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Impact of Tilpara Barrage on Back Water Reach of Kushkarni River: A Tributary of Mayurakshi River

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Abstract **-Tilpara barrage over Mayurakshi River has exerted crucial impact on backwater reach of river Kushkarni (4.5 km upstream reach) which debouches to Mayurakshi River at immediate upstream head of this barrage. Study area is located at the Chota Nagpur plateau fringe highly erodible Rarh tract of Birbhum district of West Bengal. From this study, it is found that due to storage of water in the reservoir, backwater created and confluence part of the Kushkarni River is submerged. Stagnation of reservoir water reduced carrying capacity of channel by 26 %, and it is facilitated by declining trend of channel bed slope and velocity of flow. Depth of channel is attenuated by 17–71 cm depositing 919,342.6 m3 of coarser sediment load. In this circumstance, high flood level frequency in same inflow state has increased by 26.5 % and channel braiding has started to nucleate. Alternate textural sequence of materials from river bed reveals some irregular episodic inflow events within reservoir. Episodic discharge and consequent large flood have created thick sand splay cover in the left side of the channel and damaged agricultural land. Potential bank erosion hazard index or BEHI is considerably high (27.35–31.73) in this backwater reach, and the process is mainly triggered by liquefaction. Considering existing forms and functions of the study segment, it is evaluated with existing reservoir upstream channel morphology model of Skalak et al. (2013) and found to be proximate. Such alteration of channel morphology in this segment is linked with socio-ecological fabric of the surrounding area. Along with channel morphological readjustment, socio-ecological setup is also moving toward new adjustment.**

Keywords**- Tilpara reservoir, channel backwaters, aggradations, coarsening of bed, arrhythmic sediment succession, sand splay, etc.**

I. INTRODUCTION

An electric vehicle is an automobile that is propelled by one or more electric motors, drawing energy from rechargeable batteries. The fig.1. Electric vehicle block diagram shows the main components of electric vehicle such as batteries, charger, junction box, traction inverters & regeneration unit, controller, drive unit, motor and DC-DC for auxiliary supply for lamps, horn and body control.

One of the greatest modifications of the fluvial landscape in the Anthropocene is the construction of dams. Merritts et al. (2011) rightly termed those rivers as ‘‘Anthropocene Stream’’ referring a stream set apart by deposits, forms and processes that are the triggered by human impacts. Approximately 800,000 dams have been constructed worldwide up to last century (Friedl and Wuest 2002). India’s share on world total dam is 15 % (Graf 999a, b) which is unexpectedly high, and in India, up to 2014, large dam above 15 m height is 5193 (NRLD 2014). On a global scale, river damming has increased the mean residence time of river waters from 16 to 47 days and has increased the volume of standing water more than 700 % (Friedl and Wuest 2002). The timescale of major dam building was contemporaneous globally, with an extreme acceleration in activity in 1950 and a peak in Dams provide valuable services such as irrigation, hydroelectric power, flood protection and recreational prospects (Collier et al. 1996; Graf 1999a, b), but they have had a dramatic effect on river form and function. Dam effects on river morphology and fluvial processes have become increasingly important to watershed management during recent decades. Flow regimes, channel morphology, sediment transport and ecological processes such as the quality of riparian and aquatic habitats have been influenced by dams (Heinz Center 2002). The downstream impact of dams is well documented by Petts and Lewin (1979), Petts (1982), Galay (1983), Gregory (1987), Higgs and Petts (1988) Graf (2005, 2006), Zhou (1996), Petts and Gurnell (2005a, b), Schmidt and Wilcock (2008), Hupp et al. (2009), Grant (2012), Pal (2015), etc. But very few have documented the upstream impact of reservoir. Petts (1980), Xu (2001a, b), Pollock et al. (2007), Evans et al. (2007), Skalak et al. (2009), Alibert et al. (2011), Skalak et al. (2013), Kumar and Dev (2014) etc. focusing mainly on hydrological, morphological and ecological aspects upstream of reservoir. Particular emphasis is given in most of the works on sedimentation of reservoirs, sediment type, coarseness of sediment, sediment succession and types of deposit formations. Skalak et al. (2013) scientifically established the fact that the coarser sediment is deposited in the delta front and finer sediment in the reservoir through either stratified or disrupted manner based on the sediment supply from the upstream contributing areas and operation principles of reservoir. Other mechanisms such as landslides and shoreline erosion also play a part in reservoir dynamics (Skalak et al. 2013). Reservoir sedimentology and prevailing geomorphic processes shape various landscape units like headwater deltas, deep water fine-grained deposits and turbidity currents which are generally well characterized by Vischer and Hager (1998) and Annandale (2006) and quantified by Morris and Fan (1998) and Annandale (2006). Pal (2013) reported that in post-reservoir period, crosssectional area of the upstream reach has increased, declining velocity has reduced carrying capacity of channel, and this caused gradual aggradations of reservoir and reservoir head channel bed aggradations in Dwarka River of India. Liro (2014) constructed conceptual models of channel changes upstream of reservoir emphasizing hydrological characters, sediment load character, carrying capacity, river bed aggradations, terrace sedimentation, vegetation impacts, etc.

