Sediment Monitoring Protocols for Churia Originating River Systems

DHM

Prepared by:

Community Based Flood and Glacial Lake Outburst Risk Reduction Project (CFGORRP)

Department of Hydrology and Meteorology
Ministry of Science Technology and Environment
Government of Nepal

June 2015

Prepared and Published by: **Community Based Flood and Glacial Lake Outburst Risk Reduction Project (GoN/GEF/UNDP)**

Citation:
Community Based Flood and Glacial Lake Risk Outbrust Reduction Project, Department of Hydrology and Meteorology, 2015. Sediment Monitoring Protocols for Churia Originating River Systems, pp 17

FOREWORD

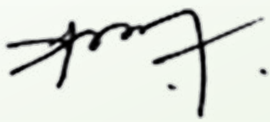
It has been well understood that Churia Originating Rives are extremely flashy in nature and carry large amount of sediment from the up hills and then deposits in the southern low land because of typical geological and terrain condition. The sediment transport behaviour has now been dramatically changed due to impact of land-use/land-cover change and human interventions.

Data related to sediment in Nepal is very limited. Additionally, we have also limited sediment database on Churia originating river systems. One of the reasons behind this is due to lack of adequate resources and programs. However, sediment data is important for designing and implementing river training interventions, climate change study, flood hazard mapping and implementing disaster risk management plan. This leads to the importance of sediment monitoring protocols.

The Sediment Monitoring Protocols for Churia Rivers prepared by DHM/CFGORRP is a first of its kind expecting to contribute in establishing standardised methodology in sediment monitoring of Churia Rivers. The Protocol is handy and provides comprehensive information on sediment sampling, measurement and quanitification techniques in a river system with due emphasis on Churia Originating Rivers. I hope the use of this Protocols will have dual benefits that it helps enhancing the knowledge of the users and contributes to understand the sediment related problems in Churia region.

I take this opportunity to thank our Consultants Mr. Om B Raut and Mr. Sanjaya Devkota for generating and brining this document to this shape.

Finally, I would like to express my sincere gratitude to UNDP and GEF for providing the technical and financial support through CFGORRP in realizing the document.



Dr. Rishi Ram Sharma

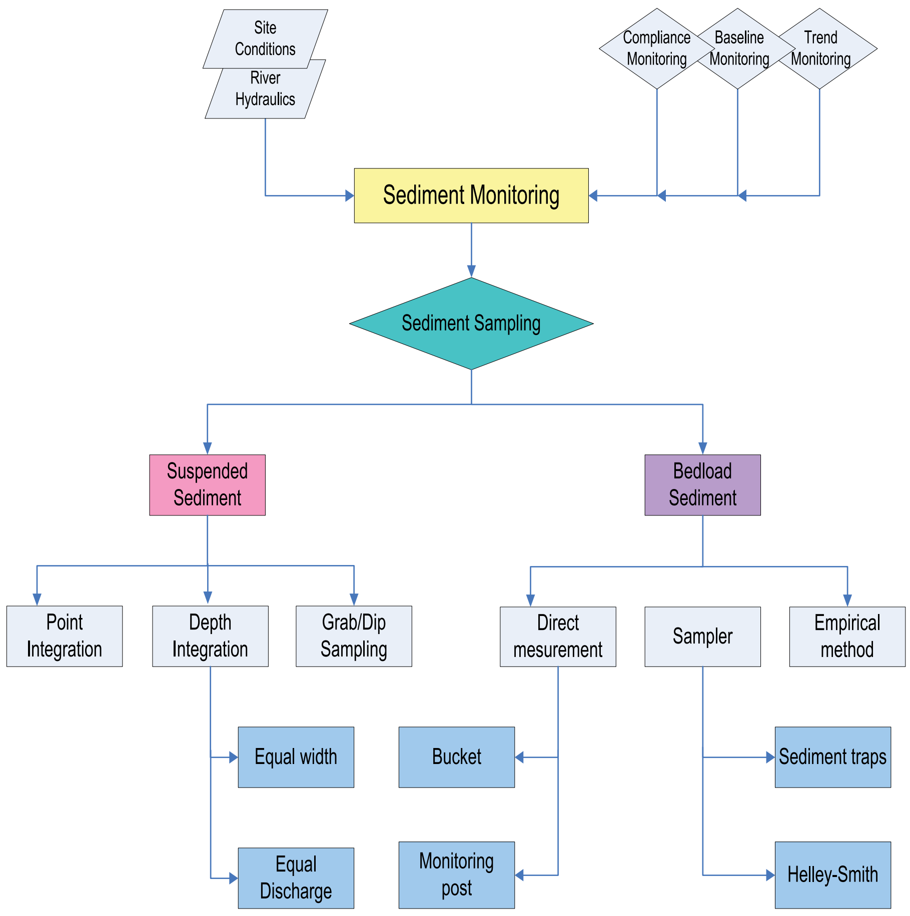
Director General & National Project Director

Community Based Flood and Glacial Lake Outbrust Risk Reduction Project/ Department of Hydrology and Meteorology

June 2015

CONTENTS

Sediment Monitoring – Flow Chart



1. Introduction

The rivers in Nepal can be broadly classified into three types depending on their sources and discharge. The first type (e.g. Mahakali, Karnali, Gandaki, Koshi etc.) originates in the Himalaya and carries snow-fed flows with significant discharge even in dry season. The second type originates in the Midlands or the Mahabharat Range and is fed by precipitation as well as groundwater regeneration. Babai, West Rapti, Tinau, Bagmati, Kamala, Kankai etc. fall under this type. Apart from these two types, there are large numbers of non-perennial rivers having many ephemeral tributaries originating from Churia range for example Ratu, Khando, Gagan, Lothar, Lakhandehi, etc.

