**BUTWAL POWER COMPANY LIMITED**

Buddhadanagar-10, Kathmandu

**JHIMRUK HYDROELECTRIC AND RURAL ELECTIRFICATION PROJECT (12 MW)**

**Hydrological Study report**

**February 2023**

**Prepared by:**

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**Hydrological STUDY REPORT**

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**February 2023**

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# LIST OF ACRONYMS

AMSL above Mean Sea Level

ASCE American Society of Civil Engineers

AR Access Road

B/C Benefit/Cost

BL Base Line

BM Bench Mark

BoQ Bill of Quantities

CBR California Bearing Ratio

DBM Design Base Memorandum

DC Direct Current

DCPT Dynamic Core Penetration Test

DDR Detailed Design Report

DEM Digital Elevation Model

DHM Department of Hydrology and Meteorology

DoED Department of Electricity Development

D/S Downstream

EDR Eastern Development Region

EIA Environmental Impact Assessment

EIRR Economic Internal Rate of Return

EPC Engineering, Procurement, Construction

ERMC Environment and Resource Management Consultant

ERT Electric Resistivity Tomography

FAT Factory Acceptance Tests

FDC Flow Duration Curve

FIDIC International Federation of Consulting Engineers

FSR Feasibility Study Report

GLOF Glacial Lake Outburst Floods

GoN Government of Nepal

GPS Global Positioning System

GWh Gigawatt Hour

HCE Hydro-Consult Engineering

HEC-RAS Hydrologic Engineering Centres River Analysis System

HP Hydropower Project

HFT Himalayan Frontal Thrust

HRT Head Race Tunnel

H/W Headworks

ICIMOD International Center for Integrated Mountain Development

lEC International Electrotechnical Commission

lEE Initial Environment Examination

IEO International Electro Technical Commission

INPS Integrated Nepal Power System

IPP Independent Power Producers

IRR Internal Rate of Return

ITP Inspection and Test Plan

KV Kilo Volt

MASL Meters Above Sea Level

MBT Main Boundary Thrust

MCT Main Central Thrust

MDE Maximum Design Earthquake

MHPP Ministry of Housing and Physical Planning

MKHPP Myagdi Khola Hydropower Project

MW Mega Watt

NBM New Bench Mark

NEA Nepal Electricity Authority

NPV Net Present Value

O&M Operations and Maintenance

OBE Operating Basis Earthquake

ODWFS Oil Directed Air Forced

OFWF Oil Forced Water Forced

ONAF Oil Natural Air Forced

ONAN Oil Natural Air Natural

PGA Peak Ground Acceleration

PH Powerhouse

PPMO Public Procurement Monitoring Office

PRoR Peaking Run of River

RM Rural Municipality

RoR Run of River

SEIA Supplementary Environmental Impact Assessment

SPT Standard Penetration Test

SRTM Shuttle Radar Topography Mission

S/S Substation

STDFS South Tibetan Detachment Fault System

ToR Terms of Reference

UFSR Updated Feasibility Study Report

UNCHS United Nations Commission on Human Settlements

U/S Upstream

V Volt

WECS Water and Energy Commission Secretariat

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# HYDROLOGY

## Introduction

Jhimruk Hydroelectric and rural electirfication Project is under operation since 1994 with an installed capacity of 12 MW. The power plant has 3 horizontal Francis Turbines of capacities 4 MW each. This project was also built under the agies of United Mission to Nepal (UMN). The project is located in Darimchaur, Pyuthan in Lumbini Province. The powerhouse is semi-undergrouind and is located on the bank of Madi River. The Jhimruk Power Plant is also a basin transfer plant wherein water from Jhimruk River is drawn and after generation of the power is discharge into Madi river.

