AN ASSESSMENT OF MORPHOLOGICAL FEATURES OF DONGOL STREAM IN KASHERE WATERSHED, GOMBE STATE, NIGERIA

(FUWJSS)

Volume2 Number 1
March, 2023

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Abstract

This paper examined the morphological features of Dongol stream in Kashere watershed area to determine their influence on the nearby environment. Data emerged through direct field observation and measurements involving survey equipment such as measuring tape, Global Positioning System, ranging poles and camera. Morphological parameters measured include stream length, depth, width, boulders, pools, riffles, wetted and dry perimeters of the stream. The descriptive statistic (mean) showed variation in the data, why the Pearson's Product Moment correlation statistic evaluated the relationship between the morphological parameters of the stream. Results of the study show that the mean depth of the Dongol stream is 4.77m and the mean width is 36.48m. The Dongol stream is considered to be moderately deep around Kashere area, with a wide top width. With the increasing width of the stream, this threatens nearby cultivated farmlands thereby leading to loss of reparian vegetation along the stream banks. The stream has a lower mean wetted perimeter (11.96m) than the mean dried perimeter (24.33m). The study concludes that the stream drier part is larger, thereby influencing small amount of water available for usage in the stream for agricultural and domestic purposes. Also, the pools, riffles, sand bars and boulders observed do influenced siltation in the stream, thus impacting negatively on the stream depth and flow pattern of the stream. The study recommends that vegetation should be planted along Dongol river banks to help reduce siltation, stream bank erosion and mass wasting for enhanced stream bank stabilisation and environmental sustainability.

Keywords: Dongol stream, Morphological features, Kashere Watershed, perimeter

Introduction

Fluvial features of a stream are essential in understanding the geomorphic character of the basin and how the river system responds to changes in fluvial processes taking place on the river banks and the stream bed. Phillips (2014) noted that streams in disturbed watershed tend to respond to the processes that shape them, as well as anthropogenic factors influencing flow regime in a particular drainage basin. Such streams overtime are likely to change their direction of flow resulting to meadearing, development of pool-riffle sequence, dry stream bed and differential wetting of the stream bed. According to Thompson (2018), pools are most easily seen in a meandering stream where the outer edge of each meander loop is deep and undercut; riffles form in the shallow water of the short, straight, wide reaches between adjacent loops. The pools and riffles form sequences spaced at a repeating distance of about five to seven widths of the channel and often appear in stream development long before the stream produces visible meanders. These patterns are thought to be associated with a form of wave phenomenon and may be initiated by a single gravel patch in a channel; the first channel deviation requires an overcompensation of counter-deviation and sets off a chain reaction type of development. Also, Durry (2015) reported that pools and riffles are present in nearly all perennial channels where the size of the bed material is greater than coarse sand, and they are relatively stable in their position along the channel. At low water stages, the pools generally have a smooth surface while the riffles may show white water. Rapids, similar formations that show white water at all stages of flow, are common in bedrock channels, are generally composed of boulders, and are more random in distribution along the channel.

The morphometry of a river therefore relates to the hydrological and geomorphic response of processes such as runoff, soil erosion, floods and droughts, river sedimentation, changing river flows and branching habit of the streams, flow characteristics and the performance and sustainability of the associated dams and reservoirs if available within the basin (Strahler, 1957). Most streams serve as tributaries to rivers, lakes as well as other larger streams. Dongol stream is no exception, as it is a tributary to river Kashere and river Kaltanga. Dongol stream is a major source of water to the surrounding communities, because it still retains some of its water after the rainy season is gone. Although its full potential can only be seen during the rainy season. However, there have been several changes in its morphology as a result of natural (rainfall, flooding) and human activities (sand mining), over the years. Every year the stream banks get wider and wider, threatening the farmlands, reparian vegetation along the river bank, major roads and settlements. The open system concept was considered in this study. The open system is a system that receives input from the environment and releases output to the environment. Whereas, a closed system is one which only receive inputs without given output (Gregory, 2012). A system's input is therefore defined as the movement of matter or energy from the environment into the system. Output is the movement of matter or energy from the system to the environment. Both input and output involves crossing the boundaries that define the system (Gregory & Walling, 1973). The river system is an open system that is made up of different components such as widths, slope gradient, depth, length and hydro-geomorphological features such as boulders, riffles and pools among others which continually depend on one another and exist in a state of dynamic equilibrium with the prevailing environmental conditions and processes (Gregory, 2012). There are also inputs into the system in form of precipitation and runoff; and output in form of discharge and sediment yield (sand, silt and clay) from a river system (Gregory, 2012). This study determined the hydro-geomorphological features of Dongol stream such as stream length, depth, width, stream boulders, riffles and pools development as well as, wetted and dry parameters of the stream. This was to assess how the processess taking place in the stream have influenced development of the stream morphology and features and the nearby environment at a steady state of dynamic equilibrium.

