WATER QUALITY RESPONSE TO CLEAR FELLING TREES FOR FOREST PLANTATION ESTABLISHMENT AT BUKIT TAREK F.R., SELANGOR

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WATER QUALITY RESPONSE TO CLEAR FELLING TREES FOR FOREST PLANTATION ESTABLISHMENT AT BUKIT TAREK F.R., SELANGOR

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Abstract: *Hydrological study was carried out at Bukit Tarek F.R., Kerling Selangor with the establishment of forest plantation. Seven years of water quality data were analysed to determine the effects of forest clear felling and buffer zone to the stream flow. Three experimental catchments: C1, C2 and C3 were established for monitoring the changes. C1 was a control catchment, C2 was clear felled and the residual trees were left on the site, while C3 was also clear felled but the site was burnt prior to forest planting. The parameters observed were pH, conductivity, turbidity and colour. The values of each parameter increased during and after clear felled. The values of water quality in C3 were higher compared to C2. During clear felling, catchment C3 indicated that pH increased was about 1.6%, conductivity 49.2% and turbidity 350.8% while, catchment C2: pH increased 0.96%, conductivity 25.7% and turbidity 279%. Parameters in control catchment (C1) did not show significant changes for the whole observation period, which during tree clear felling, pH, turbidity and conductivity increased at only 0.06, 0.20 and 0.40%, respectively. Colour did not show any significant trend for all catchments. The establishment of buffer zone in C2 reduced the direct effect of sediment that flows into the river. Two years after clear felled, the water quality parameter started to decrease again and it is expected to be consistent and return to its normal level along with forest recovery.*

Keywords: catchment, plantation establishment, physical water quality

1. INTRODUCTION

Water related problem is one of the major issues confronting human kind today. The problem arises due to the rapid development and new area is developed to accommodate population growth. Bosch and Hewlett[1] have reviewed and synthesized results of many experiments, which have clearly demonstrated that reduction in forest covers will increase the amount of stream flow. The initial impacts of forest harvesting are the increment in the amount of water reaching the soil surface due to reduce interception by a forest canopy.[2] Therefore, more suspended sediment enters the stream and adversely affect other hydrological parameters.

The greatest potential for reducing water quality in forested catchments come from roads on steep slopes or erodible soils, and stream crossing.[3] Based on research finding, it has shown clearly that 90% of the sediment that ends up in the water from forested areas is associated with improperly designed and maintenance of logging roads. This situation is further aggravated by the intensity and frequency of rainfall recorded within the study area. In tropical areas, seasonal rainfall plays an important role in water quality changes which is influenced by monsoon season called northeast (November to March) and southwest (May to September) monsoon. Usually, monsoon season will bring severe rainfall, especially in March, April and September ranging from 482 to 593 mm.

The study at Berembun F.R. shows supervised logging operation gives only moderate impacts on water quality.[4] The impacts observed within the first year after logging show the suspended solids and turbidity levels in the experimental catchment are two times higher compared to that of control catchment.[4] However, it would eventually restore to pre-disturbed levels in the second year after logging.

Hydrological and meteorological studies have been initiated at Bukit Tarek F.R., Kerling, Selangor since the studies had been established in 1989. Some findings include soil physical and preferential flow pathway,[5] analysis on stream chemistry[6,7] climate observation,[8] evaporation[9] and soil moisture and suspended solids.[10–13] The objective of the presented study is to determine and evaluate the effect of forest plantation establishment on the changes in water quality at the mentioned area.

It is important to monitor the changes because forested catchment is the source of clean water. The fluctuation of water quality in the experimental catchment shows the ecosystem response to any change in the system. It is assumed that forest disturbance might lead to the reduction in water quality. Hence, the study is initiated to examine the extent of water quality impairment caused by forest disturbance.

