

# A Review of Riverbed Extraction and its Effects on Aquatic Environment with Special Reference to Tinau River, Nepal



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**Abstract:** Rivers not only maintain the ecological balance but also generate resources. Fishes and riverbed materials such as sand, cobble, pebble, boulders, etc. are the sources of income from natural rivers; and these are the important resources in the construction industry.

There exist very few studies on the effects of riverbed extraction in the rivers like Tinau. The lack of generic hydrological and climatic data in the river catchment leads to the lack of knowhow regarding the hydrological behavior of the river basin and its consequences over time. This study is the outcome of the literature review on riverbed extraction and its effects on the aquatic environment particularly in the Tinau River. Riverbed extraction can cause many effects on the environment. But this paper mainly focuses on the effects of riverbed extraction on the hydraulic structures, ground water, river morphology, cost externalization, fish species and fisheries for livelihood.

**Key words:** Riverbed extraction, Tinau River, river morphology, cost externalization, aquatic environment, Nepal

## A Brief Introduction of the Tinau River

**T**he Tinau, a Class- II category River (Figure 1) originates from the Mahabharat Mountains and flows through the Siwalik Hills and debouches into the Terai Plain at Butwal, Nepal before entering the Indian Territory to join the Ganges.

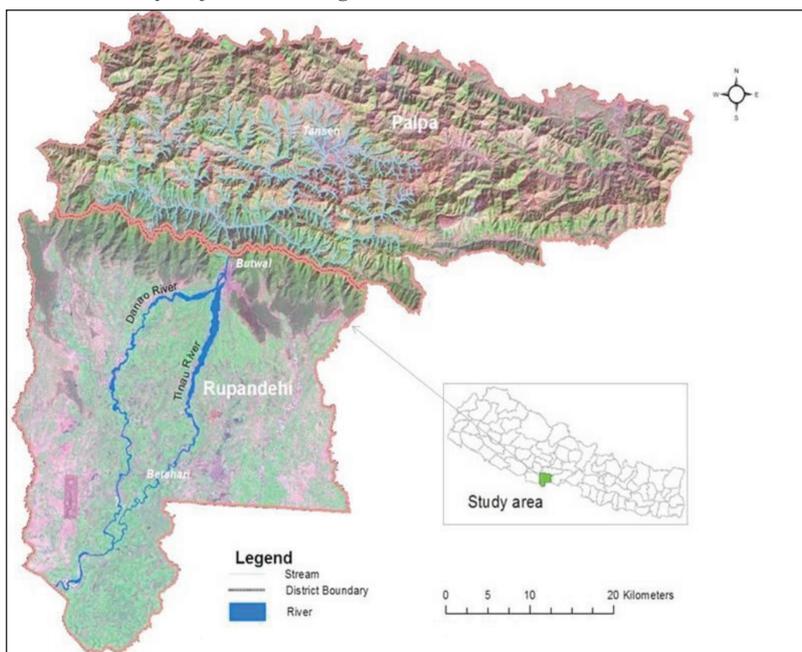


Figure 1. Map Showing Study Area.

The length of this river is about 95 km from Palpa (source) to the Indo-Nepal Border at Marchawar (Rupandehi), Nepal (Guragain 2012). The width of this River varies from place to place. Generally, the width is very less in upstream and it is larger in the downstream. The total catchment area of the Tinau Basin is 1,081 sq. km (at the Nepal-India Boarder). The width of the Tinau at the suspension bridge just after debouching from the hills is 75m whereas after 1 km it becomes 110m. The dry season discharge measured in April is about 2.2 m<sup>3</sup>/s, whereas the 100 year (return period) flood discharge is over 2500 m<sup>3</sup>/s (Guragain 2012).

The Tinau is in the degrading stage in the upstream, and it changes its regime to aggrading stage after entering the Terai plain. The deposition of debris from different sources in the Tinau increases when the river flows towards the Terai Plain (especially from Butwal to Bethari about 26 km downstream from the Highway Bridge on Tinau River at Butwal).

River resources like sand, gravels, cobbles, pebbles and boulders were used by the ancient people in the pre-historic age. This is one of the reasons that many ancient civilizations flourished on the banks of rivers. Butwal at the bank of Tinau River is also considered as one of the ancient cities of this region. The Ramapithecus jaw was found on its bank. Similarly, Butwal is also considered as an old city of commerce and industries. The city provides business services to many districts of the western and mid-western region of Nepal.