A. Study Area

Kushkarni River is an upper catchment tributary of Mayurakshi River situated in Birbhum district of West Bengal and Jamtara district of Jharkhand. The basin is demarcated by 23.95°N 86.8°E latitudes and 87º14º24z018º30ºE longitudes with a total area of 172 sq km (Fig. 1.). the east-west elongated basin of the 35 km long river is physio graphically situated in the eastern margin of the Chota Nagpur plateau, where the highest elevation (155 m) is seen in the western side near the source of the river and lowest elevation (62 m) is seen in the eastern side near its confluence where at present Tilpara. (Fig. 1). Maximum area of the basin is occupied by undulated topography with an average elevation of 108 meters. On an average, 120-m contour roughly demarcates upper catchment and 80-m contour delimits middle and lower catchments. Entire basin area comes under Rarh tract (Bagchi and Mukerjee 1983) with secondary laterite formation (Chak rabarty 1970) mainly carried by some of the rivers like Kushkarni coming from Chota Nagpur plateau (Jha 1996; Jha and Kapat 2003, 2009). Average slope, measured as per Wentworth's method (1930), is 3–5 %, whereas it is \l % in the confluence segment. Geologically 90 % of the basin area is composed of granitic gneissic rock of Pleistocene age (50 lakh years old) overlain by coarse-grained lateritic soil, and a few isolated patches covering 08 and 02 % area of the lower catchment are made with older and newer alluvium, respectively, of Holocene period over granitic basement (Fig. 1). Just below 4 km below the confluence point Farakka–Midnapore fault passes through. Average annual rainfall of this basin as gauged by Suri meteorological station is 1444.432 mm. High degree of seasonality of rainfall is reflected by 82 % rainfall during the months of June to September. Rainfall analysis since 1980–2013 focused that there is no significant trend of rainfall as also indicated by linear regression model (y - 2.137x ? 5704) and coefficient of determination (R^2 = 0.005). This trend is identical with the general trend of rainfall in India as estimated by many a scholars. Parthasarathy et al. (1994), Dash et al. (2007), etc. reported that in all India scale there is no significant change in rainfall in last 110 years except few regional pockets (Sinha Ray and De 2003). Average potential evaporation of this area since 1901–2014 is 73.45 mm/year which indicates one of the controlling factors of surface water.

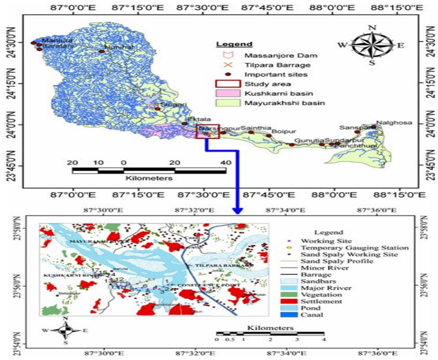

Figure 1 Study site map showing working sites

II. MATERIAL & METHOD

For land use land cover change in the confluence segment, Toposheets of US Army Map Services (No. NF 45-3; surveyed on 1922–1943; published on 1954), Toposheets of Survey of India (Map nos. 73 and 73 M/9, surveyed on 1968–1969; published on 1972), Landsat TM, ETM Image of 1992, 2002 (Path row: 139/43) and Google Earth (2015) have been used. As the toposheets have used for representing the contemporary land use, supervised classification from the landsat imageries has not been done considering the comparability of the maps. Therefore, manual digitization has been done from toposheets and Google Earth image and Landsat images mainly to see the changing water-logging condition, reservoir front island, vegetation and agricultural land, etc. After construction of Tilpara barrage, backwater created in Kushkarni River as it is infused into the reservoir. Gradually, in last 40 years, width, depth as well as cross-sectional area are being modified. To show the changes in cross-sectional area of this

