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Research article

Potential interaction between transport and stream networks over the lowland rivers in Eastern India

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ABSTRACT

Extension of transport networks supports good accessibility and associated with the development of a region. However, transport lines have fragmented the regional landscape and disturbed the natural interplay between rivers and their floodplains. Spatial analysis using multiple buffers provides information about the potential interaction between road and stream networks and their impact on channel morphology of a small watershed in the Lower Gangetic Plain. Present study is tried to understand the lateral and longitudinal disconnection in headwater stream by rural roads with the integration of geoinformatics and field survey. Significant ($p < 0.001$) growth of total road length and number of road-stream crossing in the last five decades (1970s–2010s) contribute to making longitudinal and lateral disconnection in the fluvial system of Kunur River Basin. Channel geometry from ten road-stream crossings shows significant ($p = 0.01$) differences between upstream and downstream of crossing structure and created problems like downstream scouring, increased drop height at outlet, formation of stable bars, severe bank erosion, and make barriers for river biota. The hydro-geomorphic processes are also adversely affected due to lateral disconnection and input of fine to coarse sediments from the river side growth of unpaved road (1922%). Limited streamside development, delineation of stream corridor, regular monitoring and engineering efficiency for the construction of road and road-stream crossing might be effective in managing river geomorphology and riverine landscape.

1. Introduction

The study of anthropogenic pressure on river geomorphology is still in its early stage (Tarolli and Sofia, 2016). Hence, the construction of road network is relatively new and faces a lack of research interest particularly focusing on the effect of transport infrastructure on channel morphology. The negative effects of transport infrastructure on river system are often inversely correlated with the distance between road and streamlines. The degree of connectivity between road and stream networks is often expressed by number of road-stream crossing (RSC) and distance between roads and streamlines (USDA, 2001). In brief, three-dimensional viz. lateral, longitudinal and vertical interactions have been encountered by river scientists and all three dimensions have significant effects on the geomorphology, hydrology, and ecosystem of river system. Natural rivers at the site of road-stream crossings from longitudinal dimension and section of roads along the streamline from lateral dimension may negatively affect by direct sediment input, fragmentation of floodplain, longitudinal disconnectivity, input of solid wastes (Jones et al., 2000; Merril and Gregory, 2007; Bouska et al., 2010; Fu et al., 2010; Blanton and Marcus, 2009, 2014; Thomaz et al., 2014; Thomaz and Peretto, 2016; Roy and Sahu, 2016).

The channel morphology and hydrology of streams are largely affected by the transport line along the stream, and undersized and architecturally poor RSC for causing lateral and longitudinal disconnectivity respectively. However, vertical connectivity refers to the surface-subsurface interaction of water, sediment, and nutrients (Brierley et al., 2006). The vertical connectivity is mostly hampered by the removing of Hyporheic Zone (HZ), a layer composed of the shallow, saturated sediment below and to the sides of the stream bottom (Schindler and Krabbenhoft, 1998). HZ is often used as a unit of study about the dynamics of in-stream vertical processes on hydrological and biological components of most sand and gravel-bedded streams (Marmonier et al., 1993; Merril and Gregory, 2007; Hancock, 2002; Chen, 2011) (Fig. 1). Smith (1957) has examined the drop of kinetic energy at the outlet

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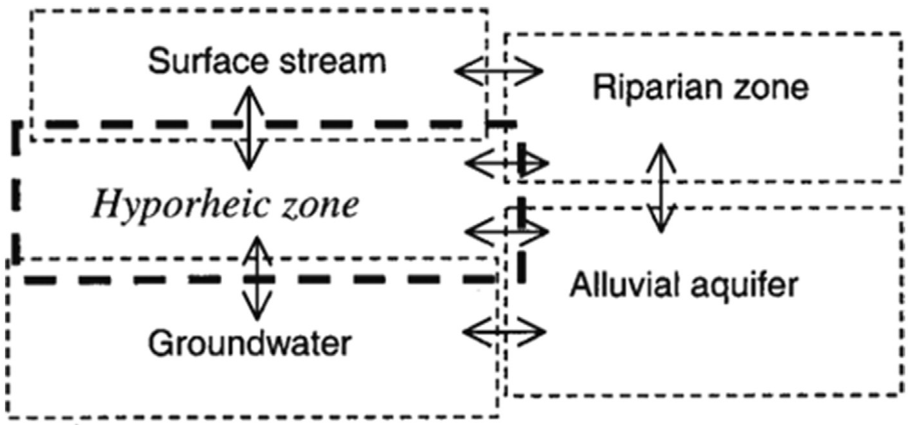

Fig. 1. Role of Hyporheic Zone as a modulator for linkages between the stream, groundwater, riparian, and alluvial aquifer systems (after Boulton et al., 1998).

of circular culverts and its impact upon the removal of bed materials. Southard (1992) have predicted scour depth around the bridge piers based on data obtained on scouring from different bridge sites in the Arkansas.