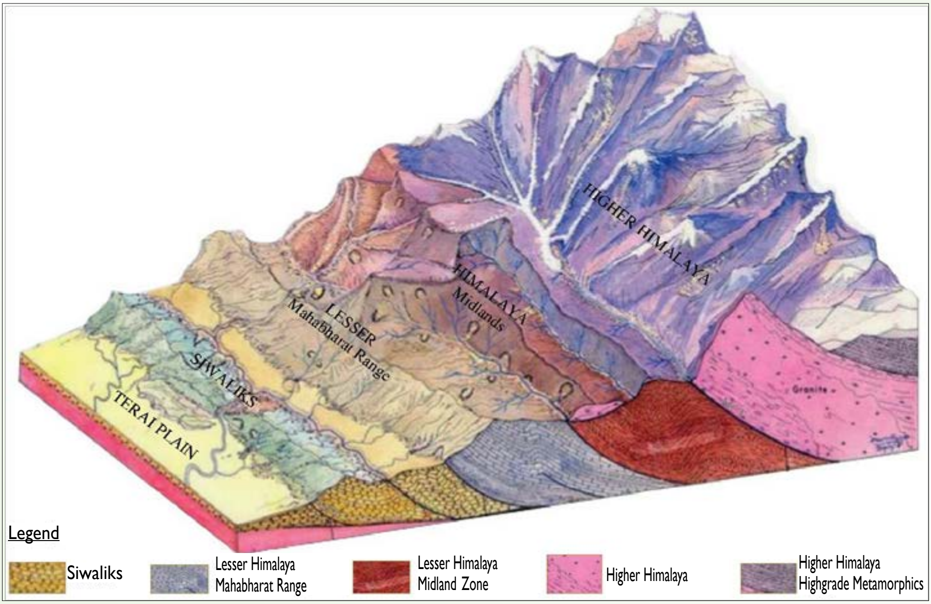


Figure 1: General north-south profile & river system of Nepal

Churia ranges can be classified into three formations: i) Lower, ii) Middle and iii) Upper Churias. The Lower Churia consists of hard sandstone with conglomerates containing pebbles of clay and shale, whereas the Upper Churia is composed of coarse conglomerates, sands, girt and clay. The region is highly influenced by specific climate patterns of intense rainfall, weak geology and excessive human activities leading to mass wasting and sediment transport towards low land.

The rivers are extremely flashy, threatening to lives and are prone to damage of properties, and lead to desertification.

Sediment is a naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of water, wind, or ice, and/or by the force of gravity acting on the particles. In the fragile Churia hillslope, the earth materials start to move down slope due to their weakened strength by water and under the action of gravity that helps to modify the existing topography and land-cover. The quantity of material flowing together with the water in the form of sediment is highly dependent on energy of flowing water also known as stream power (also known as transport capacity), which is influenced by several other factors among which river gradient is highly recognized – higher the river gradient higher is the stream power and therefore plays a great role in sediment transportation. Fluvial is a term used in geography and geology to refer to the processes associated with rivers and streams, the deposits and landforms created by them. River channel deposits are the examples of fluvial transport and deposition.

Figure 2: View of water action in Churia Hill

2. Fluvial Sediment

Fluvial sediment loads may be classified according to their (a) mode of movement and (b) origin or sources of supply. In general, sediment load is classified as suspended load or bed load according to the mode of movement in a river. Suspended load is the sediment that moves in suspension in water under the influence of turbulence. Bed load is the part of sediment that moves in almost continuous contact with the

stream bed by saltation and traction, i.e., by bouncing, sliding and rolling on or near the stream bed by the force of water. On the other hand according to its origin or source of supply, total amount of sediment transported in rivers may be divided into two parts: wash and bed loads. Wash load consists of fine particles, which generally refers to sediment size finer than 0.062 mm, and the amount depends mainly upon supply from the source area. The discharge of bed material is controlled by the transport capacity of the stream, which also depends on bed composition and other hydraulic characteristics. Wash load moves entirely in suspension, while the bed load may move either as temporarily suspended load or as bed load.

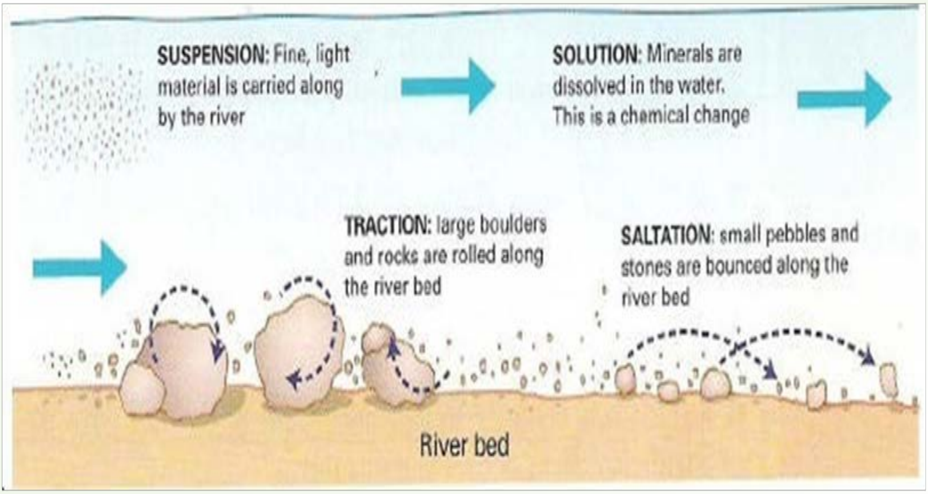


Figure 3: General view of sediment transportation (suspended and bed load)

