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Practical Insights during Hydrological and sedimentological field works in Hydropower Projects

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Abstract

Assessment of accurate hydrological and sedimentological data is very important for the technical and economic assessment of any water resource projects. Hydropower is not separate from this need. This article presents the experience gathered and lesson learned in field during hydrological and sedimentological investigations carried out from Project Development Department (PDD) of Nepal Electricity Authority (NEA) across seven hydropower projects in Nepal. The installed capacity of these seven hydropower ranges from small 0.6 MW to large 683 MW. The activates included river discharge measurements, installation and operation of manual staff gauges as well as Automatic Water Level Recorders (AWLRs), installation and operation of V-notch weirs, and suspended sediment sampling using USGS D-74 and handheld samplers. Site-specific challenges including boulder dominated rivers, diurnal flow fluctuations in snow-fed rivers, lake seepage quantification, and accessibility are documented along with adaptive remedial measures. Findings of this article highlight the necessity of continuous data recording through automated instruments, careful site selection, and periodic update of rating curve. This paper recommends adoption of site appropriate technologies, adherence to national and international guidelines to improve data quality.

Keywords: *hydropower; hydrological field work; sediment sampling; discharge measurement; AWLR; staff gauges; rating curve*

1. Introduction

Most of the world civilizations are developed in the river basins. Our civilization is not far from this reality. River has been part of our life since the beginning. However, we do not have too big rivers in Nepal, though Nepalese culture is closely related with water and rivers [4]. Like any Water Resource Projects, Hydropower by name itself shows the importance of water. Hydropower converts the potential and kinetic energy of water at sufficient head into the electrical energy. The electrical energy produced from the hydropower directly depends on the availability of water in the rivers and streams. Hydrological and sedimentological study forms the technical as well as financial backbone of any hydropower project. This determines both feasibility and financial viability for the project.

The Project Development Department (PDD) under the Engineering Services Directorate (ESD) of Nepal Electricity Authority (NEA) is mandated to conduct various studies like geological, hydrological, topographical etc. at multiple stages of hydropower project development [9]. These stages vary from the initial identification and screening stage to detailed feasibility and detailed design stage of study.

Depending upon the stage of study and the need for a specific project, the level of hydrological study varies from empirical and regional equation-based study to more detailed field-based study. Generally, for ungauged catchments during the initial stage of study like identification and screening stage, regional and empirical formulas developed by the Water and Energy Commission Secretariat (WECS), Department of Hydrology and Meteorology (DHM), as well as the Catchment Area Ratio (CAR) method, are used to estimate river discharge and sediment quantity. However, as the stage of hydropower study advances towards feasibility and detailed design, the study will focus more on primary field data. In such case field data are acquired over a long period of time using various standard equipment and methodology.

In context of Nepal, The Department of Hydrology and Meteorology (DHM), under Ministry of Energy, Water Resources and Irrigation, is the national authority responsible for monitoring, processing, publishing, and disseminating hydrological and meteorological data countrywide. They acquire primary hydrological and sedimentological through their 112 hydrological stations, 579 Meteorological stations etc. [5]. Most of the hydropower project whether carried out by private sector or the government sector relay on these data for the preliminary study. However, with the advancement of study the project establishes their own stations to acquire the data.

In case of Hydropower projects, recently The Department of Electricity Development (DOED) of Nepal has published the “Guidelines for Study of Hydropower Projects” in 2018. This guideline has prescribed the scope of hydrological and sedimentation studies based on installed capacity, head, and scheme type. These guidelines have made provisions like establishment of gauging stations, discharge measurements and their intervals, river cross-section surveys, sediment sampling and their intervals, and laboratory analysis at various stages of study.

Nepal’s possess diverse climate and topography ranging from high altitude glaciated catchments to mid hill boulder bed rivers. Due to this reason, despite the existence of guidelines, hydrological and sedimentological study frequently require adaptive and innovative approaches that go beyond standard procedures.