The power generatated by the plant is being transmitted to NEA 132 kV Substation at Lamahi through 41 km long 132 kV transmission line. It aslo supplies power to Local NEA’a consumers in Pyuthan, Rolpa and Arghakhachi Districts in addition to its own consumenrs in these districts. The project was financed by NORAS through UMN and Government of Nepal.

|  |  |
| --- | --- |
| location | Darimchaur, Pyuthan, Lumbini Province, Nepal |
| Type | Run of the River with daily pondage |
| Capacity | 12 MW |
| Head | 205m |
| Annual Energy Generation | 72 GWh |
| Interconnection Point | 132 Kv Substation at Lamahi |
| CoD | 17 August 1994 |

accurate assessment of long-term hydrology is essential to any hydropower project. The longer the hydrological records, more reliable are the estimation of design parameters for the project. In the case of ungauged (i.e., either limited or no stream flow records) river, direct measurements of hydrological parameters are not available, so, it is necessary to look at catchments that have similar catchment characteristics and meteorological records for the estimation of the hydrological data.

The hydrological study of the project area comprises the desk study, field investigation, collection of hydrological and meteorological data from nearby project area, and various literature reviews. Briefly the hydrological study covers the following:

* Collection of Hydrological data from the gauging stations,
* Processing of the data as required,
* To evaluate climate cycle and the impact of climate change based on the collected data,
* Preparation of report