2. MATERIALS AND METHOD

2.1 Study Site

Figure 1 shows the study area at Bukit Tarek F.R. Kerling, Selangor. It is lies between latitude 3^{o} 31' N to longitude 101^{o} 35' E with the altitude ranged from 48 to 213 m. Surficial geology of this area is metamorphic rocks consisting of quartzite, quarts mica schist, graphitic schist, and phyllite from Arenaceous

Series.[10,11] The average annual precipitation is 2414 mm based on the record at Kuala Kubu Baru.[14]

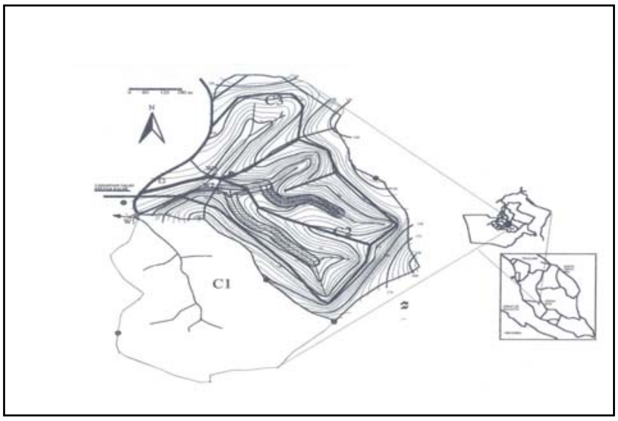


Figure 1: Hydrological study at Compartment 41, Bukit Tarek F.R., Kerling, Selangor

The pair-catchments method was used in the study which three experimental catchments were established side by side. The total area of the study site is 79.5 hectares which is divided into three sub-catchments; C1 (32.8 ha), C2 (34.2 ha) and C3 (12.5 ha). The study area is surrounded by rubber plantation. Two types of treatment were applied into the study areas in order to see the impacts on water quality following the establishment of forest plantation. The catchment C2 was clear felled and the trees were left weathered on the site. Buffer zone of 20 m width was established on both sides of the river. The catchment C3 was also clear felled but the trees were burnt prior to the forest planting and buffer zone was not established. The trees were felled at the end of 1999 and early 2000. Each catchment was installed with v-notch weir and water sampling was collected at this respective points.

2.2 Water Sampling and Analysis

Water samples were collected twice a month from weir 1, weir 2 and weir 3 using bottle samplers and brought back into the laboratory within 24 hours for analysis. These baseflow samples were collected continuously before tree felling (1996–1998), during tree felling (1999–2000), and after tree felling (2001–2003). Colour was measured using spectrophotometry technique (Hach portable datalogger spectrophotometer DR 12010), turbidity using Hach 2100P turbidimeter, pH using expandable ion analyser EA 940 and conductivity using YSI model 32 conductance meter.

2.3 Statistical Analysis

Four types of data available for investigating the properties of random variables related to the distribution of water quality. Data from this study fall under the first category: historic or chronologic data or observations of processes in time, with the resulting continuous and discrete time series. Majority of present-day water quality data belongs to this type.[15] Statistical analysis plays a very important role in order to extract relevant phenomena for practical decisions. However, environmental time series, such as water quality data often possess characteristic, which do not allow the series to be easily analysed statistical techniques.[16] This was due to the missing data observation caused by the unavoidable reason. Detection of water quality changes in definite way is imperative in evaluating the trend, either improving or deteriorating over time. The T-test is probably the most commonly used statistical test for this purpose. In general, the test is for comparing the mean of two sets of data, which can be expressed as:

$$\frac{T = (u_1 - u_2)}{Sp\sqrt{1/n_1 + 1/n_2}}$$

where

T	=	test statistic
u_1	=	mean of first group
u_2	=	mean of second group
n_1	=	sample size of first group
n_2	=	sample size of second group
S_2p	=	$\frac{(n_1 - 1)S_1^{\,2} + (n_2 - 1)S_2^{\,2}}{(n_1 + n_2 - 2)}$

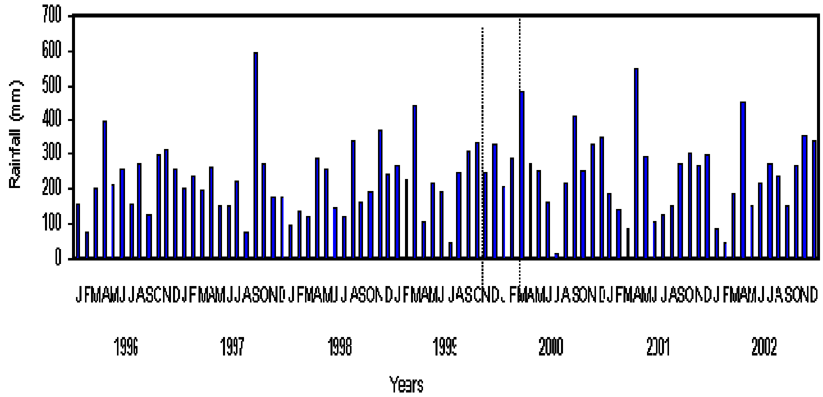
with S_1 and S_2 being the standard deviation of group 1 and group 2, respectively.