Confluence reach, such comparison is done. For doing this for contemporary period (2015), dumpy level survey has been carried out at different upstream sites of the reservoir. Cross-sectional area of just pre-reservoir period, i.e., 1968-1969, was roughly calculated using depth and width information available from Topo sheet of Survey of India (SOI), 971–1972. According to toposheet scale, width of the river is measured and average depth of contemporary survey period (1968–1969) of the channel is denoted in toposheet at the different river sites along river. Multiplying width of the channel with depth, cross-sectional area is roughly measured. Of course, irregular cross section is not captured in this approach, but average information is provided.

A. Assessing spatial dynamics of backwaters

Inflow–outflow ratio of Tilpara reservoir has been calculated to predict the spatial spread of water. This value[l does indicate water stagnation in reservoir and transgression of water through channel. Coefficient of variation (CV) of inflow and outflow has also calculated to determine the degree of discharge fluctuation in relation to the CV of rainfall in this region (based on rainfall data of Suri Meteorological station). Yearly peak or maximum discharge from Massanjore dam, a prime source of water in Tilapara barrage, has been plotted to understand the probability of maximum area of spread of backwaters in Kushkarni River. Trend analysis of discharge data of different seasons has also been done to apprehend the direction of discharge change. Discharge rating curve using the data of Tilpara gauge station has been prepared to understand the control of discharge on water level as well as to determine the threshold discharge limit of maximum control. From this graph, one can also predict water level and water transgression condition in river.

B. Detetecting channel bed aggradations and sediment succession

Channel bed aggradations due to increasing residence time of water in the barrage reservoir have been measured based on the sediment characters over channel and below it. Samples soil and sand of 5 cm depth interval up to 80 cm each in six sites (2, 4, 6, 8, 10, 13, 16) at channel bed have been selected (Fig. 1). Textural characteristics of each sample have been analyzed based on digital sieve shaker. The fact is that if settling time of water increases, it does mean enhanced possibility of depositing finer materials too over the channel bed (Chavez et al. 2004; Shabani and Shabani 2012). Depth of aggradations has been detected based on the textural break point. Textural break point means sudden change in textural composition. The extent of depth possesses trace finer textural composition which is recognized as deposition in post-reservoir period (1971). Channel depth reference from topo sheets and present field measurement is also another way used for measuring extent of deposition.

C. Submergence of confluence segment

Extent of confluence submergence, longitudinal transgression and areal spread of backwaters due to closing of gates of the barrage, etc. in post-reservoir condition have been detected based on present Google Earth satellite imageries, Landsat images after the periods of 1971 in reference to the Toposheets of Survey of India (SOI) of 1921–1922 and toposheets of US Army Map Services of 1951 showing pre-reservoir conditions.

D. Reservoir front braiding analysis

A good number of methods are available for determining braiding pattern of a channel-like braiding index (BI) of Brice (1964), braiding index of Rust (1978), braid–channel ratio of Friend and Sinha (1993), etc. Here, braiding analysis of the selected four braided reaches has been done following ‘‘braid–channel ratio’’ (BI) of Friend and Sinha (1993).

III. RESULT AND ANALYSIS

A. Land use land cover change (LULC)

In post-reservoir period, forested area in the interfluves of Kushkarni and Mayurakshi rivers (Fig. 5a) has submerged and about 2-km reach of river Kushkarni is captured by reservoir domain. Reservoir front deltaic deposition as bar has started to form immediately after installing barrage (Fig. 5b) and has increased and modified over time in response to the discharge rhythm. After episodic flood 2000, thick coarse sand deposited over this island formation (Fig. 2d). Size of the bar is increased over different phases and extended in forward direction (Fig. 2e). Confluence segmentof the study area is submerged, and neighboring low land is converted to reservoir. In fact, a good amount of agricultural land is now under reservoir domain. Surrounding forest land turns into agricultural land. Island part and sand splay sheets are covered with long and stiff grasses. Formation of backwater triggered by reservoir is the primary cause of land use land cover alteration in this area. Subsequent changes occurred due to formation of island and regeneration of stiff grass land thereon.