Rupandehi District is located nearly at the centre of the national highway (Mahendra Rajmarga). The district has an open border with India on the south. The access roads are available throughout the district. The industrial development of this district is made easy due to the short distance from India. Thus the riverbed materials are easily exported to India.

There are many rivers in the districts which are massively exploited beyond their regenerating capacities for riverbed materials. The Tinau, Danao, Rohini, and Kanchan rivers are the examples of such cases.

The Tinau River is being extracted massively since 2004 generating high incomes for the Village Development Committees (VDCs), Municipalities and District Development Committee (DDC) (DWIDP 2011). The income of local bodies (i.e. VDCs, DDCs and Municipalities) is given in Table 1. The data shows that the income was in an increasing trend from 2004/05 to 2009/10. There is a slight decrease in income in the year 2007/08 which again increased during 2008-2010.

S. No.	Local Body	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	Total Income (NRs.)
1	Total (NRs.)	153.91	155.94	189.17	174.45	355.82	354.33	1383.65
2	Equivalent USD (1\$=NRs. 88.39)	1.729	1.752	2.125	1.960	3.998	3.981	15.548

(Source: DDC, VDCs and Municipality Records 2012.)

Table 1. Income Generated by Local Bodies (of Rupandehi district) from the Tinau Riverbed Materials.

### Previous Research Focuses on Tinau River

There have been numerous studies in the Tinau River in diverse aspects. Some of the local organizations involved in the study of the Tinau River are, Tinau Watershed Project, Butwal Municipality, DDC etc. Some other organizations involved in collaborative research are: Japan International Cooperation Agency (JICA), Institute of Development Research (Jaipur, India), Institute for Social and Environmental Transition (Boulder, USA), Madras Institute of Development Studies (Chennai), Nepal Water Conservation Foundation, and Vikram Sarabhai Centre for Development Interaction (India). Besides, some academic studies have also been conducted on this river (Jha 2006; Sharma 1996).

A descriptive Environmental Impact Assessment (EIA) study report was prepared by the DDC (Rupandehi) to continue the extraction activities in the Tinau River. The report has been severely criticized by the environmental experts, stakeholders, and researchers who are directly or indirectly involved in river conservation, particularly in the Tinau River. Despite the criticism, the report consists of some scientific information, especially in respect to biological assessment. The report mentions that the environment of the Tinau River is continuously deteriorating due to water pollution and deforestation. Human activity is one of the main causes for such adverse impacts on the aquatic ecosystem. The extraction has caused a lot of loss of aquatic lives. Thus, the Tinau needs rehabilitation measures such as establishment of restricted areas for extraction of boulders, sand and aggregates from the river (DDC 2011). This clearly underscores the unsustainable the over-extraction status of the river. In 2010, some social activists filed a case in the Supreme Court against the extraction of riverbed materials from the Tinau River. The court ordered to make an EIA report. Thus, the DDC with some hired experts prepared the EIA report. But there was already devastation in the river and it was impossible to extract any more materials from the riverbed or floodplain. The EIA report was made available for public hearing. The general public, social activists and journalists denied passing the EIA report. Thus the report was kept pending (Parliament, 2010). This is the evidence of the general people being concerned at the over extraction of river bed material from the Tinau River.

Sharma (1996) conducted a study on the 'Fish biodiversity and fishery resources of the Tinau River during the period of 1994-1995'. The author selected different stations in the Tinau River from Damkada to

Bethari. During the study, he found 12 fish species at Butwal (Near Siddhababa Temple) station and 13 species at Bethari. The most dominant fish species at Butwal station were *Barilius bendelisis* (Fageta), *Garragotyla* (Buduna) and *Puntiussophere* (Sidre). At Bethari station among 13 species the most dominant species were *P. conchoniuss* (Sidre) and *P. sopher* (Sidre). Generally, fish in the Tinau River migrate upstream in the early monsoon (May-June) and migrate in downstream in September-October.

Jha (2006) conducted a research on fish in the Tinau River during the course of his PhD. His study was entitled "Fish ecological studies and its application in assessing ecological integrity of rivers in Nepal". He studied some fish base parameters such as the number of species, composition and the abundance in nine rivers including Tinau. In the case of the Tinau River he found 29 fish species and Catch Per Unit Effort (CPUE) 95.95. The density of fish species recorded was 23.51 (number/100 m<sup>2</sup>). The study was carried out one decade ago; and at present, the same status of the fishes in the Tinau River cannot be expected due to riverbed extraction; however, scientific data is yet to be collected.

