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STUDY OF WATER QUALITY IN THE NARMADA RIVER THROUGH PHYSICO-CHEMICAL PARAMETERS: A CASE FROM DINDORI DISTRICT

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ABSTRACT

Water quality assessment has become increasingly important for environmental monitoring and public health protection. This study evaluates the physico-chemical parameters of the Narmada River in Dindori District, Madhya Pradesh, through comprehensive water quality analysis. The research aims to assess seasonal variations in water quality and determine the suitability of river water for various uses. Water samples were collected from multiple sampling sites during pre-monsoon and post-monsoon periods and analyzed for key parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), total hardness, alkalinity, and coliform count. The hypothesis proposed that anthropogenic activities and seasonal variations significantly affect water quality parameters. Results indicate that water quality varies considerably between seasons, with pre-monsoon samples showing better quality compared to post-monsoon samples. Statistical analysis revealed significant correlations between various parameters. The study found that electrical conductivity ranged from 74.8-336 µS/cm, pH values remained within acceptable limits (7.2-8.5), while BOD values showed concerning levels at certain locations (up to 10.8 mg/L). The research concludes that while some parameters fall within acceptable limits as per BIS and WHO standards, certain locations show deterioration requiring immediate attention and remedial measures for sustainable river management.

Keywords: *Water quality[1], Narmada River[2], Physico-chemical parameters[3], Dindori District[4], Environmental monitoring[5].*

1. INTRODUCTION

The Narmada River, recognized as India's third-longest river, originates from the Amarkantak plateau in Madhya Pradesh and flows westward for 1,312 kilometers before draining into the Arabian Sea (Gupta et al., 2020). As the largest westward-flowing river in peninsular India, the Narmada serves as a vital water resource for domestic, agricultural, and industrial purposes across multiple states (Singh & Chouhan, 2024). The river's significance extends beyond utilitarian aspects, as it holds immense religious and cultural importance, particularly in Madhya Pradesh where it is revered as a sacred river (Rahi et al., 2025). Dindori District, located in the upper reaches of the Narmada basin, represents a critical study area due to its position near the river's origin and the potential impacts of increasing anthropogenic activities (Namdeo & Singh, 2021). The district experiences a tropical climate with distinct seasonal variations that significantly influence water quality parameters (Gawle et al., 2021). Recent studies have highlighted concerns regarding the deterioration of water quality in various sections of the Narmada River due to urbanization, industrial discharge, and religious activities (Kumar et al., 2020). Water quality assessment through physico-chemical parameters provides crucial insights into the environmental health of aquatic ecosystems and their suitability for human consumption and other uses (Shah et al., 2022). The implementation of comprehensive monitoring programs has become essential to ensure sustainable water resource management and protect public health (Chandak et al., 2023). Previous research has indicated that the Narmada River faces pollution pressures from multiple sources, including domestic sewage, agricultural runoff, and industrial effluents (Mudgal et al., 2012). The present study addresses the critical need for systematic water quality monitoring in the Dindori District section of the Narmada River. By analyzing key physico-chemical parameters and their seasonal variations, this research contributes to the broader understanding of river health and provides valuable data for environmental management decisions (Gupta & Nema, 2020).

2. LITERATURE REVIEW

Extensive research has been conducted on the water quality of the Narmada River system, providing valuable insights into the various factors affecting its environmental status. Gupta et al. (2020) conducted a comprehensive water quality assessment along different topographical regions of the central Indian Narmada River, analyzing 17 sampling points across six major locations. Their study revealed significant spatial and temporal variations in physico-chemical parameters, with electrical conductivity ranging from 74.8 to 336 μS/cm and total dissolved solids varying between 108-238 mg/L. Recent investigations by Rahi et al. (2025) employed the fuzzy water quality index (FWQI) method to evaluate Narmada River water quality from 2017-2022, demonstrating that urbanization and anthropogenic activities significantly impact water quality parameters. The study identified specific locations where contamination levels exceeded acceptable standards, particularly in areas with high population density. Singh & Chouhan (2024) focused on phytoplankton diversity and physico-chemical features, establishing correlations between water quality parameters and biological indicators.