This article presents the experience gathered and lesson learned in field during hydrological and sedimentological investigations carried out for seven hydropower projects investigated by PDD of NEA. These studies were carried out between 2023 and 2026 A.D. This paper aims in contributing actionable knowledge to practitioners engaged in hydropower hydrology and sedimentology study in Nepal and similar Himalayan contexts.

2. Study Area and Projects

The seven projects included in this paper are distributed across diverse physiographic zones of Nepal, from the high Himalayan region to mid hill areas (Table 1; Table 2). Source rivers of these seven projects include trans-boundary rivers (Sunkoshi, Tila), lesser Himalayan tributaries (Jhiku Khola), glacier and snow fed streams (Solu Khola), and lake system (Syarpu Lake). The installed capacity under the study ranges from 0.6 MW (Salleri Chialsa Small HEP) to 683 MW (Sunkoshi-3 Storage HEP).

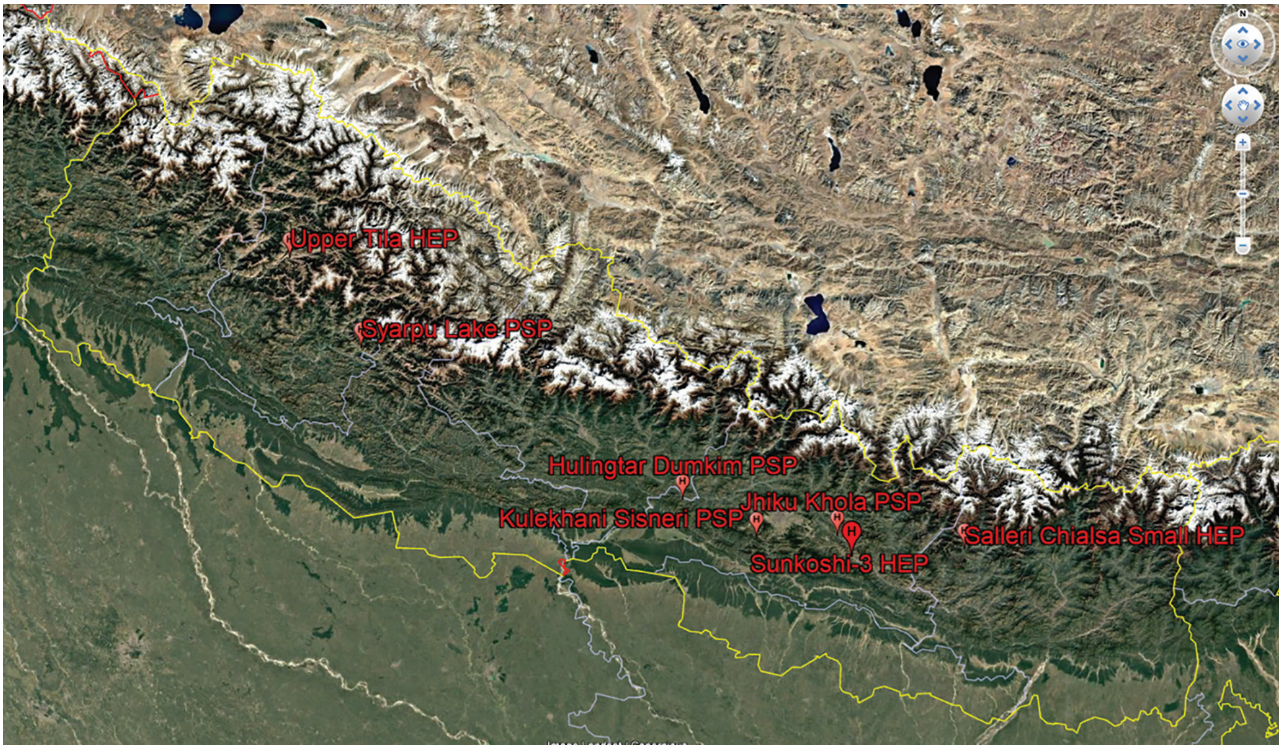

Figure 1: Location Map of Seven Hydropower Projects across the Country.