Inspite of the importance of morphological analysis of fluvial features in watershed management, which helps to understanding the workings of a river system viz-a-viz how they influence the hydrological and geomorphic character of a basin, little or no studies have been deployed to investigate the morphological features of Dongol stream, thus creating paucity of knowledge in literature. In is in this regard, that this study therefore sought to assess the morphological features of Dongol stream in relation to the hydrological and geomorphic response of processes such as runoff, soil erosion, mass wasting, floods, sedimentation, changing flows and how the dynamics of the fluvial features and processes affect the nearby environment. The main aim of this study therefore was to identify and quantify the morphological features in Dongol stream such as dry and wetted perimeters of the stream bed, boulders, riffles and pools among others with the puprpose of understanding the dynamics in the river processes and the impacts on the nearby surroundings.

The Study Area

Dongol is a settlement with an estimated population of 3,231 people in Akko Local Government Area (LGA), Gombe State (NPC, 2006). Dongol is located on Latitude 9° 53' 00" N and 9º 54' 30"N and Longitude 11° 1' 30" E and 11º 3' 00" E respectively. Cities, towns and places near Dongol includes Lakelambu by the East, Jauro Sule by the North and Kulkul by the south. The closest major cities include Gombe, Bauchi, Jimeta and Damaturu.

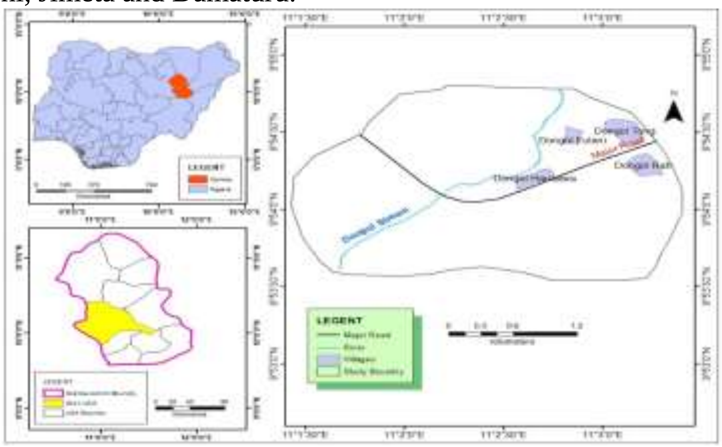
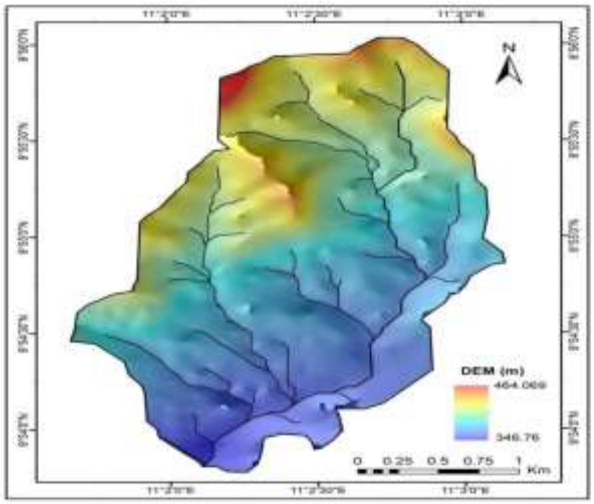


