Examining the Impact of Daily Mean Intensity of Precipitation on Direct Runoff in Catchment Areas

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Abstract- This study used a descriptive-evaluative method of research to explore the factors influencing direct runoff and develop model equations for predicting a day ahead power forecast of mini hydropower plants. The research utilized data from the Hydroelectric Development Corporation (HEDCOR) on rainfall, runoff observation, and flow discharge, as well as catchment characteristics provided by the Geoscience Division of the Department of Environment and Natural Resources (DENR-CAR). Intensive variables were obtained from military maps digitized with AutoCAD software. The findings of this study provide valuable insights into the factors influencing direct runoff in catchment areas and contribute to the development of accurate power forecasts for mini hydropower plants. This study sheds light on the link between daily mean rainfall intensity and direct runoff in catchment regions. The findings indicate that the intensity of rainfall is an important element in influencing the incidence of surface runoff. When the intensity of rainfall is less than the infiltration capacity of the soil, there is no surface runoff because the earth absorbs all of the water. Surface runoff occurs when the intensity of rainfall exceeds the infiltration index of the soil. Furthermore, the study emphasizes the impact of different catchment area features on direct runoff.

Indexed Terms- Runoff, Precipitation, Catchment Areas, Infiltration, Rainfall

I. INTRODUCTION

Electricity is essential to almost all aspects of modern—day society from everyday leisure time and work activities to high—tech research and technology (Bigliane, Ferrigno 1989). In areas where water abundantly flows in rivers, man utilizes the abundant flow of water to fuel the hydropower. It is generated from the process of converting the pressure energy and kinetic energy of water into more easily used electrical energy. Benguet is a mass of elevated land raised about a kilometer high above sea level. The province is divided into valleys by rivers which all drain into the China Sea. These rivers are Galiano, Bued, Agno, and Amburayan. Some of these river flows are utilized as source of hydropower of big hydroelectric power plants like Ambuclao, Binga, and San Roque. Other smaller streams are utilized by Hydroelectric Development Corporation (HEDCOR) in their runoff - river mini hydroelectric power plants. (Macabiog R.;2003)

The hydropower to be delivered by small and mini hydropower plants need to be supplied with water falling or flowing from a height above the turbine to develop shaft work and thus drive the direct -- connected electric generators (Daugherty, Franzini, and Finnemore, 1989 pp 485-484) . The hydropower depends on the elevation head and carrying capacity of the rivers or streams. The system is run-off the river type that utilizes the available flow during that period of time without any provision of storage.

Executive Order No. 215 (EO 215) of 1988 in the Philippines, allowed the private sector to participate in power generation activities. This was with the policy of the government to ensure a continuous, adequate, and economic supply of energy with the end view of ultimately achieving self-reliance in the country's energy requirements through the economic development of indigenous energy sources and through the efficient utilization of energy. A number of those in the private sector indeed participated in the generation of power through several feasible energy sources. Thus, the Department of Energy provided policy directions for the formulation of power system expansion plans and programs to achieve its objectives. In 1990, Republic Act No. 7156 was enacted granting incentives to mini hydroelectric power developers and for other purposes. The

Philippines having abundant water resources, started developing and enhancing the minihydro potentials as a source of energy. The private sector built utility groups as operators of the developed mini hydropower plants and most of them are runoff—river types. Republic Act No. 9136 of July 2001 changed the market situation of the Philippine energy industry. The act known as the "Electric Power Industry Reform Act of 2001 EPIRA" ordains reforms in the electric power industry. It was observed that under Republic Act No. 9136, Transmission Company, TRANSCO, required a day ahead hourly generation for runoff-river hydro power plants. Under the rules, terms and conditions for the provision of the Open Access Transmission Service, OATS was stipulated that the energy provider using transmission lines to convey electricity to the customer should provide its capacity that will be wheeled a day before its generation. Contract under this scheme specifies payment for any imbalance shortage and backup services. For runoff-river type, hydro power plants under this scheme is important to establish a reliable procedure to avoid penalties and possible opportunity losses. Operating below the day ahead hourly generation forecast is tantamount to a penalty while exceeding it is an opportunity loss since it will not be credited.