3. Importance of the Protocols

Department of Hydrology and Meteorology (DHM) has sediment sampling facility established in a number of important gauging stations of the larger rivers such as Karnali, Narayani and Koshi. Sediment samples are collected on regular basis during monsoon months. The collected samples are analyzed in its laboratory and database is maintained. Additionally, there are some other institutions and hydropower companies that have some sediment data for their own purposes such as specific research, design of civil and hydro-mechanical equipment etc. However, it is

important to mention here that there has been a lack of consistency on sampling techniques, measurement and database management probably because of non-availability of standardized document related to sediment monitoring procedures.

It has been understood that very little efforts have been made on sediment dynamics of Churia originating river systems because of their nature and complexity. Studies on the spatial distribution pattern of sediment production, deposition, and sediment sampling and analysis are still lacking.Development of sediment control techniques for Churia Hills and protecting infrastructures in Terai region from the consequences of floods are the most concerned issues for which a complete sediment monitoring protocols is required.

The Protocols aims to guide, define, and standardize the followings:

- *Trend Monitoring – to determine the temporal variability of sediment influenced by natural or human-induced factors on regular basis.*
- *Baseline Monitoring – a temporal sampling to collect information prior and posterior to any intervention*
- *Effectiveness or Compliance Monitoring- short term spatial sampling of sediment up and downstream of a prescribed activity to determine how the activity preventing sediment entering into the river/water body.*
- *Project or Impact Assessment Monitoring – a spatial program employed to determine if an activity has a negative or positive effect at a specific site.*

Community Based Flood and Glacial Lake Outburst Risk Reduction Project (CFGORRP)/Department of Hydrology and Meteorology (DHM) has devised a basic protocols in order to establish systematic procedures for sediment sampling and analysis of sediment data, database management and monitoring procedures for the establishment of uniformity in sediment monitoring methods specially applicable to Churia originating rivers.

Box 1: Steps for sediment monitoring planning and assessment

- Establish Objectives and Determine Sediment to be Analyzed (Suspended or Bed Load)
- Develop Methods Determine Scale of Variability and Techniques
- Identify Sampling Sites
- Identify and Select Sampling Techniques
- Collect Samples, Analysis and Interpret
- Reporting

4. Sediment Monitoring

Sediment data acquisition involves data collection on i) site conditions, ii) river hydraulics and iii) other sediment properties:

Box 2: Data Acquisition

Description	Parameter
Site condition	a) Bed forms at the time of data collection b) Instrumentation c) Site Description d) Water Temperature e) Aquatic Animal Habitat Units
River Hydraulics	a) Width b) Cross Sectional Area c) Velocity d) Stream Depth and Slope/Gradient e) Flow Discharge f) Placement Depth g) Channel Morphology
Sediment Analysis	a) Sediment Discharge / Concentration b) Suspended Load c) Bed Load d) Size Distribution e) Mineralogical Content f) Specific Gravity

The sediment sampling should be on regular basis and depends on the width of the river at specified depth, which depends on adopted method. Location and frequencies for suspended sediment sampling should be:

- Sampling distances from one edge to the other of river – 25%, 50% and 75% of total river width
- Single sample at the middle of the section - low flow season (November – June 14)
- Additional sample atthe center of the river - pre-monsoon period, (June 15 - June 30)
- 3 samples every day, one each at 3 verticals - monsoon and post-monsoon (July – October)
- Discharge measurements - at the time of sediment sampling

Box 3: Ideal Condition for Site Selection

S. N.	Description	Characteristics
1	Flow	Uniform and Mixed
2	Cross Section	Uniform, Straight and Stable as far as possible
3	Accessibility	Accessible and able to be Sampled during High Flow Season
4	History	Any previous records and data availability

While doing the sediment sampling, it is important to keep the records of the date, name of the river, name of the person who is sampling, as in Box 4:

Box 4: Labeling of Samples	
• Date: • Name of River: • Sampling station: • Location of station: • Coordinates:	• Name of Sampler:: • Sample No:: • Time: • Discharge: • River Morphology:

5. Suspended Sediment Sampling Methods

There are different methods of suspended sediment sampling which primarily depend on the type of study, available budget and time, type of experts to be involved etc. The methods that can be used for Churia Originating Rivers are:

Methods

- Point Integrated Sampling
- Depth Integrated sampling
    - Equal Width Increment (EWI) Method
    - Equal Discharge Increment (EDI) Method
- Grab or Dip Sampling

5.1 Point Integrated Method

The point-integrating sampler remains at a fixed point in a stream and samples continuously during the time it takes for the bottle to be filled in. Opening and closing the valves of the sampler are controlled from the surface electrically or by cables. Samples should be taken at a number of depths i.e. at relative depths 0, 0.2, 0.6, 0.8 and 1.0 (i.e. ratio of the depth of the sampler to the depth of flow).

Another method of obtaining samples at various depths of flow is to use automatic samplers which will take a sample at a predetermined depth of flow. A typical example is shown in Figure 4 using a milk bottle and two lengths of bent tube. Factory-made versions generally use copper tubing accurately bent to shape, but a simple field version can be made using plastic tubing which is tied to a rigid framework to hold it in place. The bottle starts to fill in it when the depth of flow reaches point A and starts syphon flow into the bottle, and ceases when the depth of flow rises to point B (fig. 4) which is the outlet of the air exhaust pipe. The range of sampling is controlled by adjusting the distance between points A and B.

