BUTWAL POWER COMPANY LIMITED

Buddhadanagar-10, Kathmandu

HYDROLOGICAL STUDY REPORT OF ANDHI KHOLA HYDROPOWER PROJECT (9.4 MW)

SYANGJA

February 2023

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ANDHI KHOLA HYDROPOWER PROJECT (9.4 MW)

HYDROLOGICAL STUDY REPORT

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HYDRO-CONSULT ENGINEERING

LIST OF ACRONYMS

AMSL	above Mean Sea Level
AHREP	Andhi Khola 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
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 (UFSR,2008)

Descriptions	Parameters
Catchment area	444 km^2
Type of power plant	Run-of the-river
Design Discharge	4.87 m3/s
Low flow(1 in 2 years period)	1.4 m3/s
Capacity	9.4 MW
Diversion weir	
Diverion weir type	Concrete gravity with obermeyer crest gate
Weir Length/Height	60 m /6.5 m above natural bed (0.5 m concrete added on top of the existing weir and 1.2 m inflatable dam (Obermeyer Spillway Gates)
Intake chamber/gravel trap	
Length	10 m
Trash rack opening sixe, width x height	2 m x 3 m (Three Opening width 6 m)
Intake gate opeing size, width x width x height	1.5 m x 2 m, 2 nos
Intake canal size, length x width x height (river side wall)	20 m x 1.5 m x 5.2 m (max.), 2 nos
Settling Basin	
No. of bays	4 nos
Flushing system	Serpent sediment sluicing system (S4)
Length	Inlet transiton 23.68 m, uniform section 30 m
Width of inlet transition, start Width of uniform section	1.5 m 2 nos (3 m total) 4.0 m (width of one bay)
Total depth (including hopper)	6.9 m

Descriptions	**Parameters**
Hopper Depth	1.7 m
Transition section between the settling basin outlet and the headrace tunnel portal	18.5 m long and 6.0 m wide side channel
Headrace tunnel	
Shape	D-shped fully lined (concrete /stone Masonry)
Length	1284 m
Corss sectional area	4.25 m^2
Irrigation system	
Pump irrigation system	350 mm dia, propeller pump, Max head 1.2 m located at intake
Irrigation water supply pipe for pump	350 mm dia, 4 mm thick, located close to the irrigation outlet.
Surge shaft	Addition of 1.5 m height in the existing surge tank with c/s area 12 m^2
Penstock -diameter	 1000-900 mm twin steel pipe (vertical, not embedded)
-length	Vertical 244 m, Horizontal 32 m
Entrance shaft to powerhouse -length	 234 m
-diameter	4 m
Powerhouse -type	 Underground
-size	37 m long, 6.6 m wide and 11 m high with semicircular shape above the spring line
Head -gross	 247. 25 m

Descriptions	**Parameters**
-net	239.60m
Design Flow	4.87 m^3/s
Tailrace tunnel -Shape	D-shaped fully lined (concrete /stone masonry), with 600 mm deep cut in the existing tunnel bed
-length	1087 m
-cross-sectional area	5.25 m^2
Turbines -type	Pelton (3 jets horizontal shaft arrangement)
-no of units	3 nos
Generators -type	Synchronous, brushless, self excited
No of units	3 nos
Capacity	5 MVA
Voltage	6.6 kV
Transmission Line	
-length	0.5 km
-voltage	132 kV
Mean annual saleable energy Production	66.23 GWh in a normal year
Dry Energy (Mid December-mid April)	16.60 GWh
Wer Energy (mid April-mid December)	49.63 GWh
Commissioned date	22^{nd} of Chaitra 2072

1 HYDROLOGY

1.1 Introduction of the Project

Andhi Khola hydroelectric and rural electrification Project (AHREP) is located near Galyang Bazar, about 80km south-west from Pokhara on the Siddhartha Rajmarga in Syangja District, Gandaki Province, Nepal. Andhi Khola Hydroelectric & Rural Electrification Project (AHREP) was commissioned in 1991 and has installed capacity of 5.1 MW. The Project was jointly funded by Government of Nepal (GON) and United Mission to Nepal (UMN). Butwal Power Company Ltd. owns and operates the power plant.

The power produced is being mostly supplied to the 33kV national grid owned and operated by Nepal Electricity Authority (NEA) and part of power produced is distributed directly by BPC to local communities in Syangja and Palpa Districts.

Later on, the project was upgraded to 9.4 MW in from 2011. The upgradation work completed on 2016. This project is now called Andhi Khola Hydropower Project Upgrading (AKHP(U)).

1.2 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 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 this 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

1.3 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 Andhi Khola is one of the major tributaries of the kali Gandaki river which belongs to the Narayani Basin. It originates from Dahare Lek and its catchment extends up to Panchase Danda (hill). The highest point on the catchment area has an elevation of 2517 m above mean sea level, while lowest point is at 640 m (Figure 1-1). Average gradient of the river within the project area is about 1 in 135.