Fig.1: Location of the study area
Source: Authors' GIS analysis, 2021

The Dongol stream flows from the Pindiga hill around Dongol Tong and Dongol Rah settlements into Kashere, then finally empties into the River Kashere. The Kashere catchment area contributing to stream flow, is therefore within the middle course of the stream channel. The geology of Dongol settlement is developed on basement complex rocks with adjoining sedimentary rock formations. Subsequent dissection and stream incision in the area have therefore, resulted in pediment landscape that extends into some part of Gombe in the north and east. There is also discontinuous escapement rising in some places particularly along Gombe - Kumo road to form sandstone hills and cliffs which are over 150m above sea level (asl) around the plains. The Pindiga formation extends to Dongol environment. The relief and drainage of Dongol is characterised by undulating landform with ephemeral streams. The rivers are seasonal and their flow regimes are high at the peak of the raining season in August and September and their volume is considerably reduced during the dry season (Balzerek, Werner, Jürgen, Klaus-martin, & Markus, 2003). The relief of the study area as determined from the Digital Elevtion Model (DEM) of the study area ranged from 346.76m to 464.069m northwards. The basin slopes southwards, and this has influenced the direction of flow in the Dongol river in a north-south ward direction as shown in Figures 2 and 3. The Dongol steam is 4.884km long, with a mean bifurcation ratio of 1.658 as analysed from Digital Elevation Models of the study area.



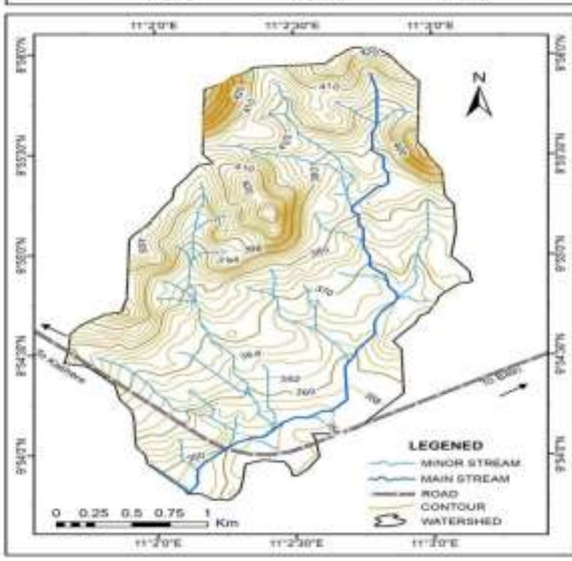


Fig. 2: DEM showing variation in relief of the Dongol basin
Fig. 3: Dongol drainage basin
Source: Authors' GIS analysis, 2021

The climate of Dongol is a reflection of Gombe State climate. Using the Koppen's climatic classification scheme, Gombe State is within the

Aw climatic type. The climate is described as tropical continental climate. The temperature is high all year round with a mean annual temperature of 30^0C. The highest temperatures are recorded during the dry heat wave months of March, April and May with maximum air temperature above 37^0C. During the raining season, the temperature drops considerably due to the cloud cover between July and August as well as during the harmattan periods of November to February. The area records three to four months of rainfall and is concentrated in the month of July August and September (Balzerek etal., 2003). The soil is typically a ferruginous type and brownish in color with a pH value of 4-6 depending on the location. The soil is formed from weathering of the basement complex rocks. Traditional management practice such as clearing, annual burning and livestock grazing have however, made them susceptible to erosion and reduce their water holding capacity. The vegetation of Dongol comprise of light trees and shrubs as well as sparse growth of grasses. There are also stunted trees and dense growth of grasses. Common tree species found in this area include Acasia, Neem, Baobab, Tamarind, Locus beans and orchard of mango, cashew guava among others (Balzerek etal., 2003).

Materials and Methods

This study adopted the field survey and observation research design. The research design was structured as follows:

(i) Using field equipment such as measuring tape, GPS and camera to assess and measure some morphological features such as dry and wetted parameters, pool, riffle and boulders in the Dongol river channel. The morphological features were measured at interval of 20m along the stream channel in metres using a measuring tape and research assistants. The 20m interval was considered because there were only little observed variation in dimensions of the morphological features within these sections of the stream. To measure the wetted and dry perimeters, boulders, riffles and pool, the tape was stretched across the identified feature with somebody holding the other end of the tape. The reading in terms of length (m) and width (m) of the features were taking as the case may be and recorded in a field note book. In terms of the wetted and dry perimeters, the tape was streched across the stream bed to measure the dry area and and total stream bed diameter. Then the dry perimeter was then substracted from the total diameter of the stream bed to get the value of the wetted perimeter. In carrying out the filedwork, the systematic sampling technique was adopted using interval of 20m from the stream head point down stream. Systematic sampling was adopted because of the long length of the stream as well as, insignificant changes observed within short distances along the stream bank, hence to identify and observe morphological features along the stream bed, 20m interval was considered relevant in this study. The systematic sampling procedure was considered along the stream profile, by selecting eight (8) measuring points each from the upper, middle and lower course of the stream, thus making twenty-four (24) measuring points along the stream profile.

