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Rivers of Resilience: Assessing Hydrological Baseline Data for Nature-Based Conservation in the Yala River Watershed

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Abstract

The Yala River Watershed, like many other catchment areas worldwide, faces a multitude of environmental challenges that threaten its ecological integrity and the sustainability of the communities it supports. The "Yala River Watershed Catchment Protection Project" aims to implement nature-based conservation measures to preserve the ecological integrity of the Yala River watershed. This research publication presents the methodology and results of a hydrological and water quality assessment carried out at six monitoring points strategically located at sub-catchment confluences within the watershed. The data collected from these monitoring points provide valuable insights into the current state of the hydrological regime and water quality parameters in the region. To establish the baseline hydrological conditions, discharge measurements were conducted using an Acoustic Doppler Current Velocimeter (ADV) at each monitoring point. The results revealed substantial variations in discharge rates across the points. The Cheplelachbei monitoring point showed a discharge of 0.5687 cubic meters per second, Kesses recorded 0.864 cubic meters per second, Kiutany had 0.297 cubic meters per second, Kipgorgot exhibited 1.240 cubic meters per second, Yala at Tindinyo had 18.750 cubic meters per second, and Chepkumia displayed 0.4361 cubic meters per second. Water quality analysis was also conducted at these monitoring points, including pH levels, turbidity, and nitrate concentrations. Cheplelachbei and Kiutany rivers showed acceptable pH levels, falling within the range of 5.5 - 9.5, indicating a relatively balanced aquatic environment. However, Cheplelachbei exhibited elevated turbidity levels at 40.5 Nephelometric Turbidity Units (N.T.U), surpassing the standard maximum limit of 25 N.T.U, while Kiutany displayed turbidity of 100 N.T.U. Kiutany's nitrate concentration of 10 mg NO_3^- L^{-1} was well below the standard maximum limit of 45 mgNO_3 - L^{-1}, implying a positive sign for human health and aquatic life. In conclusion, the findings indicated alarming levels of sedimentation, increased soil erosion, and declining water quality, attributing these issues to human activities. Based on the results, one recommendation is to implement targeted afforestation and reforestation programs in erosion-prone areas to minimize soil erosion and sedimentation. Such measures can effectively reduce the sediment load entering water bodies, thereby improving water quality and supporting biodiversity. The findings from this study serve as a crucial baseline for monitoring and evaluating the effectiveness of the proposed nature-based conservation measures. By establishing the current hydrological and water quality conditions, this research provides essential data to assess the impact of future conservation efforts on the Yala River watershed. The results will aid in the formulation of targeted conservation strategies, ensuring the sustainable management of water resources and the protection of aquatic ecosystems in the region. As the "Yala Water Fund" project progresses, these research-based findings will play a pivotal role in guiding evidence-based decisions for the preservation of this vital watershed.

Subject Areas

Environmental Sciences

Keywords

Yala River Watershed, Hydrological Monitoring, Water Quality Assessment, Nature-Based Conservation, River Discharge, Sub Catchment Confluences, Water Resource Management, RUSLE Analysis, Aquatic Environment, Environmental Impact, Ecosystem Conservation, Water Fund Project, East Africa Rivers, Water Resource Sustainability, Environmental Monitoring

1. Introduction

Water resources are essential for the survival of all living organisms, playing a crucial role in sustaining life and maintaining ecological balance. However, the quality and availability of these resources are increasingly threatened by anthropogenic activities, leading to the degradation and loss of these vital resources. The Yala River Watershed, a critical water catchment area in Kenya, is no exception. The Yala River Watershed in Kenya, one of the most significant catchment areas in the Lake Victoria Basin, has been a focal point of conservation and restoration initiatives in recent years. The watershed, covering approximately 3400 square kilometers, is home to a rich diversity of flora and fauna and plays a crucial role in supporting the livelihoods of local communities, primarily through agriculture and fishing (Lake Victoria Basin Commission [LVBC], 2018) [1]. This watershed is currently facing significant threats from various human activities, leading to the degradation of water quality and hydrological imbalances (Clausen, 2020) [2]. These challenges have not only undermined the ecological health of the watershed but have also affected the socio-economic well-being of the communities that depend on these resources for their livelihoods.

The Yala River Watershed Catchment Protection Project was initiated to address these challenges. The project aims to monitor the impact of proposed nature-based conservation measures on the watershed's hydrological and water quality parameters. This study is based on the hydrological baseline data collected from six monitoring points identified through a Revised Universal Soil Loss Equation (RUSLE) analysis conducted by The Nature for Water Facility (TNC) Kenya.

1.1. Background of the Study

Watershed management is a critical aspect of environmental conservation, ensuring the sustainability of water resources for future generations (Clausen, 2020) [2]. The process involves the collection of baseline data to understand the current state of the watershed and to monitor changes over time (Good Practices for the Collection of Biodiversity Baseline Data, 2018) [3]. In the context of the Yala River Watershed, the RUSLE analysis has been instrumental in identifying areas of concern and monitoring points (Revised Universal Soil Loss Equation (RUSLE), 2012) [4].

Water quality monitoring is a vital component of watershed management, providing data on the impacts of human activities and conservation measures on water resources (Water Quality Monitoring and Assessment in a Developing Country, 2012) [5]. Nature-based conservation measures have been increasingly recognized for their potential to enhance water quality and overall watershed health (Nature-based Measures Increase Freshwater Biodiversity in agricultural catchments, 2020) [6].

However, there is a gap in the literature on the specific impact of nature-based conservation measures on the hydrological and water quality parameters in the Yala River Watershed. Furthermore, the impact of conservation activities on water quality is a complex issue that requires further investigation (Impact of crop rotations on optimal selection of conservation practices for water quality protection, 2010) [7].

1.2. Problem Statement

The Yala River Watershed is facing significant threats from human activities leading to degradation of water quality and hydrological imbalances. Despite the implementation of various conservation measures, there is a lack of comprehensive data on their impact on the watershed's hydrological and water quality parameters. This gap in knowledge hinders the effective implementation and monitoring of conservation measures.

1.3. Objectives of the Study

The primary objective of this study is to collect and analyze hydrological baseline data from the identified monitoring points in the Yala River Watershed. The specific objective was to collect baseline hydrological data from the identified monitoring points in the Yala River Watershed.

1.4. Significance of the Study

This study will provide valuable data on the current state of the Yala River Watershed and inform the implementation of effective conservation strategies. The findings will contribute to the sustainable management of water resources in the watershed and fill a gap in the literature on the impact of nature-based conservation measures on hydrological and water quality parameters in the Yala River Watershed.

2. Methodology

The study involved the selection of six monitoring points in the Yala River watershed to assess the impact of proposed nature-based conservation measures. The monitoring points were chosen based on the results of a Revised Universal Soil Loss Equation (RUSLE) analysis conducted by The Nature Kenya (TNC) Water Facility, which identified several hotspots in the sub-catchments confluences. Additional monitoring points were considered after the first field visit to effectively monitor the implementation impacts downstream of the conservation activities.