Both Sharma and Jha were focused on finding the fish abundance, species richness of fishes in the Tinau River. The activities of riverbed extraction increased with time; and, ultimately it destructed the fish habitat (WIDP 2011). If the habitat is disturbed, this means that there is loss of fish species and abundance. But the scientific proof is lacking.

Dixit and Gyawali (1999) studied the various uses of water in the Tinau River. As a whole, their study describes the uses of water from the Tinau River and the water management systems throughout the river basin. They mentioned about the deposition in the Tinau River but did not mention about the balanced way of extraction in the Tinau River.

Chhetri (2011) studied the social equity in Chaar Tapaha Irrigation System (3,500 ha) (CTIS) of Rupandehi District. The water in Chaar Tapaha is diverted from the Tinau River. She studied the social justice, water distribution, social norms and values, women's participation in the management, rules and regulation of the Farmer Managed Irrigation System (FMIS), equity in information sharing, equity in cost and benefit sharing, equity in organizational structure, transparency and accountability, equity in wage management, equity in conflict resolution and difficulties in the command area of the canal. The canal is completely farmers managed.

It had no permanent headwork. Thus the diversion of water into the canal was very difficult. The reason was the deepening of the river bed. Farmers faced this trouble for many years and last year the Department of Irrigation (DOI) made the permanent type of headworks in the Chaar Tapaha Irrigation System. Similarly, DOI constructed a semi-permanent intake system in the Tinau for Soarah Chhatis Mauja Irrigation System (SCMIS).

The People's Embankment Program (PEP 2009) prepared a Detailed Project Report (DPR) in 2009 from Butwal to Marchawar for the conservation of the Tinau River. The study focused mainly on general information of the river hydrology, socio-economic condition of the area, existing condition of the river and proposed remedial measures. The main objective of the program was to construct the required infrastructures on the bank of the Tinau River to prevent the land erosion due to floods. This project is new (started in 2010). The birth of this program is due to the degradation of the river environment. The river bed was extracted massively from 1997 and the bank erosion, river incision and change in morphology of the river took place. The general people were affected by these activities. Thus the government started to build the embankments and other protection measures for the conservation of the river.

Kharel (2002) also studied and prepared a report on 'Description of the Tinau River' which provides only short information related to the Tinau River. But he did not study the effects of riverbed extraction.

The Butwal Municipality (2001) conducted a study on the Tinau River under "Save the Tinau Program". The study was focused on hydrology, geology and geomorphology, river sanitation, irrigation systems, floods and river training works, urbanization and road corridor development of the Tinau River. Since the riverbed extraction is the main problem of the degradation of the river environment, the report describes a little bit in this regard. The riverbed mining is one of the important activities which have been going on over the flood plain and channel of the Tinau River for many years. This activity lowers the riverbed level and increases the bed gradient toward the upstream side. Thus its effects can be seen as increase in the flow velocity and decrease in the discharge of the river. As a result, it leaves behind the non-flooded riverbank (flood plain) like Maina Bagar. Boulder, sand and gravel of the Tinau River are potential sources of construction materials to fulfill the need of Rupandehi as well as its nearby districts. The construction materials from the Tinau River are being exported to India. The undulated riverbed along the course or many man-made ditches, which do not fill up after the main flood, show that there is a clear deficit in sediment deposition as compared to the present mining rate. If the situation continues, there could be a problem of riverbed lowering, which affects riverbank erosion causing damage to the bridge, embankment protection, and intake of the canal in the upstream side. It can also damage all man-made structures (especially hydraulic

structures) (Butwal Municipality 2001). Ultimately, the extraction activities incur increased cost for the maintenance SCMIS and CTIS, which is called external cost.

JICA (1999) conducted a study on the flood mitigation plan for selected rivers in the Terai Plain in Nepal. The study covers eight major rivers of Nepal including the Tinau.