The basin has characteristic of mountainous catchment. The total catchment area upstream of the intake site is 444 km2 as calculated in Table 1-1. The intake site is located at an elevation about 630 m and is approximately 1 km North-West from the Galyang Bazaar.

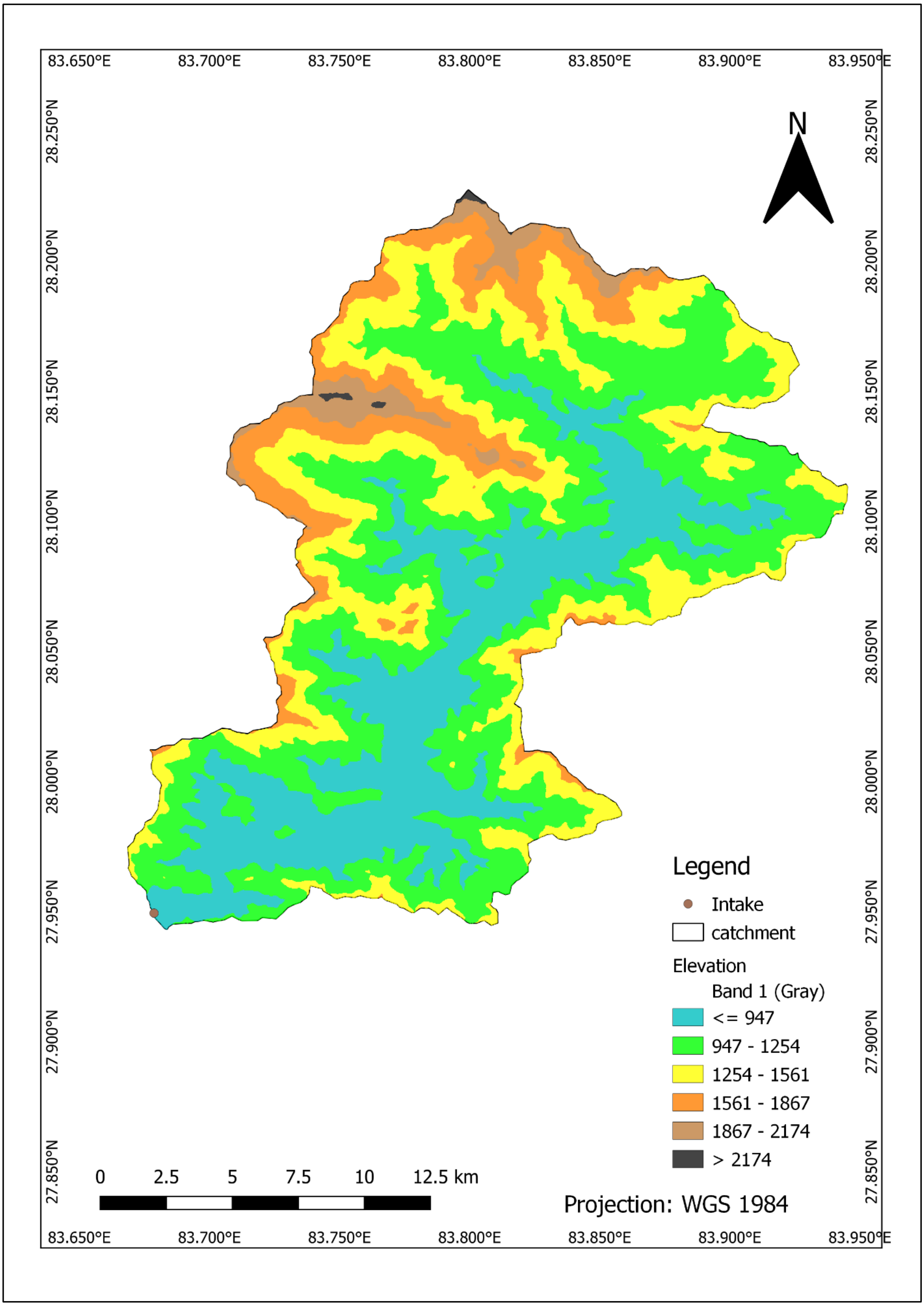

Figure 1-1: Catchment of Andhi Khola at Intake

Table 1-1: Catchment characteristics of Andhi Khola at Intake

Elevation	Area (Km^2)	%
<3000	444	100
>3000	0	0
Total	444	100

1.4 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:

The climatological data (1991-1994) of Chapakot published by DHM is considered. The absolute maximum and minimum temperature is 42^0 C and 4^0 C respectively and relative humidity is between 47 and 90 percent depending on the time variation (UFSR, 2008).