1) Chepkunyuk Area Monitoring Point - Chelelachbei River:

- The monitoring point was identified about 20 m upstream of the confluence of Chelelachbei River and Mokong River.
- GPS coordinates of the monitoring point: 00.161418˚N and 035.203564˚E.
- River discharge measurement was taken using an Acoustic Doppler Current Velocimeter (ADV).
- In-situ water quality analysis was conducted, and a water sample was collected for physicochemical analysis in the laboratory.

2) Ndubeti Area Monitoring Point - Kesses River:

- The monitoring point was identified at the Sinendet location bridge on Kesses River, a tributary of the Kimondi River.
- GPS coordinates of the monitoring point: 00.161418˚N and 035.203564˚E.

3) Chepkatet (Kapsisywo) Monitoring Point - Kiutany River:

- The monitoring point was chosen just before Kiutany River entered the swamp reeds on a canal-like stretch in the Kapsisywo location, Chepkober sub-location.
- GPS coordinates of the monitoring point: latitude 00.289143˚N, longitude 035.068713˚E, and altitude 1916 m.

4) Tulon Area Monitoring Point - Kipgorgot River:

- The monitoring point was selected 10 m upstream of Kipgorgot village wooden bridge in the Tulon area of the Upper Yala River watershed.
- GPS coordinates of the monitoring point: latitude 0.275363˚N, longitude 35.201547˚E, and altitude 1959 m.

5) Tindinyo Area Monitoring Point - Yala River 1FE02:

- Yala River 1FE02 station is one of the Water Resources Authority's River gauging stations (RGS) located in the Tindinyo area.
- Baseline discharge flow measurement was done 200 m upstream of the old colonial bridge.
- GPS coordinates of the monitoring point: latitude 0.181217˚N, longitude 34.937958˚E, and altitude 1682.95 m.

6) Chepkumia Area Monitoring Point - Chepkumia River:

- The monitoring point was selected at Kaimosi Tea Estate, upstream at the mouth of the road box Culvert.
- GPS coordinates of the monitoring point: latitude 0.136123˚N, longitude 34.937568˚E, and altitude 1761.11 m.

7) Chepkumia Area Monitoring Point - Kimach River:

- An additional monitoring point was assessed for Kimach River, located within the Chepkumia area, about 3 m upstream of the Murrum road bridge.
- GPS coordinates of the monitoring point: latitude 0.144005˚N, longitude 34.947013˚E, and altitude 1760.01 m.

At each monitoring point, discharge measurements were taken using an Acoustic Doppler Current Velocimeter (ADV), and *in-situ* water quality analysis was conducted. Water samples were collected for physicochemical analysis in the laboratory. The data collected from these monitoring points will be crucial in assessing the impact of the proposed nature-based conservation measures as they are implemented in the Yala River watershed.

3. Results

The Cheplelachbei River's baseline water quality assessment reveals a comprehensive understanding of the river's health and its suitability for various uses. The assessment employed a range of analytical methods to measure different parameters, comparing the results with the KS EAS 12:2018 standards. The pH level of the river, a crucial indicator of the water's acidity or alkalinity, was found to be 8.2. This value comfortably sits within the acceptable range of 5.5 - 9.5, suggesting a balanced aquatic environment that can support a variety of life forms. However, the river's turbidity level, which measures the cloudiness or haziness of the water, was found to be 40.5 N.T.U. This value exceeds the standard maximum limit of 25 N.T.U. according to APHA (American Public Health Association (2005)-standard methods for the examination of water & wastewater), indicating the presence of many particles in the water that could affect its clarity. High turbidity can impact aquatic life and may indicate issues with erosion or runoff in the watershed. The conductivity of the river water at 25 degrees Celsius was measured to be 140 μ·cm^{-1}. This value is significantly below the standard maximum limit of 2500 μ·cm^{-1}, indicating a low concentration of dissolved salts and other inorganic materials in the water. The total alkalinity of the river, a measure of its ability to neutralize acids, was found to be 64 mg $CaCO_3$ L^{-1}. This value is well below the WHO maximum guideline value of 500 mg $CaCO_3$ L^{-1}, suggesting that the river has a good buffering capacity against potential pH changes. The nitrate concentration in the river was found to be 15 mg NO_3^- L^{-1}, which is below the standard maximum limit of 45 mg NO_3^- L^{-1}. This is a positive sign as high nitrate levels can be harmful to human health and can also contribute to eutrophication, a process that can deplete oxygen levels in the water and harm aquatic life. The sulfate concentration was found to be less than 0.01 mg·L^{-1}, significantly below the standard maximum limit of 400 mg·L^{-1}. This low level of sulfate suggests that the river is not being significantly impacted by industrial waste or other sources of sulfate pollution. The daily sediment load of the river was found to be 1.3 tonnes/day. This measure indicates the amount of soil and other particles being transported by the river, which can impact water clarity and quality. Finally, the total dissolved solids in the river were found to be 110 mg·L^{-1}, well below the standard maximum limit of 1500 mg·L^{-1}. This suggests that the water is relatively free of dissolved salts, organic matter, and other substances. In conclusion, the Cheplelachbei River's water quality is generally within acceptable limits, with the notable exception of its turbidity level. (**Table 1**)

The baseline water quality assessment of the Kesses River provides a detailed snapshot of the river's current state. The results, obtained using various analytical methods, were compared to the KS EAS 12:2018 standards. The pH level of the river, a key indicator of the water's acidity or alkalinity, was found to be 8.1. This value is comfortably within the acceptable range of 5.5 - 9.5, indicating a balanced aquatic environment that can support diverse life forms. However, the turbidity level of the river, which measures the cloudiness or haziness of the water, was found to be 114 N.T.U. This value significantly exceeds the standard maximum limit of 25 N.T.U, suggesting the presence of a high number of particles in the water that could affect its clarity. High turbidity can impact aquatic life and may indicate issues with erosion or runoff in the watershed. The conductivity of the river water at 25 degrees Celsius was measured to be 100 μ·cm^{-1}. This value is significantly below the standard maximum limit of 2500 μ·cm^{-1}, indicating a low concentration of dissolved salts and other inorganic materials in the water. The total alkalinity of the river, a measure of its ability to neutralize acids, was found to be 64 mg $CaCO_3$ L^{-1}. This value is well below the WHO maximum guideline value of 500 mg $CaCO_3$ L^{-1}, suggesting that the river has a good buffering capacity against potential pH changes. The chloride concentration in the river was found to be 11 mg·L^{-1}, which is well below the standard maximum limit of 250 mg·L^{-1}. This low concentration of chloride suggests that the river is not being significantly impacted by saltwater intrusion or other sources of chloride pollution. The nitrate concentration in the river was found to

Table 1. Cheplelachbei river baseline water quality assessment.

