**BUTWAL POWER COMPANY LIMITED**

Buddhadanagar-10, Kathmandu

**DRAFT**

**Hydrological Study report of**

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

**Pyuthan**

**February 2023**

**Prepared by:**

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JHIMRUK HYDROELECTRIC AND RURAL ELECTRIFICATION PROJECT (12 MW)

**Hydrological STUDY REPORT**

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**February 2023**

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# LIST OF ACRONYMS

AMSL above Mean Sea Level

JHREP Jhimruk Hydroelectric and Rural Electrification Project

DHM Department of Hydrology and Meteorology

D/S Downstream

EIA Environmental Impact Assessment

FDC Flow Duration Curve

GLOF Glacial Lake Outburst Floods

GoN Government of Nepal

GWh Gigawatt Hour

HCE Hydro-Consult Engineering

HRT Head Race Tunnel

H/W Headworks

IPCC Intergovernmental Panel on Climate Change

MW Mega Watt

NORAD The Norwegian Agency for Development Cooperation

NEA Nepal Electricity Authority

PH Powerhouse

PPMO Public Procurement Monitoring Office

RoR Run of River

SRTM Shuttle Radar Topography Mission

S/S Substation

UFSR Updated Feasibility Study Report

UMN United Mission to Nepal

U/S Upstream

WECS Water and Energy Commission Secretariat

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# SALIENT FEATURES

Table 0‑1: Salient features of the project as per the previous study

| **SN** | **Description** | **Value** | **Unit** |
| --- | --- | --- | --- |
| **1** | **General** |  |  |
|  | Type of Power Plant | Run off river with daily pondage |  |
|  | Capacity | 12 MW |  |
|  | Type of Scheme | Run-of-river |  |
|  | Net Head | 205 | m |
|  | Discharge | 7 | m3/s |
|  | Annual Energy Production | 72 | GWh |
| **2** | **Headworks** |  |  |
|  | **River Training:** | Gabion stabilisation of 2km long channel |  |
|  | **Diversion Weir:** |  |  |
|  | Overflow length | 205 | m |
|  | Weir Crest Elevation | 738.00 | masl |
|  | **Sluiceway** |  |  |
|  | Size of sluiceway opening (b x h) | 2 x 5 | m |
|  | No. of sluiceweay gates | 3 | Nos. |
|  |  |  |  |
|  | **Intake** |  |  |
|  | Size of Inlet gates (b x h) | 3.30 x 5.00 | m |
|  | Tunnel Inlet gate | 2.30 x 3.00 | Nos. |
|  | **Desilting Basin** |  |  |
|  | No of basins: | 2 |  |
|  | Dimension of each basin (l x b x h) | 42 x 5 x 5.5 | m |
|  | **Flushing System:** | Intermittent by Serpent Sediment Sluicing System into Spillway |  |
| **3** | **Headrace Tunnel** |  |  |
|  | Shape | D-Shaped |  |
|  | Total length (inlet portal to surge shaft offset point) | 1100 | m |
|  | Gradient | 1: 350 |  |
|  | Section Area | 5.5 | m2 |
|  | Excavated area | 8.5 | m2 |
|  | Stone masonry lining thickness | 350 | mm |
| **4** | **Surge Shaft** |  |  |
|  | Type | Simple surge shaft | |
|  | Finished Diameter | 3.00 | m |
|  | Total height including freeboard and submergence | 25 | m |
| **5** | **Penstock Pipe** |  |  |
|  | Diameter of main penstock pipe | 1.5 | m |
|  | Length (From surge shaft to the first bifurcation) | 1195.45 | m |
|  | Thickness | 6mm to 12mm | mm |
| **6** | **Powerhouse and Control Building** |  |  |
|  | Superstructure | RCC frame with blockwork walls |  |
|  | Roofing | Steel truss |  |
|  | Superstructure Level | 541 | masl |
|  | Crane | 30 T |  |
| **7** | **Tailrace culvert** |  |  |
|  | Tailrace Type | Gabion Lined Open channel | m |
|  | Length | 200 | m |
| **8** | **Turbine** |  |  |
|  | Type | Francis Turbine | |
|  | Number of units | 3 |  |
|  | Speed | 1000 | rpm |
| **9** | **Generator** |  |  |
|  | Number of Units | 3 |  |
|  | Voltage | 6.6 | kV |
| **10** | **Switchgear** |  |  |
|  | Elevation of top of foundation | 541 | masl |
| **11** | **Transmission Line** |  |  |
|  | Length | 41 | km |
|  | Voltage | 132 | kV |
|  | Tower Type | Cable guyed lattice towers |  |

# HYDROLOGY

## Introduction of the Project

Jhimruk Hydroelectric and Rural Electrification 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 generated by the plant is being transmitted to NEA 132 kV Substation at Lamahi through 41 km long 132 kV transmission line. It also supplies power to Local Neal’s consumers in Pyuthan, Rolpa and Arghakhachi Districts in addition to its own consumenrs in these districts. The project was financed by NORAD through UMN and Government of Nepal.