3. Methodology

3.1 Hydrological Field Investigations

The hydrological monitoring of flow data is important for flood prevention and modern river management [3]. Under the Hydrological field Investigations, majority of the work was Discharge Measurement. Generally discharge measurements were conducted using the mid-section method with current meters. When flow velocities and the velocity coefficient are known, the area of the river cross section is needed to calculate the discharge with the velocity–area method [7]. Guidelines on discharge measurement such as ISO 748:2021[8]; Measurement of liquid flow in open channels, WMO Guide to Hydrological Practices were followed as far as possible. Manual staff gauges were installed at accessible, stable river cross-sections. The gauge readings were recorded twice daily (morning and evening) by locally engaged gauge readers. Where continuous and more reliable stage data were required, Automatic Water Level Recorders (AWLRs) were installed. In most of the installed AWLRs the data was logged at 10-minute intervals. Though for long term flow measurement daily data is enough, however these short interval data helps additionally for flood prediction and early warning system.

In case of very low flows (< 0.05 m^3/s), a sharp-crested V-notch weir was constructed across the stream. A staff gauge attached at a stilling pool upstream of the notch provided the necessary head data for discharge measurement.

Rating curves (stage vs discharge relationships) were developed from paired measurements of gauge height and discharge. These data were fitted using power-law regression in accordance with standard practice. The curves were periodically updated to account for change in channel geometry, rise and fall of river bed and so on.

The hydrological field works conducted for these rivers along with the corresponding date is summarized in the following table.

Table 1: Summary of hydrological field works conducted for various projects under PDD/NEA (2023–2026).

S.No.	Project Name	Field Works	Date	Source River/ Lake
1	Sunkoshi-3 Storage Hydropower Project (683 MW)	Discharge Measurement Installation of Manual Gauge Installation of AWLR	Feb 2023, Apr 2024, Aug 2024, Dec 2024, Feb 2025, Jun 2025, Oct 2025, Dec 2025, Feb 2026	Sunkoshi River
2	Upper Tila Hydroelectric Project (72 MW)	Discharge Measurement Installation of Manual Gauge Installation of AWLR	Mar 2023, Apr 2024, Sep 2024	Tila River
3	Kulekhani Sisneri Pump Storage Hydroelectric Project (100 MW)	Discharge Measurement Installation of Manual Gauge Installation of V-Notch Weir	Mar 2026, Apr 2026	Kulekhani River
4	Syarpu Lake Pump Storage Hydropower Project (334 MW)	Discharge Measurement Installation of Manual Gauge Installation of AWLR	Sep 2023, Apr 2026	Syarpu Lake / Thar Khola
5	Salleri Chialsa Small Hydropower Project (0.6 MW)	Discharge Measurement Installation of Manual Gauge	Aug 2025, Apr 2026	Solu Khola
6	Hulingtar Dumkim Pumped Storage HEP (494.50 MW)	Discharge Measurement Installation of Manual Gauge Installation of AWLR	Apr 2026, May 2026	Rigdi Khola / Mauwa Khola
7	Jhiku Khola Pumped Storage Project	Discharge Measurement	Sep 2023	Jhiku Khola

3.2 Sedimentological Field Investigations

Monitoring and Investigation of sediment data is very important to hydropower, especially for high head Run of the River Projects. The application of sediment monitoring shows the high potential for value added of such a monitoring system to support maintenance planning. The system proved useful in terms of suggesting optimized time windows for inspections and maintenance, while possibly reducing non-planned maintenance costs and unavailability [2]. Increased erosion following land use or climate change and rapid downstream transport of eroded sediment is thus the biggest threat for the sustainability of reservoirs [1].

Apart from the hydrological field works sedimentological field investigations was also carried out for these projects. Under these field investigation, suspended sediment sampling in major rivers (Sunkoshi, Tila) were carried out using the USGS D-74 sediment sampler. A depth integrating method was used for collection of sediment sample, where the sediment sampler was lowered from a stable platform like bridge structures in most of the cases.