3. RESULTS

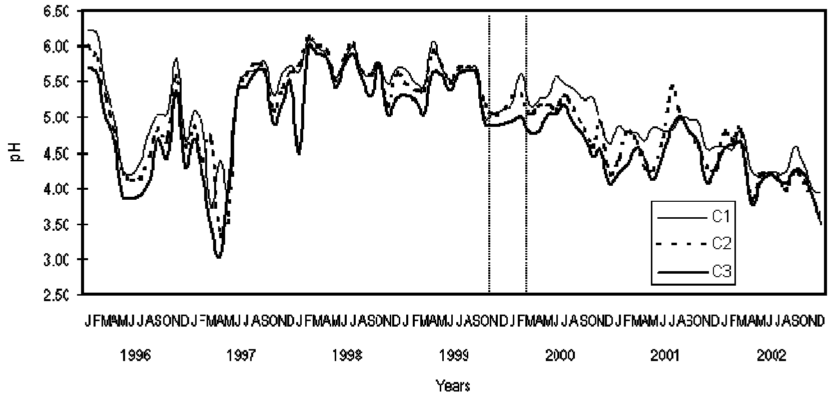
3.1 pH

Data analysis on pH did not show extreme changes before and after clear felling. The pH of the undisturbed forest (1996–1998) was relatively acidic for the whole catchments ranging from 3.04 to 6.22. During clear felling (November–December 1999), pH water did not show obvious fluctuation. The pH was consistent at the range of 4.06 to 5.61 but within two years after the felling it dropped to 3.49 but increased to 4.82 on the third year.

In terms of comparison between the catchments, C2 and C3 were found to be relatively acidic compared to C1 (Fig. 2). C1 as a control catchment showed the lowest pH value compared to the others. The area without buffer zone (C3) was more acidic compared with an area with buffer zone (C2). Figure 2 shows the monthly pH observation for C1, C2, and C3 during seven years observation. Table 1 shows the summary of all the parameters analysed from their mean values before logging, during logging and after logging for the three catchments. The average trend in pH slightly increased during felling period. Based on the data observation, clear felling activities in this area did not influence much on the pH value.



(a)



(b)

Figure 2: (a) Rainfall pattern of Bukit Tarek (1996–2002) and (b) monthly values of water pH in catchments C1, C2 and C3 (1996–2002)

Table 1: Data summary statistics for parameters in catchments C1, C2 and C3

Catchment		Before clear felling (1996–1998)				During clear felling (1999–2000)				After clear felling (2001–2002)			
		pH	Cond	Turb	Col	pH	Cond	Turb	Col	pH	Cond	Turb	Col
C1	Mean	5.32	9.26	0.82	40.05	5.38	8.85	1.02	24.41	4.56	8.78	2.19	10.56
	Std	0.65	2.91	0.94	22.63	0.31	1.40	0.64	22.64	0.32	2.81	1.89	3.94
	Range	2.49	17.45	5.03	68.74	1.43	6.98	2.48	75.00	1.08	13.94	7.56	8.00
C2	Mean	5.19	10.26	1.11	38.91	5.24	12.90	4.21	20.41	4.41	13.51	3.38	18.64
	Std	0.72	3.19	1.69	21.23	0.38	5.26	5.08	19.09	0.43	5.46	2.57	20.69
	Range	2.78	19.03	8.14	99.60	1.72	20.81	21.67	67.50	1.83	28.00	11.30	49.00
C3	Mean	4.97	10.98	1.24	36.15	5.05	16.38	5.59	21.90	4.32	16.11	3.15	18.33
	Std	0.78	2.30	1.71	17.36	0.41	7.00	8.23	20.42	0.36	5.11	2.06	14.94
	Range	2.97	7.92	7.95	89.50	1.59	26.93	34.77	73.00	1.52	22.71	8.43	32.75

Notes: Cond – Conductivity
Col – colour

3.2 Turbidity

Water turbidity recorded the increasing trend in mean value. In C2 the mean ranged from 1.11 to 4.21 NTU during clear felling and decreased to 3.38 NTU two years after. Turbidity in C3 ranged between 1.24 to 5.59 NTU during clear felling and decreased to 3.15 NTU after the clear felling. Figure 3 shows the variation in turbidity for three catchments before and after logging. In the first three years observation before clear felling, turbidity concentration in C3 ranged from 0.37 to 5.16 NTU (1996), 0.34 to 8.29 NTU (1997), and 0.37 to 5.27 NTU (1998). Whereas, at C2 the concentration ranged between 0.33 to 2.26 NTU (1996), 0.40 to 8.47 NTU (1997) and 0.44 to 6.14 NTU (1998).