## Hydrological Study

An 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. The hydrological study is comprised the desk study, field investigation, collection of hydrological and meteorological data, and various literature reviews.

However, the scope of this hydrological study is limited to 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

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.

The Jhimruk Khola is one of the major tributaries of the Rapti river which belongs to the Karnali Basin. It originates from Kothibhir. The highest point on the catchment area has an elevation of 3580 m above mean sea level, while lowest point is at 737 m above mean sea level (Figure 1‑1).

The basin has characteristic of mountainous catchment. The total catchment area upstream of the intake site is about 645.86 km2 as calculated in Table 1‑1. The intake site is located at an elevation about 740 m and is approximately 5.5 km South-West from Pyuthan Bazaar.

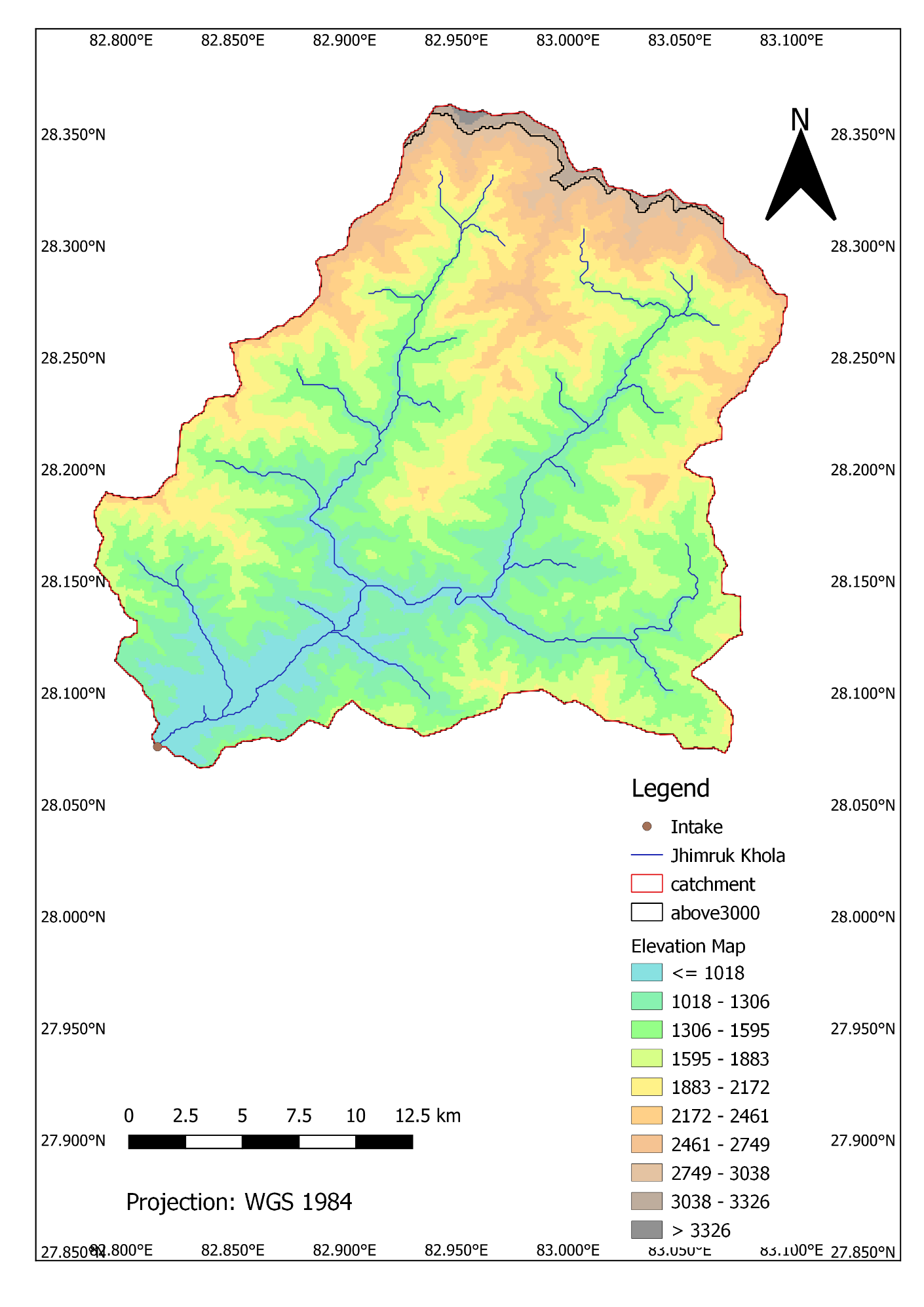


Figure 1‑1: Catchment of Jhimruk Khola at Intake

Table 1‑1: Catchment characteristics of Jhimruk Khola at Intake

| Elevation | Area (Km2) | % |
| --- | --- | --- |
| >3000 | 7.73 | 1.2 |
| <3000 | 638.13 | 98.8 |
| Total | 645.86 | 100 |







## Climate

Climate is a major factor influencing the water cycle and hydrology of a region. Precipitation patterns, temperature, atmospheric circulation, climate extremes, Land use and land cover changes are the aspects of climate that should be considered when preparing a report on the impact of climate on hydrology.

No information about the temperature, humidity, evapotranspiration, wind speed is collected during this study. Moreover, there are no documents available to refer the climatic values in the previous studies.

## 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.

No information about the basin rainfall is collected during this study. There are no documents such as previous study or reports available to refer the value of basin rainfall. The study of climate in this study is beyond the scope.

## Available Data

### Hydrological Data

There is a provision of daily data recording station at the intake of the Jhimruk project. No Instantaneous discharge data are found during the data collection procedure. The daily discharge measurement from the gauge is recorded from 1991-2022. This 29-years data is used to evaluate the mean monthly discharge, mean annual discharge, flood discharge and low flow discharge as discussed below in this report.