For smaller streams (Thar Khola, Solu Khola, Rigdi Khola, Mauwa Khola), a handheld sampler was used. In this case a point integration method was used. As far as possible samples were collected daily during the monsoon season (June–September) and at reduced frequency during the dry season (October–May), following DOED 2018 guidelines [6]. Sediment concentrations were determined in the laboratory of Nepal Electricity Authority and other private companies. As per the need of the project different analysis like sediment concentration test, particle size distribution, mineral content, organic matter content etc were carried out.

Table 2: Summary of sedimentological field works conducted for various projects under PDD/NEA (2023–2026).

S.No.	Project Name	Field Works	Date	Source River/Lake
1	Sunkoshi-3 Storage Hydropower Project (683 MW)	Sediment Sampling	Feb 2025, Oct 2025, Dec 2025, Feb 2026	Sunkoshi River
2	Upper Tila Hydroelectric Project (72 MW)	Sediment Sampling	Apr 2024, Sep 2024	Tila River
3	Syarpu Lake Pump Storage Hydropower Project (334 MW)	Sediment Sampling	Sep 2023	Syarpu Lake / Thar Khola
4	Salleri Chialsa Small Hydropower Project (0.6 MW)	Sediment Sampling	Aug 2025, Apr 2026	Solu Khola
5	Hulingtar Dumkim Pumped Storage HEP (494.50 MW)	Sediment Sampling	May 2026	Rigdi Khola / Mauwa Khola

4. Results and Lessons Learned

4.1 Hydrological Field Work: Findings and Challenges

4.1.1 Sunkoshi-3 Storage Hydropower Project (683 MW): Sunkoshi River

Discharge measurements in the Sunkoshi River has been conducted continuously since February 2023. The largest instantaneous discharge recorded during this time period was 1,225 m^3/s. The discharge was recorded in the month of September 2024 AD. The maximum cross-sectional velocity recorded for this time was 4.77 m/s.

During the initial monitoring phase, a one-meter manual staff gauge was installed on the river bank. The gauge reading was taken manually using locally hired staffs. These data were recorded two times a day. However, during these works several reliability issues were experienced like (i) local staff occasionally interpolated or estimated readings rather than direct observation; (ii) wave action on the riverbank introduced subjectivity in stage reading; and (iii) high-flow conditions forced gauge readers to observe staff gauges from the opposite bank, increasing the risk of misreading.

Apart from this though an extension plan was prepared to increase the gauge height before monsoon, a critical failure occurred when an unseasonal early flood completely submerged the one-meter gauge. This resulted a gap in the stage record. As a remedial measure to this problem, an AWLR was installed on a motorable bridge, positioned well above the High Flood Level (HFL). The instrument now provides uninterrupted and continuous stage data at an interval of 10 minute throughout the year.

An additional gap identified during these works is the absence of in-country current meter calibration facilities in Nepal. Calibration of current meter at defined intervals is essential for maintaining measurement accuracy. Establishment of such a facility would significantly improve the quality of hydrology data not only for Nepal Electricity Authority but also to all concerned agencies throughout the country.

4.1.2 Upper Tila Hydroelectric Project (72 MW): Tila River

Discharge measurements in the Tila River have been carried out from a wooden bridge located in the project area. This bridge is located just downstream of the confluence of two tributaries. This makes the site ideal for the discharge measurement as it capture the flow from both the stream for the project. However, one of the demerits of this location is that the section is very narrow and is characterized by large boulders. These boulders concentrate the flow between them.

This arrangement of boulders configuration introduces errors in discharge measurement through mid-section method as the method assumes the uniformity of section between measurement verticals of measurement. Additionally, concentrated high velocity flow increase the risk of damage to the current meter. Furthermore, these high velocities of flow frequently cause bedload movement and hence result in the instability of the stage–discharge relationship. To address these issues, a wider and more hydraulically stable reach should be selected for discharge measurement. Where bed instability is unavoidable, the rating curve must be verified and updated more frequently through concurrent stage and discharge measurements, especially after major flood events.