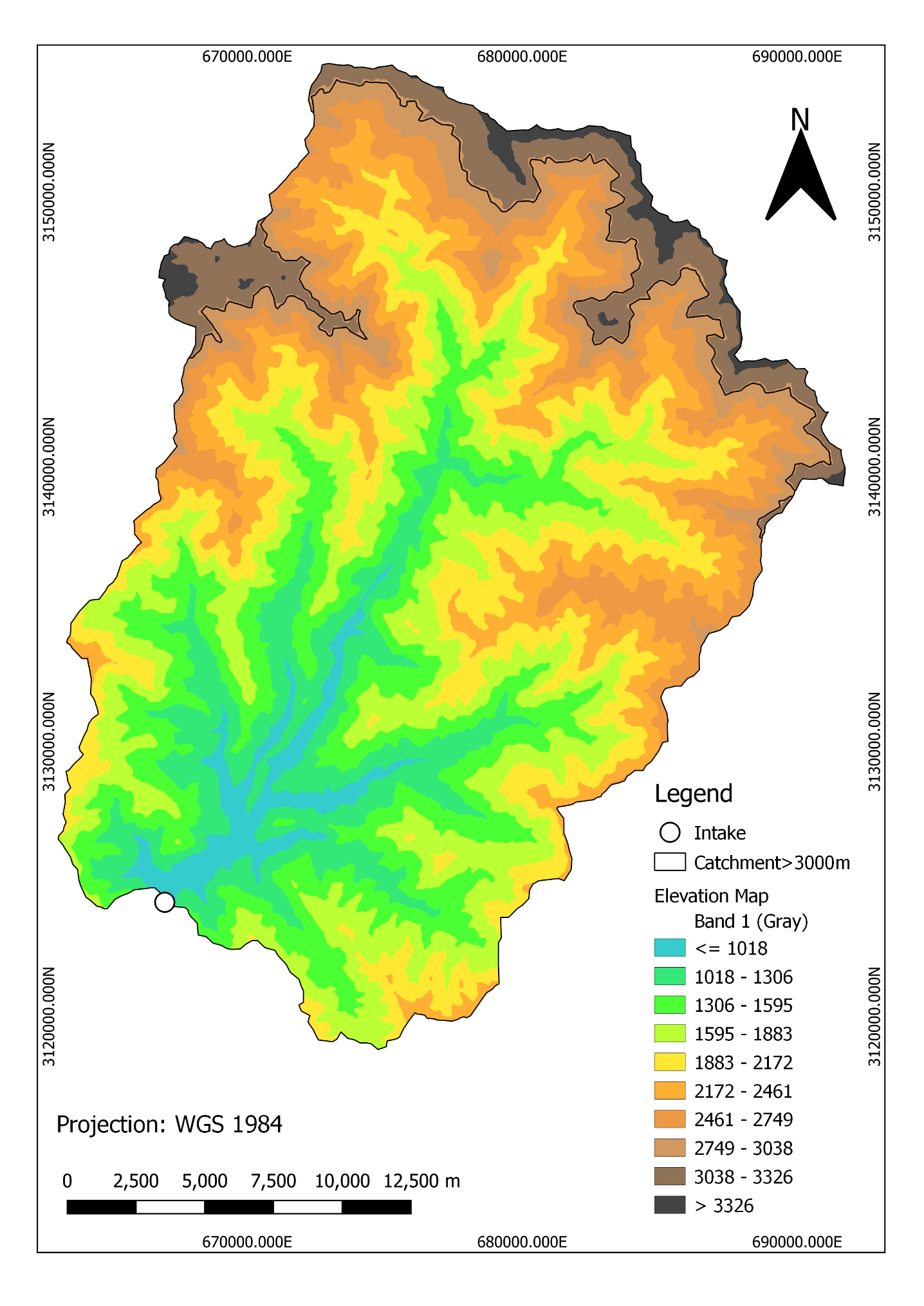
## Catchment Characteristics

In hydrology, catchment properties refer to the physical and geographical features of an area that influence the flow of water in a watershed. These properties include the size, shape, slope, soil type, vegetation cover, and land use. The interaction of these properties affects the amount and distribution of rainfall that becomes runoff and contributes to the overall water balance of the catchment. Understanding catchment properties is important for effective water management, as it helps in predicting the response of a watershed to precipitation events and in designing appropriate water management strategies.

Additionally, catchment properties play a crucial role in determining the rate and duration of runoff, as well as the potential for flooding, erosion and sedimentation. They also impact water quality by affecting the movement and distribution of pollutants in the watershed. By considering catchment properties in hydrological models, engineers and scientists can more accurately predict and manage water resources, ensuring a sustainable water supply for future generations. Thus, a comprehensive understanding of catchment properties is essential for effective water resource management and decision making.

In Jhimruk hydropower the catchment 620.83

|  |  |  |
| --- | --- | --- |
| Elevation | Area (Km2) | % |
| >3000 | 51.55 | 8 |
| <3000 | 569.28 | 92 |
| Total | 620.83 | 100 |



Catchment area of Jhimruk.







## Climate

Climate is a major factor influencing the water cycle and hydrology of a region. The following aspects of climate should be considered when preparing a report on the impact of climate on hydrology:

* Precipitation patterns: The amount, frequency, and distribution of precipitation in a region greatly affect the water balance and runoff.
* Temperature: Temperature influences the rate of evaporation and snowmelt, which can affect runoff and water supply.
* Atmospheric circulation: The distribution of pressure systems and prevailing wind patterns can alter the amount and distribution of precipitation in a region.
* Climate variability and change: Climate variability and change can alter precipitation patterns, temperature, and atmospheric circulation, which can have significant impacts on the hydrology of a region.
* Climate extremes: Climate extremes, such as droughts and floods, can have severe impacts on water resources, including water availability and quality.
* Snowpack and glaciers: Snowpack and glaciers store large amounts of water, which can be an important source of water in many regions. Climate change can alter snowpack and glacier dynamics, which can have impacts on water availability and water resources.
* Land use and land cover changes: Climate change can also impact hydrology through changes in land use and land cover. Deforestation, urbanization, and other forms of land use change can alter the water balance and runoff in a region.

By considering the impacts of climate on hydrology, engineers and scientists can better understand the water cycle and make informed decisions about water resource management. Additionally, understanding the impacts of climate change on hydrology can help to develop strategies for adapting to future changes in the water cycle.

It is important to note that the impacts of climate on hydrology can be complex and interrelated, and can vary greatly between regions. A thorough understanding of the impacts of climate on hydrology is essential for making informed decisions about water resource management, and for developing effective strategies for adapting to a changing climate.