The Tinau floodplain extends over 5,700 ha. Its major tree flora is *Dalbergia sisso* (Sisau), *Terminallia tomentosa* (Asana), *Acacia catechu* (Khayar), *Ficus glomerata* (Bar) and *Bombax ceiba* (Simal). The principal ground species are *Clenodendrum visussum* (Bhaat), *Cynodon dactydon* (Dubo), *Ipomoea fistulosa* (Ajambari/behaya), and *Saccharum spontaneum* (Kansh). This wetland is an important feeding and breeding ground for several aquatic birds including *Grus antigon* (sarus crane), *Egretta alba* (Seto Bakulla), *Ciconia nigra* (Black stork/Kalo Bhundifor), *Ibidorhyncha struthensii* (Tilhari Chara), *Sterna albifrons* (Laghu fyalfyale), and *Nettapus coromandelianus* (Hari Hans) (JICA 1999). JICA has estimated the soil erosion rate of the watershed area of the Tinau River but did not mention about the deposition and debris flow by landslides of the Tinau corridor. Similarly, it did not study about the extraction of riverbed materials and its effects on the aquatic environment.

Paudel (2011) studied the Tinau Basin with a focus on the analysis of floods for different return periods. In addition, he analyzed flood vulnerability and flood risk along the Tinau corridor. But he did not study the effects of riverbed extraction.

## Research Gap

Many organizations and individual researchers have performed different kinds of studies on the Tinau River. However, the studies focusing on *Riverbed Extraction and its Effects on the Aquatic Environment*, one of the key problems at present time is lacking. Therefore, we hope that this article will help to provide a new insight for the researchers, community based organizations, environmentalists and policy makers.

## History of Riverbed Extraction

Significant riverbed extraction in Nepal for using the raw materials like sand and gravel started since 1963-1964 (Baidya 2003).

Tinau is one of the richest rivers in sand, gravels and boulders. The history of extraction of this river is very old. But the official record is not available. The massive extraction in the Tinau was begun with the dawn of democracy. The Local Self Governance Act (1999) and Local Self Governance Regulation (1999) provided the local governance bodies the right to use the local natural resources for their development. Thus the extraction of riverbeds to use as raw material was expanded and the local bodies are keeping the record of riverbed extraction since then.

## Effects of Riverbed Extraction

There are diverse effects of riverbed extraction. Most of the riverbed materials are extracted from the low depth of the river. These are used in the construction of different infrastructures such as road paving, making concrete blocks, building construction etc. The extraction activities destroy the vegetative cover of the aquatic environment and reduce the nutrient inputs into the river.

Riverbed extraction induces lowering of the ground water table, creates disturbance in the aquatic habitat of wetlands, change in river morphology and loss of fish habitat (US-EPA 1995; Trites et al 2009; Scott et al 1999). Other common effects of riverbed extraction are: bank erosion, slope instabilities, river incision, head cutting, and damage to the river equilibrium. Incision of river channel drops the water table in the alluvial banks and it also reduces the storage capacity of an aquifer (Kondolf 1998). Disturbances in the natural rivers and streams are of diverse types which also depend on cultural behavior. However, no attention has been paid towards the cultural disturbances in Nepalese rivers (Khanal 2001). In addition, there are a number of transient effects of riverbed extraction such as noise pollution, air pollution, traffic jam, dust and other emissions, and spill of petrol or diesel on the ground (Kondolf 1998). Generally, in large rivers the quarries are located far from the settlements but in small rivers they may be located near the settlements. Thus the transient effects on the extraction activities are treated as the serious ones. In the case of the Tinau River, there are both types of effects, transient and permanent. But the details of these effects have not been studied yet.

There is high demand of river bed materials across the border for construction of development works such as road construction etc. Export taxes for the river bed materials must be priced considering compensation for the degradation it has caused in the river environment. For example in 2009/10, the revenue collected (for the whole of Nepal) by the local bodies from the river bed extraction was Rs.1 Billion whereas the estimated damage to the road was Rs.11 Billion due to about 23

tons of truck loads as reported by the Parliamentarian Committee of Nepal.

Riverbed extraction can cause the cost externalization. The profits of riverbed materials are taken mainly by the industrialists, whereas the environmental pollution is left to the dwellers on the bank of the rivers. The place is converted into a nuisance. It is not only harmful to live around the disturbed areas but the aesthetic beauty is also lost. Such effects are found in almost all rivers where the extraction activities are under practice. In the case of the Tinau, the external cost created by the riverbed extraction is yet to be assessed.