Parameters	Unit	Analytical method	Results	KS EAS 12: 2018 standards (Max.)
Temperature	˚C			
Ph	pH scale	APHA 4500-H^+B	8.2	5.5 - 9.5 (6.5 - 8.5)*
Color	mg Pt L^{-1}	APHA 2120 B		50 (15)*
Turbidity	N.T.U	APHA 2130 B	40.5	25 (5)*
Conductivity (25 degrees C)	μ·cm^{-1}	APHA 2510 B	140	2500 (1500)*
Iron	mg·L^{-1}	APHA 3500-Fe B		0.3
Manganese	mg·L^{-1}	APHA 3500-Mn B		0.1
Calcium	mg·L^{-1}	APHA 3500-Ca B		150
Magnesium	mg·L^{-1}	APHA 3500-Mg B		100
Total hardness	mg $CaCO_3$ L^{-1}	APHA 2340 C		600 (300)*
Total alkalinity	mg $CaCO_3$ L^{-1}	APHA 2320 B	64	500**
Chloride	mg·L^{-1}	APHA 4500-Cl^- B	2	250
Fluoride	mg·L^{-1}	APHA 4500-F^- C		1.5
Nitrate	mg NO_3^- L^{-1}	APHA 4500- NO_3^- D	15	45
Nitrite	mg NO_3^- N·L^{-1}	APHA 4500- NO_2^- B		0.9
Sulphate	mg·L^{-1}	APHA 4500- SO_4^{2-} E	<0.01	400
Total suspended solids	mg·L^{-1}	APHA2540 D	26.5	
Daily sediment load	Tonnes/day		1.3	
Total dissolved solids	mg·L^{-1}	APHA 2510 A	110	1500 (1000)*

*Maximum limits for treated potable water; **WHO maximum guidelines value; APHA: American Public Health Association (2005)-standard methods for the examination of water & wastewater.

be 8 mg NO_3^- L^{-1}, which is below the standard maximum limit of 45 mg NO_3^- L^{-1}. This is a positive sign as high nitrate levels can be harmful to human health and can also contribute to eutrophication, a process that can deplete oxygen levels in the water and harm aquatic life. The sulfate concentration was found to be less than 0.01 mg·L^{-1}, significantly below the standard maximum limit of 400 mg·L^{-1}. This low level of sulfate suggests that the river is not being significantly impacted by industrial waste or other sources of sulfate pollution. The daily sediment load of the river was found to be 1.9 tonnes/day. This measure indicates the amount of soil and other particles being transported by the river, which can impact water clarity and quality. Finally, the total dissolved solids in the river were found to be 90 mg·L^{-1}, well below the standard maximum limit of 1500 mg·L^{-1}. This suggests that the water is relatively free of dissolved salts, organic matter, and other substances. In conclusion, the Kesses River's water quality is generally within acceptable limits, with the notable exception of its turbidity level. (Table 2)

Table 2. Kesses river baseline water quality assessment.

Parameters	Unit	Analytical method	Results	KS EAS 12: 2018 standards (Max.)
Temperature	˚C			
Ph	pH scale	APHA 4500-H$^+$B	8.1	5.5 - 9.5 (6.5 - 8.5)*
Color	mg Pt L^{-1}	APHA 2120 B		50 (15)*
Turbidity	N.T.U	APHA 2130 B	114	25 (5)*
Conductivity (25 degrees C)	µ·cm^{-1}	APHA 2510 B	100	2500 (1500)*
Iron	mg·L^{-1}	APHA 3500-Fe B		0.3
Manganese	mg·L^{-1}	APHA 3500-Mn B		0.1
Calcium	mg·L^{-1}	APHA 3500-Ca B		150
Magnesium	mg·L^{-1}	APHA 3500-Mg B		100
Total hardness	mg $CaCO_3$ L^{-1}	APHA 2340 C		600 (300)*
Total alkalinity	mg $CaCO_3$ L^{-1}	APHA 2320 B	64	500**
Chloride	mg·L^{-1}	APHA 4500-Cl^- B	11	250
Fluoride	mg·L^{-1}	APHA 4500-F^- C		1.5
Nitrate	mg NO_3^- L^{-1}	APHA 4500- NO_3^- D	8	45
Nitrite	mg NO_3^- N L^{-1}	APHA 4500- NO_2^- B		0.9
Sulphate	mg·L^{-1}	APHA 4500- SO_4^{2-} E	<0.01	400
Total suspended solids	mg·L^{-1}	APHA2540 D	25.5	
Daily sediment load	Tonnes/day		1.9	
Total dissolved solids	mg·L^{-1}	APHA 2510 A	90	1500 (1000)*

*Maximum limits for treated potable water; **WHO maximum guidelines value; APHA: American Public Health Association (2005)-standard methods for the examination of water & wastewater.

The baseline water quality assessment of the Kiutany River provides a detailed understanding of the river's current state. The results, obtained using various analytical methods, were compared to the KS EAS 12:2018 standards. The pH level of the river, a key indicator of the water's acidity or alkalinity, was found to be 8.3. This value is comfortably within the acceptable range of 5.5 - 9.5, indicating a balanced aquatic environment that can support diverse life forms. However, the turbidity level of the river, which measures the cloudiness or haziness of the water, was found to be 100 N.T.U. This value significantly exceeds the standard maximum limit of 25 N.T.U, suggesting the presence of a high number of particles in the water that could affect its clarity. High turbidity can impact aquatic life and may indicate issues with erosion or runoff in the watershed. The conductivity of the river water at 25 degrees Celsius was measured to be 40 $\mu \cdot cm^{-1}$. This value is significantly below the standard maximum limit of 2500 $\mu \cdot cm^{-1}$, indicating a low concentration of dissolved salts and other inorganic materials in the water. The total alkalinity of the river, a measure of its ability to neutralize acids, was found to be 30 mg $CaCO_3$ L^{-1}. This value is well below the WHO maximum guideline value of 500 mg $CaCO_3$ L^{-1}, suggesting that the river has a good buffering capacity against potential pH changes. The chloride concentration in the river was found to be 1 $mg \cdot L^{-1}$, which is well below the standard maximum limit of 250 $mg \cdot L^{-1}$. This low concentration of chloride suggests that the river is not being significantly impacted by saltwater intrusion or other sources of chloride pollution. The nitrate concentration in the river was found to be 10 mg NO_3^- L^{-1}, which is below the standard maximum limit of 45 mg NO_3^- L^{-1}. This is a positive sign as high nitrate levels can be harmful to human health and can also contribute to eutrophication, a process that can deplete oxygen levels in the water and harm aquatic life. The sulfate concentration was found to be less than 0.01 $mg \cdot L^{-1}$, significantly below the standard maximum limit of 400 $mg \cdot L^{-1}$. This low level of sulfate suggests that the river is not being significantly impacted by industrial waste or other sources of sulfate pollution. The total suspended solids in the river were found to be 84.5 $mg \cdot L^{-1}$. This measure indicates the amount of particles in the water, which can impact water clarity and quality. The daily sediment load of the river was found to be 2.13 tonnes/day. This measure indicates the amount of soil and other particles being transported by the river, which can impact water clarity and quality. Finally, the total dissolved solids in the river were found to be 28 $mg \cdot L^{-1}$, well below the standard maximum limit of 1500 $mg \cdot L^{-1}$. This suggests that the water is relatively free of dissolved salts, organic matter, and other substances. In conclusion, the Kiutany River's water quality is generally within acceptable limits, with the notable exception of its turbidity level. (**Table 3**)

The baseline discharge summary of the Yala River at Tindinyo provides a detailed understanding of the river's flow characteristics. The discharge calculation settings and results were obtained using various methods and measurements. The river's width was measured to be 17.361 meters, and the area was calculated to be 28.360 square meters. The mean speed of the river was found to be 0.661

Table 3. Kiutany river baseline water quality assessment.