4.1.3 Kulekhani Sisneri Pump Storage Hydroelectric Project (100 MW): Kulekhani River

Kulekhani River in its lower stretch located downstream of Kulekhani-I Storage Hydroelectric Project carries only a residual (environmental) flow, as the majority of discharge is stored in the reservoir itself. Measurement of river discharge at this stretch is not that important from technical point of view like other Hydropower Project. This is because Kulekhani Sisneri Pump Storage Hydroelectric Project is a pump storage type of hydropower project which reuses a constant volume of water between the two reservoirs. However, in case of this project accurate measurement of this minimum flow is essential for environmental flow compliance assessments.

Initially a standard discharge measurement through mid-section method was performed using a cup type current meter. However, this method proved to be inadequate for discharge measurement. The shallow and narrow stream with minimum stream flow did not allow for sufficient submergence of instrument. As a result, the cup of the current meter could not rotate stably. Furthermore, discharge could be taken at the mid-section only and hence use of a single vertical measurement overestimated the river discharge.

As a remedial measure, a sharp-crested V-notch weir was installed in April 2026 A.D. The notch was sealed with red clay to prevent seepage losses, and the approach velocity (approximately 0.5 m/s, corresponding to a velocity head of 0.013 m) was judged acceptable for accurate head-based discharge calculation. This configuration provides reliable low-flow data for environmental flow analysis.

4.1.4 Syarpu Lake Pump Storage Hydropower Project (334 MW): Syarpu Lake / Thar Khola

For this natural lake-based pump storage scheme, manual gauges were established at both the lake inlet as well as outlet. Apart from this an AWLR was installed at the bank of the lake in order to monitor the change in lake water level. During the measurement of discharge for considerable time period, a consistent discrepancy was observed, with inlet discharge exceeding outlet discharge. This indicated that the lake has considerable amount of seepage losses. Quantification of this seepage water is critical for water balance of the lake.

An AWLR was installed at the lake shore to continuously monitor lake water level fluctuations, enabling volumetric seepage estimation through water balance analysis. Additional measurements of evaporative losses from the lake surface are recommended for a more comprehensive water balance.

4.1.5 Salleri Chialsa Small Hydropower Project (0.6 MW): Solu Khola

The Solu Khola is a snow and glacier fed river. This river is characterized by marked diurnal discharge fluctuations driven by daytime snowmelt. In this river measurement of discharge is was challenging. These challenges include steep river gradient, vertical rock walls on both banks, low water temperature, and the absence of permanent river-crossing infrastructure near the project site.

During low flow periods, discharge measurements were conducted by placing a portable ladder across the channel as a temporary crossing. This approach is impracticable during the monsoon season due to high flow velocities and depths. Alternatively, non-contact methods such as surface velocity radar (SVR) or index-velocity techniques should be explored for year-round discharge monitoring in such environments. Furthermore, due to distinct diurnal fluctuation in river discharge, river stage data should be recorded accurately for both the periods of a day.

4.1.6 Hulingtar Dumkim Pumped Storage HEP (494.50 MW): Rigdi and Mauwa Khola

Rigdi Khola and Mauwa Khola are small hilly rivers originating in mid-mountain terrain. Low flows in both these streams presented the same current-meter submergence difficulties noted for the Kulekhani River. Additionally, poor mobile network coverage around the dam location required the AWLR to be installed at an alternative location. This created a potential for under/over estimation of discharge for the project. Installation of manual gauge for this project was carried out during low flow season. However, due to local topographic condition a stable and firm river bank (at high elevation) with rock outcrop near the AWLR location could not be found. This made selection of an appropriate gauge installation site difficult. The gauge was ultimately installed on a sloping rock outcrop at a lower elevation. There is some sort of risk for washout of the gauge during major flood events.

4.2 Sedimentological Field Work: Findings and Challenges

Apart from the hydrological field work, sedimentological field work provided more challenges during our study. In case of larger rivers like Sunkoshi and Tila rivers suspended sediment sampling was carried out with the help USGS D-74 sampler. This sampler usually weights approximately 30 kg. This heavier weight required locally fabricated iron frames with sounding reels for safe deployment from bridge structures. This improvisation, though effective, highlights the need for dedicated field equipment suited to high energy Himalayan rivers of Nepal.