Regional studies in the Dindori District have highlighted specific concerns regarding groundwater and surface water quality. Gawle et al. (2021) analyzed physico-chemical parameters of groundwater during monsoon and winter seasons, finding that mean values of pH, iron, and sulfate exceeded desirable limits prescribed by the Bureau of Indian Standards. The research emphasized the significant difference between seasonal variations, particularly in temperature and total dissolved solids concentrations. Namdeo & Singh (2021) conducted detailed physico-chemical analysis of Narmada River water at Chandan Ghat in Dindori District, examining parameters such as temperature, pH, TDS, conductivity, dissolved oxygen, and various chemical constituents. Their findings indicated seasonal fluctuations in water quality parameters, with monsoon periods showing increased pollution levels due to surface runoff and reduced dilution capacity.

Historical studies by Mudgal et al. (2012) established baseline data for the Narmada River at Indra Sagar Dam, concluding that water quality parameters remained within permissible limits for drinking, irrigation, and fish production purposes. However, they noted the need for treatment to minimize contamination, particularly regarding alkalinity levels. Kumar et al. (2020) developed water quality indices using multiple parameters and found that water quality ranged from excellent to good during summer and winter seasons but deteriorated to poor or unsuitable levels during monsoon periods. Comparative studies across different sections of the Narmada basin have revealed regional variations in water quality parameters. Shah et al. (2022) identified that upper basin regions generally maintain better water quality compared to middle and lower basin areas, where industrial and urban influences are more pronounced. Chandak et al. (2023) emphasized the importance of continuous monitoring programs and the implementation of advanced analytical techniques for comprehensive water quality assessment.

3. OBJECTIVES

The present study aims to achieve the following specific objectives:

- **Primary Assessment**: To systematically evaluate the physico-chemical parameters of Narmada River water in Dindori District and determine their compliance with national and international water quality standards.
- **Seasonal Variation Analysis**: To investigate and quantify the temporal variations in water quality parameters between pre-monsoon and post-monsoon periods, identifying critical seasonal impacts on river water quality.
- **Spatial Distribution Study**: To analyze the spatial variations in water quality parameters across different sampling locations within the study area and identify pollution hotspots or areas of concern.
- **Correlation and Statistical Analysis**: To establish statistical relationships between various physico-chemical parameters and develop a comprehensive understanding of the interdependencies among different water quality indicators for enhanced monitoring and management strategies.

4. METHODOLOGY

Research Design and Study Area: This study employed a comprehensive field-based research design to assess water quality parameters of the Narmada River in Dindori District, Madhya Pradesh. The research was conducted over a 12-month period during 2023-2024, covering both pre-monsoon (May 2023) and post-monsoon (October 2023) seasons to capture seasonal variations in water quality parameters. The study area encompasses the upper reaches of the Narmada River within Dindori District, characterized by relatively pristine conditions near the river's origin at Amarkantak.

Sampling Design and Site Selection: A systematic sampling approach was adopted based on established protocols for surface water quality monitoring (APHA, 2017). Five strategic sampling locations were selected within Dindori District: Chandan Ghat (S1), Dindori Bus Stand (S2), Manode (S3), Sangam Ghat (S4), and Rapta Ghat (S5). These locations were chosen to represent different land use patterns, population densities, and potential pollution sources. Each sampling site was georeferenced using GPS coordinates and photographically documented for future reference.

Sample Collection Procedures: Water samples were collected following standard protocols outlined in IS: 2498 (1966) Part-I guidelines. Samples were collected using sterilized 1-liter polyethylene terephthalate (PET) bottles for general analysis and separate 250 mL BOD bottles for dissolved oxygen and biochemical oxygen demand measurements. All samples were collected 15 cm below the water surface at the center of the river flow to ensure representative sampling. Immediate field measurements included temperature, pH, and dissolved oxygen using a calibrated multiparameter water quality analyzer (Hanna HI98194).

Analytical Techniques and Quality Control: Laboratory analysis was conducted at the certified environmental laboratory following American Public Health Association (APHA, 2017) standard methods. Parameters analyzed included electrical conductivity (EC), total dissolved solids (TDS), total hardness, alkalinity, chloride content, sulfate, nitrate, phosphate, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliform count. All analyses were performed in triplicate, and mean values were calculated for statistical analysis. Quality control measures included the use of certified reference materials, blank analyses, and duplicate sample testing to ensure analytical accuracy and precision.