## Available Data

### Hydrological Data

There is a provision of daily data recording station at the intake of the Jhimruk project. The automatic data recorder records at 8 am. No Instantaneous data are found during the data collection procedure. The daily discharge measurement from the gauge is recorded from 1995-2022. This latest data is used to evaluate the mean monthly discharge, mean annual discharge, flood discharge and low flow discharge as discussed below in this report.

### Gauge Installation and data recording

Method of measurement, gauge installation or what? Photograph??

### Meterological Data

Since there is no rain gauge at the intake location, no rainfall data are collected. However, there is rainfall station set up by Department of Hydrometeorology (DHM), whose data can be acquired and used for the rainfall analysis. One rainfall station is within the catchment area; whose influence is relatively high. There is a provision of daily data recording station at the intake of the Jhimruk Hydropower Project. The automatic data recorder records at 8 am everyday. No Instantaneous data are found during the data collection procedure. The daily discharge measurement from the gauge is recorded from 1995-2022. This latest data is used to evaluate the mean monthly discharge, mean annual discharge, flood discharge and low flow discharge as discussed below in this report.

## Basin Rainfall

Basin (or catchment) rainfall refers to the total amount of precipitation that falls within the boundaries of a specific watershed or catchment area. The spatial and temporal distribution of rainfall in a basin plays a crucial role in determining the water balance and runoff of the watershed. Basin rainfall is influenced by a number of factors, including climate, geography, topography, and land use. Accurate measurement and monitoring of basin rainfall is essential for understanding the water balance of a watershed and for effective water resource management. Basin rainfall data is used in hydrological models to predict runoff, inform water resource planning, and design water management strategies. Understanding the patterns and variations of basin rainfall over time is also important for assessing the impacts of climate change on the water cycle and for making informed decisions about water resource management in a changing climate.

In addition, basin rainfall is also used to evaluate the impacts of land use and land cover changes on the water cycle. For example, changes in land use from natural vegetation to urbanization can result in increased runoff, while changes in land cover from forests to agriculture can result in changes in the distribution of precipitation and runoff.

Accurate measurement of basin rainfall is achieved through a network of rain gauges, which measure precipitation at regular intervals. The data collected from these gauges is then used to create rainfall maps and to estimate the total amount of precipitation that falls within the boundaries of a watershed.

Basin rainfall is also an important factor in the design of flood management systems, as the total amount of precipitation, as well as the rate and duration of runoff, can influence the likelihood and severity of flooding. Basin rainfall data is also used to monitor drought conditions, as reduced precipitation can result in decreased water availability and increased water stress in a watershed.

In conclusion, basin rainfall is a critical component of the water cycle and has important implications for water resource management and decision making. A comprehensive understanding of basin rainfall patterns and variations is essential for effective water resource management and for adapting to a changing climate.

## Long Term Mean Monthly Flow

### Direct measured data

Long-term mean monthly flow is a critical component of hydropower project design and management, as it affects the energy production and efficiency of the project. In the context of hydropower projects, long-term mean monthly flow refers to the average flow of water in a river or stream over a period of several decades.

Hydropower projects rely on a consistent flow of water to generate energy, and the long-term mean monthly flow provides crucial information about the availability and reliability of this resource. By understanding the long-term mean monthly flow of a river or stream, hydropower project developers can design and operate the project in a manner that optimizes energy production while also considering the impacts on the river and its associated ecosystems.

In the context of hydropower projects, the long-term mean monthly flow is used to estimate the potential energy generation of the project, and to determine the size and capacity of the project's infrastructure. This information is critical for the planning and design of the project, as it helps to ensure that the project is appropriately sized to meet the energy needs of the region, while also ensuring that the project operates in a sustainable and responsible manner.

The long-term mean monthly flow also helps to inform decisions about the operation of the project, including the scheduling of energy generation, the management of water releases, and the maintenance of the project's infrastructure. By understanding the long-term mean monthly flow, hydropower project managers can optimize the project's operation and efficiency, and ensure that the project is meeting the energy needs of the region while also protecting and preserving the health of the river and its associated ecosystems.