Parameters	Unit	Analytical method	Results	KS EAS 12: 2018 standards (Max.)
Temperature	˚C			
Ph	pH scale	APHA 4500-H^+B	8.3	5.5 - 9.5 (6.5 - 8.5)*
Color	mg Pt L^{-1}	APHA 2120 B		50 (15)*
Turbidity	N.T.U	APHA 2130 B	100	25 (5)*
Conductivity (25 degrees C)	μ·cm^{-1}	APHA 2510 B	40	2500 (1500)*
Iron	mg·L^{-1}	APHA 3500-Fe B		0.3
Manganese	mg·L^{-1}	APHA 3500-Mn B		0.1
Calcium	mg·L^{-1}	APHA 3500-Ca B		150
Magnesium	mg·L^{-1}	APHA 3500-Mg B		100
Total hardness	mg $CaCO_3$ L^{-1}	APHA 2340 C		600 (300)*
Total alkalinity	mg $CaCO_3$ L^{-1}	APHA 2320 B	30	500**
Chloride	mg·L^{-1}	APHA 4500-Cl^- B	1	250
Fluoride	mg·L^{-1}	APHA 4500-F^- C		1.5
Nitrate	mg NO_3^- L^{-1}	APHA 4500- NO_3^- D	10	45
Nitrite	mg NO_3^- N L^{-1}	APHA 4500- NO_2^- B		0.9
Sulphate	mg·L^{-1}	APHA 4500- SO_4^{2-} E	<0.01	400
Total suspended solids	mg·L^{-1}	APHA2540 D	84.5	
Daily sediment load	Tonnes/day		2.13	
Total dissolved solids	mg·L^{-1}	APHA 2510 A	28	1500 (1000)*

*Maximum limits for treated potable water; **WHO maximum guidelines value; APHA: American Public Health Association (2005)-standard methods for the examination of water & wastewater.

meters per second. The total discharge, or the volume of water moving through a cross-section of the river per unit of time, was measured to be 18.750 cubic meters per second. The maximum measured depth and speed were 2.622 meters and 1.979 meters per second, respectively. The table also provides a series of measurements taken at different times, from 11:44:58 AM to 12:06:11 PM. These measurements include the time, duration, temperature, track distance, width, area, boat speed, water speed, and discharge for both the left and right sides of the river, as well as the top, middle, and bottom sections. The percentage of the total measured discharge is also provided for each measurement. The mean values for these measurements show that the river has a consistent temperature of around 20.7 degrees Celsius, a mean track distance of 30.52 meters, and a mean width of 16.76 meters. The mean area is 17.361 square meters, and the mean boat and water speeds are 0.121 and 0.661 meters per second, respectively. The mean total discharge is 18.750 cubic meters per second, which represents 72.6% of the total measured discharge. The standard deviation values indicate the variability in these measurements. For example, the standard deviation of the width is 0.925 meters, indicating that the width measurements are closely clustered around the mean. The coefficient of variation (COV) values provide a measure of relative variability. For example, the COV for the width is 0.053, indicating a low level of relative variability in the width measurements. In conclusion, the Yala River at Tindinyo has a consistent flow with a relatively stable discharge. (Table 4)

Table 4. Yala River at Tindinyo baseline discharge summary.

Discharge Calculation Settings				Discharge Results	
Track Reference	Bottom-Track	Left Method	Sloped Bank	Width (m)	17.361
Depth Reference	Vertical Beam	Right Method	Sloped Bank	Area (m^2)	28.360
Coordinate System	ENU	Top Fit Type	Power Fit	Mean Speed (m/s)	0.661
		Bottom Fit Type	Power Fit	Total Q (m^3/s)	18.750
Start Gauge Height (m)	1.18			Maximum Measured Depth	2.622
End Gauge Height (m)	1.18			Maximum Measured Speed	1.979

Measurement Results

Tr		Time		Distance				Mean Vel		Discharge							%
#	Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MB Total	Measured
1	11:44:58 L AM	0:05:36	20.8	40.57	16.71	17.305	27.865	0.121	0.647	0.00	0.01	1.55	12.84	3.62	18.018	-	71.3
2	11:50:39 R AM	0:04:51	20.7	32.42	15.98	16.578	28.317	0.111	0.673	0.00	0.01	1.59	13.83	3.63	19.054	-	72.6
3	11:55:33 L AM	0:03:45	20.7	26.79	15.60	16.196	27.988	0.119	0.659	0.00	0.00	1.53	13.42	3.48	18.436	-	72.8
4	11:59:22 R AM	0:03:38	20.6	27.80	17.89	18.489	28.619	0.128	0.637	−0.01	0.01	1.63	13.43	3.17	18.232	-	73.6
5	12:03:05 L PM	0:03:01	20.6	23.75	16.33	16.930	27.596	0.131	0.674	0.00	0.00	1.56	13.52	3.52	18.603	-	72.7
6	12:06:11 R PM	0:04:40	20.6	31.82	18.07	18.668	29.776	0.114	0.677	0.00	0.01	1.75	14.72	3.68	20.158	-	73.0
		Mean	20.7	30.52	16.76	17.361	28.360	0.121	0.661	0.00	0.01	1.60	13.63	3.52	18.750	0.000	72.6
		Std Dev	0.1	5.38	0.93	0.925	0.712	0.007	0.015	0.00	0.00	0.08	0.57	0.17	0.707	0.000	0.7
		COV	0.0	0.176	0.055	0.053	0.025	0.058	0.023	−2.813	0.744	0.047	0.042	0.048	0.038	0.000	0.010

The baseline discharge summary of the Cheplelachbei River provides a comprehensive understanding of the river's flow characteristics. The discharge calculation settings and results were obtained using various methods and measurements. The river's total width was measured to be 4.500 meters, and the total area was calculated to be 1.250 square meters. The mean depth of the river was found to be 0.278 meters, and the mean velocity was calculated to be 0.4549 meters per second. The total discharge, or the volume of water moving through a cross-section of the river per unit of time, was measured to be 0.5687 cubic meters per second. The table also provides a series of measurements taken at different locations along the river, from 0.00 to 4.50 meters. These measurements include the time, location, method, depth, measured depth, velocity, correction factor, mean velocity, area, flow, and percentage of total discharge. The measurements show a general trend of increasing velocity and flow as the location increases from 0.00 to 3.50 meters. After this point, the velocity and flow begin to decrease. This pattern suggests that the river's flow is strongest in the middle and weaker near the edges, which is a common characteristic of natural river systems. The mean values for these measurements show that the river has a consistent temperature of around 18.47 degrees Celsius, a mean signal-to-noise ratio (SNR) of 30.1 dB, and a mean depth of 0.278 meters. The mean velocity is 0.4549 meters per second, and the mean total discharge is 0.5687 cubic meters per second. In conclusion, the Cheplelachbei River has a consistent flow with a relatively stable discharge. (**Table 5**)

The baseline discharge summary of the Chepkumia River provides a comprehensive understanding of the river's flow characteristics. The discharge calculation settings and results were obtained using various methods and measurements. The river's total width was measured to be 3.250 meters, and the total area was calculated to be 1.075 square meters. The mean depth of the river was found to be 0.331 meters, and the mean velocity was calculated to be 0.4057 meters per second. The total discharge, or the volume of water moving through a cross-section of the river per unit of time, was measured to be 0.4361 cubic meters per second. The table also provides a series of measurements taken at different locations along the river, from 0.00 to 3.25 meters. These measurements include the time, location, method, depth, measured depth, velocity, correction factor, mean velocity, area, flow, and percentage of total discharge. The measurements show a general trend of increasing velocity and flow as the location increases from 0.00 to 3.00 meters. After this point, the velocity and flow begin to decrease. This pattern suggests that the river's flow is strongest in the middle and weaker near the edges, which is a common characteristic of natural river systems. The mean values for these measurements show that the river has a consistent temperature of around 19.99 degrees Celsius, a mean signal-to-noise ratio (SNR) of 36.2 dB, and a mean depth of 0.331 meters. The mean velocity is 0.4057 meters per second, and the mean total discharge is 0.4361 cubic meters per second. In conclusion, the Chepkumia River has a consistent flow with a relatively stable discharge. (**Table 6**)

Table 5. Cheplelachbei river Baseline discharge summary.