For remote projects like Upper Tila Hydroelectric Project, Syarpu Lake Pump Storae Hydropower Project, Salleri Chialsa Small Hydropower Project possess difficulty in transportation of sediment samples. These difficulties include handling risks, logistical delays etc. These potentially affect sample integrity causing the consistency of the result for the sample. Furthermore, some analysis like organic matter content needs laboratory test to be carried out in short duration of time. Location of these projects far away from the country's capital possess the risk of delay in transportation of sample to laboratory in Kathmandu. This will ultimately affect the result of the test. As a remedy establishing regional or mobile sediment analysis facilities, or adopting in-situ test facilities with periodic calibration improves the data quality.

The DOED 2018 guidelines [3] require daily sediment sampling during the monsoon season. In practice, maintaining this frequency demands permanent on-site presence of trained personnel and a complete sampling/preservation kit at each site. This is resource intensive. Apart from these constraints, careful attention should be made for not disturbing bedload during suspended sediment sampling. This is very essential, as any disturbance during sampling process artificially overestimate the measured concentrations.

Measurement of bed load on field for a river is very challenging. These require specialized equipment. They are both labor as well as capital intensive and require trained professional for their use. At current time period, the bed load is taken as a certain percentage of the suspended sediment which might not be representative for Himalayan rivers of Nepal. Training program must be conducted for the measurement of bed load of these rivers. Furthermore, more research is need for calculation of bed load in Himalayan rivers of Nepal.

Generally, during our study we correlated the sediment data with river discharge to generate sediment rating curve. Based on this sediment rating curve, we calculate sediment for a particular day and its corresponding discharge (measured through discharge rating curve). Due to this approach, there is possibility of error in sediment data.

6. Discussion

The field experiences documented here reinforce several principles that are well established in literature but are frequently underappreciated in practice use. First, the shift from manual to automated water level recording is essential for ensuring data continuity and eliminating observer induced errors. This is particularly true in rivers located in remote areas and having high gradient settings. The deployment of AWLRs above the High Flood Level at the Sunkoshi-3 Storage Hydropower Project site exemplifies this principle.

Second, the selection of an appropriate measurement cross-section, one that is hydraulically stable, free of large boulders/obstructions, and accessible under all flow conditions is a prerequisite for reliable discharge data. The boulder dominated Tila River section illustrates the consequences of a suboptimal site selection.

Third, the adaptation of measurement instrumentation to site specific low flow conditions (V-notch weirs for Kulekhani; ladder-based access for Solu Khola) demonstrates the need for flexibility in field methodology. Future investigations should consider the potential of non-contact technologies such as surface velocity radar and acoustic Doppler current profilers, which are less sensitive to low-flow or high hazard conditions.

Finally, the capacity gap in current meter calibration represents a systemic limitation for hydrometric data quality in Nepal. Investment in national calibration infrastructure would improve the accuracy and comparability of discharge measurements across the country's hydropower sector.

7. Conclusions

This study presents field-based evidence from seven hydropower projects studies from Project Development Department across Nepal, documenting practical challenges and adaptive solutions in hydrological and sedimentological data collection. Following conclusions are drawn from the experience collected during hydrological and sedimentological studies:

(1) Automated Water Level Recorders (AWLRs) installed above the High Flood Level significantly improve stage data continuity and quality compared to manual gauge readings in remote, high-

energy rivers of Nepal.

(2) V-notch weirs provide an effective and accurate solution for measuring very low flows (including environmental flows) in narrow, shallow streams where conventional current meters cannot be used.

(3) Rating curves in morphologically dynamic and boulder bed rivers must be updated frequently and particularly following flood events.

(4) Lake water balance studies require simultaneous quantification of all water budget components, including seepage and evaporation.

(5) Establishment of a national current meter calibration facility in Nepal is recommended to improve measurement accuracy across the hydrology sector.

(6) Adherence to national guidelines (DOED, 2018) and international standards (ISO, WMO), combined with site-specific methodological adaptation, is essential for obtaining reliable primary data in Nepal's diverse hydrology context.

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