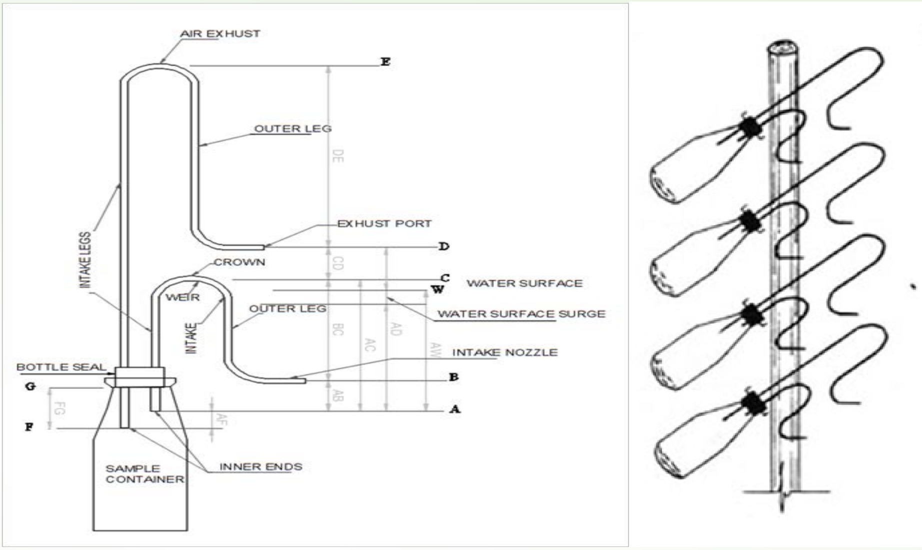


Figure 4: (left) view of typical US U 59 point integrated sampler (right) an array of samplers for progressive sampling during the rising stage of water level

5.2 Depth Integration Methods

It allows to measure sediment concentration at different points in a stream by using an integrating sampler that is one which gives a single sample combined from small sub-samples taken from different points. A typical sampler is illustrated in Figure 5 and 6 below and consists of a glass bottle inserted in a fish-shaped frame mounted on a rod when gauging small streams or suspended on a cable for larger streams. For the bottle to fill in smoothly and evenly when below the surface, it is necessary to have a nozzle or an orifice for entry of water, and a second pipe (air vent) through which the displaced air is ejected. The entry nozzle is usually designed with a slightly expanding cross-section behind the point of entry in order to reduce the risk of back pressure which could interfere with the flow into the bottle. In operation, the sampler is moved from the surface down to the bed and back up to the surface while sampling continuously. A few trial runs will establish how long it is required for the bottle to be filled in during this double journey. In some depth-integrating samplers, the bottle is lifted out of the flow when or just before it is filled; other types of sampler may have some devices to stop further sampling once the bottle is full.

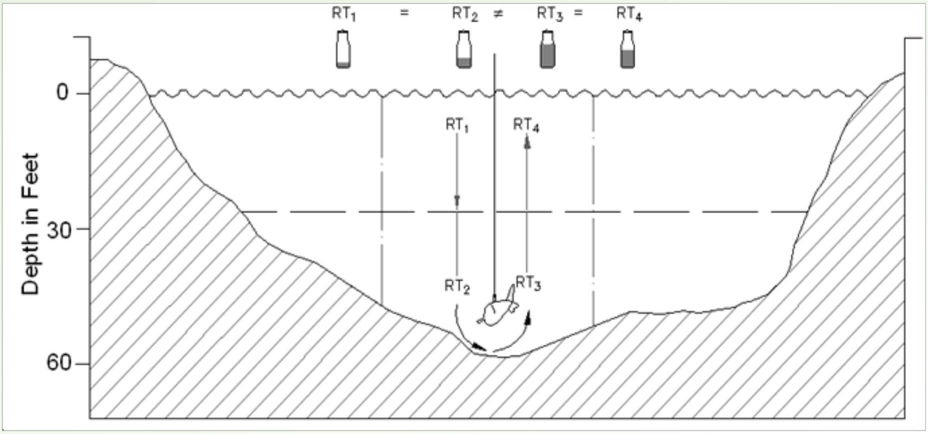


Figure 5: Depth integrated method

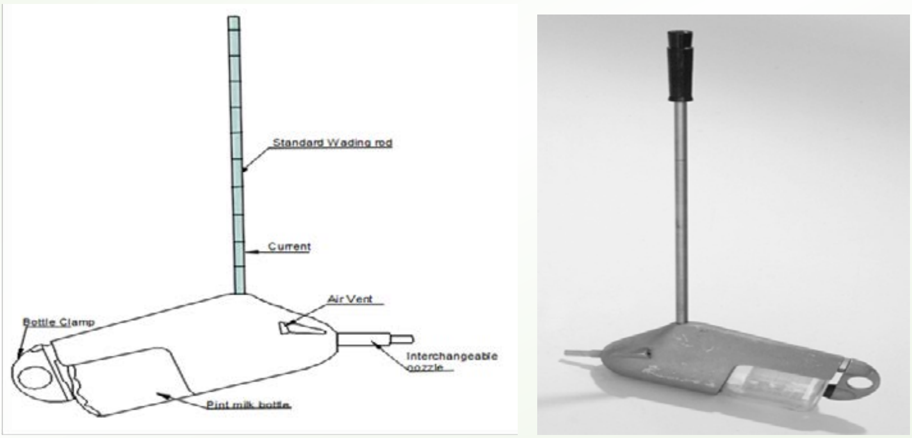
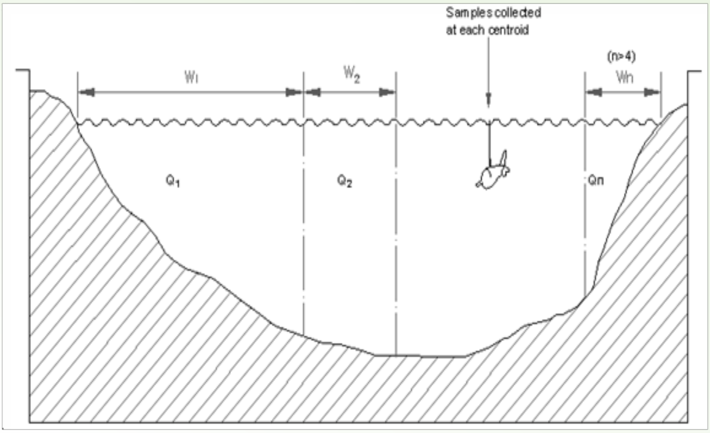