Summary			
Averaging Int.	30	# Stations	19
Start Edge	LEW	Total Width	4.500
Mean SNR	30.1 dB	Total Area	1.250
Mean Temp	18.47˚C	Mean Depth	0.278
Disch. Equation	Mid-Section	Mean Velocity	0.4549
		Total Discharge	0.5687

Measurement Results

St	Clock	Loc	Method	Depth	% Dep	Meas D	Vel	Corr Fact	Mean V	Area	Flow	% Q
0	12:48	0.00	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0
1	12:48	0.25	0.6	0.340	0.6	0.136	0.2926	1.00	0.2926	0.085	0.0249	4.4
2	12:49	0.50	0.6	0.320	0.6	0.128	0.4452	1.00	0.4452	0.080	0.0356	6.3
3	12:51	0.75	0.6	0.360	0.6	0.144	0.4295	1.00	0.4295	0.090	0.0387	6.8
4	12:53	1.00	0.6	0.370	0.6	0.148	0.3274	1.00	0.3274	0.093	0.0303	5.3
5	12:57	1.25	0.6	0.380	0.6	0.152	0.4465	1.00	0.4465	0.095	0.0424	7.5
6	12:58	1.50	0.6	0.380	0.6	0.152	0.4489	1.00	0.4489	0.095	0.0426	7.5
7	12:59	1.75	0.6	0.380	0.6	0.152	0.5155	1.00	0.5155	0.095	0.0490	8.6
8	13:02	2.00	0.6	0.380	0.6	0.152	0.4811	1.00	0.4811	0.095	0.0457	8.0
9	13:03	2.25	0.6	0.340	0.6	0.136	0.4401	1.00	0.4401	0.085	0.0374	6.6
10	13:04	2.50	0.6	0.200	0.6	0.080	0.5694	1.00	0.5694	0.050	0.0285	5.0
11	13:06	2.75	0.6	0.280	0.6	0.112	0.5351	1.00	0.5351	0.070	0.0375	6.6
12	13:07	3.00	0.6	0.280	0.6	0.112	0.5697	1.00	0.5697	0.070	0.0399	7.0
13	13:08	3.25	0.6	0.280	0.6	0.112	0.5894	1.00	0.5894	0.070	0.0413	7.3
14	13:09	3.50	0.6	0.250	0.6	0.100	0.5332	1.00	0.5332	0.063	0.0333	5.9
15	13:10	3.75	0.6	0.200	0.6	0.080	0.4309	1.00	0.4309	0.050	0.0215	3.8
16	13:11	4.00	0.6	0.160	0.6	0.064	0.3958	1.00	0.3958	0.040	0.0158	2.8
17	13:13	4.25	0.6	0.100	0.6	0.040	0.1727	1.00	0.1727	0.025	0.0043	0.8
18	13:13	4.50	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0

Table 6. Chepkumia river baseline discharge summary.

Summary			
Averaging Int.	30	# Stations	14
Start Edge	LEW	Total Width	3.250
Mean SNR	36.2 dB	Total Area	1.075
Mean Temp	19.99˚C	Mean Depth	0.331
Disch. Equation	Mid-Section	Mean Velocity	0.4057
		Total Discharge	0.4361

Continued

Measurement Results													
St	Clock	Loc	Method	Depth	% Dep	Meas D	Vel	Corr Fact	Mean V	Area	Flow	% Q
0	14:14	0.00	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0
1	14:16	0.25	0.6	0.300	0.6	0.120	0.1197	1.00	0.1197	0.075	0.0090	2.1
2	14:20	0.50	0.6	0.290	0.6	0.116	0.3732	1.00	0.3732	0.073	0.0271	6.2
3	14:24	0.75	0.6	0.290	0.6	0.116	0.3687	1.00	0.3687	0.073	0.0267	6.1
4	14:26	1.00	0.6	0.180	0.6	0.072	0.2407	1.00	0.2407	0.045	0.0108	2.5
5	14:29	1.25	0.6	0.360	0.6	0.144	0.2114	1.00	0.2114	0.090	0.0190	4.4
6	14:31	1.50	0.6	0.350	0.6	0.140	0.4114	1.00	0.4114	0.088	0.0360	8.3
7	14:35	1.75	0.6	0.380	0.6	0.152	0.5268	1.00	0.5268	0.095	0.0500	11.5
8	14:37	2.00	0.6	0.410	0.6	0.164	0.4490	1.00	0.4490	0.103	0.0460	10.6
9	14:39	2.25	0.6	0.380	0.6	0.152	0.4475	1.00	0.4475	0.095	0.0425	9.7
10	14:43	2.50	0.6	0.420	0.6	0.168	0.5092	1.00	0.5092	0.105	0.0535	12.3
11	14:45	2.75	0.6	0.460	0.6	0.184	0.4713	1.00	0.4713	0.115	0.0542	12.4
12	14:48	3.00	0.6	0.480	0.6	0.192	0.5104	1.00	0.5104	0.120	0.0612	14.0
13	14:48	3.25	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0

The baseline discharge summary for the Kesses River provides a detailed overview of the river's flow characteristics. The discharge calculation settings and results were obtained using various methods and measurements. The total width of the river was measured to be 7.268 meters, and the total area was calculated to be 3.287 square meters. The mean depth of the river was found to be 0.263 meters, and the mean velocity was calculated to be 0.263 meters per second. The total discharge, or the volume of water moving through a cross-section of the river per unit of time, was measured to be 0.864 cubic meters per second. The table also provides a series of measurements taken at different locations along the river. These measurements include the time, location, method, depth, measured depth, velocity, correction factor, mean velocity, area, flow, and percentage of total discharge. The measurements show a general trend of increasing velocity and flow as the location increases from 0.00 to 2.51 meters. After this point, the velocity and flow begin to decrease. This pattern suggests that the river's flow is strongest in the middle and weaker near the edges, which is a common characteristic of natural river systems. The mean values for these measurements show that the river has a consistent temperature of around 22.6 degrees Celsius, a mean signal-to-noise ratio (SNR) of 8.50 dB, and a mean depth of 0.263 meters. The mean velocity is 0.263 meters per second, and the mean total discharge is 0.864 cubic meters per second. In conclusion, the Kesses River has a consistent flow with a relatively stable discharge. (Table 7)

Table 7. Kesses river baseline discharge summary.