The Mean monthly flow from the collect data over the period of 29 years of data is presented in the

Table 1‑1: Mean Monthly Flow of Jhimruk River

| **Month** | **Discharge (m3/s)** |
| --- | --- |
| Baishakh | 3.69 |
| Jestha | 6.38 |
| Ashadh | 36.22 |
| Shrawan | 75.01 |
| Bhadra | 75.34 |
| Ashwin | 43.92 |
| Kartik | 16.98 |
| Mangsir | 9.07 |
| Poush | 6.66 |
| Magh | 5.72 |
| Falgun | 4.81 |
| Chaitra | 4.00 |

Figure 1‑1: Hydrographical representation of Mean Monthly flow of Jhimruk River

### Comparision with implemented Mean Monthly Flow

Figure 1‑2: Comparision of mean monthly flow

### Riparian Release

Riparian release is a critical component of hydropower project management, as it affects the water quality, aquatic ecology, and overall health of the river and its associated ecosystems. In the context of hydropower projects, riparian release refers to the discharge of water from the project back into the river downstream.

Hydropower projects can have significant impacts on the natural flow regime of rivers and streams, and riparian release is used to mitigate these impacts and maintain the health of the river and its associated ecosystems. Riparian release involves the release of water from the project at specific rates, times, and seasons to mimic the natural flow regime and to maintain the ecological and hydrological balance of the river.

In the context of hydropower projects, riparian release is used to maintain the water quality, temperature, and flow regimes required for the survival and productivity of fish and other aquatic species. This helps to maintain the overall health and diversity of the river and its associated ecosystems, as well as to support the recreational and commercial uses of the river, such as fishing, boating, and wildlife watching.

Riparian release is also critical for the water quality management of the river, as it helps to maintain the natural water chemistry, including pH, dissolved oxygen levels, and nutrient levels, which are important for the health of the river and its associated ecosystems.

By implementing appropriate riparian release strategies, hydropower projects can be designed and operated in a sustainable and responsible manner, providing clean and reliable energy while also protecting and preserving the health of the river and its associated ecosystems.

The long-term mean monthly flow for driest month, Falgun at the intake of is 4.36 m3/s. As per prevailing environment act of Nepal, the downstream release should be 10% of minimum long-term mean monthly flow, i.e., 0.436m3/s will be released downstream as the riparian release for aquatic life.

## Flow Duration Curve (FDC) and Design Discharge

Flow duration curve (FDC) is an important tool in the assessment of the reliability and sustainability of hydropower projects. The FDC graphically represents the relationship between flow volume and frequency, showing the proportion of time that a river or stream experiences various flow rates.

FDC provides important information on the expected flow regime, including the magnitude and frequency of low flow, high flow, and average flow conditions. This information is critical for the design and operation of hydropower projects, as it affects the availability of water for power generation and the environmental impacts of the project.

By using FDC analysis, hydropower project developers and operators can determine the most appropriate design for the project, including the size of the dam, the capacity of the power generation equipment, and the water management practices to be implemented. This information can also be used to assess the project's reliability and sustainability, including its ability to generate power during low flow periods, its capacity to meet energy demands, and its potential to impact the environment.

FDC analysis is also an important tool in water resources management, as it provides valuable information on the flow regime of a river or stream, including the occurrence of low flow, high flow, and average flow conditions. This information can be used to determine the water availability for various uses, including irrigation, drinking water, and industrial water supply, and to assess the potential impact of hydropower projects on the environment.

Overall, the flow duration curve is an essential tool in the analysis of hydropower projects, providing important information on the expected flow regime, water availability, and environmental impacts of these projects. By using FDC analysis, hydropower projects can be designed and operated in a sustainable and resilient manner, providing clean and reliable energy for communities and businesses.