Figure 6: Wade type sampler for depth integrated method

5.2.1 Equal Discharge Increment (EDI) Method

In this method, a river cross section is generally divided into 3 to 10 different segments having nearly equal discharge (Figure 7). Verticals are arranged according to the distribution of water discharge across a section. The transit rate for each vertical may not be equal, but the sample volume for each vertical should be kept approximately equal. For round trip depth integration in a vertical, the transit rate during descending and ascending should be the same. The discharge distribution across the section must be estimated prior to the sampling work.

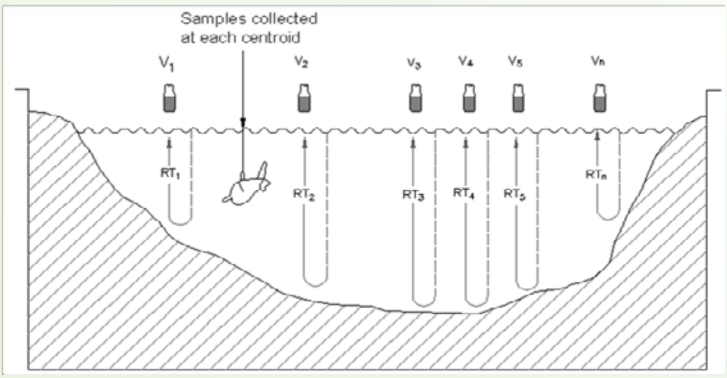


Explanation:
W - Width between verticals (not equal)
Q – Discharge in each increment (equal, EDI)

Figure 7: Equal discharge increment method

5.2.2 Equal Width Increment (EWI) Method

A river's width is divided into six to ten equal segments under this method (Figure 8). The transit rate of the sampler for all the verticals should be kept same i.e. established at the deepest and shallow verticals in a cross-section. In round trip depth integration, the descending and ascending transit rates should also be kept the same. The same nozzle is used at all verticals. The sample bottle should not be allowed to fill in completely. Ideally, the sample volume will be directly proportional to the water discharge represented by the vertical. The average concentration in the cross-section will be the concentration of the composite sample made up by combining all samples at the cross-section.



Explanation:
RT – Transit rate at each centroid (not equal)
V – Volume collected at each centroid (equal)

Figure 8: Equal width increment method

Box 5: Summery Monitoring of Suspended Sediment

S. N.	Method	Description	Field Sampling			Lab measurement		Remarks
			Sampling Procedures	Sampling Location	Sampling Schedule	Sediment Concentration	Particle Size	
1	Point Sampling	Grab the sample	One Sample at a chosen point	Middle section	Peak flood season	discharge measurement	Hydrometric or sieve analysis	common in the project
2	Integration							
2.1	Depth Integration	Velocity at the nozzle should be equal to ambient flow velocity	Sampler from surface to bottom & lifting up to surface at a transient rate so that it gets filled	Divide the section into 3 number of verticals at 1/6, 1/2 and 5/6 of the width	Daily during flood	discharge measurement	Hydrometric or sieve analysis	Suitable for medium cross section
2.2	Point Integration	Velocity at the nozzle should be equal to ambient flow velocity	sampler at the specified sampling point at the vertical	two points in the vertical 0.2 and 0.8 times the depth	Daily during flood	discharge measurement	Hydrometric or sieve analysis	Suitable where concentration variation is high across the section

5.3 Grab or Dip Sampling

The simplest way of obtaining suspended sediment sample is to dip a bucket or other container into astream, preferably at a point, where it will be well mixed, such as downstream from a weir or rock bar. For a single sample taken by scooping, a depth of 300 mm below the water surface is recommended as a better sample than sampling at the surface. If the single sample can be taken at any chosen depth, half the depth of flow is recommended as giving the best estimate of average sediment concentration.

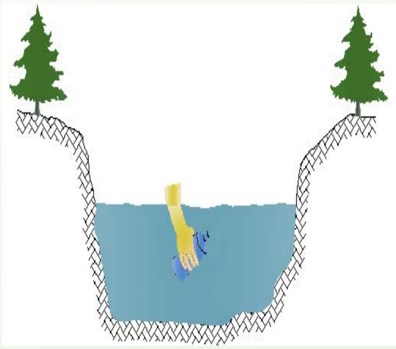


Figure 9: A view of grab or point sampling


5.4 Recommendations

Suspended sediment sampling in Churia River seems to be difficult for which special precaution is needed while sampling as the rivers are flashy and bring huge quantity of sediments. The method of sampling depends on the objectives, available resources, time and nature of the river. However, point integration method would be good to have general pictures of the suspended sediment load/discharge as it is fast and relatively easier method of sampling. The depth integration method is also good but it is time consuming and requires sufficient preparatory works, resources and budget to understand the river morphology and flow pattern. Among the two integration methods, equal width increment (EDI) method is found to be easy and gives reasonable results. In most case of Churia River, handheld wade type suspended sampler would be a better practice.