Discharge Calculation Settings				Discharge Results	
Track Reference	Bottom-Track	Left Method	Sloped Bank	Width (m)	7.268
Depth Reference	Vertical Beam	Right Method	Sloped Bank	Area (m^2)	3.287
Coordinate System	ENU	Top Fit Type	Power Fit	Mean Speed (m/s)	0.263
		Bottom Fit Type	Power Fit	Total Q (m^3/s)	0.864
Start Gauge Height (m)	0.00			Maximum Measured Depth	1.195
End Gauge Height (m)	0.00			Maximum Measured Speed	1.127

Measurement Results

Tr	Time			Distance				Mean Vel		Discharge							%
#	Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MB Total	Measured
1	2:40:58 R PM	0:01:44	22.7	8.40	6.66	7.260	3.195	0.081	0.264	0.00	0.00	0.30	0.37	0.17	0.843	-	44.4
2	2:42:49 L PM	0:01:40	22.6	7.97	6.45	7.050	3.315	0.080	0.273	0.00	0.00	0.31	0.39	0.21	0.904	-	42.7
3	2:44:37 R PM	0:01:28	22.6	7.84	5.87	6.475	2.954	0.089	0.243	0.00	0.00	0.26	0.30	0.16	0.717	-	41.5
4	2:46:10 L PM	0:01:48	22.5	9.65	7.71	8.312	3.626	0.089	0.248	0.00	0.00	0.32	0.38	0.20	0.900	-	42.2
5	2:51:11 L PM	0:01:50	22.5	8.65	6.64	7.244	3.346	0.079	0.285	0.00	0.00	0.35	0.38	0.23	0.954	-	39.6
		Mean	22.6	8.50	6.67	7.268	3.287	0.083	0.263	0.00	0.00	0.31	0.36	0.19	0.864	0.000	42.1
		Std Dev	0.1	0.64	0.59	0.595	0.219	0.005	0.016	0.00	0.00	0.03	0.03	0.03	0.081	0.000	1.6
		COV	0.0	0.076	0.089	0.082	0.066	0.056	0.059	0.000	0.000	0.094	0.091	0.131	0.094	0.000	0.037

The baseline discharge summary for the Kipgorgot River provides a comprehensive overview of the river's flow characteristics, including the discharge calculation settings and results. The total width of the river was measured to be 7.168 meters, and the total area was calculated to be 7.821 square meters. The mean speed of the river was found to be 0.208 meters per second, and the total discharge, or the volume of water moving through a cross-section of the river per unit of time, was measured to be 1.240 cubic meters per second. The table also includes a series of measurements taken at different times along the river. These measurements include the time, temperature, distance, mean velocity, discharge, and percentage of total discharge. The measurements show variations in temperature, distance, mean velocity, and discharge. The mean temperature across the measurements was 23.0 degrees Celsius, and the mean distance was 11.64 meters. The mean velocity was 0.208 meters per second, and the mean total discharge was 1.240 cubic meters per second. The standard deviation values indicate the spread of the data, with a standard deviation of 0.1 for temperature, 2.85 for distance, 0.90 for mean velocity, and 0.098 for total discharge. The coefficient of variation (COV) provides insight into the relative variability of the measurements, with values ranging from 0.0 to 4.053 for different parameters.

The maximum measured depth and speed were 1.954 meters and 1.200 meters per second, respectively. In conclusion, the Kipgorgot River's baseline discharge summary reveals a consistent flow with some variations in velocity and discharge. The detailed measurements provide valuable insights into the river's behavior and can serve as a reference for future studies, conservation efforts, or infrastructure planning. The relatively high mean discharge and the variations in the measurements may also indicate the presence of specific features in the river, such as rapids or confluences, that could be further investigated. (Table 8)

The baseline discharge summary for the Kiutany River provides a comprehensive overview of the river's flow characteristics, including the discharge calculation settings and results. The total width of the river was measured to be 3.054 meters, and the total area was calculated to be 1.457 square meters. The mean speed of the river was found to be 0.205 meters per second, and the total discharge, or the volume of water moving through a cross-section of the river per unit of time, was measured to be 0.297 cubic meters per second. The table also includes a series of measurements taken at different times along the river. These measurements include the time, temperature, distance, mean velocity, discharge,

Table 8. Kipgorgot river baseline discharge summary.

Discharge Calculation Settings				**Discharge Results**	
Track Reference	Bottom-Track	Left Method	Sloped Bank	Width (m)	7.168
Depth Reference	Vertical Beam	Right Method	Sloped Bank	Area (m^2)	7.821
Coordinate System	ENU	Top Fit Type	Power Fit	Mean Speed (m/s)	0.208
		Bottom Fit Type	Power Fit	Total Q (m^3/s)	1.240
Start Gauge Height (m)	0.00			Maximum Measured Depth	1.954
End Gauge Height (m)	0.00			Maximum Measured Speed	1.200

Measurement Results

Tr		Time		Distance				Mean Vel		Discharge							%
#	Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MB Total	Measured
1	1:45:26 L PM	0:03:33	23.1	17.15	8.36	8.961	9.414	0.081	0.143	0.00	0.01	0.13	0.99	0.21	1.348	-	73.5
2	1:49:13 R PM	0:03:42	23.1	8.75	6.26	6.863	9.016	0.039	0.142	0.00	0.00	0.13	0.94	0.21	1.278	-	73.5
3	1:53:22 L PM	0:03:18	22.9	10.41	5.71	6.314	8.315	0.053	0.145	0.00	0.00	0.11	0.89	0.20	1.206	-	73.7
4	1:56:56 R PM	0:03:02	23.0	10.40	6.98	7.582	9.071	0.057	0.149	0.00	0.00	0.13	0.96	0.26	1.351	-	71.2
5	2:00:16 L PM	0:04:21	22.8	13.43	6.26	6.863	8.949	0.051	0.120	0.00	−0.01	0.09	0.90	0.10	1.071	-	82.4
6	2:07:58 R PM	0:03:22	23.0	9.72	5.83	6.427	2.159	0.048	0.549	0.00	0.00	0.12	0.88	0.19	1.185	-	74.2
		Mean	23.0	11.64	6.57	7.168	7.821	0.055	0.208	0.00	0.00	0.12	0.93	0.19	1.240	0.000	74.7
		Std Dev	0.1	2.85	0.90	0.899	2.553	0.013	0.153	0.00	0.01	0.02	0.04	0.05	0.098	0.000	3.5
		COV	0.0	0.245	0.137	0.125	0.326	0.231	0.735	2.925	4.053	0.132	0.045	0.248	0.079	0.000	0.047

and percentage of total discharge. The measurements show variations in temperature, distance, mean velocity, and discharge. The mean temperature across the measurements was 20.3 degrees Celsius, and the mean distance was 3.74 meters. The mean velocity was 0.205 meters per second, and the mean total discharge was 0.297 cubic meters per second. The standard deviation values indicate the spread of the data, with a standard deviation of 0.0 for temperature, 0.67 for distance, 0.19 for mean velocity, and 0.013 for total discharge. The coefficient of variation (COV) provides insight into the relative variability of the measurements, with values ranging from 0.0 to 0.545 for different parameters. The maximum measured depth and speed were 0.735 meters and 1.655 meters per second, respectively. In conclusion, the Kiutany River's baseline discharge summary reveals a consistent flow with some variations in velocity and discharge. The detailed measurements provide valuable insights into the river's behavior and can serve as a reference for future studies, conservation efforts, or infrastructure planning. The relatively low mean discharge and the variations in the measurements may also indicate the presence of specific features in the river, such as rapids or confluences, that could be further investigated. (Table 9)

Table 9. Kiutany river baseline discharge summary.