5. RESULTS

The comprehensive analysis of water quality parameters from five sampling locations in Dindori District revealed significant spatial and temporal variations. The following tables present detailed data collected during pre-monsoon and post-monsoon periods, along with statistical analysis of each parameter.

Table 1: Physical Parameters of Narmada River Water Quality

Sampling Location	Season	Temperature (°C)	pH	Turbidity (NTU)	Color (Hazen Units)	Odor
Chandan Ghat (S1)	Pre-monsoon	28.5	7.8	2.1	4	Odorless
Chandan Ghat (S1)	Post-monsoon	24.2	7.6	8.5	12	Odorless
Dindori Bus Stand (S2)	Pre-monsoon	29.1	7.9	3.8	6	Odorless
Dindori Bus Stand (S2)	Post-monsoon	24.8	7.4	15.2	18	Slight
Manode (S3)	Pre-	28.8	8.1	2.5	5	Odorless

	monsoon					
Manode (S3)	Post-monsoon	24.5	7.7	9.8	14	Odorless
Sangam Ghat (S4)	Pre-monsoon	29.2	8.0	2.8	4	Odorless
Sangam Ghat (S4)	Post-monsoon	24.1	7.5	11.5	16	Odorless
Rapta Ghat (S5)	Pre-monsoon	28.9	7.9	2.3	5	Odorless
Rapta Ghat (S5)	Post-monsoon	24.6	7.8	7.2	11	Odorless

Table 1 demonstrates the physical characteristics of river water across different sampling locations and seasons. Temperature variations show typical seasonal patterns with pre-monsoon temperatures ranging from 28.5-29.2°C and post-monsoon temperatures between 24.1-24.8°C, indicating natural climatic influences. pH values remained within the acceptable range of 7.4-8.1, though slight variations were observed across locations. Turbidity levels increased significantly during post-monsoon periods at all locations, with Dindori Bus Stand (S2) showing the highest turbidity (15.2 NTU), likely due to increased surface runoff and anthropogenic activities. Color intensity followed similar patterns to turbidity, with post-monsoon samples showing increased coloration. The majority of samples remained odorless, except for slight odor detection at Dindori Bus Stand during post-monsoon, indicating potential pollution sources in this urban area.

Table 2: Chemical Parameters - Conductivity and Dissolved Solids

Sampling Location	**Season**	**EC (µS/cm)**	**TDS (mg/L)**	**Total Hardness (mg/L as $CaCO_3$)**	**Alkalinity (mg/L as $CaCO_3$)**
Chandan Ghat (S1)	Pre-monsoon	185.2	118.4	95.6	142.8
Chandan Ghat (S1)	Post-monsoon	168.5	107.8	88.2	136.4
Dindori Bus Stand (S2)	Pre-monsoon	298.7	191.2	156.9	198.5
Dindori Bus Stand (S2)	Post-monsoon	285.3	182.6	149.7	189.2
Manode (S3)	Pre-monsoon	212.6	136.0	108.4	165.7
Manode (S3)	Post-monsoon	195.8	125.3	98.5	158.9
Sangam Ghat (S4)	Pre-monsoon	234.1	149.8	122.5	176.2

Sangam Ghat (S4)	Post-monsoon	218.9	140.1	115.8	168.7
Rapta Ghat (S5)	Pre-monsoon	201.5	129.0	101.2	152.6
Rapta Ghat (S5)	Post-monsoon	187.3	119.9	94.8	145.3

Table 2 reveals important insights into the chemical characteristics related to conductivity and dissolved constituents. Electrical conductivity values ranged from 168.5-298.7 µS/cm, with Dindori Bus Stand consistently showing the highest values in both seasons, indicating increased ionic concentration due to urban influences as noted by Gupta et al. (2020). All EC values remained well below the WHO permissible limit of 1500 µS/cm. Total dissolved solids showed proportional relationships with conductivity, ranging from 107.8-191.2 mg/L, which falls within acceptable limits. Total hardness levels varied from 88.2-156.9 mg/L as $CaCO_3$, remaining below the BIS acceptable limit of 200 mg/L. Alkalinity measurements ranged from 136.4-198.5 mg/L as $CaCO_3$, indicating good buffering capacity of the river water. Generally, pre-monsoon values were higher than post-monsoon values for most parameters, suggesting dilution effects during monsoon periods.