B. Channels development upstream dam reservoir

Some prominent channel development parameters have been identified, have been quantified and are given in Table 2, and this will help to validate this study with idealized upstream reservoir morphology model and help to judge it in light of the existing land mark findings by the stall wards scholars in this field. In the long-term approach (at least 25–30 years), the capacity of channels upstream of a reservoir is reduced due to swallowing and declining of channel slope. The width–depth ratio has been increasing over time in the present study, but reverse result is reported by Xu (1990), Xu and Shi (1997) and Xu (2001a, b). Due to the increasing content of silt and clay fractions in channel forms, its erosion resistance has increased and the thread of flow has shifted toward right bank, thus causing rising channel sinuosity. Depositing fine-grained sediments on the bed forms and astride banks, vegetation cover increases as also detected by Maddock (1966) and Xu and Shi (1997) in their respective study. Accretion of sediments inside channel, wetted width and effective channel command area is expanded. The floodplain sedimentation rate is increased. A channel of lower capacity and slope as well as of higher sinuosity formed in relatively finer sediments is a result of long-term changes which is reported by Xu (1990, 2001b) in his study.

C. Cahnges in cross-sectional area

Cross-sectional area and associated properties for 18 sites from SOI Toposheets (1972) and field survey (2015) for prereservoir and post-reservoir periods, respectively, are given in Table 2. Width and cross-sectional area have increased in postreservoir period, and their trend has decreased toward reservoir upstream sites and this finding is very usual. Van Haveren et al. (1987) and Lu et al. (2010) have also established this fact earlier. Such width change does not reflect that empowering stream and enhanced erosion is responsible for widening of channel, wetted width and river water command area. It rather highlights submergence of channel astride zones and widening of channel. But after passing through 40 years such submerged area gradually became a channel-like natural shape.

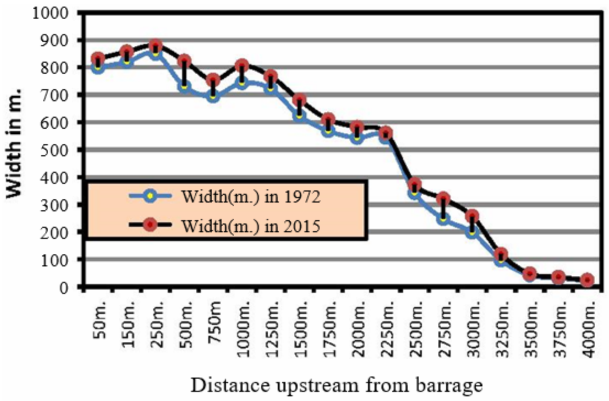

Figure 2 Comparative pattern of width in pre- and post-reservoir conditions.

From table 2, widening of channel after barrage construction can clearly be understood. This rate decreases upstream and becomes almost zero at 4.5 km upstream from reservoir site (Fig. 2.)

Table 1 State of research on the channels upstream dam reservoir.