Discharge Calculation Settings				Discharge Results	
Track Reference	Bottom-Track	Left Method	Sloped Bank	Width (m)	3.054
Depth Reference	Vertical Beam	Right Method	Sloped Bank	Area (m^2)	1.457
Coordinate System	ENU	Top Fit Type	Power Fit	Mean Speed (m/s)	0.205
		Bottom Fit Type	Power Fit	Total Q (m^3/s)	0.297
Start Gauge Height (m)	0.00			Maximum Measured Depth	0.735
End Gauge Height (m)	0.00			Maximum Measured Speed	1.655

Measurement Results

Tr	Time			Distance				Mean Vel		Discharge							%
#	Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MB Total	Measured
1	5:14:07 L PM	0:01:35	20.3	4.06	2.20	2.798	1.477	0.043	0.201	0.00	0.01	0.08	0.16	0.04	0.297	-	54.6
2	5:17:03 R PM	0:01:10	20.3	3.17	2.19	2.793	1.316	0.045	0.246	0.00	0.00	0.10	0.16	0.06	0.324	-	49.6
3	5:18:35 L PM	0:01:15	20.3	3.20	2.65	3.249	1.529	0.043	0.195	0.00	0.03	0.09	0.15	0.04	0.298	-	50.0
4	5:20:08 R PM	0:01:20	20.3	5.01	2.52	3.115	1.451	0.063	0.198	0.00	0.03	0.08	0.15	0.03	0.287	-	51.0
5	5:21:35 L PM	0:01:29	20.3	3.84	2.67	3.274	1.505	0.043	0.195	0.00	0.01	0.09	0.15	0.04	0.293	-	51.1
6	5:23:09 R PM	0:01:14	20.3	3.18	2.49	3.094	1.464	0.043	0.194	0.00	0.02	0.08	0.14	0.04	0.283	-	51.1
		Mean	20.3	3.74	2.45	3.054	1.457	0.047	0.205	0.00	0.02	0.09	0.15	0.04	0.297	0.000	51.2
		Std Dev	0.0	0.67	0.19	0.194	0.068	0.007	0.019	0.00	0.01	0.01	0.01	0.01	0.013	0.000	1.6
		COV	0.0	0.178	0.079	0.063	0.047	0.156	0.091	0.000	0.545	0.091	0.045	0.190	0.044	0.000	0.031

4. Discussion

The water quality assessments of the Cheplelachbei, Kesses, and Kiutany rivers provide a comprehensive understanding of the rivers' health and their suitability for various uses. All three rivers have pH levels within the acceptable range of 5.5 - 9.5, suggesting balanced aquatic environments that can support a variety of life forms. This finding aligns with the study by Salmiati *et al.* (2017) [8], which emphasizes the importance of maintaining pH levels within this range for the health of aquatic ecosystems. This is consistent with the findings of a study on the Mekong River, which also reported pH levels within the acceptable range, suggesting a healthy aquatic environment (Mekong River Report Card on Water Quality, 2017) [9].

However, the turbidity levels of the rivers were found to be higher than the standard maximum limit. All three rivers have turbidity levels that exceed the standard maximum limit of 25 N.T.U, indicating the presence of many particles in the water that could affect its clarity. High turbidity can impact aquatic life and may indicate issues with erosion or runoff in the watershed. This is a concern shared by the Mekong River Commission Secretariat (2022) [10], which found similar turbidity issues in the Mekong River. This is a common issue in rivers worldwide, as evidenced by a study on the Malaysian River, which also reported high turbidity levels (Integrated Approaches in Water Quality Monitoring for River Health Assessment, 2022) [11]. The study by Al-Asadi *et al.* (2020) [12] on the Shatt Al-Arab River in Iraq also found that the river sediments were polluted with heavy metals, while pollution levels in the water were still within permissible limits for drinking, irrigation, and aquatic life, highlighting the importance of monitoring both water and sediment quality.

The conductivity of the river water at 25 degrees Celsius in all three rivers is significantly below the standard maximum limit of 2500 $\mu\cdot cm^{-1}$, indicating a low concentration of dissolved salts and other inorganic materials in the water. This is a positive sign as it suggests that the rivers are not being significantly impacted by industrial waste or other sources of pollution. This is in line with the findings of the study by Ahmad *et al.* (2021) [13] in Pakistan, which found that anthropogenic activities were the main driver of Spatio-temporal variability in groundwater quality.

The nitrate concentrations in the rivers are below the standard maximum limit of 45 mg $NO_3^- L^{-1}$, which is a positive sign as high nitrate levels can be harmful to human health and can also contribute to eutrophication, a process that can deplete oxygen levels in the water and harm aquatic life. This finding is consistent with the study by the US Geological Survey (2018) [14], which also found acceptable nitrate levels in the Sacramento River Basin. This is also in line with a study on the Cross River Basin in Nigeria, which also reported nitrate concentrations below the standard maximum limit (Temporal Assessment of River Stages and Discharge Regimes of the Cross River Basin, SE-Nigeria, 2018) [15]. The study by Ahmad *et al.* (2021) [13] also found high nitrate concentration levels in the vicinity of agricultural areas due to the excessive use of nitrogenous fertilizers and pesticides, highlighting the potential impact of agricultural activities on water quality.

The discharge summaries of the Yala, Cheplelachbei, Chepkumia, Kesses, and Kipgorgot rivers provide a detailed understanding of the rivers' flow characteristics. The total discharge, or the volume of water moving through a cross-section of the river per unit of time, varies among the rivers, with the Yala River having the highest discharge and the Cheplelachbei River having the lowest. These variations in discharge may be due to differences in the size of the rivers, the amount of rainfall they receive, and the characteristics of their watersheds. The discharge summaries of the rivers reveal consistent flows with relatively stable discharges. This is a common characteristic of natural river systems, as evidenced by studies on the major Indian River Catchments (Skill assessment of GloFAS-ERA5 operational river discharge for the major Indian River Catchments, 2023) [16] and rivers in Japan (Assessment of climate change impacts on river discharge in Japan using the super-high-resolution MRI-AGCM, 2023) [17]. The study by Khaleefa and Kamel (2021) [18] on the Euphrates River in Iraq also found that the river's quality was classified as "very poor quality", highlighting the importance of continuous monitoring and management of river discharge to maintain water quality.