## Long Term Mean Monthly Flow

### Daily Series, Monthly Series and Mean Monthly Flow

Daily flow series plots are widely used in hydrology to visualize the changes in water flow in a river or stream over time. Daily flow series plots help to identify patterns in the flow of water, such as seasonal changes, drought periods, and flood events. This information can be used to understand the water cycle and make informed decisions about water management.

Daily series has been carried out using the measrued daily inflow series (2051/52-2079/80) of Jhimruk Khola at the intake and shown in Figure 1‑2.

Figure 1‑2 shows the daily variation of discharge over the period of the time. Considering the temporal range of collected data, there was highest flood flow with discharge 527.97 m3/s in Shrawan 11, 2073. There are spikes in the rainy season where there is excessive rainfall because of monsoon. The graph clearly shows the seasonal variation of the discharge. The peak of the graph represents the rainy season, whereas depression shows the dry season. The graph also shows that there is no significant seasonal discharge variation. For instance, the variation in peak of each year is not significantly noticeable, same is the case of depression in the graph.

Figure 1‑2: Daily discharge series of Jhimruk Khola

Monthly series has been carried out using the measured daily inflow series (2051/52-2079/80) of Jhimruk Khola at the intake and shown in Figure 1‑3.

Figure 1‑3 shows the monthly flow series of Jhimruk Khola measured at the intake. The spikes in the graph is representation of wet season, whereas depression in the plot shows the dry season. The gap in the plot indicates the water being used for irrigation as well as repair work in the headwork of the Project. There was discontinuation of the discharge measurement in that period of time. This plot provides a comprehensive view of the changes in water flow over the course of a year, taking into account seasonal variations. Monthly flow series plots allow to analyze water flow patterns over a longer period of time, such as several decades. This information can be used to detect trends in water flow and make predictions about future water resources. Monthly flow series plots can be used to compare current water flow patterns with historical data. This information can be used to identify changes in water flow patterns over time. The graph shows there is no significant variation in peaks and depression over the period of time.

Figure 1‑3: Mean monthly discharge series of Jhimruk Khola.

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 long-term mean monthly flow has been carried out using the measured daily inflow series (2051/52-2079/80) of Jhimruk Khola at the intake. The mean monthly flow from the collect data over the period of 29 years of data is presented in Table 1‑2.