At the beginning of clear felling in November to December 1999, extreme fluctuation in turbidity was recorded in C3 at 35.12 NTU (Fig. 3). A higher concentration of turbidity in C3 also occurred in March 2000 at 23.05 NTU. C2 recorded 23.95 NTU of turbidity concentration in September 2000. However, this concentration is less compared to C3. The concentration of turbidity decreased in the next two years after clear felling for C2 and C3. Correlation analysis between turbidity and suspended solid at C2 and C3 during logging is r=–0.252 (C2) and r=–0.269 (C3) while r=–0.247 (C2) and r=–0.191 (C3). Figure 6 shows monthly variation in turbidity and suspended solid (SS) during logging at C2 and C3. Generally, from the average values, turbidity increased by 0.517 NTU and 2.422 NTU for C2 and C3, respectively during logging compared to before logging; and 1563 mg/l (C2) and 5940 mg/l (C3) were recorded for suspended solid.

The results showed that clear felling operation affects the water turbidity in catchments C2 and C3 (Fig. 3), compared to turbidity recorded before the clear felling operation in 1996, 1997, and 1998 where most of the turbidity was less than 5.00 NTU in catchments C1, C2 and C3.

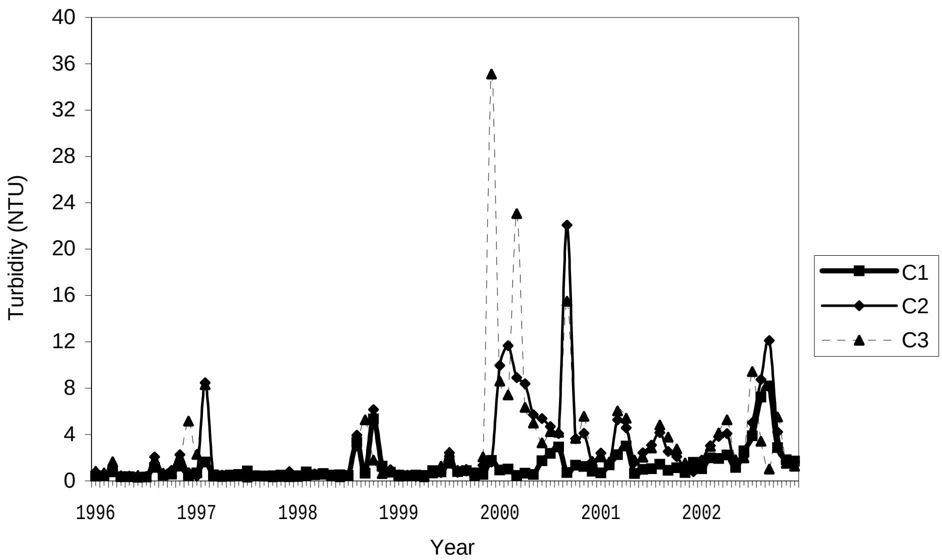


Figure 3: Monthly values of water turbidity for catchments C1, C2 and C3 (1996–2002)

3.3 Conductivity

Most of conductivity observation showed high mean value in clear felled area. The average value increased during the clear felling particularly in C3 where the mean recorded from 10.98 μScm^{-1} before clear felling reaches 16.38 μScm^{-1} during clear felling and 16.11 μScm^{-1} after the clear felling. Figure 4 shows the variation of conductivity for the three catchments before and after logging. The conductivity before clear felling was relatively low for the whole catchments. The value ranged from 6.31 to 26.05 μScm^{-1} (1996), 5.16 to 17.10 μScm^{-1} (1997), and 7.29 to 16.29 μScm^{-1} (1998). It remained unchanged for the whole catchments in 1999 until the clear felling operation started. However, there was a sudden increase in conductivity values in year 2000 at C2 and C3, where the value exceeded 52.80 μScm^{-1} for C2 and 69.00 μScm^{-1} for C3 during peak flow. It took about two years for the conductivity values to return to its stable condition and this was clearly shown by the result collected during post clear felling (Fig. 4).