Channel parameters	Short-term changes	Long-term changes	Location, reference
Channel capacity	$\pm^{7,\ 9}$	$-^{9,}\ ^{4}$	[1] Southern USA (Leopold et al. 1964)
Width and/or depth	$\pm^{7,\ 9}$	$-^{4,}\ ^{5,\ 9,\ 13,14}$	[2] Southern USA, Iran, flume studies (Maddock 1966)
Bed level	$\pm^{7,\ 9}$	$?^{3,}\ ^{7,\ 9,\ 14}$	[3] Southern USA (Leopold and Bull 1979)
Slope	$\pm^{7,\ 9}$	$-^{1,3,7,9}$	[4] Sheep Creek, USA (Van Haveren et al. 1987)
Sinuosity	$\pm^{7,\ 9}$	$?^{7,8}$	[5] Illinois, Mississippi River, USA (Bhowmik et al. 1988)
Braiding index		$-^{8}$	[6] Dunajec River, Poland (Klimek et al. 1990)
River bed vegetation expansion^{2,8,10}			[7] Weihe River, China (Xu 1990)
Channel form stabilization^{12}			[8] Laohahe River, China (Xu and Shi 1997)
Higher rate of floodplain deposition^{7,8,9}			[9] Laohahe and Yangtze River, China (Xu 2001a)
Higher water elevation during floods^{11}			[10] Słupia River, Poland (Florek et al. 2008)
Buried plants remains in backwaters deposits^{6}			[11] Skawa River, Poland (Ksia̧z ek 2006)
Reform of channel and floodplain boundary condition with more cohesive content^{8}			[12] Huron River, USA (Evans et al. 2007)
Planform transitions			[13] Yangtze and Jialing River, China (Lu et al. 2010)
Braided to meander^{8}			[14] Pal 2013

D. The changes in the longitudinal profile of river

The maximum water level in a reservoir determines the maximum backwater extent in the longitudinal profile of a river (Leopold et al. 1964). However, the changes will not occur at the same time in the whole backwater area. This results from different frequencies of occurrence of water levels of a specified height that cause changes in a specified backwater reach. In this study, it is observed that 6- to 8-m rise of water in Tilpara reservoir transgresses water up to 4 km, 4- to 5-m rise extends water up to 2.1 km and 2- to 3-m rise extends water up to 1.4 km upstream of the reservoir site. Channel bed aggradation in reservoir after condition has raised the bed level of channel (Fig. 5). This rate of deposition declines upstream. Influx of water volume is not reduced, but raising of river bed level has been creating possibility of further transgression of water upstream and usually, it is also conveyed by the bank dwellers who experience this in their day-to-day life.

Table 2 Characteristics of channel development. Source: Tabulated based on author's investigation

Channel parameters	Long-term changes
Channel capacity	Decreased by 26 %
Width	3–30 % increased
Depth	14–71 cm reduced
Cross-sectional area	?11.78 % - 16.88 %
Velocity	During releasing period: 0.3–0.7 m/s During closing period: '0.1 m/s
Bed slope	Decreased from 3.1 to 1.2 %
Sinuosity	13 % Increased
River bed vegetation expansion	Seasonal and expand astride
Channel form stabilization	More stabilized
Bank erosion	In short term it was severe
Mean flood plain deposition rate	?21 cm since 1971
Flood plain deposition type	Finer during normal inflow and coarser during excess discharg
Flood level frequency	High flood level frequency in same inflow raised by 26.5 %
Flood stagnation period	Mean water availability and ponding time raised by 43 %
Buried plant remains in backwaters	Accumulated

E. Change in load characters

Reservoirs lock in the entire bed load and a fraction of the suspended load carried by a river. The most palpable effect of this is loss of reservoir capacity, as the reservoir fills with

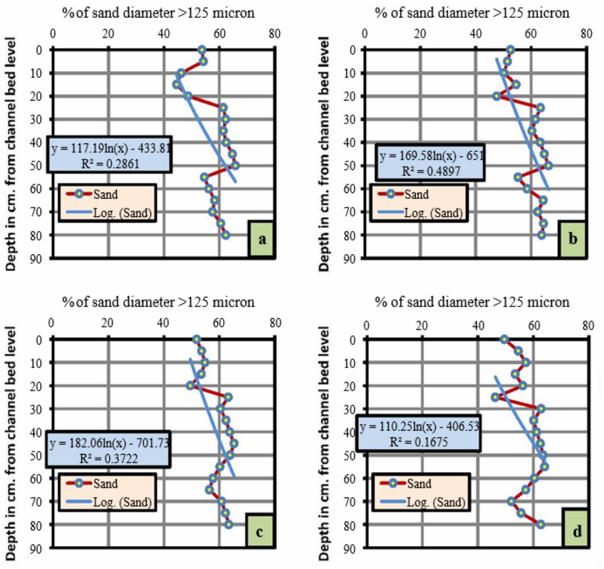

Figure 3 Depth wise distribution of sand diameter 125 lm at different upstream sites of Tilpara reservoir