6. Laboratory Works for Suspended Load

The bottles or dry samples are taken to the laboratory after primary field processing such as labeling, handling and transportation. The laboratory analysis depends on the objectives of the study however filtering and drying are first stage which is followed by grain size analysis, chemical analysis, etc. For each set of measurement, the dry weight of the sediment (W_s), is taken in mg, divided by the volume of the sample water (V_w) in cm^3 and then multiplied by 1000. The result is the suspended sediment concentration in mg/lit.

Sediment concentration, mg/lit

$$(SC) = \frac{Ws}{Vw} * 1000$$

where,

W_s = dry weight of the sediment in mg,
V_w = Volume of sample water in cm^3

7. Computation of Suspended Sediment Discharge

When point samples of suspended sediment are taken for each vertical,

the sediment discharge per unit width is obtained by using following equation in the Box 6. Sediment discharge of the entire cross-section can then be computed by integration of the sediment discharge per unit width along the entire width of the stream. In practice, this is carried out by summing the products of the sediment discharge per unit width and the section width each vertical represents.

Box 6: An Example of Sediment Computation Procedures

$$q_s = \frac{d}{m}\sum_{i=1}^{n} k_i C_i V_i$$

where

- q_s - sediment discharge per unit width (kg/sec/m)
- m - number of measuring points
- C_i - sediment concentration at the measuring point or in situ instruments (g/liter or kg/m^3)
- V_i- velocity at measuring point (m/sec)
- d - depth (m)
- k_i- fraction ofdepth of each measurement (k_i for 4 equal section = 0.25, 3 equal section = 0.33),
- n - sum oftheweighting factors at a vertical distance

For integration method (either the EDI or EWI), the sedimentdischarge in the entire cross-section is then computed as:

$$Q_s = C_m Q$$

where

- Q_s - sediment discharge of the entire cross-section (kg/sec)
- Q - water discharge expressed (m^3/s) and
- C_m- cross-sectional average concentration expressed (kg/m^3)

Example:

Number of measuring points (m) = 4
Sediment concentration at measuring point (C_i) = 0.25kg/m^3
Velocity at measuring point (V_i) = 2.5 m/sec
Depth (d) = 1.25 m
Fraction of depth of each measurement (k_i) = 0.25
Sum of weighting factor (n) = 0.15
River discharge (Q) = 80 m^3/sec
Width of river (w) = 12 m

$$q_s = \frac{d}{m}\sum_{i=1}^{n} k_i C_i V_i$$

= 1.25/4[0.25 *0. 25 * 2.5]
= 0.04kg/sec/m

Q_s = C_m * Q
= 0.04 * 12*2.67 * 80
= 102.53 kg/sec

8. Bed Load Monitoring

Bed load movement is quite uneven in both transverse and longitudinal direction and fluctuates considerably. In practice, it is more difficult to measure the bed load discharge accurately than suspended load. More importantly, bed load transport rate and the velocity of water close to the bed vary considerably with respect to both space and time. Therefore, any sample obtained at a given point may not be representative of the mean transport rate for a reasonable interval of time because the bed particles move intermittently at a mean velocity much less than that of the water. Thus, a bed load sampler must be able to representatively sample, directly or indirectly, the mass or volume of particles moving along the bed through a given width in a specified period of time if bed load discharge is to be accurately determined. It is often estimated as apportion of suspended load, which depends on the type of river morphology and concentration of

suspended sediment in the flow.

Methods:

- Direct measurement
- Samplers
- Empirical method

8.1 Direct measurement

Field measurement of bed-material discharge is difficult due to the erratic sediment movement which takes place in the form of moving ripples, dunes, bars, etc. No instruments have proved to be reliable for trapping the large and small sediment particles with the same efficiency, while remaining in a stable and flow-oriented position on the stream bed and not altering the natural flow pattern and sediment movement.

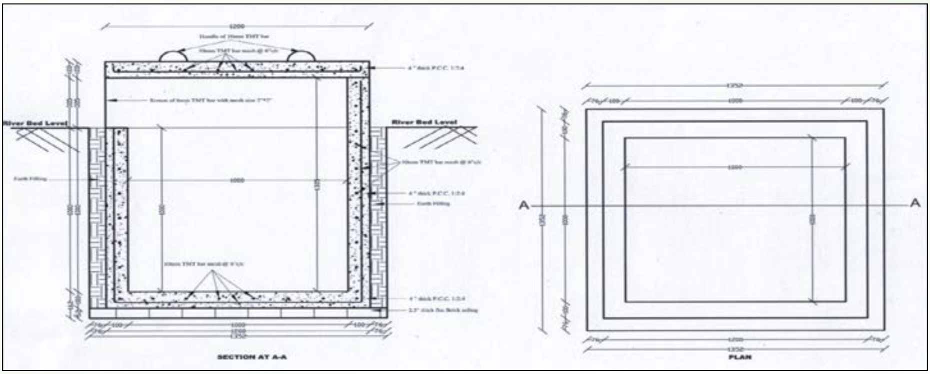


Figure 10: Sectional and Plan view of bucket sediment collection method

Prior to 1940, most bed load was measured using some type of direct-collecting samplers. Bed load samplers developed during this era can be grouped into four categories: (1) box or bucket, (2) pan or tray, (3) pressure difference, and (4) slot or pit samplers. Essentially, box or bucket samplers consist of a heavy open-front box or bucket apparatus, which is lowered to the stream bed and positioned toal low collection of bed load particles as they migrate downstream. The bucket type, displaying various sampling efficiencies, has been used preferentially over box types. Pan or tray samplers consist of an entrance ramp leading to a slotted or partitioned box.