1.5 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.

The average annual basin rainfall is 1897 mm. The catchment is medium precipitation type with respect the basin rainfall. The 24-hour maximum precipitation is 324 mm, which is one sixth of the average annual rainfall indicating potential hydrological risk (UFSR, 2008).

1.6 Available Data

1.6.1 Hydrological Data

There is a provision of daily data recording station at the intake of the Jhimruk project. 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.

1.7 Long Term Mean Monthly Flow

1.7.1 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.

Figure 1-2 shows the daily variation of discharge over the period of the time. There are spikes in the rainy season where there is excessive rainfall because of monsoon. Considering the time period of collected data, there was a flood with discharge 833.36 m3/s in Shrawan 23, 2073. The graph clearly shows the seasonal variation of the discharge. The gap in the plot indicates the upgrading work of Andhi Khola Hydropower Project. The graph shows the reduction in flood flow in the recent years.

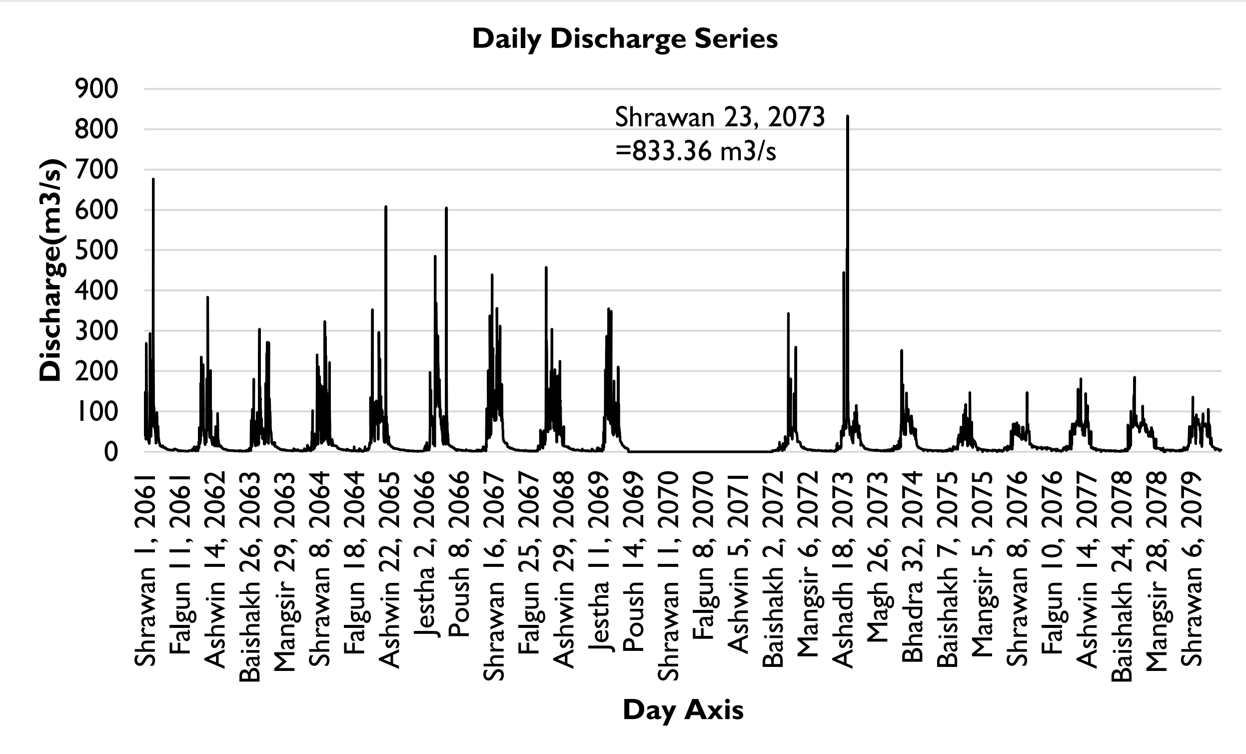

Figure 1-2: Daily discharge series of Andhi Khola

Figure 1-3 shows the monthly flow series of Andhi 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 upgrading of Andhi Khola Hydropower 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.