The lateral diversion are disconnect the main channel from its floodplain, which alters the natural fluxes of sediment, nutrients, flood water, biotic elements, and obstruction for animal's migration (Junk et al., 1989; Shuangcheng et al., 2005; James and Marcus, 2006; Liu et al., 2014). Study shows about 44–69 percent of Holocene floodplain of the Yakima River in Washington State is laterally disconnected due to the construction of roads, railroads, and levees (Snyder et al., 2002; Blanton and Marcus, 2014). According to Cong et al. (2014), constructions of lateral roads (trunk and town road) have destroyed the riparian forests because the zones close to roads are relatively easy to destroy and streams are receiving more sediment than earlier. Transport network is also able to remove (directly or indirectly) a large quantity of soil and in turn directly influenced the processes of earth surface (Tarolli and Sofia, 2016).

The longitudinal connectivity deals with upstream-downstream and tributary-trunk stream relationships, which are significantly altered by in-stream engineering works, such as construction of dams and road-stream crossings, which are frequently criticised for causing river instability (Rankin, 1982; Brookes, 1985, 1988; Erskine, 1990; Cong et al., 2014; Roy and Sahu, 2016). Thomaz and Peretto (2016) estimated at the point of RSC on the headwater streams, suspended sediment and discharge have been increased about 413% and 50% respectively than the unaffected area. Culverts and bridges are increased the flow velocity, shear stress, turbulence of flow, change threshold of degradation and aggradation, development of deep scours, channel braiding and accelerating the rate of bank erosion (Singh, 1983; Grade and Kothyari, 1998; Richardson and Richardson, 1999; Kothyari and Ranga Raju, 2001). According to Gregory and Brookes (1983), width–depth ratio and channel carrying capacity have nearly doubled in the downstream of bridge sites in comparison with the upstream channel due to deep incision and scouring. Douglas (1985) has noticed that channel enlargement takes place immediate downstream of the bridge only because of constricted channel under the bridge induced to raised water level and increased flow velocity. Merril and Gregory (2007) examined 14 RSC (six bridges and eight culverts) at North Carolina and reported that channel cross-section area has been increased in the downstream of crossing structure and also decreased the riffle habitat area in downstream. Bouska et al. (2010) have also studied the comparative effects of three different types of RSC (low-water crossing, box and pipe culverts) on stream geomorphology, particularly on riffle spacing, bankfull width, mean depth, width-depth ratio and channel material between upstream and downstream of the crossing sites. The study also shows mean riffle spacing in the upstream of low-water crossing (8.65 m) are nearly double followed by downstream reach (4.4 m), although, there is no significant difference between upstream and downstream of the box and pipe culverts.

In context of riverine ecosystem, landscape fragmentation and its modification is key driver of global species loss (Fischer and Lindenmayer, 2007). Roadways are one of the major factors to exaggerate such loss. A range of studies has investigated such problems across the world. Dávid et al. (2010) have examined that about 1–2 km strip of roadways are suffering from ecological alternation, which is more profound during the construction work because plenty of materials are transported to the construction sites. Demars and Harper (2005) explored the structure and connectivity of aquatic vascular plants in lowland rivers and define that spatial connectivity along and inter-rivers is more important than in-channel physical characteristics in shaping species assemblages and neither any other chemical factors. Lateral disconnection might cause significant ecological damage, including loss of riparian forest, channel and floodplain habitat loss and/or simplification, and loss of riverine biodiversity (Wemple et al., 1996; Bravard et al., 1986; Wemple et al., 2001; Ziegler et al., 2004; Wheeler et al., 2005; Ward and Stanford, 1995; Blanton and Marcus, 2009). Nevertheless, the roadways can also increase the connectivity between two ecosystems by a homogeneous path of movement (NRC, 2005). The movement of fish and other river water community are severely affected by the RSCs due to increased drop height at the outlet of culverts (Wellman et al., 2000; Bouska et al., 2010). Camana et al. (2016) have successfully represented the importance of channel slope on fish species richness in southern Brazil. From the perspective of vertical disconnectivity, riverine biota is significantly influenced by removing HZ because it works as a biological filter and a refuge for macro and microinvertebrate fauna from the shear stress of the surface (Boulton et al., 1998; Hancock, 2002).

Inadequate crossing structure also affects the capacity of road used when the overflow of flood water occupied the road surface and became a serious danger for traffic (Conesa-Garcia and Garcia-Lorenzo, 2013; Kalantari et al., 2014). In addition to the threatening safety and endangering human lives, such induced flooding poses a considerable threat to the infrastructure also and increased the repair bills (Hansson et al., 2010; Kalantari et al., 2014). For example, during the period of 1995–2007, the total cost of road infrastructure damage due to high water flows and landslides in Sweden were estimated as 1200 million Swedish Krona or SEK