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Radhanagari Dam: A Statistical Exploration

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Abstract: *This study presents a statistical analysis of water level and water storage of the Radhanagari Dam, Kolhapur, using daily data from June 2012 to May 2024 (4,316 observations). The objective was to examine the relationship between water level and storage. Exploratory analysis revealed clear seasonal fluctuations and a strong positive relationship between water level and storage. A log-linear regression model provided an excellent fit ($R^2 = 0.9829$), indicating that water level is a strong predictor of storage. The findings provide useful insights for effective water resource planning and sustainable dam management.*

Keywords: Water Level, Log-Linear Regression Model

I. INTRODUCTION

The Radhanagari Dam, located in the Kolhapur district of Maharashtra, is an important water resource that supports irrigation, water conservation, and hydroelectric power generation in the region. It plays a crucial role in meeting agricultural and domestic water needs while also contributing to environmental sustainability. A distinctive feature of the dam is its seven automatic gates that operate without electrical or mechanical power, along with five manually operated gates. The dam has a height of 42.68 meters and a total length of 1,143 meters, with a gross storage capacity of approximately 236,810,000 cubic meters.

This study analyzes historical operational data of the dam to understand the relationship between key hydrological variables such as water level, water storage, and water discharge. In particular, regression analysis is used to examine the relationship between water level and water storage in order to understand how changes in water level influence the storage capacity of the reservoir. Overall, the study demonstrates the importance of statistical analysis in understanding reservoir behavior and provides insights that can support effective water resource management and planning.

Data Collection

The data used in this study were obtained from historical records of the Radhanagari Dam covering the period from June 1, 2012, to May 31, 2024. The data were provided in separate Excel files for each year from 2012–13 to 2023–24, with each file containing monthly records of the variables: Date, Water Level, Water Storage, and Water Discharge. During data preprocessing, a few missing values and outliers were identified. Mean imputation was applied to handle missing values, and outliers were removed to ensure data quality. After preprocessing, the final dataset contained 4,316 daily observations.

The dataset includes several important variables related to dam operations. Date represents the day on which the observation was recorded. Water Storage refers to the total volume of water stored in the reservoir, which was originally measured in cubic feet. Water Level indicates the height of water in the reservoir and is measured in meters.

For the purpose of statistical analysis, water storage values were converted from cubic feet to cubic meters to maintain consistency and improve interpretability. The conversion used was 1 cubic meter = 35.315 cubic feet, and all storage values reported in this study are expressed in cubic meters.

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II. RESULTS AND DISCUSSION

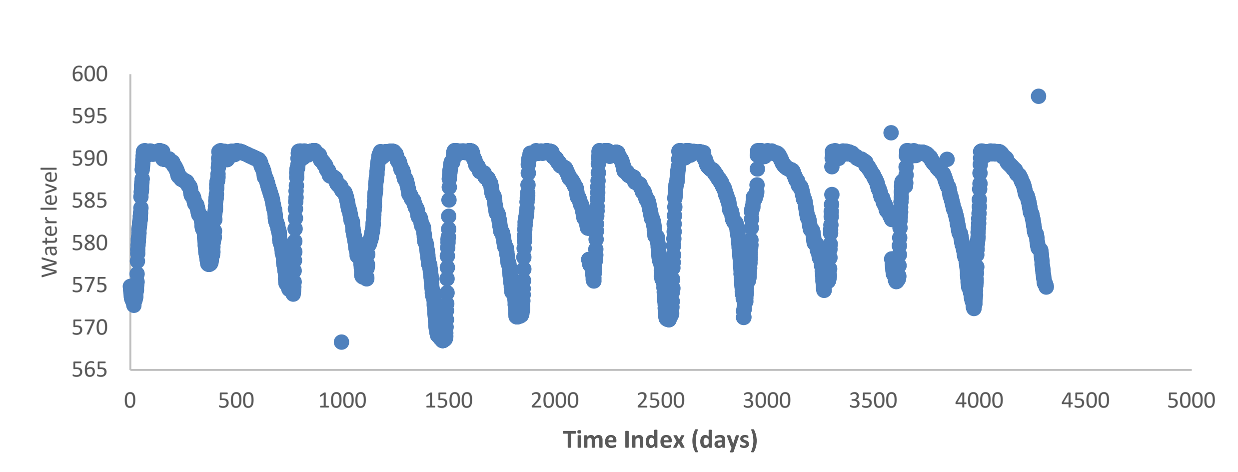

Figure 1: Water Level (meters) Observations in the Dam over time

Figure 1 shows that the water level fluctuates over time but generally remains within a specific range of approximately 570 to 600 meters. This variation indicates a relatively stable operating range of the reservoir. The observed pattern also suggests the presence of seasonal variations, which are likely influenced by rainfall patterns and controlled water releases from the dam.