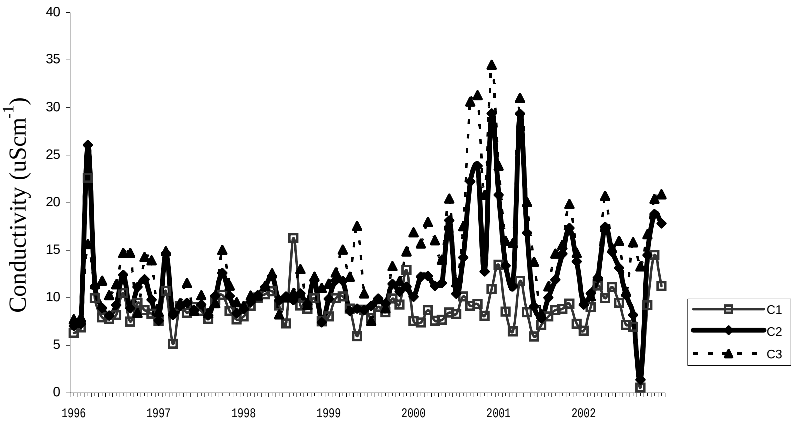


Figure 4: Monthly values of water conductivity for catchments C1, C2 and C3 (1996–2002)

3.4 Colour

Mean value for colour was high before the clear felling. The trend in mean value of colour decreased during and after the clear felling. The mean value of colour ranged between 18.33 to 40.05 PtCo APHA. The colour of water in the control catchment (C1) ranged between 7.00 to 68.74 PtCo APHA while in C2 and C3 the value ranged between 2.00 to 104.60 PtCo APHA (Fig. 5).

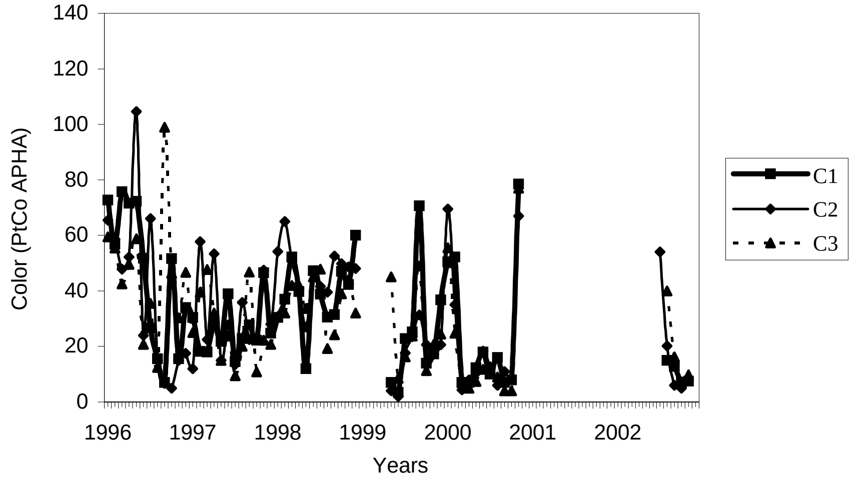


Figure 5: Monthly values of water colour for catchments C1, C2 and C3 (1996–2002)

3.5 Mean Statistical Analysis

Table 2 shows the result of the T-test on the parameters in catchments C1 and C3. The treatment applied in C3 has affected most of the parameters except for color. The pH in control catchment (C1) and treated catchment (C3) are significantly different at p value 0.002. This shows that, disturbance in C3 change the acidity of water compared to the undisturbed catchment. Conductivity and turbidity of the water was also affected by the disturbance in catchment C3. The difference between conductivity and turbidity concentration in control catchment compared to treated catchment was at p value of 0.00 and 0.002. It shows that disturbance on the forest ecosystem affected the water quality.