### FDC from the measured data

### Comparision of implemented FDC

## Flood Analysis

Flood flow is the maximum flow of water that occurs in a river, usually caused by heavy rainfall or the rapid melting of snow. Flood flows are typically much higher than the normal or average flow of a river, and can cause significant damage to property and infrastructure along the river banks. Flood flows are often characterized by their magnitude, duration, frequency, and timing. In hydrology, understanding flood flows is important for managing and mitigating the risk of flood damage, designing and building flood protection infrastructure, and ensuring the safe and sustainable use of water resources. To better understand flood flows, hydrologists use various tools and techniques, such as monitoring streamflow data, conducting hydrological modeling, and studying historical flood events. Knowledge of the characteristics of flood flows in a certain river basin is critical for making informed decisions and developing effective flood management strategies.

In addition to monitoring and modeling, hydrologists may also use flood frequency analysis to estimate the probability of a flood of a certain magnitude occurring in a river basin. This information can be used to set flood warning thresholds, design flood protection infrastructure, and plan for emergency response. Furthermore, knowledge of the distribution of flood flows in a river basin can also provide insights into the vulnerability of different communities and ecosystems to flooding, and help guide decision-making in terms of land use planning, urbanization, and other human activities that may impact the flood regime.

It is important to note that climate change and human activities, such as deforestation and land use changes, can impact the magnitude and frequency of flood flows. As a result, ongoing monitoring and analysis of flood flows is critical to ensure that flood management strategies remain effective over time. By better understanding flood flows, we can ensure the safe and sustainable use of water resources, reduce the risk of flood damage, and protect communities and ecosystems from the impacts of flooding.

### Diversion during Construction Flood

Construction flood flow is the maximum flow of water that is calculated for a dry period, typically during the construction phase of a project that is located near a river or stream. This flow rate is an important consideration in the design and construction of projects, as it represents the highest flow rate that can be expected during the driest period of the year. The purpose of calculating the construction flood flow is to ensure that the project is designed and built to withstand the highest possible flow of water, and to prevent damage or failure of the project during a flood event.

Construction flood flow is typically calculated based on historical streamflow data and/or hydrological modeling, taking into account the local climate, land use, and other factors that can impact the flow of water in the river or stream. The calculation of construction flood flow is important for a variety of projects, including bridges, dams, levees, and other infrastructure that are located in or near a river or stream. It is also a critical consideration for projects that have the potential to impact the flow regime of a river or stream, such as large scale land use changes or the construction of new reservoirs.

By taking into account the construction flood flow in the design and construction of projects, we can ensure that these projects are safe, sustainable, and resilient to the impacts of flooding. This helps to reduce the risk of damage or failure, and protects communities and ecosystems from the impacts of flooding.

## Low Flow

Low flow is a term used in hydrology to describe a period of reduced flow in a river or stream, typically characterized by a decrease in the volume and velocity of water. Low flow can occur due to a variety of reasons, including low rainfall, high evaporation, increased water withdrawals for human use, or a combination of these factors. Low flow is an important consideration in water resources management, as it can impact the availability of water for various purposes, including drinking water, irrigation, and hydroelectric power generation.

Low flow can have a significant impact on hydropower projects, as it affects the ability of the project to generate electricity. Hydropower projects rely on a steady flow of water to generate electricity, and low flow can result in reduced electricity generation and revenue. This is particularly relevant for hydropower projects that operate with limited storage capacity and are dependent on streamflow for power generation.

In addition to the financial implications, low flow can also impact the operation of hydropower projects and the environment. For example, low flow can increase the risk of water quality problems, such as increased water temperature and reduced oxygen levels, which can harm aquatic ecosystems and fish populations. Low flow can also result in increased erosion, which can impact the stability of the dam and its ability to function properly.

To minimize the impacts of low flow on hydropower projects, project operators use various management strategies, such as using advanced forecasting tools and water management practices, such as reducing water withdrawals during low flow periods, increasing water releases during high flow periods, and implementing fish passage measures. By managing low flow effectively, hydropower projects can maintain their operational efficiency and minimize their impacts on the environment.