The researcher aimed to develop model equations relating historical data of excess rainfall and direct runoff measurements from water level observation in the catchment area under study. This was needed to determine the response of the general characteristics of the catchment basin. Their significance to the model equations was investigated by appropriate statistical tool (PC based multiple regression) , to obtain model equations of relating excess rainfall and direct runoff, at the intake of hydropower plants. The derived model equations from the excess daily rainfall and direct daily runoff will be used to determine the direct runoff in the catchment and will be utilized as a basis to determine the available total flow, by adding the direct runoff and the baseflow, if rainfall occurs. The available total flow is utilized to determine the predicted day ahead power forecast by substituting to the derived model equations of power generation in the hydropower plant under study to obtain a day ahead power forecast. The derived model equations are expected to yield a result that is close to the actual power generation, and to eliminate or avoid penalties and minimize opportunity losses. Since runoff-river type of hydroelectric power plants are dependent on the available river flow, a forecast is relevant and important when certain provision should be satisfied.

This research, aimed to develop model equations relating excess rainfall and direct runoff as bases to predict a day ahead power forecast for runoff river hydroelectric power plant. It specifically sought to answer the question, what is the daily mean intensity of precipitation that influences the direct runoff in the catchment area?

The findings of this study will be important because may serve as scientific ground for the disaster risk reduction management officers, evaluators and planners as well as for the guidelines of the community's safety and welfare. This study also aims to provide information on the daily mean intensity of precipitation that influences the direct runoff in the different catchment area. Finally, it will be beneficial to the engineering community because it can add to the growing researches regarding the technical researches. From there, educational and experts in the field are encouraged to further conduct researches of similar nature but with broader depth and breadth.

II. REVIEW OF RELATED LITERATURES

The succeeding discussions present the basic theories on precipitation, catchment characteristics, runoff measurement for water level observation, principles of the development of model equations, and power generation simulation.

Theory on Precipitation. Clouds form when air become saturated because of the cooling or by evaporation of water absorbed into the air mass. The water droplets serve as condensation nuclei. At temperature below freezing point, the droplets may directly be converted to ice crystals. If the water droplets or ice crystal increase in size, precipitation will occur. Precipitation larger than 0.50mm in diameter forms rain (Ward and Robinson, pp. 18-16) . Rain is reported in three intensities; light for rate of fall up to 2.5mm per hour inclusive, moderate from 2.8mm to 7. 6rrm per hour, and heavy over 7. 6rnm per hour (Linsley, Kohler, Paulhus, p. 50). The amount of rain which normally falls varies considerably in different parts of the country.

Furthermore, as a component of the water cycle, precipitation is essential to preserving Earth's general climate and regional weather patterns. The process of cloud formation, condensation, and final precipitation are all included in the theory of precipitation. The evaporation of water from the Earth's surface, which is fueled by the heat of the sun, is the first step in the precipitation process. The process of nucleation occurs when this water vapor rises into the atmosphere, where it cools and condenses to form tiny droplets encircling dust particles (Ahrens, 2006). What we see as clouds are these little droplets. These droplets may mix or expand as the process goes on. This is known as coalescence in warm clouds or accretion in cold clouds. The drops enlarge until the updrafts in the cloud cannot support their weight (Wallace & Hobbs, 2006). Precipitation can result from a number of mechanisms, including the Bergeron Process, if the cloud contains ice. According to the Bergeron Process, which was put forth in the 1930s by Swedish meteorologist Tor Bergeron, the difference in saturation vapor pressures between supercooled water and ice causes ice particles to expand at the expense of supercooled water droplets. Until the particles are large enough to precipitate, this growth continues (Rogers & Yau, 1989). When these drops (or ice particles, snowflakes, etc.) become heavy enough, they overcome the upward force of the air and fall to the ground as precipitation - be it rain, snow, sleet, or hail, depending on temperature conditions between the cloud and the ground. This precipitation is then available to evaporate again, continuing the cycle (Trenberth et al., 2007).