These samplers also have varying sampling efficiencies. Pressure-difference samplers are designed to create a pressure drop at the sampler's exit and thus maintain entrance velocities approximately equal to the ambient stream velocity. Sampling efficiencies may be higher with this type of sampler than with others. Sediment trapped in the trough during sampling is removed

by means of a continuous conveyor belt, which carries the sample to a weighing station.

The weight of the sample taken by these samplers in a specific time interval represents the bed load discharge over the width of the sampler.

Direct observation of river cross section profile can also be made by establishing bench marks on either side of the river. The location of such bench marks (or sediment monitoring posts) should be selected according to the river size, sediment load and nature of the river. Coordinates of the bench mark established on either side of the river should be recorded and transferred to national gridding system precisely while doing the cross section survey. The change in cross section profile of the river can be monitored before and after monsoon and accordingly sediment volume can be estimated.

Box 7: Summery Monitoring of Bed Load

S. N.	Method	Description	Field work				Office work		
			what to measure	where	when	How	what	How	When
1	Sediment Monitoring Post	Establishment of permanent concrete posts as benchmarks	Cross section of the river	along the line joining the two posts	Before & after monsoon and after large flood	cross section survey	cross sections	Compare cross section	After every survey
2	Sediment bucket	Establishment of a concrete bucket in the middle of a river section	Particle size distribution and material composition	at selected monitoring station	after each major flood	Empty the bucket after every major flood	Particle size distribution	sieve analysis	After every major flood
3	Bed load sampler such as Haley Smith	Analysis of the instantaneous concentration	Bed load concentration	near a monitoring station	During high flood	sampling standard bed load sampler	Concentration of bed load	sediment load in the standard volume sampler	During high flood

8.2 Samplers

Estimates of bed load sediment (gravel, sand, hard clay) may be obtained from samples captured in a device which is lowered to the stream bed for a measured time then brought up for weighing the catch. Many such devices have been used, and the variety demonstrates the difficulty of taking an accurate and representative sample. The limitations with bed-load samplers are:

- The sampler disturbs the river/ stream flow hydraulics and changes the hydraulic conditions at the entry into the sampler.
- The sampler is to rest on the stream bed and tends to dig in as scour occurs round it.
- To remain stable on the bed, it has to be heavy, and this restricts the use to lowering from bridges or purpose-built gantries.
- A sampler needs to rest on a reasonably smooth bed and not perch on large stones or boulders.

The simplest form is a wire basket with a stabilizing tail fin as illustrated in Figure 11. The catch of such devices is low because they interfere with the flow and some material is deflected round the sampler, increasingly as the basket fills up. This is described by saying that back pressure reduces the flow into the sampler, and this description conveys the right image without going into the mechanics of fluid flow.

8.2.1 Sediment Traps

Sediment Traps are generally made of mesh material with an opening on the upstream end, through which the water-sediment mixture passes. The mesh should pass the suspended material, but retain the sediment moving along the bed. These are the devices that collect particles as they pass over, deposit on, or infiltrate through the sample media. Different types of sediment traps are available as shown:

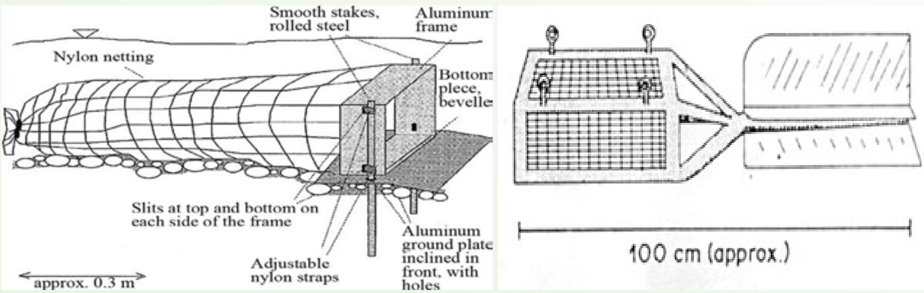


Figure 11: View of different gravel traps/infiltration bags (left) developed by Bunte and Potyondy

8.2.2 Helley-Smith Bed Load Sampler

The sampler enables collection of particle sizes less than 76 mm at mean velocities to 2.9 m/sec. The sampler has a 7.5 cm x 7.5 cm square entrance nozzle, an area ratio (ratio of nozzle exit to entrance area) of 3.22, and a 1840 sq.cm polyester mesh sample bag that is 45 cm long with mesh openings of varying sizes (0.25 mm most commonly used), attached to the rear of the nozzle assembly with a rubber "0" ring. Two different models are available i) heavy weight and ii) light weight. A heavier sampler requires the use of a cable-reel suspension system whereas the lighter version is incorporating a wading rod assembly. A scaled-up version of the sampler having a 15 cm x 15 cm square entrance has been used to sample streams with large particle sizes. Tests of a Helley-Smith type sampler, which has a 7.5 cm x 7.5 cm nozzle with less expansion than the standard nozzle (an area ratio of 1.40), resulted in fairly constant efficiencies close to 100 percent for all transport rates and particle sizes.