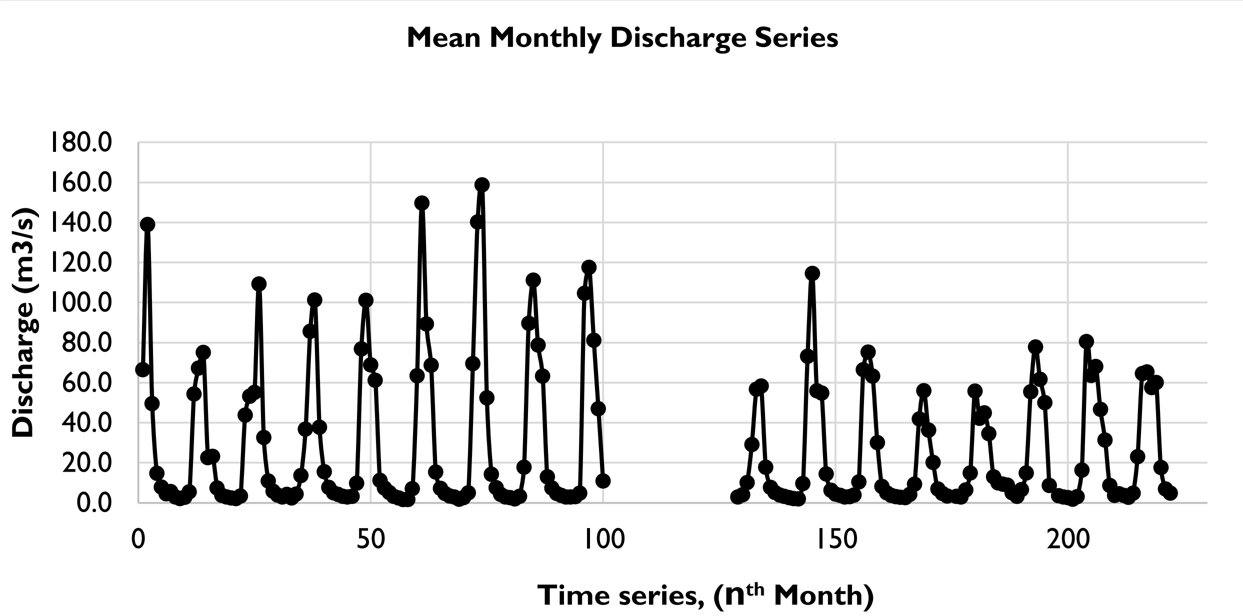

Figure 1-3: Mean monthly discharge series of Andhi Khola.

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.

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 19 years of data is presented in Table 1-2.

Table 1-2: Mean Monthly Flow of Andhikhola River

Month	Discharge (m3/s)
Baishakh	3.7
Jestha	13.5
Ashadh	63.5
Shrawan	85.1
Bhadra	79.3
Ashwin	44.1
Kartik	14.0
Mangsir	7.0
Poush	4.6
Magh	4.0

Month	Discharge (m3/s)
Falgun	3.1
Chaitra	2.5

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

Figure 1-4 shows the comparison of mean monthly flow of Andhi Khola as per the UFSR, 2008 and as per the data collected at the intake of the Andhi Khola.