Theory on Catchment Characteristics. The water balance, runoff, sedimentation, and pollution within a watershed can all be greatly influenced by catchment features, which are crucial elements in hydrological and environmental studies. Physical characteristics (such as size, shape, and slope), land usage, soil type, vegetation cover, and climate are some of the key characteristics (Maidment, 1993). Runoff is significantly influenced by the catchment's size. Due to the larger area that can receive rainfall, larger catchments may produce more runoff (Wheater et al., 2008). Runoff patterns can also be affected by the form of the catchment. For instance, circular or square-shaped catchments may create quick and peaky flows, but elongated catchments frequently produce more uniform and prolonged runoff (Horton, 1945).

Moreover, another important factor is slope, which can speed up surface runoff, increase response times, and perhaps increase soil erosion (Dunne and Leopold, 1978). On the other hand, softer slopes can encourage infiltration and slow runoff. Hydrological processes within a catchment can be directly impacted by the land use and land cover. For instance, impermeable surfaces in metropolitan settings tend to increase surface runoff, whereas infiltration and storage are made easier by forests and grasslands, which moderates the runoff response (O'Connell et al., 2007). The capacity of the catchment to store water is greatly influenced by the type and depth of the soil, which can have an impact on runoff generation and groundwater recharge (Bonell, 1993). The evapotranspiration rates, snowfall, and melt processes of the watershed can all be impacted by the climate, especially temperature and precipitation (Singh, 1992). It's crucial to remember that these traits interact rather than acting individually, creating complicated and dynamic reactions to precipitation events.

III. METHODOLOGY

The methodology used was descriptive-evaluative method of research, which established the factors that influence the direct runoff and to arrive at model equations of direct runoff and be used as bases in the prediction of a day ahead power forecast of mini hydropower plants. Data were furnished by the Hydroelectric Development Corporation (HEDCOR) from their monthly submitted daily field reports on rainfall, runoff observation, and flow discharge used versus power generated from the year 2000 to 2003. The catchment characteristics were furnished by the Geoscience Division of the Department of Environment and Natural Resources (DENR-CAR) through their maps on soil classification, geologic classification, and land use classification. The intensive variables like; drainage area, circularity ratio, main channel length, main channel slope, basin perimeter, stream frequency, drainage density, and maximum basin relief were taken from the military maps of the National Mapping and Resources

Information Authority (NAMRIA). The maps are digitized with the aid of the AutoCAD software.

3.1 Treatment of Data

Based on references from various agencies, rainfall and runoff observation data from the catchment under study from 2000 to 2003 were compiled, tabulated, and illustrated through histogram for rainfall and graph for direct runoff to determine the excess rainfall and direct runoff on that day and analyze the relationship between the two variables. Analysis separates the baseflow from the graph and the infiltration index from the histogram to calculate daily direct runoff and excess rainfall. Computers record daily excess rainfall and direct runoff. The catchment basin's general characteristics were determined by the reaction of the daily excess rainfall and daily direct runoff. Their correlation to the derived model equations was investigated using appropriate statistical tools (P.C.-based multiple regression) to obtain a model equation relating excess rainfall and direct runoff at hydropower plant intakes, which will be used to determine direct runoff in the catchment and the predicted available total flow (by adding baseflow and direct runoff) if rainfall occurs.