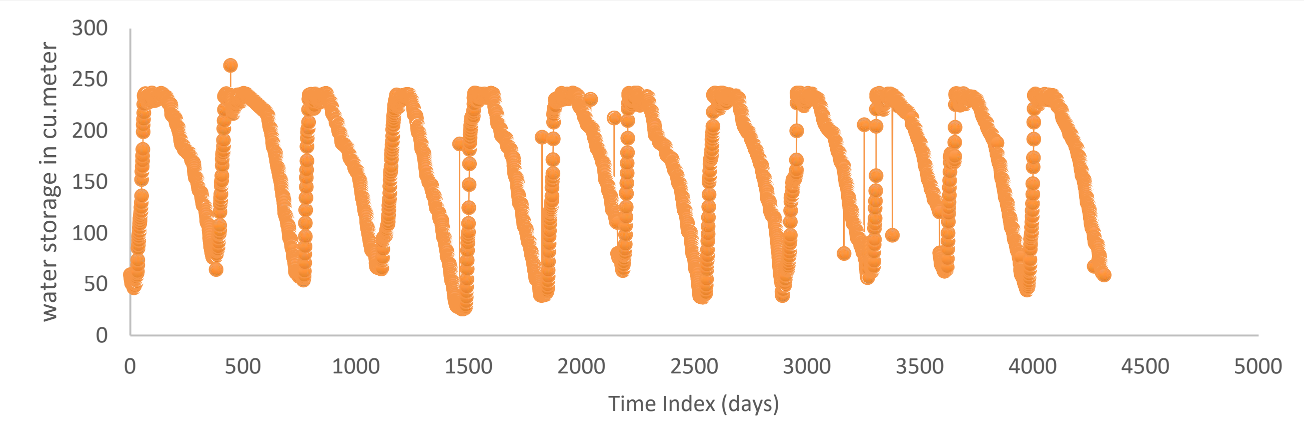

Figure 2: Water storage (cu.meter) Observations in the Dam over time

Figure 2 shows the water storage (in cubic meters), which also shows a fluctuating pattern over time. This pattern corresponds closely with the changes in water level, indicating that higher water levels are associated with higher storage volumes in the reservoir, which is consistent with the expected relationship between these two variables.

Analysis of the Relationship between Water Level and Water Storage

The objective of this analysis is to examine the relationship between water level (in meters) and water storage (in cubic meters) in the Radhanagari Dam. Understanding this relationship is important for efficient reservoir management because variations in water level directly influence the volume of water stored in the reservoir. By analyzing this relationship, the study aims to provide insights that may assist in better water resource planning and dam operation.

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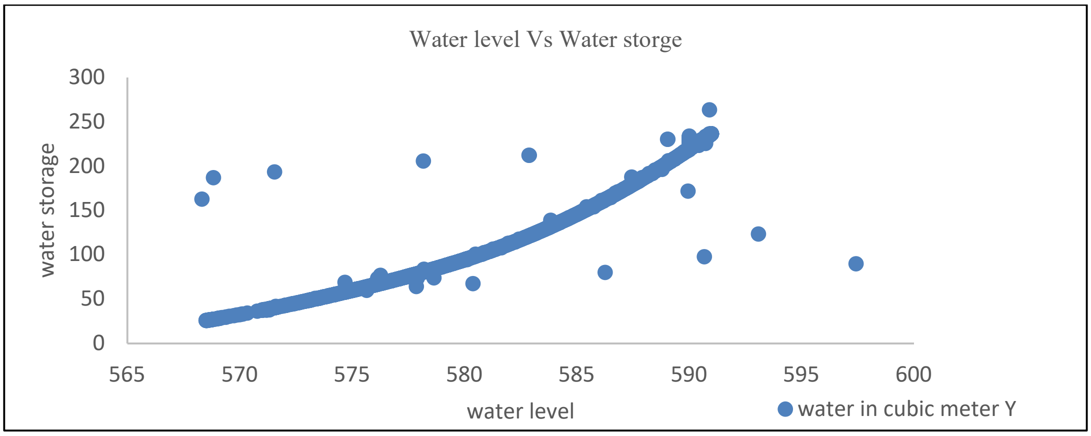

Figure 3: Scatter plot water level and water storage

To explore the relationship between water level and water storage, an initial scatter plot of water level (X) against water storage (Y) was examined (Figure 3). The scatter plot indicated a nonlinear pattern, suggesting that the relationship between these variables may not follow a simple linear trend. Instead, the observed pattern suggested the possibility of a quadratic or exponential relationship.