Overall, low flow is an important consideration in the design, operation, and management of hydropower projects, as it affects the financial performance and environmental impacts of these projects. By taking a proactive and strategic approach to low flow management, hydropower projects can be designed and operated in a sustainable and resilient manner, providing clean and reliable energy for communities and businesses.

## Glacier Lake Outburst Flood (GLOF)

## Trend Analysis

### Methodology

The Mann-Kendall test is a statistical test used to determine whether there is a monotonic trend in a time series data set. The test is non-parametric, which means that it does not assume any particular distribution for the data.

The test statistic for the Mann-Kendall test is based on the number of "concordant" and "discordant" pairs in the data set. A concordant pair is a pair of values that are either both increasing or both decreasing, while a discordant pair is a pair of values that are increasing and decreasing. The test statistic is calculated as the difference between the number of concordant pairs and the number of discordant pairs, divided by the total number of pairs.

The null hypothesis for the Mann-Kendall test is that there is no trend in the data, while the alternative hypothesis is that there is a trend. If the test statistic is positive and the p-value is less than a certain threshold (such as 0.05), then the null hypothesis is rejected, and it can be concluded that there is a monotonic trend in the data.

The Mann-Kendall test is often used in climate research to detect trends in temperature and precipitation data, as well as in other fields where time series data is collected such as hydrology, economics, and finance.

It is important to mention that Mann-Kendall test is sensitive to the presence of outliers, so it's important to preprocess the data accordingly.

The Mann-Kendall test is a nonparametric statistical test used to determine if there is a monotonic trend in a time series. The p-value is the probability of obtaining a test statistic as extreme or more extreme than the one calculated from the sample, assuming that the null hypothesis is true. A small p-value (typically less than 0.05) indicates that the trend is statistically significant and that the null hypothesis can be rejected.

The p-value for the Mann-Kendall test can be calculated using the following steps:

* Calculate the test statistic, S. This is the sum of the signed ranks of the differences between each pair of observations in the time series.
* Determine the number of observations in the time series, n.
* Calculate the standard normal deviate, Z. This is given by: Z = (S - (n \* (n - 1) / 4)) / sqrt((n \* (n - 1) \* (2 \* n + 5) / 18))
* Look up the p-value for the Z-score in a standard normal table or calculate it using a software package.
* Interpret the p-value. A small p-value (typically less than 0.05) indicates that the trend is statistically significant, and the null hypothesis can be rejected.

Note that this method assumes that the data is independent and the time series is not serially correlated. Also, different software packages might have different method to calculate the p-value.

## Glacier Lake Outburst Flood (GLOF)

## Conclusions

Based on the above studies on hydrology, followings conclusions can be drawn for the design of hydropower project components.

* The design discharge has been adopted to be 12.50 m3/s.
* 100 years return period flood at the proposed intake of Myagdi river is 497m3/s, at intake of Kunaban river is 170.32 m3/s and tailrace site of the project is 691.70 m3/s respectively.
* The construction flood of 1 in 20 years return period at the proposed headworks sites of the project is 33.13 m3/s and 17.35 m3/s for Myagdi Intake and Kunban Intake.
* Similarly, based on the final report on Glacier Lakes and Glacial Lake Outburst Floods in Nepal prepared by ICIMOD (2011) the project does not have any glacier lake and hence, it is considered out of GLOF risk.

## Recommendations

For reliability of the adopted monthly flow at proposed intake site of the project, it is recommended for further work prior to the detail design as;

* Continuous measurement of the flows at intake site of the Myagdi Khola to obtain long-term time series of the flow data.

Similarly, for improvement of the rating curve developed at weir axis and tailrace of the Myagdi Khola,

* the rating curve has to be developed based on the measured flow data in the future.

Moreover, based on the final report on Glacier Lakes and Glacial Lake Outburst Floods in Nepal prepared by ICIMOD (2011), the project area is out of GLOF risk. However;

* Monitoring of large glaciers in upper part of the catchment has to be recommended in the future for considering the formation of glacier lakes.

# REFERENCES