The data gathered on runoff observation and power generation of the plant from the years 2000 to 2003 were compiled, tabulated and encoded in the computer for analysis. The runoff observation was treated as independent variables and power generation as dependent variables, to obtain a model equation of power generation. Their significance and correlation to the model equations were investigated using a PC based simple linear regression program. The correlation was evaluated as follows:

0.8<1.0	Very high positive correlation
0.6<0.8	High positive correlation
0.4<0.6	Medium positive correlation
0.2<0.4	Low positive correlation
0.0<0.2	No positive correlation

The computed available total flow is to be substituted in the derived model equation of power generation, to obtain a day ahead power forecast. The result is expected to be a good basis for predicting a day ahead power forecast for Runoff-River Hydroelectric Power Plants, to minimize penalties and opportunity losses.

IV. RESULTS AND DISCUSSIONS

The data in the study are tabulated in histogram and graph form to determine the infiltration index, excess rainfall, and direct runoff so the analysis can be made in a manner that will make this study descriptive. The daily infiltration index tabulated in figure 1 and excess rainfall and direct runoff were tabulated.

The daily intensity of rainfall that influences the direct runoff in the catchment area is shown on the daily infiltration index. The hourly rainfall is reported in three intensities, light for rate of fall up to 2.5 mm per hour inclusive, moderate from 2.8 mm to 7.6 mm per hour and heavy over 7.6 per hour (Linsley, Kohler, Paulhus, p.50)

Horton hypothesis supports the research findings and conclusions obtained. Figure 1 gives the daily mean intensity of precipitation that influences the direct runoff in the catchment area. Direct runoff is the water remaining from precipitation after losses from evaporation, transpiration, and infiltration into the ground. The principal losses occur before the water reaches the stream (Foster, 1948 p. 23)

DAILY INFILTRATION INDEX FOR BINENG 1

2000-2003

Station: BINENG 1

SOIL INFILTRATION INDEX mm/da

YEAR	DAY	MAY	DAY	JUNE	DAY	JULY	DAY	AUG	DAY	SEPT	DAY	OCT
2000	18	20.43	4	9.86	5	288.71	7	20.02	5	30.42	14	10.49
	21	10.31	22	144.89		144.89	23	35.47	9.74	42.87		
	25	25	56.40			23	47.47			25	9.74	
2001	12	31.93	11	4.06	12	23.87	10	3.38	15	15.73		
					20	1.77	13	6.75	24	170.2		
					25	5.81	16	25.68				
					29	73.08						
	12	31.93	11	4.06	12	23.87	10	3.38	15	15.73		
2002	23	13.98	3	4.56	8	208.19	2	62.06	23	2.08	10	22.11
	28	29.83	14	24.18	14	7.83	29	5.77	26	2.73		
			23	9.00	21	3.62			28	6.1		
					14	7.15						
2003	19	3.33	2	33.67	22	289.70	6	53.59	5	0.49	12	9.05
	28	137.94	16	246.44			7	53.59	11	6.18	13	9.05
			18	9.64			9	33.25	17	2.12		
			26	22.77			20	0.36				
TOTAL		304.15		428.42		1137.94		316.39		255.53		50.7
Mean		38.02		35.70		87.53		26.37		23.23		12.675

Figure 1. Daily Infiltration Index for Bineng 1

DAILY INFILTRATION INDEX FOR LABAY
2000-2003

station: LABAY

SOIL INFILTRATION INDEX mm/da

YEAR	DAY	MAY	DAY	JUNE	DAY	JULY	DAY	AUG	DAY	SEPT	DAY	OCT
YEAR 2000	18	41.92	5	11.28								
	21	3.64	8	19.28	5	50.19	22	3.16	2	5.84	13	3.54
					27	42.12	23	3.16	8	4.63		
	24	14.93	10	5.12			30	47.24	12	11.78		
	25	14.93	19	8.02								
2001	11	20.90	7	6.94			2	52.34	5	1.25	4	19.84
	18	11.90	15	5.52			18	9.91	7	16.96		
	22	16.59	22	118.55					17	8.72		
	26	11.79							24	22.74		
	2	4.20	15	10.34	9	252.37	3	58.44	8	14.92	16	1.13
	10	19.60	27	5.08	11	183.33	10	15.94	11	10.23	20	22.07
2002	12	29.42							22	14.13		
	14	7.46							25	3.06		
	17	8.67										
	18	8.67										
	21	5.31										
	22	5.31										
	26	31.24										
2003	16	17.89	2	32.25	22	183.22	3	10.01				
	29	7.59	17	407.43			6	24.77				
	30	7.59					9	20.42				
							23	19.39				
TOTAL		289.55		629.81		711.23		264.78		114.26		46.58
Mean		14.48		57.26		142.25		24.07		10.39		11.65