Sediment (Kondolf et al. 2014). If the backwater effect is strong, reservoir size is relatively small sediment deposition which extends quite upstream of the river (Kummu et al. 2010) and it is happened in the present study. So, the nature of load entrains in this particular reach actually plays vital role for modifying load characters. Volume of load is the function of stream energy and geomaterials of the basin. Discharge and slope of the channel highly control stream energy. Average energy level in post-reservoir condition in different seasons has attenuated significantly, and it is principally due to declining trend of slope and lowering of velocity. Increasing inflow at Tilpara reservoir from Massanjore dam inversely related to sediment load in river Kushkarni. Sediment rating curve (Fig. 3.) shows discharge strongly controls volume of suspended sediment load. Dominant samples show that about 1000 g/s suspended sediment load passes through this channel. High water volume existing in Tilpara reservoir resists free sediment trespassing of load in spite of burly increase in discharge. Arresting velocity in this condition is mainly responsible for it. In monsoon season, maximum sediment is found in river. In monsoon season, stream energy is reduced from 2582.3 to 999.6 Wm^{-1}. So such massive loss of energy level in

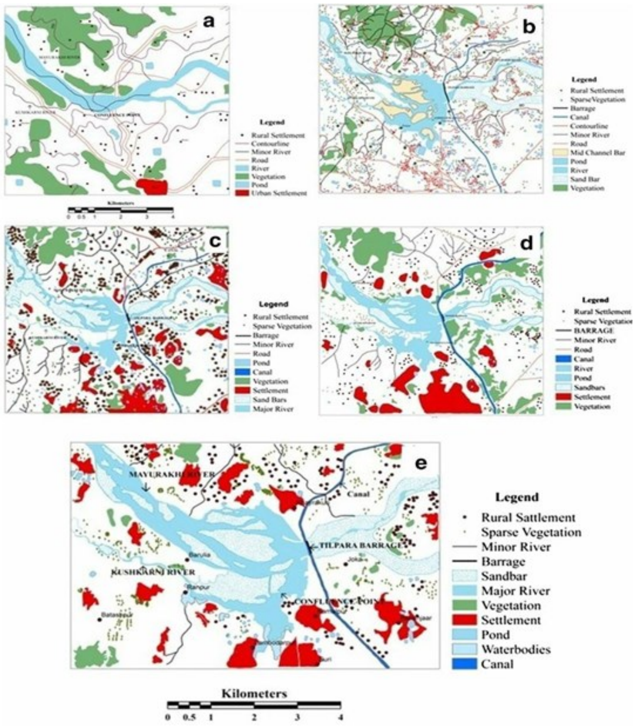

Figure 4 land use land cover map of 1954, 1972, 1992, and 2002, respectively

IV. CONCLUSION

Validation is done always for investigating whether the system runs ideally. If it is ideal what will the forward and backward effects of it? If not, what sorts of discrepancies exist thereon with their cognitive consequences? In the river-dominated interaction reach, the river experiences the beginning of backwater effects. Water velocity slows and the coarsest material is deposited. With peak discharges reduced due to dam operations, this material is not transported and is deposited on the outside of the main river channel (forming bank-attached islands) and this usual situation has developed on the left side of the river Kushkarni. Over time the size of such deposited land is increasing. Further downstream, large amounts of sediment accumulate in the Reservoir-Dominated Interaction reach and fill in the historical thalweg resulting in accumulation on the flooded banks. This phenomenon, in fact, has been reducing the water retaining the capacity of the reservoir. The inundation, in turn, is caused additional backwater effects upstream resulting in additional infilling. The exact location of these processes used to shift substantially longitudinally due to fluctuating levels of Tilpara reservoir and upstream dam discharges. The kind of channel development process in the backwater as stated by many of the scholars mentioned in Table 1 is quite identical except few of the parameters (vide Table 2). Skalak et al. have put forwarded one idealized model for inter-dam morphology. He identified three distinct zones, namely (1) reservoir segment: characterized by spread of water in associated lowland and gradual sedimentation with varying degree, (2) river dominated transitional: characterized by inundated scroll bars, large tree die off (cyclical due to changing reservoir water level) and (3) river-dominated transitional: characterized by formation of large islands on the outside of bends where sediment drops off by the river and backwater. Most of the features and process evolution are noticed in the case of the

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REFERENCES

[1] Alibert, M., Assani, A. A., Gratton, D., Leroux, D., & Laurencelle, M. (2011). Statistical analysis of the evolution of a semialluvial stream channel upstream from an inversion-type reservoir: The case of the Matawin River (Quebec, Can-ada). Geomorphology, 131, 28–34.