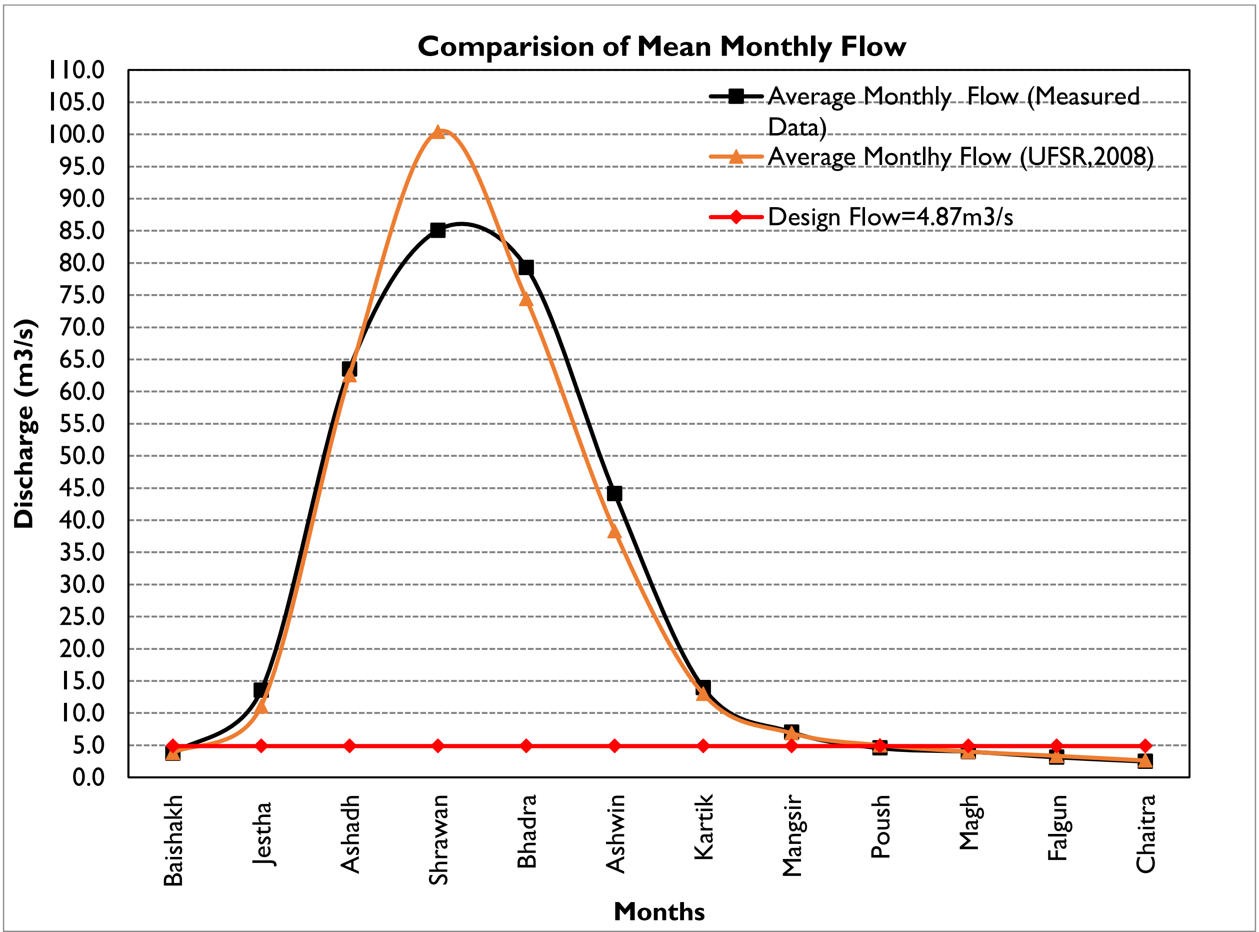

Figure 1-4: Comparison of mean monthly flow(UFSR) and measured mean monthly flow

It is observed that only the month of Shrawan has lesser discharge than that of UFSR,2008. In the dry months the measured data is almost similar as that of estimated data as per UFSR. For the wet months (Jestha, Ashadh, Bhadra, Ashwin) the measured data are greater than the estimated flow during UFSR.

1.7.3 Water Sharing in Andhi Khola

There are some irrigation systems in the Andhi Khola River Basin. Dahathum Changchangdi Irrigation scheme, Damuwa Phant Proposed scheme, Sataun Tapu Irrigation scheme, Kulbandh Irrigation schme, Lamage Phant Irrigation scheme, Thuli Benshi Irrigation Scheme, Tikaja Phant Irrigation scheme are the in operation. Some of them are in normal operation whereas some of them are damaged and operate in monsoon season only. The above mentioned irrigation systems are located in the upstream of the intake of Andhi khola. There are no schemes in the down stream of the Intake of the project.

1.7.4 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.

As per UFSR, the long-term mean monthly flow for driest month, Chaitra at the intake of is 2.63 m^3/s. As per prevailing environment act of Nepal, the downstream release should be 10% of minimum long-term mean monthly flow, i.e., 0.26m^3/s will be released downstream as the riparian release for aquatic life.

1.8 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.

As per USFR 2008, the design discharge is 4.87 m3/s is 65% exceedance flow. Now, the discharge which is available for 65% of the time in year is 4.72 m3/s. The design discharge 4.87 m3/s now becomes 63.64% exceedance flow as shown in Figure 1-5.