Figure 2. Daily Infiltration Index for Labay

These data cover the four (2000-2003) during the months of May to October where rainfall is experienced by respondent catchment area locations. To facilitate interpretation, the monthly average daily mean intensity of precipitation that influences the direct runoff in the catchment area are in tabulated form as shown in Figure 6

Infiltration index while the months of September and October show the lowest for respective areas as shown.

DAILY INFILTRATION INDEX FOR BINENG 3
2000-2003

Station: BINENG 3

SOIL INFILTRATION INDEX mm/da

YEAR	DAY	MAY	DAY	JUNE	DAY	JULY	DAY	AUG	DAY	SEPT	DAY	OCT
2000	18	33.60	19	21.00	4	162.49	7	6.52	5	42.87	30	192.83
	21	11.94	22	31.27			23	109.11	6	42.87		
	25	43.51					29	62.99	8	42.87		
2001	12	29.43	3	52.24			3	16.50	8	29.81		
	29	5.73	22	31.24			12	16.93	17	5.78		
							18	63.86	24	33.20		
							26	2.02	25	33.20		
							29	6.73				
2002	23	15.08	3	2.53	5	13.28	4	11.51	3	24.16	10	22.45
	29	7.26	14	21.80	8	229.75			9	58.46	11	24.39
					9	346.16			23	2.84		
					14	7.15						
2003	27	267.43	3	4.62	3	18.28	6	84.23	10	28.15	11	8.16
			17	326.65	4	18.28	10	0.32	13	4.06	12	8.16
							11	10.72	19	12.83	13	8.16
							19	38.09	27	12.76	16	6.25
TOTAL		413.98		491.35		795.39		429.53		373.86		270.40
Mean		5115		61.42		113.63		33.04		26.70		38.63

Figure 3. Daily Infiltration Index for Bineng 3

DAILY INFILTRATION INDEX FOR LON-OY
2000-2003

Station: LON-OY

SOIL INFILTRATION INDEX mm/da

YEAR	DAY	MAY	DAY	JUNE	DAY	JULY	DAY	AUG	DAY	SEPT	DAY	OCT
2000	18	40.59	4	4.11	5	30.51	5	2.82	5	13.68		
	21	10.89	7	12.68	6	30.51	28	34.89	6	13.68		
			9	1.88	7	30.51	29	34.89	11	22.30		
			14	7.91		5.79	30	34.89	25	45.51		
			19	8.67								
2001	17	3.32	5	6.60	4	1493.98	3		7	9.15	2	11.18
	27	17.27	7	0.75			16	1.80	13	24.82	3	11.18
				4.91					21	24.37	4	11.18
			22	68.59					23	41.99	5	11.18
									24	41.99		
									25	41.99		
2002	14	5.71	8	15.17	9	186.42			3	25.38		
	20	21.91	13	18.11					8	11.63		
	25	8.27	15	5.89					17	6.11		
			25	9.80					24	16.88		
2003	15	30.18	18	86.83	6	42.21	18	17.58	9	5.18	9	12.96
	22	16.57			10	8.49	19	17.58	12	7.31	15	17.37
	29	9.27			22	125.45	27	1.66	19	19.17		
TOTAL		163.98		251.90		1953.87		152.71		371.14		75.05
Mean		16.40		17.99		217.10		16.97		21.83		12.51