Table 1‑2: Mean Monthly Flow of Jhimruk River at Intake

| **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 |
| Average | 23.99 |

### Comparison of Mean Monthly Flow with that of during UFSR, 2008

Figure 1‑4 shows the comparison of mean monthly flow of Jhimruk Khola as per the previous study during damage repair of Jhimruk headworks and as per this study.

Figure 1‑4: Comparison of mean monthly flow as per previous study and this study

It is observed that only the months of Shrawan, Mangsir, Poush, Magh, Falgun and Chaitra have higher discharge than the previous study during damage repair of Jhimruk headworks. For the rest of the months, the discharge is lesser than the previous study. It is noted that the measured data shows that dry months have higher discharge except Baishakh whereas the wet months have lesser than previous study except Shrawan.

### Water Sharing in Jhimruk Khola

Further study is needed for the accurate information about water sharing. This study does not collect any information about the water sharing in Jhimruk Khola. This does not mean there is no water sharing in Jhimruk Khola.

### 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.

There is no information about existing riparian release in Jhimruk Khola. Hence, it is not included in this report.

## 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.

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.

Flow duration curve of Jhimruk Khola has been carried out using the data series (2051/52-2079/80) of Jhimruk Khola at the intake. As per the document called ‘A Brief Introduction of Jhimruk Hydroelectric and Rural Electrification Project”, the design discharge is 7 m3/s. However, the information about the percentile exceedance is not known. Now, the discharge of 7 m3/s is 56.25 % flow exceedance as indicated in Figure 1‑5.

Figure 1‑5: Flow duration Curve of Jhimruk Khola

## Flood Analysis

Flood flow is the maximum flow of water that occurs in a river, usually caused by heavy rainfall. 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.

Table 1‑3 summarizes the flood flow with different return period fitting the extreme values of discharge data series in Log Normal distribution, Log Pearson Type III distribution and Gumbel distribution. Among these 3 methods, Log Pearson Type III is widely used to fit extreme value distribution. However, it should be noted that Log Pearson Type III does not fit the data always. So, it is very important to check and try with other distributions as well to find the best fit.

Table 1‑3: Estimation of flood flow

| Method | Flood flow (m3/s) | | | |
| --- | --- | --- | --- | --- |
| 1 in 2-yr | 1 in 10-yr | 1 in 20-yr | 1 in 100-yr |
| Log Normal | 187 | 327 | 384 | 518 |
| Log Pearson Type III | 183 | 348 | 432 | 683 |
| Gumbel | 189 | 350 | 411 | 550 |

No previous studies are found regarding the information about flood flows for the comparison purpose. Now, the flood flows are adopted based on the Log Pearson Type III distribution. The calculated flood flows cab be utilized as per the requirement of the project in the future needs.

## 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.

Low flow analysis has been carried out using the measured daily inflow series (2051/52-2079/80) of Jhimruk Khola at the intake.

Using the daily flow series data, 1-day, 7-day, 15-day and 30-day average flow series has been developed to extract the corresponding duration minimum flows. Then using the minimum flow series data of 18 years, Weibull’s probability distribution functions were fitted to each minimum flow series. This is one of the recommended methods for calculating Low Flow Analysis which is widely used due to its reliability. The result has been presented in Table 1‑5.

Table 1‑5: Estimated Low Flow at the Intake of Jhimruk Khola

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Return period (T-year) | Minimum Daily flows, m3/s | | | |
| 1-day | 7-day | 15-day | 30-day |
| 2 | 1.42 | 1.77 | 2.09 | 2.75 |
| 5 | 0.65 | 0.92 | 1.15 | 1.72 |
| 10 | 0.39 | 0.60 | 0.78 | 1.26 |
| 20 | 0.24 | 0.39 | 0.53 | 0.93 |
| 50 | 0.12 | 0.23 | 0.33 | 0.63 |
| 100 | 0.08 | 0.15 | 0.23 | 0.47 |

According to the aforementioned calculation approach, the calculated low flows at the intake of the project for the 1-day, 7-day, 15-day, and 30-day periods are 1.42 m3/s, 1.77 m3/s, 2.09 m3/s, and 2.75 m3/s, respectively as shown in Table 1‑5.

## 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 0.01), 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 0.01) 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 0.01) 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.

The detail manual calculation is presented in the annex of this report.

Here in this analysis a java based software DScreen is used to analyze the data series. The user manual of Dscreen is provided in the annex of this report.