To measure pools and riffles, the control-point method was adopted. This method assumes water is impounded by a downstream hydraulic control composed of sediment in different sections of the stream where these features are found. Thus, such control points were identified and with the help of measuring instrument, pools and riffles in those areas were measured and recorded (Thompson, 2018). To measure the pools and riffles, they were first identified and then a measuring tape was used to stretch across the riffles and pools then measured and recorded.

(ii) Use tables and appropriate descriptive and inferential statistics such as mean and Pearson's Product Moment correlation analysis to assess the extent of the relationship between the morphological parameters of Dongol stream.

Results and Discussions

Morphological Features of River Dongol and Implication on the Nearby Environment

The results presented here were collected on Dongol stream that traverses Kashere area and drains down the neighbouring communities. Results on the stream morphological parameters taken at 20m interval are presented in Table 1.

Table 1: Length, Depth and Width of Dongol Stream in Kashere Watershed

S/No.	Stream Length (m)	Depth (m)	Width (m)
1	0	4.0	34.0
2	20	3.6	31.3
3	40	3.0	32.0
4	60	5.4	33.0
5	80	6.2	31.0
6	100	5.8	35.4
7	120	6.5	41.3
8	140	1.8	36.9
9	160	3.5	33.9

10	180	4.0	31.0
11	200	5.0	30.3
12	220	4.9	36.5
13	240	4.6	40.0
14	260	4.0	30.6
15	280	5.0	40.5
16	300	6.0	56.0
17	320	5.0	51.0
18	340	3.4	43.4
19	360	5.0	44.0
20	380	5.1	31.0
21	400	4.8	36.0
22	420	6.0	30.0
23	440	6.1	33.0
24	460	6.0	33.3
Total		**114.7**	**875.4**
Mean		**4.77**	**36.48**

Source: Authors' field work, 2021

Table 1 contain results on Dongol stream depth and width measured along its length at interval of 20m. This was to observe the changing morphology of the stream along its length and its influence on the nearby environment and flow pattern. The mean depth of the stream is 4.77m and the mean width is 36.48m. The Dongol stream is considered to be moderately deep, with a wide top width. With the increasing depth of the stream in the upper course in Kashere catchment area, it is threatening nearby farmlands which have been cultivated. Some of the nearby farmlands and the riparian vegetation are been destroyed by the expansion of the stream side walls, and some are under threats. The lateral expansion of the stream sidewalls is due to the process of mass wasting, which have been initiated by the force of gravity and nature of the soils/earth materials in the watershed. Worth of note, is that the riparian vegetation been destroyed by the expanding stream side wall is meant to help prevent siltation and soil erosion in the area. The findings of this study confirmed those of Songu, Iorkua, Ndoma and Buba (2019) who reported that lateral expansion of fluvial channels such as streams and gully erosion as a result of mass wasting resulted to unstable banks and loss of soil and vegetation. Plate 1 shows the collapse of the stream side wall due to mass wasting process.

Plate 1: Collapse of Dongol stream side walls due to mass wasting process
Source: Authors' field work, 2021

Wetted and Dry Perimeters of Dongol Stream

Results on wetted and dry perimeters of Dongol stream are contained in Table 2.