[2] Annandale, G. W. (2006). Reservoir sedimentation. Encyclopedia of hydrological sciences. New York: Wiley. Bagchi, K., & Mukerjee, K. N. (1983). Diagnostic survey of West Bengal(s) (pp. 17–19, 42–58). Pantg Delta

[3] Banerjee, M. (1999). A report on the impact of Farakka Barrage on the human fabric (a study of the upstream and downstream areas of Farakka Barrage). New Delhi: South Asia Network On Dams, Rivers and People.

[4] Bastawesy, M. E., Gabr, S., & White, K. (2013). Hydrology and geomorphology of the Upper White Nile lakes and their relevance for water resources management in the Nile basin. Hydrological Processes,

[5] Bhowmik, N. G., Adams, J. R., & Demisse, M. (1988). Sedimentation of four reaches of the Mississippi

[6] Brandt, S. A. (2000). Classification of geomorphological effects downstream of dams. Catena, 40, 375–401.

[7] Brice, J. C. (1964). Channel pattern and terraces of the Loup River in Nebraska, US Geol. Survey Pro-fessional Paper, 422 D.

[8] Bridge J. S. (1993). The interaction between channel geometry, water flow, sediment transport and depo-

[9] sition in braided rivers. In: J. L. Best, C. S. Bristow (Eds.), Braided rivers (pp. 13–71). London: Geol.Soc. Spec. Publ. 75 Geological Society.

[10] Center, Heinz. (2002). Dam removal: Science and decision making (p. 236). Washington, DC: Heinz Center for Science, Economics, and the Environment.

[11] Chakrabarty, S. C. (1970). In B. Chattopadhyay (Ed.), Some consideration on the evolution of physiography of Bengal (p. 20). West Bengal: Geog. Instt., Presidency College, Calcutta.

[12] Chavez, P., Tsukatani, T., & Kojiri, T. (2004). Operation of storage reservoir for water quality by using

[13] optimization and artificial intelligence techniques. Mathematics and Computers in Simulation, 43,

[14] Chen, G., Hay, G. J., Carvalho, L. M. T., & Wulder, M. A. (2012). Object-based change detection.

[15] International Journal of Remote Sensing, 33(14), 4434–4457.

[16] Collier, M., Webb, R. H., & Schmidt, J. C. (1996). Dams and rivers: A primer on the downstream effects of

[17] dams (Vol. 1126). Tucson, AZ: US Department of the Interior, US Geological Survey.

[18] Cuddy, J. D., & Della Valle, P. A. (1978). Measuring the instability of time series data. Oxford Bulletin of

[19] Economics and Statistics, 40(1), 79–85.

[20] Dash, S. K., Jenamani, R. K., Kalsi, S. R., & Panda, S. K. (2007). Some evidence of climate change in

[21] twentieth-century India. Climatic Change, 85, 299–321.

[22] Duan, H., Ma, R., & Hu, C. (2012). Evaluation of remote sensing algorithms for cyanobacterial pigment

[23] retrievals during spring bloom formation in several lakes of East China. Remote Sensing of Environment, 126, 126–135.

[24] Galay, V. J. (1983). Causes of river bed degradation. Water Resources Research, 19(5), 1057–1090.

[25] Graf, W. L. (1999a). Dam nation: A geographic census of American Dams and their large scale hydrologic

[26] impacts. Water Resources Research, 35(4), 1305–1311.