5. Conclusion

The comprehensive baseline water quality assessments and discharge summaries of the Cheplelachbei, Kesses, Kiutany, Yala, Chepkumia, and Kipgorgot rivers provide valuable insights into the health and flow characteristics of these rivers. Generally, the water quality of these rivers is within acceptable limits, with the notable exception of turbidity levels, which significantly exceed the standard maximum limit in all rivers. This suggests the presence of a high number of particles in the water that could affect its clarity and potentially impact aquatic life. It may also indicate issues with erosion or runoff in the watershed. The discharge summaries reveal that the rivers have consistent flows with some variations in velocity and discharge. The detailed measurements provide valuable insights into the rivers' behavior and can serve as a reference for future studies, conservation efforts, or infrastructure planning.

6. Recommendations

Addressing High Turbidity: Given the high turbidity levels in all rivers, it is recommended to investigate the sources of this turbidity and implement measures to reduce it. This could involve erosion control measures, such as reforestation or the construction of sediment retention basins, and the regulation of activities that cause soil disturbance in the watershed.

Continuous Monitoring: Continuous monitoring of both water quality and discharge is recommended to track changes over time and assess the impact of conservation measures. This could involve the establishment of permanent monitoring stations and the use of automated monitoring equipment.

Community Engagement: Engaging local communities in river conservation efforts is crucial. This could involve education campaigns, community-based monitoring programs, and initiatives to reduce pollution from domestic and agricultural sources.

Infrastructure Planning: The discharge data can inform the planning and design of water-related infrastructure, such as water supply intakes or hydropower plants. The infrastructure should be designed to cope with the range of discharge conditions observed.

Further Research: Further research could investigate the factors influencing the observed water quality and discharge characteristics, such as catchment geology, land use, and climate. The impact of potential future changes, such as land use change or climate change, on water quality and discharge could also be explored.

Policy and Regulation: Policies and regulations should be put in place to protect the rivers from pollution and over-extraction. This could involve the enforcement of existing regulations and the development of new ones as needed.

Declarations

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Conflicts of Interest

The authors hereby disclose that there are no competing interests associated with this research. The study was conducted with a commitment to scientific objectivity and impartiality, and there were no external influences that could compromise the integrity of the research or its findings.

Disclaimer

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect the official policy or position of The Nature Conservancy or any other affiliated organization. The information presented in this research is based on the data collected and analyzed at the time of the study and is subject to change with future developments or further research.

The authors have made every effort to ensure the accuracy and reliability of the data and findings presented in this publication. However, they are not liable for any errors, omissions, or misinterpretations that may arise from the use of this information. Readers are encouraged to use this research as a foundation for further investigations and consult additional sources for comprehensive insights into the Yala River watershed and its conservation.

References

[1] LVBC (Lake Victoria Basin Commission) (2018) Integrated Water Resources Management Strategy for the Lake Victoria Basin. https://www.lvbcom.org/the-lake-victoria-basin-integrated-water-resources-management-programme-lvb-iwrmp-marks-international-day-for-biological-diversity-2022/

[2] Clausen, J.C. (2020) Water Quality and Monitoring. In: CRC Press, Ed., *Fresh Water and Watersheds*, CRC Press, Boca Raton, 7 p. https://doi.org/10.1201/9780429441042-36

[3] Good Practices for the Collection of Biodiversity Baseline Data (2018) Brill. https://publications.iadb.org/en/good-practices-collection-biodiversity-baseline-data

[4] Revised Universal Soil Loss Equation (RUSLE) (2012) Springer-Verlag. https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/ru/c/1236444/

[5] Water Quality Monitoring and Assessment in a Developing Country (2012) InTech. https://www.intechopen.com/chapters/35065

[6] Williams, P., Biggs, J., Stoate, C., Szczur, J., Brown, C. and Bonney, S. (2020) Nature Based Measures Increase Freshwater Biodiversity in Agricultural Catchments. *Biological Conservation*, **244**, Article 108515. https://doi.org/10.1016/j.biocon.2020.108515

[7] Rabotyagov, S.S., Jha, M.K. and Campbell, T. (2010) Impact of Crop Rotations on Optimal Selection of Conservation Practices for Water Quality Protection. *Journal of Soil and Water Conservation*, **65**, 369-380. https://doi.org/10.2489/jswc.65.6.369

[8] Salmiati, Arman, N.Z. and Salim, M.R. (2017) Water Quality Status of Selected Rivers in Kota Marudu, Sabah, Malaysia and its Suitability for Usage. Sains Malaysiana.

[9] Mekong River Commission (2017) Mekong River Report Card on Water Quality. Mekong River Commission. https://www.mrcmekong.org/assets/Publications/2017-Lower-Mekong-Regional-Water-Quality-Monitoring-Report-7July19.pdf

[10] Mekong River Commission Secretariat (2022) State of the Basin Report 2022. Mekong River Commission. https://reliefweb.int/report/cambodia/mekong-river-commission-annual-report-2022-part-i-key-achievements-and-impact-stories#:~:text=2022%20was%20the%20second%20year,Countries%20largely%20returned%20to%20normal

[11] Salmiati, Arman, N.Z. and Salim, M.R. (2017) Integrated Approaches in Water Quality Monitoring for River Health Assessment: Scenario of Malaysian River. In:

Tutu, H., Ed., *Water Quality*, IntechOpen, London, 24-39.
https://doi.org/10.5772/65703

[12] Al-Asadi, S.A., Al-Qurnawi, W.S., Al Hawash, A.B., Ghalib, H. and Alkhlifa, N.A.H.A. (2020) Water Quality and Impacting Factors on Heavy Metals Levels in Shatt Al-Arab River, Basra, Iraq. *Journal of Water and Health*, **18**, 735-748.
https://doi.org/10.1007/s13201-020-01196-1

[13] Ahmad, W., Iqbal, J., Nasir, M.J., Ahmad, B., Khan, M.T., Khan, S.N. and Adnan, S. (2021) Impact of Land Use/Land Cover Changes on Water Quality and Human Health in District Peshawar Pakistan. *International Journal of Environmental Research and Public Health*, **18**, Article 3127.
https://doi.org/10.1038/s41598-021-96075-3

[14] US Geological Survey (2018) Water Quality in the Sacramento River Basin, California. US Geological Survey.
https://deltacouncil.ca.gov/pdf/isb/products/2018-07-26-isb-2018-water-quality-review.pdf

[15] Ekwere, A. and Kudamnya, E. (2022) Temporal Assessment of River Stages and Discharge Regimes of the Cross River Basin, SE-Nigeria.
https://doi.org/10.21203/rs.3.rs-1975626/v1

[16] Imaran, M., Chakraborty, A. and Tripathy, S. (2021) Skill Assessment of GloFAS-ERA5 Operational River Discharge for the Major Indian River Catchments. *ESS Open Archive*. https://doi.org/10.1002/essoar.10508045.1

[17] Sato, Y., Kojiri, T., Michihiro, Y., Suzuki, Y. and Nakakita, E. (2013) Assessment of Climate Change Impacts on River Discharge in Japan Using the Super-High-Resolution MRI-AGCM. *Hydrological Processes*, **38**, 3264-3279.
https://doi.org/10.1002/hyp.9828

[18] Khaleefa, O. and Kamel, A.H. (2021) On the Evaluation of Water Quality Index: Case Study of Euphrates River, Iraq. *Knowledge-Based Engineering and Sciences*, **2**, 35-43. https://doi.org/10.51526/kbes.2021.2.2.35-43