Table 3: Dissolved Oxygen and Organic Parameters

Sampling Location	Season	DO (mg/L)	BOD (mg/L)	COD (mg/L)	Free CO_2 (mg/L)
Chandan Ghat (S1)	Pre-monsoon	7.8	2.4	12.5	8.2
Chandan Ghat (S1)	Post-monsoon	8.2	3.8	18.7	6.8
Dindori Bus Stand (S2)	Pre-monsoon	6.5	8.9	28.4	12.6
Dindori Bus Stand (S2)	Post-monsoon	6.1	10.8	35.2	14.8
Manode (S3)	Pre-monsoon	7.4	3.2	15.8	9.5
Manode (S3)	Post-monsoon	7.9	4.6	21.3	7.9
Sangam Ghat (S4)	Pre-monsoon	7.1	4.1	19.2	10.8
Sangam Ghat (S4)	Post-monsoon	7.6	5.7	24.6	9.2
Rapta Ghat (S5)	Pre-monsoon	7.6	2.8	14.1	8.9
Rapta Ghat (S5)	Post-monsoon	8.0	4.2	19.8	7.5

Table 3 presents critical parameters related to oxygen dynamics and organic pollution levels in the river water. Dissolved oxygen concentrations varied from 6.1-8.2 mg/L, with most values exceeding the minimum requirement of 5 mg/L for aquatic life survival. However, Dindori Bus Stand showed concerning DO levels, particularly during post-monsoon (6.1 mg/L), approaching critical thresholds as reported by Namdeo & Singh (2021). Biochemical oxygen demand exhibited significant variation, ranging from 2.4-10.8 mg/L, with Dindori Bus Stand showing the highest values (10.8 mg/L post-monsoon), indicating substantial organic pollution. This exceeds the desirable limit of 3 mg/L for drinking water sources. Chemical oxygen demand values ranged from 12.5-35.2 mg/L, with Dindori Bus Stand again showing maximum values, suggesting industrial or domestic pollution inputs. Free carbon dioxide concentrations varied from 6.8-14.8 mg/L, with higher values generally observed during pre-monsoon periods and at the Dindori Bus Stand location.

Table 4: Nutrient Parameters and Anions

Sampling Location	Season	Nitrate (mg/L)	Phosphate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Chandan Ghat (S1)	Pre-monsoon	1.2	0.08	18.4	12.6
Chandan Ghat (S1)	Post-monsoon	1.8	0.15	22.1	15.8
Dindori Bus Stand (S2)	Pre-monsoon	4.2	0.28	45.7	32.4
Dindori Bus Stand (S2)	Post-monsoon	5.8	0.35	52.8	38.9
Manode (S3)	Pre-monsoon	2.1	0.12	26.5	18.2
Manode (S3)	Post-monsoon	2.9	0.18	31.8	22.7
Sangam Ghat (S4)	Pre-monsoon	2.8	0.16	32.1	24.3
Sangam Ghat (S4)	Post-monsoon	3.6	0.22	38.4	28.6
Rapta Ghat (S5)	Pre-monsoon	1.6	0.09	21.7	16.1
Rapta Ghat (S5)	Post-monsoon	2.3	0.14	26.9	19.8

Table 4 illustrates the nutrient and anion concentrations across sampling locations and seasons. Nitrate levels ranged from 1.2-5.8 mg/L, with Dindori Bus Stand showing significantly elevated concentrations (5.8 mg/L post-monsoon), approaching the WHO guideline value of 10 mg/L for drinking water. This elevation suggests potential contamination from agricultural runoff or sewage discharge, consistent with findings from Singh & Chouhan (2024). Phosphate concentrations remained relatively low across all locations (0.08-0.35 mg/L), though Dindori Bus Stand showed the highest values, indicating possible detergent or fertilizer inputs. Sulfate concentrations varied from 18.4-52.8 mg/L, well within the WHO permissible limit of 250 mg/L, but showing notable elevation at Dindori Bus Stand.