To determine the most appropriate model, several regression approaches were considered. These included a linear regression model (Y ~ X), a quadratic regression model ($Y \sim X^2$), and a model based on logarithmic transformation (log Y ~ X). After comparing the performance of these models, the log-linear model was selected as the most suitable. This model provided a higher coefficient of determination (R^2) and offered a clearer interpretation of the relationship between the variables. The log-linear specification effectively captures the exponential nature of the relationship between water level and water storage.

To capture the exponential relationship between water level and water storage, a simple linear regression model was applied between water level (X) and the natural logarithm of water storage (log Y). This transformation converts the nonlinear relationship into a linear form that can be analyzed using standard regression techniques.

$$\log Y = \beta_0 + \beta_1 X + \varepsilon$$

In this model, Y represents water storage, X represents the water level, β_0 represents the intercept of the regression model, β_1 represents the slope coefficient indicating the rate of change in water storage with respect to water level, and ε represents the random error term. This model allows us to quantify how changes in water level influence the storage capacity of the reservoir and helps explain the strength of the relationship between the two variables.

Table 1: Results of regression analysis

Regression Statistics	
Multiple R	0.99
R Square	0.98
Adjusted R-Square	0.98
Standard Error	0.03
Observations	4316

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	197.83	197.83	247842.6	0
Residual	4314	3.44	0.0007	-	-
Total	4315	201.27	-	-	-

	Coefficients	Standard Error	t Stat	P value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-20.02	0.04	-448.86	0	-20.10	-19.93	-20.10	-19.93
water level X	0.04	7.61E-05	497.84	0	0.04	0.04	0.04	0.04

The regression analysis reveals that the model is highly statistically significant. The F-statistic of 247,842.6 with a p-value approximately equal to zero indicates that the regression model provides an excellent fit to the data. This confirms that the water level is a significant predictor of the log-transformed water storage. The coefficient of determination (R^2 = 0.9829) further shows that approximately 98.29% of the variation in water storage is explained by variations in water level, demonstrating a very strong association between these two variables. The estimated regression equation is:

$$\text{Log (Water Storage)} = -20.016 + 0.0379 \times \text{Water Level}$$

By transforming the equation back to the original scale, the relationship can be expressed as:

$$Water\ Storage = e^{-20} \times e^{0.04 \times water\ level}$$

This result indicates that water storage increases exponentially with an increase in water level, suggesting a strong and consistent relationship between these variables. Practically, this implies that even a small increase in the water level of the dam leads to a relatively larger increase in water storage, which is important for understanding reservoir capacity and water resource management. Here, the estimated intercept of the model is −20.016, which represents the expected value of the logarithm of water storage when the water level is zero. Although this value does not have a direct physical interpretation in the context of the reservoir, it serves as a constant term in the regression model.

The slope coefficient is estimated to be 0.0379. This indicates that for every one-meter increase in water level, the logarithm of water storage increases by 0.0379 units. In terms of the original scale, this corresponds to an approximate increase of about 3.79 percent in water storage for each one-meter rise in water level. This result indicates a strong positive relationship between water level and water storage in the Radhanagari Dam.

The goodness of fit of the model is very high. The coefficient of determination (R^2) is 0.9829, indicating that approximately 98.29 percent of the variability in water storage is explained by changes in water level. In addition, the Multiple R value of 0.9914 indicates a very strong positive correlation between the two variables, further supporting the strength of the relationship captured by the model.

III. CONCLUSIONS

This study examined the relationship between water level and water storage for electricity generation in the Radhanagari Dam using historical data analysis. The results revealed a strong relationship between water level and water storage. Among the different regression models considered, the log-linear model provided the best fit, indicating that changes in water level have a significant impact on the volume of water stored in the reservoir. The model showed a very high goodness of fit, explaining a large proportion of the variability in water storage. These findings highlight the importance of water level as a key factor influencing reservoir storage.

REFERENCES

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