Table 2: Wetted and Dry Perimeters of Dongol Stream

S/No	Length	Wetted Perimeter (m)	Dry Perimeter (m)
1	00	11.0	23.0
2	20	14.90	16.4
3	40	15.0	17.0
4	60	27.0	6.0
5	80	28.0	3.0
6	100	25.4	10.0
7	120	31.3	10.0
8	140	18.6	18.3
9	160	6.0	27.9
10	180	3.5	28.5
11	200	8.5	21.8
12	220	6.0	30.5
13	240	9.8	30.2
14	260	8.5	22.1
15	280	5.0	35.5
16	300	4.0	52.0
17	320	7.0	44.0
18	340	9.0	34.4
19	360	8.0	36.6
20	380	8.0	23.0
21	400	9.0	23.0
22	420	5.6	24.4

23	440	11.0	22.0
24	460	7.0	26.3
Total		**287.1**	**583.9**
Mean		**11.96**	**24.33**

Source: Author's field work, 2021

The wetted and dry perimeter of Dongol stream along the stream length is contained in Table 2. Wetted perimeter of a stream is the area of the stream bed that contains water which flows downslope. The sources of such water for stream flow results from precipitation, runoff and ground water sippage. Rainfall especially within the tropical areas is the dominant form of precipitation. in Dongol stream; and therefore, rainfall and runoff remains the major source of Dongol stream recharge. Dry perimeter of a stream is the area of stream bed that is dried during time of field observation. The mean wetted perimeter of the stream is 11.96m and the mean dried perimeter is 24.33m. It is observed that the mean value of the dried perimeter (24.33m) of the stream is higher than the mean value of the wetted diamter (11.96m) of the stream. The value of the dry perimeter was found higher than that of the wetted perimeter because the meausurements were done in the month of March when the rains were yet to start falling so the stream was drying up. The implication of this finding is that, the stream drier part is larger, thereby influencing small amount of water available for usage in the stream for agricultural and household purposes. Also, the flow regime of the stream is influenced by siltation which has reduced the depth of the stream making it shallow and enhancing high rate of infiltration and ground water recharge. The low availability of surface water storage and stream flow in Dongol stream could be attributed to high rate of siltation from the stream banks due to mass wasting and reduced spells of rainfall as at the time of the study. The findings of this study corroborated those of Kanth and Hassan (2012) who reported that watershed management was a function of the discharge and water rentention capacity of steams within the basin and how such streams respond to changes in intrinsic and extrinsic factors affecting morphology of the streams. Plate 2 shows the dry and wetted perimeter of the Dongol stream.

Plate 2: Wetted and dry perimeters and sand deposition on the stream bed
Source: Authors' field work, 2021

Table 3: Correlation matrix of hydrological parameters in Dongol Stream

	Stream depth	Stream width	Wetted diameter	Dry diameter	Stream length
Stream depth	1.00				
Stream width	0.13	1.00			
Wetted diameter	0.19	0.17	1.00		
Dry diameter	0.06	0.71**	-0.81**	1.00	
Stream length	0.35	0.23	-0.58**	0.53**	1.00

** Correlation is significant at 0.01 level
Source: Authors' data analysis, 2021

The correlation matrix of the relationship between the geometric attributes of the morphological paramters in Dongol stream showed that there is weak and positive relationship between stream depth and wetted perimeter of the stream (*r = 0.19*), implying a weak and positive relationship. The more the depth of the stream, the more wetted that part of the stream. In a similar vein, it was observed that there is a weak and positive relationship between the stream depth and dry perimeter of the Dongol stream (*r = 0.06*), implying that part of the stream with increased depth was also dry. Stream length was found to have a negative and inverse relationship with wetted perimeter of the stream (*r* = -*0.58*). This showed that as the length of the stream increase the wetted perimeter of the stream will decrease and visce versa. However, stream length had a positive and strong relationship with dry perimeter (*r* = *0.53*), indicating that as the length of the stream increases, the dry perimeter of the stream will also increase. While, stream width correlated positively with dry perimeter (*r* = *0.71*). This was observed to be a positive and strong relationship, implying that as the width of the stream increases the dry perimeter of the stream will also increase, due to accumulation of sediments on the stream bed. Most interestingly, it was observed that dry perimeter of Dongol stream and wetter perimeter had a strong and inverse relationship, This implied that as the dry perimeter of the stream increases, the wetted perimeter will decrease. This was also evident on the field, as revealed in Plate 2. From the preceeding analysis it is obvious that the length and width of the Dongol stream greatly infleunced the dry perimeter of the stream. This could be attributed to the head ward retreat of the stream and lateral expansion of the stream side walls due to river erosion and mass wasting taking place on the stream banks and bed. This relationship also has impact on the extent of stream discharge and flow regime, which inturn affects the amount of water stored in the stream especially during dry season.

Pools, Riffles, Sand Bar and Stream Boulders

Results on the above morphological features are contained in Table 4.