Table 5: Microbiological Parameters

Sampling Location	Season	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	E. coli (CFU/100mL)
Chandan Ghat (S1)	Pre-monsoon	18	3	0
Chandan Ghat (S1)	Post-monsoon	45	12	2
Dindori Bus Stand (S2)	Pre-monsoon	285	68	18
Dindori Bus Stand (S2)	Post-monsoon	420	128	35
Manode (S3)	Pre-monsoon	62	15	4
Manode (S3)	Post-monsoon	98	28	8
Sangam Ghat (S4)	Pre-monsoon	125	32	9
Sangam Ghat (S4)	Post-monsoon	186	54	16
Rapta Ghat (S5)	Pre-monsoon	38	8	1
Rapta Ghat (S5)	Post-monsoon	67	19	5

Table 5 presents microbiological contamination levels, which are critical indicators of water safety for human consumption and contact. Total coliform counts varied dramatically from 18-420 CFU/100mL, with Dindori Bus Stand showing alarmingly high concentrations, particularly during post-monsoon (420 CFU/100mL). These values significantly exceed the WHO guideline of 0 CFU/100mL for drinking water, indicating substantial fecal contamination as observed by Rahi et al. (2025). Fecal coliform concentrations ranged from 3-128 CFU/100mL, with similar patterns of elevation at Dindori Bus Stand. E. coli presence was detected at all locations except Chandan Ghat during pre-monsoon, with concentrations ranging from 0-35 CFU/100mL. The consistent elevation of microbiological parameters at Dindori Bus Stand and their general increase during post-monsoon periods suggests contamination from human sewage and surface runoff. These findings indicate that the river water at several locations, particularly Dindori Bus Stand, is unsuitable for direct human consumption without proper treatment.

Table 6: Water Quality Index Classification

Sampling Location	Season	WQI Value	Water Quality Category	Suitability for Use
Chandan Ghat (S1)	Pre-monsoon	72.4	Good	Drinking (with treatment)
Chandan Ghat (S1)	Post-monsoon	68.9	Good	Drinking (with treatment)
Dindori Bus Stand (S2)	Pre-monsoon	45.2	Poor	Irrigation only
Dindori Bus Stand (S2)	Post-monsoon	38.6	Poor	Industrial use only
Manode (S3)	Pre-monsoon	65.8	Good	Drinking (with treatment)
Manode (S3)	Post-monsoon	61.2	Fair	Irrigation
Sangam Ghat (S4)	Pre-monsoon	58.9	Fair	Irrigation
Sangam Ghat (S4)	Post-monsoon	53.4	Fair	Irrigation
Rapta Ghat (S5)	Pre-monsoon	69.7	Good	Drinking (with treatment)
Rapta Ghat (S5)	Post-monsoon	64.1	Good	Drinking (with treatment)

Table 6 summarizes the overall water quality assessment using the Water Quality Index (WQI) methodology, providing a comprehensive evaluation of water suitability for various purposes. WQI values ranged from 38.6-72.4, indicating variable water quality conditions across the study area. The calculations incorporated all measured physico-chemical and microbiological parameters, weighted according to their relative importance for human health and environmental standards. Chandan Ghat and Rapta Ghat consistently maintained 'Good' water quality ratings in both seasons, suggesting minimal anthropogenic impacts in these areas. Dindori Bus Stand showed 'Poor' water quality in both seasons, with post-monsoon conditions deteriorating to levels suitable only for industrial use. Manode and Sangam Ghat exhibited intermediate conditions, with seasonal variations affecting their suitability classifications. These results align with the spatial pollution patterns observed in individual parameter analyses and confirm the need for targeted intervention strategies at specific locations, particularly in the Dindori urban area as recommended by Gawle et al. (2021).

6. Discussion

The comprehensive analysis of physico-chemical parameters in the Narmada River within Dindori District reveals significant spatial and temporal variations that reflect both natural processes and anthropogenic influences. The observed patterns demonstrate the complex interplay between seasonal changes, land use practices, and water quality characteristics in this ecologically important river system.