[27] Graf, W. L. (1999b). Dam nation: A geographic census of American dams and their large-scale hydrologic impacts. Water Resources Research, 35, 1305–1311.
[28] Graf, W. L. (2005). Geomorphology and American dams: The scientific, social, and economic context. Geomorphology, 71(1), 3–26.
[29] Graf, W. L. (2006). Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology, 79, 336–360.
[30] Grant, G. E. (2012). The geomorphic response of gravel-bed rivers to dams: Perspectives and prospects. In
[31] M. Church, P. M. Biron, & A. G. Roy (Eds.), Gravel bed rivers VII: Processes, tools, environments (pp. 165–181). New York: Wiley.
[32] Gregory, K. J. (1987). Environmental effects of river channel changes. Regulated Rivers, 1, 358–363.
[33] Higgs, G., & Petts, G. (1988). Hydrological changes and river regulation in the UK. Regulated Rivers:Research Management, 2, 349–368.
[34] Hoey, T. B., & Sutherland, A. J. (1991). Channel morphology and bedload pulses in braided rivers: A laboratory study. Earth Surface Processes and Landforms, 16, 447–462.
[35] Hupp, C. R., Schenk, E. R., Richter, J. M., Peet, R. K., & Townsend, P. A. (2009). Bank erosion along the dam-regulated lower Roanoke River, North Carolina. Geological Society of America Special Paper,
[36] Jha,V. C., & Kapat, S. (2003). Gully erosion and its implications on land use, a case study. In Land
[37] degradation and desertification. (pp.156–178). Jaipur and New Delhi.
[38] Jha, V. C., & Kapat, S. (2009). Rill and gully erosion risk of lateritic terrain in South-Western Birbhum
[39] District, West Bengal, India. Sociedade & Natureza, 21(2), 141–158.
[40] Klimek, K., Łajczak, A., & Zawilin´ska, L. (1990). Sedimentary environment of the modern Dunajec delta in
[41] artificial Lake Roz_no´w, Carpathian Mts., Poland. Quaestiones Geographicae, 11/12, 81–92.
[42] Kondolf, G. M., Rubin, Z. K., & Minear, J. T. (2014). Dams on the mekong: Cumulative sediment starvation. Water Resources Research, 50(6), 5158–5169.
[43] Ksia˛z_ek, L. (2006). Morfologia koryta rzeki Skawy w zasie˛gu cofki zbiornika Świnna Pore˛ba (The mor-
[44] phology of the Skawa River bed within back-water reach of Świnna Pore˛ba Reservoir). Infrastruktura I Ekologia Tereno´w Wie-jskich, 4(1), 249–267.
[45] Kumar, D., & Dev, P. (2014). Groundwater potential zone identification of Karwi area, Mandakini river basin, Uttar Pradesh using remote sensing and GIS techniques. International Journal of Engineering Science Invention, 3(11), 10–19.
[46] Kummu, M., Lu, X. X., Wang, J. J., & Varis, O. (2010). Basin-wide sediment trapping efficiency of emerging reservoirs along the Mekong. Geomorphology, 119, 181–197.
[47] Leopold, L. B., & Bull, W. B. (1979). Base level, aggradation and grade. American Philosophical Society,
[48] Morris, G. L., & Fan, J. (1998). Reservoir sedimentation handbook. New York: McGraw-Hill Book Co.
[49] Mukherjee, M. (2000). Spatio-temporal flood characters of ajoy river basin (doctoral thesis) (pp. 112–214).
[50] Visva-Bharati, Santiniketan, India: Department of Geography.
[51] Mukhoopadhyay, S., & Mukherjee, M. (2005). Hydrological characteristics of flood: A study in the lower
[52] Ajoy river (pp. 51–58). River Floods: A Socio technical Approach., acb Publication.
[53] Muller, J. E. (1968). An introduction to the hydraulic and topographic sinuosity index. Annals of the Association of American Geographers, 58, 371–385.
[54] Mustafa, Y. T., Ali, R. T., & Saleh, R. M. (2012). Monitoring and evaluating land cover change in the Duhok city, Kurdistan region-Iraq, by using remote sensing and GIS. International Journal of Engineering Inventions, 1(11), 28–33.
[55] Mustafa, Y. T., & Noori, M. J. (2013). Satellite remote sensing and geographic information systems (GIS) to
[56] assess changes in the water level in the Duhok dam. International Journal of Water Resources and
[57] Environmental Engineering, 5(6), 351–359.
[58] California, Berkeley, 24, 1-32.
[59] Situ, L. (2009, May). Electric vehicle development: the past, present & future. In 2009 3rd International Conference on Power Electronics Systems and Applications (PESA) (pp. 1-3). IEEE.