authorized institute with 8 years of experience in similar works including DGPS survey, river cross section survey, etc.	4
3	GIS/Remote Sensing Expert	MSc/Post-Graduate Diploma in Remote Sensing and GIS or BE/BSC/BA in engineering/science /geography with extensive 6 months training and 3 years experience in GIS and Remote sensing, image processing.	3
4	Hydro-meteorology Expert	MSc/Post Graduate Hydrology/Meteorology with minimum of 10 years of experiences in river flow measurement, modelling and mapping.	1

7. Outputs

Theme 1 Topography and Terrain

Digital Elevation Model (with elevation accuracy of 0.25m), ortho-rectified satellite imagery. Following points to be considered:

- DEM should determine flood extents and flood hazard lines at an accuracy stated above.
- Spot levels and break lines along all significant features including road centrelines, kerb lines, road intersections, banks of creeks are required to achieve this degree of accuracy.
- A detailed field survey may be necessary in some areas where land form is obscured by vegetation.

- The DEM accurately reflect the nature of the floodplain including roadways, major blockages to flow, e.g., large buildings and other important characteristics and critical locations along the floodplain.
- Survey shall be projected to MUTM and Everest 1830 datum
- The consultant shall produce ortho-rectified satellite imagery with RMS error not exceeding 1.5 m.

Theme 2 Koshi River sectional data.

- Cross-sectional and L-Sectional measurement of Koshi River.

The outputs shall be presented in standard reports, large scale maps in A1 size papers, cross-sections drawings in A3 maps, digital datasets in appropriate GIS and image formats. The reports and maps shall also be submitted in digital print ready PDF format along with the DEM digital data.

Theme 3 Documentation and training

A proper documentation of the consulting works and training to the DHM staff should be accomplished.

8. Work Schedule and Deliverables

The assignment shall be completed within the stipulated time of four working months with four stages of deliveries as hereunder:

SN	Deliveries	Schedule	Contents
1	Inception Report (2 sets hard copy)	2 weeks after the contract	- Detailed work plan and methodology - Data availability - Field survey plan including DGPS survey plan
2	Desk work and Field Report (2 sets)	2 months after the contract	- Cross-section data, DGPS processed data and description cards, processed DEM, ortho and georectified satellite image along with report, field photographs and other field data

SN	Deliveries	Schedule	Contents
3	Draft Report (2 sets)	3 months after the contract	- Methods and tools - Cross-section profile drawings at appropriate scales (in AutoCAD/PDF) - Georectified satellite image, ortho image and draft DEM . - Results and discussion
4	Final Report (5 sets hard copy, 3 sets soft copy, one set raw and proceeded digital data)	Within 4 months after the contract incorporating comments and suggestions from the client in the submitted Draft Report	- Cross-section data, DGPS processed data and description cards, processed DEM , ortho and georectified satellite image along with report, field photographs other field data

9. Payment Methods/ Modalities

- 25% payment after the submission of inception report
- 35% payment after the submission of report on deskwork on Orthorectifcation and DEM generation and field work.
- 40% payment after the submission and approval of final report

10. Consultant's Selection Method

- The consultant shall be selected on the basis of Consultant's Qualification Selection (CQS) method and consistent with the World Bank's Consultant Selection Guideline, 2011, and on the basis of required qualifications and related experiences.