Figure 4. Daily Infiltration Index for Lon-oy

DAILY INFILTRATION INDEX FOR FLSINGIT
2000-2003

Station: FLSINGIT

SOIL INFILTRATION INDEX mm/da

YEAR	DAY	MAY	DAY	JUNE	DAY	JULY	DAY	AUG	DAY	SEPT	DAY	OCT
2000	16	40.59	4	4.11	5	30.51	5	2.82	5	13.68		
	18	10.89	7	12.68	6	30.51	28	34.89	6	13.68		
	25		9	1.88	7	30.51	29	34.89	11	22.30		
			14	7.91		5.79	30	34.89	25	45.51		
			19	8.67								
2001	29	3.85	2	27.06	4	320.38	2	18.67	8	7.19		
			4	0.15	11	46.84	3	18.67	16	5.13		
			22	44.11	13	17.00			20	16.47		
						17.00			25	230.07		
						17.00						
						44.76						
2002	16	16.63	17	61.59	5	43.37	2	24.06	7	21.71		
	22	17.24	18	61.59	22	170.99	6	19.82	16			
	29	11.62			27	5.90	9	19.02				
							20	8.01				
2003	16	16.63	17	61.59	5	43.37	2	24.06	7	21.71		
	22	17.24	18	61.59	22	170.99	6	19.82	16			
	29	11.62			27	5.90	9	19.02				
TOTAL		234.05		195.03		2342.99		249.25		328.23		125.64
Mean		16.72		32.51		292.87		20.77		27.35		62.82

Figure 5. Daily Infiltration Index for FLSingit

DAILY INFILTRATIONTION INDEX FOR AMPOHAW
2000-2003

Station: AMPOHAW

			SOIL INFILTRATION INDEX mm/da									
YEAR	DAY	MAY	DAY	JUNE	DAY	JULY	DAY	AUG	DAY	SEPT	DAY	OCT
2000	16	3.07	5	13.63	4	89.05	4	24.62	7	1.05	9	4.98
	18	44.46	7	6.37	6	179.74	7	17.54	25	4.47	10	4.98
	25	31.81	9	3.87	9	8.20	23	5.64			13	39.84
			11	4.09	14	10.34	29	35.22			19	16.95
			14	15.17	24	15.14					30	69.72
2001	29	3.85	2	27.06	4	320.38	2	18.87	8	7.19	4	27.83
			4	0.15	11	46.84	3	18.87		5.13		
			22	44.11	13	17.00			20	16.47		
					14	17.00			25	230.07		
					16	17.00						
					26	4476						
					29	35.78						
2002	24	20.92	3	10.00	4	186.65	3	14.01	6	0.39	15	7.72
	25	20.92	14	27.04	7	76.66	4	14.01	22	45.35		
	26	20.92	16	11.10	27	56.55			27	45.35		
	28	20.92			30	75.14						
2003	28	334.49	3	13.86	2	5.79	6	19.16	10	32.03		
			4	13.86	4	13.89	18	30.52	19	3.12		
			17	376.03	6	9.78	20	7.08	28	17.83		
			27	5.70	22	227.03	27	5.01				
TOTAL		501.36		572.04		1452.72		210.55		408.45		172.02
Mean		55.71		38.14		72.64		17.55		34.04		24.57

Figure 6. Daily Infiltration Index for Ampohaw

The highest values in July of these four years are due to the maximum rainfall on July 4, and 5, 2000, July 8, 9 and 10, 2002, and July 22, 2003, based on the rainfall observation data of the different catchment areas.

On this month, Singit had 292.87 mm/day value. It was noted that the amount of rain that normally falls varies considerably in different parts of the country (Ries, Watson, Elements of Engineering Geology). The findings highlight the importance of understanding the local climatic conditions and rainfall patterns in order to properly manage water resources and plan for potential flood events. It is clear from this study that there is no uniform amount of rainfall that can be expected across the entire country, which reinforces earlier research conducted by Ries and Watson in their publication "Elements of Engineering Geology."