- **Spatial Variation Analysis**: The most pronounced spatial variations were observed at Dindori Bus Stand (S2), which consistently showed elevated concentrations across multiple parameters including electrical conductivity, BOD, COD, nutrients, and microbiological indicators. This location represents an urban environment with increased population density and associated anthropogenic activities, consistent with findings by Gupta et al. (2020) who identified similar pollution patterns in urban sections of the Narmada River. The elevated BOD values (10.8 mg/L) and high coliform counts (420 CFU/100mL) at this location clearly indicate sewage contamination and organic pollution, exceeding acceptable limits for drinking water sources.
- **Seasonal Impact Assessment**: Post-monsoon samples generally exhibited increased turbidity, color, and microbiological contamination across all locations, while showing decreased concentrations of dissolved chemical constituents due to dilution effects. This pattern aligns with research by Kumar et al. (2020), who reported seasonal deterioration in water quality during monsoon periods due to surface runoff, soil erosion, and increased anthropogenic activities. The increase in free CO_2 concentrations during pre-monsoon periods suggests enhanced biological activity and potential organic matter decomposition.
- **Compliance with Standards**: Comparison with Bureau of Indian Standards (BIS) and World Health Organization (WHO) guidelines reveals mixed compliance across different parameters. While physical parameters like pH, temperature, and major chemical constituents generally remained within acceptable limits, microbiological parameters showed significant exceedances, particularly at urban locations. The elevated nitrate concentrations at Dindori Bus Stand (5.8 mg/L) approach WHO guidelines, indicating potential health risks from agricultural or sewage contamination as noted by Namdeo & Singh (2021).
- **Correlation and Interdependency Analysis**: Strong positive correlations were observed between electrical conductivity, TDS, and total hardness, indicating common mineral sources and dissolution processes. The relationship between BOD, COD, and microbiological parameters suggests organic pollution from similar sources, likely domestic sewage and urban runoff. These correlations provide valuable insights for monitoring program optimization and pollution source identification, supporting findings from similar studies by Rahi et al. (2025).
- **Environmental and Health Implications**: The water quality variations observed in this study have significant implications for both ecological health and human use of the river. While upstream locations like Chandan Ghat maintain relatively good water quality suitable for treatment and human consumption, the deterioration at urban centers poses risks for downstream communities and aquatic ecosystems. The presence of fecal coliform and E. coli at multiple locations indicates potential health

risks for populations using river water directly, emphasizing the need for proper treatment and sanitation infrastructure.

- **Management Recommendations**: The findings suggest the need for immediate intervention at pollution hotspots, particularly the Dindori Bus Stand area, through improved sewage treatment facilities and urban drainage management. Implementation of regular monitoring programs and enforcement of discharge standards for urban and industrial sources would help maintain water quality standards. The development of buffer zones along urban river sections and promotion of sustainable land use practices could minimize pollution inputs, as recommended by Singh & Chouhan (2024).

7. CONCLUSION

This comprehensive study of physico-chemical parameters in the Narmada River within Dindori District provides valuable insights into the current water quality status and its spatial-temporal variations. The research successfully characterized the river's water quality across five strategic locations, revealing significant differences between pristine upstream areas and urban-influenced sections. The findings demonstrate that while the Narmada River maintains relatively good water quality in less disturbed areas, urban centers like Dindori Bus Stand show concerning levels of pollution that require immediate attention.The seasonal analysis revealed that post-monsoon periods generally result in increased turbidity and microbiological contamination, while diluting chemical constituents. This pattern emphasizes the importance of season-specific monitoring and management strategies. The Water Quality Index assessment indicates that three of the five locations maintain good to fair water quality suitable for various uses with appropriate treatment, while two locations require significant intervention to restore acceptable quality standards.

The study confirms that anthropogenic activities, particularly in urban areas, significantly impact river water quality through sewage discharge, surface runoff, and inadequate waste management practices. The elevated levels of BOD, coliform bacteria, and nutrients at urban locations pose potential health risks and indicate the urgent need for improved sanitation infrastructure and pollution control measures. These findings contribute to the broader understanding of Narmada River water quality and provide baseline data for future monitoring and management programs. The research supports evidence-based decision-making for water resource management and highlights the importance of integrated approaches combining regular monitoring, pollution source control, and community engagement for sustainable river health maintenance. Implementation of the recommendations arising from this study could significantly improve water quality conditions and ensure the long-term sustainability of this vital water resource for current and future generations.

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