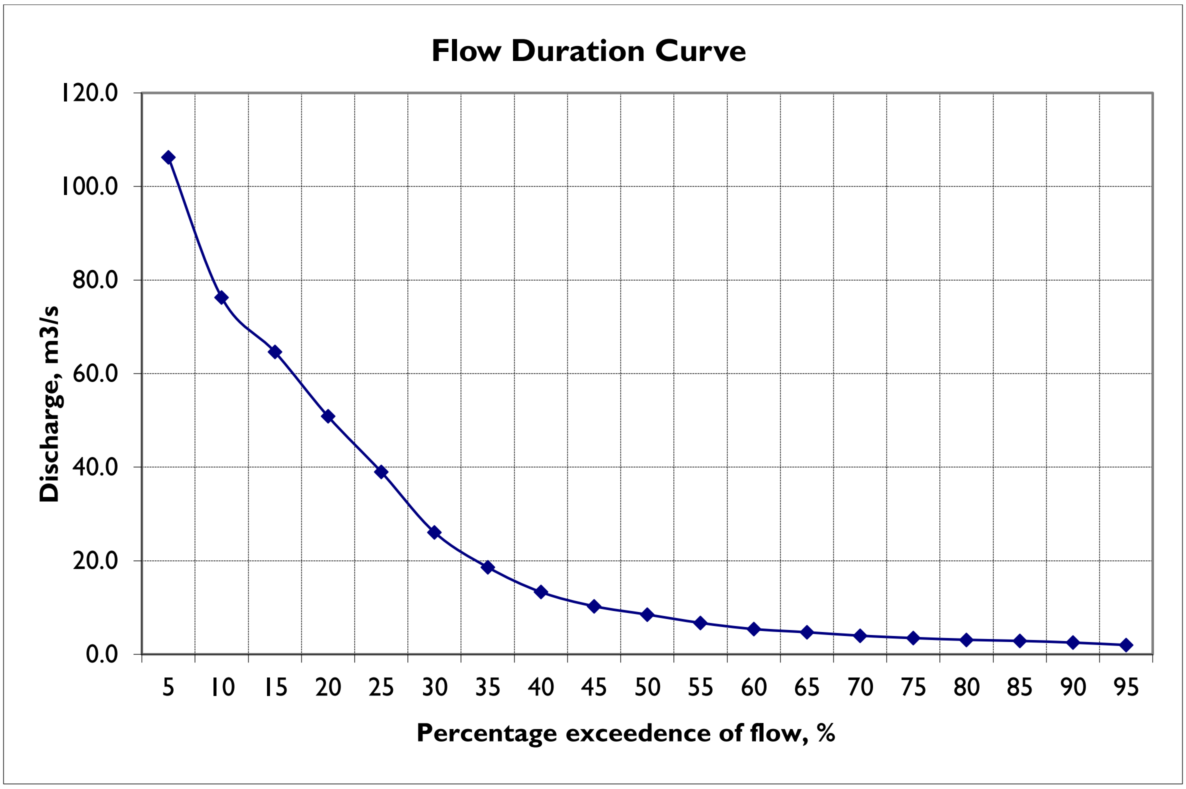

Figure 1-5: Flow duration Curve of Andhi Khola

1.9 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	328	678	834	1227
Log Pearson Type III	332	672	815	1158

Method	Flood flow (m3/s)			
	1 in 2-yr	1 in 10-yr	1 in 20-yr	1 in 100-yr
Gumbel	345	646	761	1021

Table 1-4 summarizes the flood flow as per UFSR, 2008, in which the flood flows calculated from Log Normal 2 distribution was considered as the standard error of Log Normal 2 distribution was minimum among other all distributions.

Table 1-4: Estimation of flood flow (UFSR, 2008)

Method	Flood flow (m3/s)			
	1 in 2-yr	1 in 10-yr	1 in 20-yr	1 in 100-yr
Normal	561	907	1005	1189
Log-Normal-2	509	900	1058	1432
Log-Normal-3	509	899	1057	1430
Gumbel	516	863	996	1297
Pearson Type III	517	895	1033	1334
Log Pearson Type III	507	893	1052	1434

Since, the flood flow calculated now is found to be in lower side, the flood flow in the previous report is still recommended for the further application to design, modification or any other purpose.

The lower values of flood flows in this hydrological study could be the result of the sample size. As per UFSR, 2008, during hydrological analysis, past 26 years' data (from 1964 to 1990) was incorporated. In this study only 19-years data is used including the missing data during upgrading work.

1.10 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 derived daily inflow series (2061/62-2079/80) of Andhi 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 Andhi Khola

Return period (T-year)	Minimum Daily flows, m^3/s			
	1-day	7-day	15-day	30-day
2	1.17	1.61	1.96	2.24
5	2.80	3.24	2.89	3.20
10	4.97	5.15	3.74	4.05
20	8.63	8.04	4.79	5.07
50	17.61	14.29	6.60	6.79
100	30.05	22.00	8.38	8.44

According to the aforementioned calculation approach, the adopted low flows at the MKHPP intake for the 1-day, 7-day, 15-day, and 30-day periods are 1.17 m3/s, 1.61 m3/s, 1.96 m3/s, and 2.24 m3/s, respectively as shown in Table 1-5.

1.11 Trend Analysis

1.11.1 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 0.05) 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.

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.

1.11.2 Result

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
61-62	29.7			
62-63	25.7			
63-64	23.6			
64-65	29.5			
65-66	27.9	27.2		
66-67	35.1	28.3		
67-68	41.3	31.5		
68-69	33.4	33.4		
69-70	64.2	40.4		Incomplete data
70-71		43.5	34.5	Data missing
71-72	11.6	37.6	32.5	Incomplete data
72-73	20.2	32.3	31.9	
73-74	28.4	31.1	32.4	
74-75	20.8	20.3	31.4	
75-76	19.2	20.0	30.5	
76-77	20.7	21.9	28.9	
77-78	28.2	23.5	27.4	
78-79	27.2	23.2	26.7	
79-80	35.4	26.1	23.5	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 Andhi 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.