Table 2: T-test result for parameters in catchments C1 and C3

C1 vs. C3							
pH		Conductivity		Turbidity		Colour	
T-value	p-value	T-value	p-value	T-value	p-value	T-value	p-value
3.180	0.002	7.590	0.000	3.140	0.002	0.230	0.822

4. DISCUSSION

Forest opening affects the physical water quality and it is important to monitor the changes especially if it involves a large water catchment area as the source of water supply comes from this area. According to Friday,[17] one of the biggest forestry activities that affect water quality is accelerated sediment delivery to streams at road crossings. Good road building and maintenance practices will minimize the erosion hazard and related negative impacts on water quality.

The results showed that all selected parameters experience degradation in relation to the clear felling operation in this area. The measurements of physical water quality of pH, turbidity, conductivity and colour showed slightly changes in their values after the logging applied. Even though the effects are small but if the forest opening is in large scale, it would give more impact to the water quality.

Another factor is the important roles of buffer zone (C2) in order to minimize the impact of logging to the stream flow compare to that of without buffer zone (C3). After the trees fell down, rainfall reaches the nearest stream because of no filtering by the trees. Trees help in preventing erosion by intercepting rainfall directly and protecting the soil surface.[17] The root will act as a filter to minimize the sediment entering the stream. The root also has the ability to hold the soil and preventing erosion and turbidity in water. C3 reflected this situation where there is no buffer zone applied and cause the turbid water. C3 recorded highest turbidity level because of no buffer zone applied in this area as compared to C2 with buffer zone. The buffer zone minimizes the rate of sediment movement into the river.

The movement of sediment and dissolved solid into the stream flow increased the conductivity in the stream. This shows that there was high movement of dissolved solid into the stream without buffer zone. This situation is referring to the C3 where high conductivity was recorded most of the time. This means that extensive dissolved material was flushed through the stream in C3 because there was no buffer that filters the material compared to C2 and C1. According to AWRI,[18] a sudden change in conductivity can indicate a direct discharge or other source of pollution into the water. This shows that the conductivity value increased after clear felling operation. Furthermore, rainfall event also contribute to this situation, which support the organic loading into water.

Generally, human activities and land use practices in the catchments can affect the colour of water. It is difficult to determine the significant changes shown in the result as no other human activity interferes in these catchments except the forest logging operation that can influence this parameter. According to Robert and Gene,[19] colour of stream water varied with the amount of intensity of rainfall. This was due to the presence of organic material discharged into the stream during rainfall.

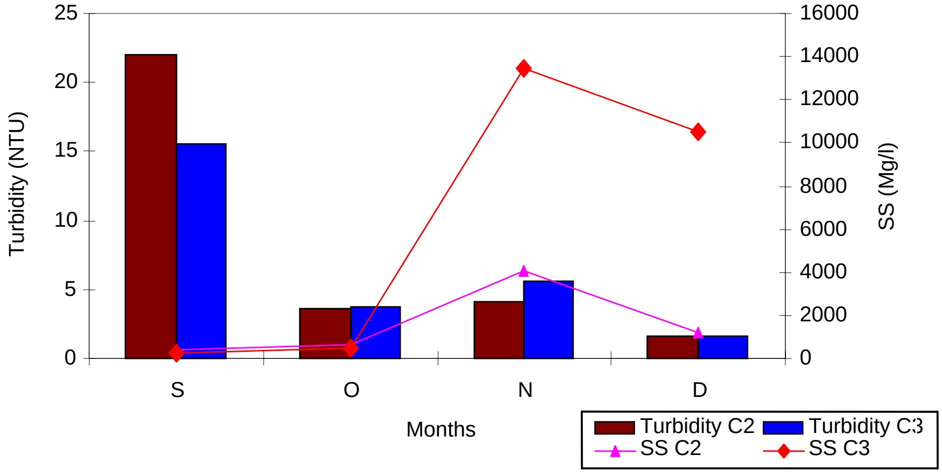


Figure 6: Turbidity and suspended solid (ss) observed at catchments C2 and C3 during logging

5. CONCLUSION

The result showed that clear felling and plantation affect water quality parameters. Increased in pH, turbidity, and conductivity values indicate that clear felling was not only degrading soil and plant but affected the water body. The changes in physical water quality mostly effect the water turbidity followed by conductivity, pH and colour. To minimize the effect of treatment on hydrological parameters, the most important mechanism to be considered is the establishment of buffer zone (at least 20) along the riverbank. The stream buffer with sufficient width intercept sediment, nutrients and other materials in surface runoff and reduces nutrients and other pollutants in water.

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