### Result

Trend analysis has been carried out using the measured daily inflow series (2051/52-2079/80) of Jhimruk Khola at the intake. The mean annual discharge, 5-years moving average and 10-years moving average is calculated and presented in the Table 1‑6. This series is employed for the trend analysis to find if there is significant trend or not in the data series.

Table 1‑6: Mean annual discharge, 5-years moving average, 10-years moving average

| Fiscal Year | Mean annual discharge (m3/s) | 5-years moving average (m3/s) | 10-years moving average (m3/s) | Remarks |
| --- | --- | --- | --- | --- |
| 51/52 | 17.8 |  |  | Irrigation in Shrawan |
| 52/53 | 20.2 |  |  |  |
| 53/54 | 29.3 |  |  |  |
| 54/55 | 30.6 |  |  |  |
| 55/56 | 31.1 | 25.8 |  |  |
| 56/57 | 33.1 | 28.9 |  |  |
| 57/58 | 32.1 | 31.2 |  |  |
| 58/59 | 26.8 | 30.7 |  |  |
| 59/60 | 28.0 | 30.2 |  | Headworks Maintenance |
| 60/61 | 27.2 | 29.4 | 27.6 |  |
| 61/62 | 16.0 | 26.0 | 27.4 | Data of Jestha NA |
| 62/63 | 23.2 | 24.2 | 27.7 |  |
| 63/64 | 15.7 | 22.0 | 26.4 |  |
| 64/65 | 25.3 | 21.5 | 25.8 |  |
| 65/66 | 21.5 | 20.4 | 24.9 |  |
| 66/67 | 21.3 | 21.4 | 23.7 |  |
| 67/68 | 25.1 | 21.8 | 23.0 |  |
| 68/69 | 21.8 | 23.0 | 22.5 |  |
| 69/70 | 25.1 | 23.0 | 22.2 |  |
| 70/71 | 25.3 | 23.7 | 22.0 |  |
| 71/72 | 20.6 | 23.6 | 22.5 |  |
| 72/73 | 21.5 | 22.8 | 22.3 |  |
| 73/74 | 29.8 | 24.5 | 23.7 |  |
| 74/75 | 18.8 | 23.2 | 23.1 |  |
| 75/76 | 16.5 | 21.4 | 22.6 |  |
| 76/77 | 24.3 | 22.2 | 22.9 |  |
| 77/78 | 28.3 | 23.6 | 23.2 |  |
| 78/79 | 29.4 | 23.5 | 24.0 |  |
| 79/80 | 46.6 | 29.0 | 26.1 | Incomplete data |

The mean annual data series, 5-years moving average and 10-years moving average are plotted in the Figure 1‑6. The presence of gap in the plot of mean annual discharge indicates the upgrading work in Jhimruk Khola. The data is not available in that period of time. 5-year moving average and 10-year moving average is also plotted in the plot.

Figure 1‑6: Plot of Mean annual discharge, 5-years moving average, 10-years moving average

The different series presented in Table 1‑6 is analyzed to find correlation with same series but with different lag to obtain the plot of auto correlation function (ACF) vs different lags as shown in Figure 1‑7.

Figure 1‑7 shows the plot of auto correlation function (ACF) vs different lag for the mean annual discharge of Jhimrukkhola. Here in the plot, the shaded region in y-axis from [-0.515 0.515] is the confidence limit for the significance value of α=0.01. Since, Lag (1), 0.39, lies within the confidence limit it is concluded that there is no persistence in the series of mean annual discharge. The persistence in the data is said to be present if the correlation of the lag (1) lies outside of the confidence limit. On such case, pre whitening of data is necessary to remove the persistence.

Now, the Man-Kendall test can be proceeded. The result of Man-Kendall test is simple and represented by MK test statistics, tau and probability of exceedance values.

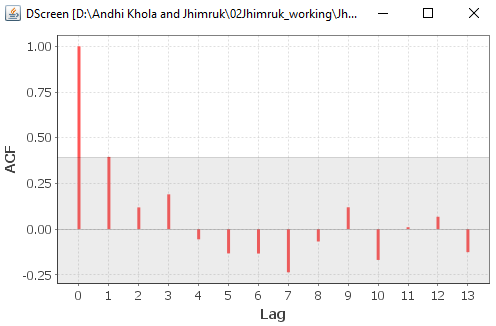


Figure 1‑7: Auto correlation function of mean annual discharge series of Jhimruk River

The monthly average of each month for different years is also analyzed. The result of the Man-Kendall test is tabulated in Table 1‑7. The correction of pre-whitening is only performed for 5-years moving average and 10-years moving average series. These series are originated from the mean annual discharge series so there is trace of the original data in the series. The detail calculation and result are presented in the annex of this report.