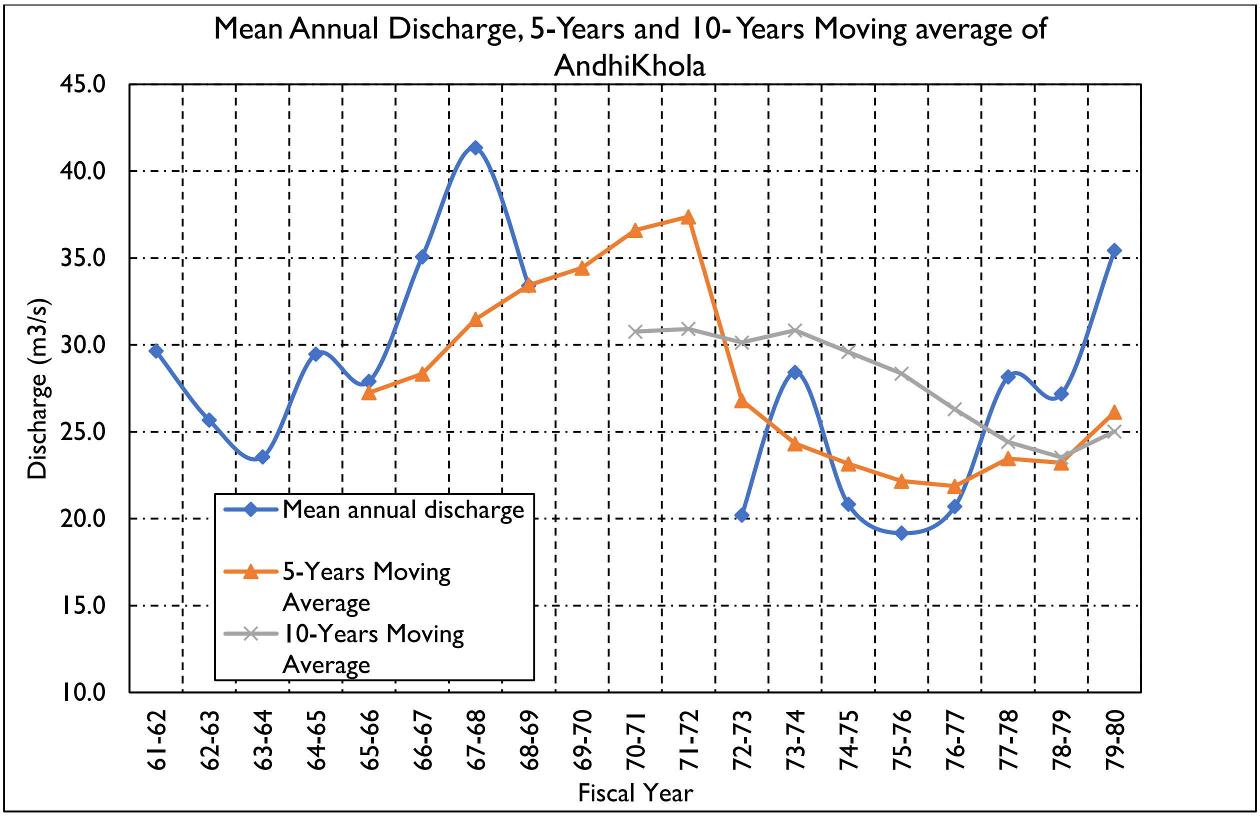

Figure 1-6: Plot of Mean annual discharge, 5-years moving average, 10-years moving average

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 Andhikhola. Here in the plot, the shaded region in y-axis from [-0.5 0.5] is the confidence limit. Since, Lag (1) 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.