Table 4: Dimension of pools, riffles, sand bar and boulders in Dongol stream

Stream	**Feature**	**Dimension**
	Stream Pool	
	Length (m)	**Width (m)**
Pool 1	126.98	52.1
Pool 2	197.11	69.3
Mean	**162.1**	**60.7**
	Sand Bar	
	Length (m)	**Height(m)**
Sand Bar 1	608.66	3
Sand Bar 2	452.20	2
Mean	**530.43**	**2.5**
	Riffle	
	Length (m)	**Width (m)**
Riffle 1	93.56	37.3
Riffle 2	124.5	62.11

Mean	**109.03**	**49.71**
	Stream Boulders Height (m)	**Width (m)**
Boulder 1	1.0	0.3
Boulder 2	0.7	0.2
Mean	**0.85**	**0.25**

Source: Authors' field work, 2021

Pools, riffles, sand bars and stream boulders were also observed along the stream banks and bed of Dongol stream. Two pools were observed with a mean length of 162.1m and mean width of 60.7m. The mean length of the sand bars was 530.43m with a mean height of 2.5m. The large sand bar experienced on stream bed has implication on the depth of the stream in such areas, making the streams shallow and dried and thereby negating, water storage, stream flow and velocity. The mean value of the riffles was 109.03m, with a mean width of 49.41m (Table 4). The Dongol stream is filled with many stream boulders, and in some areas there are boulder clusters along the stream beds. Two boulders were measured, and the mean height of the boulders was 0.85m, with a mean width of 0.25m. In streams that are sinuous such as Dongol stream, with a sinuosity value of 0.371 shows that the stream is highly sinuous and covulated due to changing pattern of stream flow. Such sinuous streams are likely to develop riffle-pool sequence which results from alteration along the banks and stream bed due to geological and anthropogenic processes taking place along the stream bed and banks. Notwithstanding, the pools and riffles observed in Dongol stream are moderate in size, but have implication on the flow regime of the stream. In areas where riffles are formed, the velocity of the stream flow in those areas were observed to be low, due to the friction between the boulders and water. While, the pools that developed at the downslope of the stream serves as storage for surface water for agricultural and domestic purposes, thereby reducing the amount of water available for stream flow. The pools and riffles observed in the study area are attributed to the perennial nature of the Dongol channel where the size of the bed material is greater than coarse sand, and they are relatively stable in their position along the channel. At low water stages, the pools generally have a smooth surface while the riffles may show water. The findings of this study confirmed those of Thompson (2018) that reported slow flow of water regime in sizeable pool-riffle sequence due to accumulation of gravel pebbles and boulders. Plates 3, 4 and 5 are pools, riffle and boulder cluster respectively, observed in the Dongol stream.

Plate 3: Pool at the downslope of the Dongol stream
Source: Authors' field work, 2021

Plate 4: Riffle observed along the stream bed of Dongol stream
Source: Authors' fieldwork, 2021

Plate 5: Boulder bar clusters on the Dongol stream bed at the middel course of the stream
Source: Authors' field work, 2021

Conclusion and Recommendations

Morphological parameters are important for water resource management and valuation in a river basin. The geomorphic and morphological character of the Dongol stream reflects the extent of the fluvial processes taking place in the stream. The lateral expansion of the stream due to mass wasting process has significantly influenced the environment negatively through destruction of farmlands and raprian vegetation along the rive banks interfacing with the land. The formation of stream features such as sand bar and riffles in the stream bed, indicates the extent of siltation process taking place in the stream, which has impact on the stream depth and fluvial characteristics. It is hereby concluded that the morphological characteristics of Dongol stream reflects the surface expressions of the variables persuading the stream dynamics and processes, which have implications on the nearby environment. Therefore, the study recommends that vegetation should be planted along Dongol river banks to help reduce siltation and mass wasting. Farmlands should be located atleast 20m away from the stream banks to reduce the rate of siltation in the river, which decreases the river depth, thereby making it shallow. Cultivating of ridges at the river bank along slopes down the river channel should be minimised to help reduce the amount of earth materials such as sand, gravel, pebbles and boulders transported into the stream. This increases the amount of bulders and sand obsrerved in the Dongol stream, and could also result to stream poisoning, a process known as eutrophication.

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