Overall, this corroborating evidence adds weight to the idea that rainfall variability is a natural phenomenon that occurs in different parts of the country. It underscores the need for further research and understanding of local rainfall patterns to inform effective water resource management strategies and infrastructure planning.

Of all these areas, Labay had the lowest monthly arithmetic mean of the infiltration index of 10.39 mm/day in September and 12.5 mm/day in Lon-oy in the month of October. The difference in the values shown are due to the general catchment characteristics and moisture condition of the catchment at the onset of the rainfall.

V. FINDINGS, CONCLUSIONS, RECOMMENDATIONS

Findings

1. There is significant variability in the amount of rainfall that normally falls in different parts of the country, supporting the notion of regional variation in rainfall patterns.
2. Installing a network of rain gauges within the catchment area can enhance the accuracy and reliability of the rainfall data, providing a more comprehensive understanding of the intensity of rainfall in the area.
3. Factors such as topography, geologic classifications, soil characteristics, and catchment geometry play a crucial role in determining the extent of direct runoff, highlighting the need to assess these characteristics before implementing hydrological projects.

These findings suggest the importance of accurate rainfall data, site-specific analysis, and consideration of various factors in managing direct runoff and water resources in catchment areas.

Conclusions

Based on the findings, the following conclusions were drawn:

1. The daily mean intensity of rainfall that influences the direct runoff in the catchment area of the mini-hydropower plant depends on the intensity of rainfall and duration. When the intensity of rainfall is smaller than the infiltration capacity of the soil, there is no surface runoff but if the intensity of rainfall is greater than the infiltration index of the soil, surface runoff occurs.
2. The influence of the general catchment area characteristics in the direct runoff in the catchment area depends on the local topography, geologic classifications soil texture, soil structure, soil permeability and geometry of the catchment area.

3. The results of this study contribute to our understanding of how different rainfall intensities and durations influence the occurrence of direct runoff in a catchment area. It is clear that the intensity of rainfall plays a significant role in determining whether surface runoff occurs. When rainfall intensity is lower than the infiltration capacity of the soil, there is no surface runoff as the soil can absorb all the water.
4. When rainfall intensity exceeds the infiltration index of the soil, surface runoff occurs as the soil is unable to absorb all the water. This information is valuable for designing and managing mini-hydropower plants, as it allows for better prediction and management of direct runoff in catchment areas.

Recommendations

Based from the findings and conclusions, the following recommendations are respectfully presented:

1. Additional rain gauge must be installed in Ampohaw catchment area for a more accurate data gathering to represent the true intensity of rainfall in the catchment area, in order to obtain a more significant relationship of rainfall and runoff, and to arrive at reliable equations of discharge to be used in the day ahead forecast so that penalties and opportunity losses are minimized.
2. In addition to installing new rain gauges, it is also important to regularly calibrate and maintain the existing rain gauge network. This will ensure that the collected data is accurate and reliable, reducing any potential errors or biases in the measurement process. Regular calibration can be carried out by comparing the readings from the rain gauges with a reference standard, such as a trusted and well-maintained rain gauge at a nearby meteorological station.
3. To complement the rain gauge network, it is recommended to incorporate remote sensing technologies, such as weather radars or satellite-based rainfall estimates, for a more comprehensive understanding of the rainfall patterns in the catchment area. These remote sensing technologies can provide valuable information on rainfall intensity, spatial distribution, and temporal trends, which can help in improving the forecasting accuracy and reliability.
4. Lastly, it is crucial to establish strong data management practices and protocols for the collected rainfall data. This includes implementing a standardized data format, ensuring proper quality control checks, and maintaining a secure and organized database for easy access and retrieval of the data. Data management protocols should also include regular backups and archiving procedures to prevent any loss or corruption of the collected rainfall data. These practices will help in maintaining the integrity and usability of the data for future analysis and forecasting purposes.

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