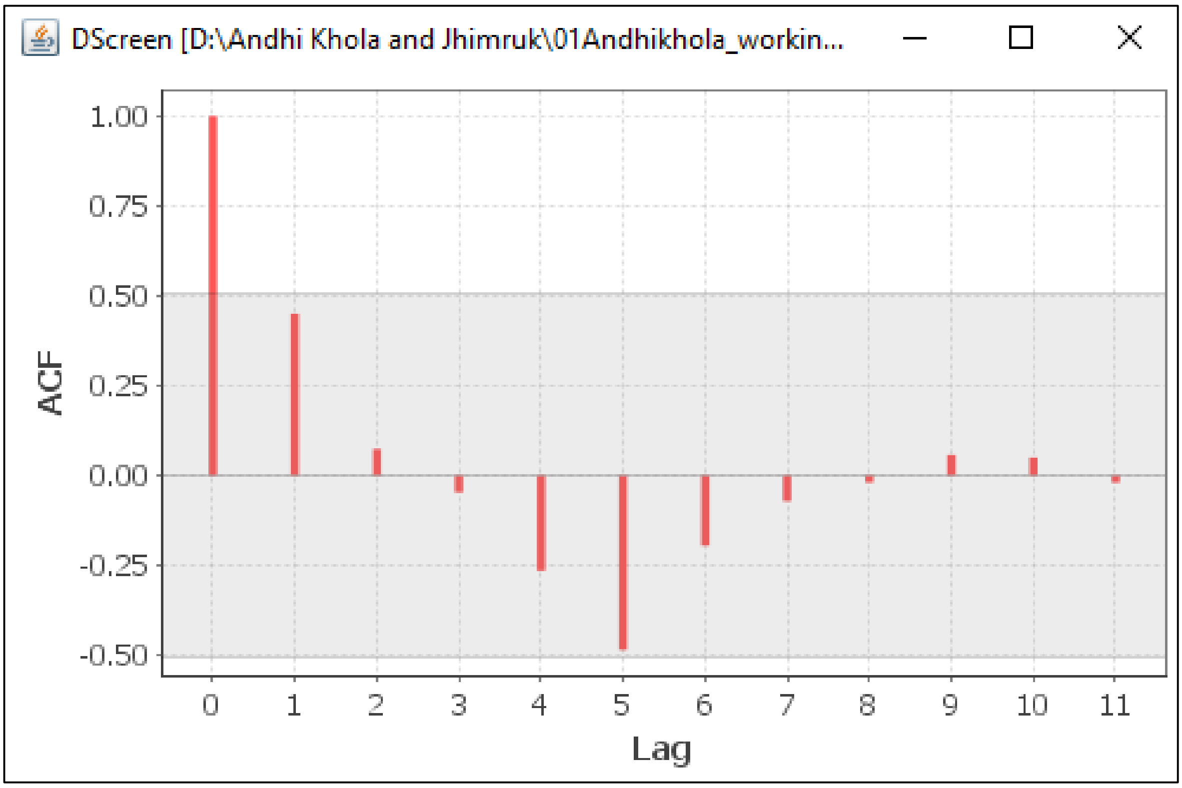

Figure 1-7: Auto correlation function of mean annual discharge series of Andhikhola.

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	S = -25	tau = -0.2381	p = 0.2365	-0.405/year
5-Years moving average	S = -15	tau = -0.1429	p = 0.4923	-0.851/year
10-Years moving average	S = -41	tau = -0.9111	p = <0.0001 ***	-0.726/year
Baishakh	S = 42	tau = 0.3500	p = 0.06257 *	0.149/year
Jestha	S = 31	tau = 0.2594	p = 0.1764	-0.017/year
Ashadh	S = 12	tau = 0.1000	p = 0.6238	0.343/year
Shrawan	S = -20	tau = -0.1471	p = 0.4372	-1.535/year
Bhadra	S = -74	tau = -0.5441	p = 0.06738 *	-4.174/year
Ashwin	S = 2	tau = 0.01471	p = 0.9675	0.050/year
Karkit	S = -22	tau = -0.1618	p = 0.3901	0.027/year
Mangsir	S = -21	tau = -0.2000	p = 0.3252	-0.005/year
Poush	S = -22	tau = -0.1833	p = 0.3474	0.033/year
Magh	S = 13	tau = 0.1429	p = 0.5154	0.072/year
Falgun	S = 13	tau = 0.1238	p = 0.5565	0.040/year
Chaitra	S = 28	tau = 0.2333	p = 0.2254	0.039/year

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 Andhikhola. With the increment in sample size the numerical value of apparent trend may change slightly in the future years.

1.11.3 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 Andhi Khola, it is clearly seen that most of the 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.

On the other hand, in case of 10-years moving average series and monthly average series for the month of Bhadra show that there is significant trend of decreasing discharge. Since, 10- years moving average series has only 10 number of data in the series, the result is not reliable. It cannot be concluded there is decreasing trend. However, for the month of Bhadra, it could be related with the hydrological change. The reason could be climate change, environmental change or physical change. Study of climate models, land use survey, study of water uses in the upstream of the river verify the change in flow.

For the months Jesth, Shrawan, Bhadra and Mangsir, the apparent trend of discharge appears to be decreasing whereas for the rest of the months the apparent trend appears to be increasing.

1.12 Glacier Lake Outburst Flood (GLOF)

No sign of GLOF is recorded in the catchment.

1.13 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 Andhi 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. However, for the data of 10-years moving average, there is significant trend.
- The flood extreme values are less than the values obtained for UFSR, so it is recommended to stay with the same values as obtained in the UFSR.

1.14 Recommendations

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

Moreover, the monthly average of Bhadra shows significant trend of decreasing discharge. Hence, it is recommended to opt the detailed analysis of impact of climate change using climate model such as General Circulation Model (GCM), Regional Climate Model (RCM). 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.

2 REFERENCES

1. Updated Feasibility Study Report (9.4 MW), Volume 1 Main Report, June 2008 (Jestha 2065)