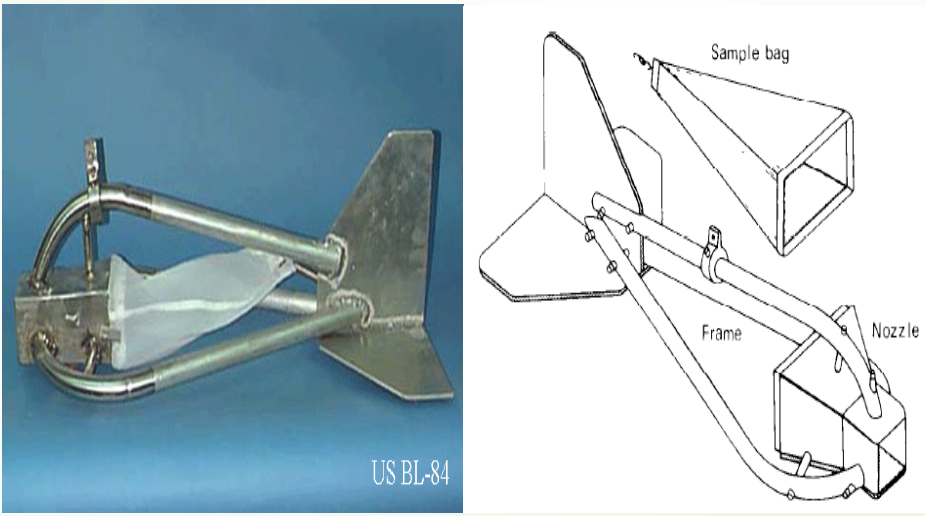


Figure 12: Helley-Smith bed load sampler

8.3 Empirical Method

There is always difficulty in obtaining reliable measurements of bed load and has led to some attempts to calculate it from more easily measured parameters but these are not widely used. A very simple method based on knowing the suspended sediment concentration and the texture of both suspended and bed materials is given in Box 8 below. A sophisticated

approach was developed by Einstein (1950) and has been later modified, simplified and improved. There are many other theoretical formulas, and much debate on their accuracy and reliability.

Box 8: Empirical relation between suspended and bed load materials (Source: FAO, corporate document repository)			
Suspended sediment concentration (PPM)	**River bed material**	**Suspended elements texture**	**Bed load discharge expressed as % of suspended discharge**
Less than 1000	Sand	Similar to the river bed	25 to 150
Less than 1000	Gravel, rocks hard clay	Low sand content	5 to 12
1000-7500	Sand	Similar to the river bed	10 to 35
1000-7500	Gravel, rocks, hard clay	25% sand or less	5 to 12
More than 7500	Sand	Similar to the river bed	5 to 15
More than 7500	Gravel, rocks, hard clay	25% sand or less	2 to 8

8.4 Recommendations

Bed load sediment monitoring/ sampling is a complex and difficult task and is more complex in the Churia originating rivers. The monitoring and assessment of sediment however depends on the objectives of the study but it is highly controlled by the available resources, time and tools. Considering the nature of the Churia originating rivers, the simplest method that could give reasonable results for which bucket method is recommended. During the monsoon season, Churia River swells and brings significant amount of bed load because of which the small size bed load sediment samplers may not be suitable however the large size Helley-Smith sampler might also be a good choice. The sediment monitoring post although it is still being tested, seems to be a good to practice.

The Protocols is the first initiation to standardize the procedures of sediment sampling, quantification and database management for flashy river systems in Nepal. It is also important to note here that like in other fields, advancement on methodology and technology for sediment monitoring system may also be a usual process, which may demand regular updates of the current document. Therefore, the Protocols is expected to be improved based on the feedbacks, reviews by users and researchers including advancement in the use of tools, techniques and methodologies in the days to come.

Community Based Flood and Glacial Lake Outburst Risk Reduction Project (CFGORRP) is a joint undertaking of the Government of Nepal (GoN), Global Environment Facility (GEF) and the United Nations Development Programme (UNDP). The project is being implemented by the Department of Hydrology and Meteorology (DHM) under the Ministry of Science, Technology and Environment (MoSTE) as the lead Implementing Agency. Department of Water Induced Disaster Prevention (DWIDP), Department of Soil Conservation and Watershed Management (DSCWM) and Department of National Park and Wildlife Conservation (DNPWC) are the three collaborating partners of the project.

The CFGORRP has two outcomes: The First Outcome / Component I focuses on the Imja Glacial Lake Outburst Flood (GLOF) risk reduction in Solukhumbu (covering Chaurikharka, Namche and Khumjung VDCs) and the Second Outcome / Component II is aimed at reducing the flood risk in Terai and Churia covering 8 Village Development Committees (VDCs) namely Sarpallo and Nainhi in Ratu (in Mahottari district), Tulsipur and PipraPra Pi in Gagan (in Siraha district), Dighawa and Pakari in Khando (in Saptari district) and Hadiya and Jogidaha in Triyuga Watersheds (in Udayapur district).

Government of Nepal
Ministry of Science, Technology and Environment
Department of Hydrology and Meteorology
Community Based Flood and Glacial Lake
Outburst Risk Reduction Project (CFGORRP/DHM)
Nagpokhari, Naxal, Kathmandu Nepal
Tel: 977-1-4436895 / 4436896
Email: info.cfgorrp@dhm.gov.np
URL: www.cfgorrp.dhm.gov.np