Table 1‑7: Result of Man-Kendall test for different discharge series

| Description/Data Series | Man-Kendall's statistical value | Man-Kendall's tau | Man-Kendall's P-value | Apparent trend |
| --- | --- | --- | --- | --- |
|
| Mean Annual Discharge | -64 | -0.2133 | 0.1409 | -0.1962 |
| 5-Years moving average | -16 | -0.0533 | 0.7279 | -0.2181 |
| 10-Years moving average | 22 | 0.1158 | 0.4986 | -0.1913 |
| Baishakh | 57 | 0.1624 | 0.2440 | 0.0447 |
| Jestha | 7 | 0.0215 | 0.8955 | -0.0923 |
| Ashadh | -56 | -0.1481 | 0.2785 | -0.1749 |
| Shrawan | -54 | -0.1429 | 0.2964 | -0.6388 |
| Bhadra | -120 | -0.2956 | 0.02421 \*\* | -0.9571 |
| Ashwin | 52 | 0.1281 | 0.3404 | 0.3175 |
| Karkit | 58 | 0.1432 | 0.3901 | 0.2515 |
| Mangsir | -20 | -0.0493 | 0.7231 | 0.0097 |
| Poush | -42 | -0.1114 | 0.4177 | 0.0006 |
| Magh | -5 | -0.0133 | 0.9370 | 0.0047 |
| Falgun | -18 | -0.0476 | 0.7385 | -0.0092 |
| Chaitra | 2 | 0.0057 | 0.9834 | -0.0066 |

The rate of change of discharge per year is given in Table 1‑7 in the column called “Apparent trend”. This trend is expected to be present in the next few years.

However, the sample size of discharge data will increase in coming years because there is continuous measurement of discharge in the intake of Jhimruk Khola. With the increment in sample size the numerical value of apparent trend may change slightly in the future years.

### Discussion

Alterations in the hydrological regime occur due to the influence from changing climatic conditions such as GHG emissions, pollution, environmental changes such as deforestation, plantation etc. Moreover, the change could be the influence from physical changes at the land surface such as Land use, infrastructure, water use etc. In order to determine the impacts on the hydrology, continuous, long record and good quality data are required.

From the analysis of the data series of Jhimruk Khola, it is clearly seen that the considered series do not have significant trends as suggested by the Mann-Kendall’s test. The p-value is greater than the significance level, which is taken as 0.01 for this study. This means we are 99 percent sure that there is no trend. However, it indicates there is still 1% chance of having significant trend.

For the months Baishakh, Ashwin, Kartik, Mangsir, Poush, Magh, the apparent trend of discharge appears to be increasing whereas for the rest of the months the apparent trend appears to be decreasing.

## Glacier Lake Outburst Flood (GLOF)

No sign of GLOF is recorded in the catchment.

## Conclusions

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

* The available discharge data of Jhimruk Khola reveals that there is no significant trend of changing discharge either increasing or decreasing because of the climatic reason, environmental reason and physical changes.
* The mean annual flow for the considered data series is found to be 23.99 m3/s.
* The design discharge of 7 m3/s is 56.25 % flow exceedance as per this study report.
* The flood flow is calculated as per Log Pearson Type III distribution. The flows with return period 2 years, 10 years, 20 years and 100 years is found to be 180 m3/s, 348 m3/s, 432 m3/s and 683 m3/s.
* The calculated low flows at the intake of the project for the 1-day, 7-day, 15-day, and 30-day periods are 1.42 m3/s, 1.77 m3/s, 2.09 m3/s, and 2.75 m3/s, respectively.

## Recommendations

It is recommended to continue to measure the daily average data of Jhimruk Khola.

Since, there is no significant trend seen in the considered daily discharge series (2051/52-2079/80), it is not recommended to opt the detailed analysis of impact of climate change.

Trend analysis can be performed in the future too. If that analysis will show significant trend then the study of the climate change using climate model such as General Circulation Model (GCM), Regional Climate Model (RCM) could be performed. These model uses the available temperature and rainfall series to predict the future temperature and precipitation series using predictor tools. Ultimately, the predicted temperature and precipitation is incorporated to obtain runoff (discharge) by using hydrological models such as HEC HMS, NAM, BHV.

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