In addition to the ecological and cultural aspects, riverbed mining has threatened infrastructures near the rivers (such as bridges, dams and weirs) even in the developed nations (Kondolf et al 1993). Bridges over the Tinau River at Butwal and Bethari are also threatened due to riverbed extraction. However, the extent of this effect has not yet been studied in the Tinau River.

There are various effects of riverbed extraction. Some effects are visible and some are not visible. The general direct effects of gravel extraction are: change in river morphology, impacts on hydraulic structures like dams, spur, revetment wall, culverts and bridges, destruction of fish habitat, loss of livelihoods and cost externalization (Kondolf 1993, 1994, 1997, 1998). These effects can be seen in the Tinau River.

Figures 2, 3, 4, 5 and 6 are the evidences of degradation of the health of the river due to riverbed extraction. Figure 2, shows the bank scouring Figure 3, shows the scour of bridge pier due to extraction; Figure 4 shows the construction of bed bar to prevent further erosion due to extraction; Figure 5 shows the degraded aquatic environment; Figure 6 shows the broken headwork of the canal (built with assistance of the Government of India) at Hattisunde; and Figure 7 shows the damaged spur/river training work due to riverbed extraction.

The illegal and haphazard extraction of riverbed materials is harmful and can damage the overall river environment. Thus the Natural Resources Committee of the Constituent Assembly (CA) recommended extracting the materials after the preparation of an IEE/EIA report



Figure 2. Bank Scouring.



Figure 3. Bridge Pier exposed due to bed Scouring.



Figure 4. Construction of Bed Bar.



Figure 5. Disturbed Site.



Figure 6. Damaged Headworks.



Figure 7. Damaged Spur.

with a detailed environmental management plan (UNDP 2011).

The natural resources like sand, gravel and boulders are the good sources of income and revenue generation. Many districts of the Terai (15 districts) and some of mid-hills like Makawanpur, Kavre, Udayapur, Bhaktapur, Kathmandu, Dhading, Kaski and Nuwakot are also the potential districts for riverbed materials. However, it raises the external cost too. The total revenue from the riverbed materials in the last fiscal year (2009/10) was 1 billion, whereas the repair and maintenance cost of the road was 11 billion (UNDP 2011). Thus the cost of road repair and maintenance and other environmental cost must be included while awarding the contract for extracting natural resources.

Butwal Municipality collected more than Rs. 150 million as revenue in the fiscal year 2009/10. The riverbed materials are not only beneficial for revenue collection but also for the overall social development. In some cases, it also contributes to the protection from a catastrophic event. For example, the high flood of Tinau in 2009 was dangerous for Butwal city. If the river would not have been deepened, it could cause the damage of the city including surrounding areas of the river channel (UNDP 2011).

The Tinau River is one of the important rivers to be investigated in terms of ecology and sustainability. This is the heart of Rupandehi District and can attract domestic as well as international tourists. The river could be one of the important tourist destinations, but it has not got considerable priority for development and conservation. At present, this river is generating income for the DDC, VDCs and the municipality by extraction of sand and gravel from the channel and flood plains. The monitoring and evaluating of the health of the river need to be done to prevent the over-stressing the river and keep it healthy. Therefore, to study the overall disturbances of riverbed extraction in the Tinau River, we have to give attention to its ecological as well as cultural aspects. Assessment of impacts on infrastructures should also be given due consideration.

The riverbed materials must be extracted in an environment friendly way. The extraction should be guided by a technical manual. The river warden should be appointed and all resources should be studied in a scientific way (UNDP 2011).

From the literature review and the investigation made by the past researchers, the following problems are caused by the riverbed material extraction in the Tinau (DWIDP 2011; Butwal Municipality 2001; Guragain

2012; Kharel 2002; Guragain 2012).

- Lowering of the riverbed thereby dangerously scouring the bridge foundation and other hydraulic structures;
- Difficult to divert water from the river for irrigation;
- Negative effects on aquatic life/ fish habitat, livelihoods of fishermen, change in water chemistry/ water quality, and
- Lowering of ground water table.
- Cost externalization

*Lowering of riverbed:* At the Tinau Bridge in the East-West Highway at Butwal, the bed level has been lowered by about 2.5m during the last 15 years. The pier foundation is scoured and became dangerous for the bridge (see photo Figure 3). Further, the floods have damaged spurs, revetment walls etc due to river deepening (DWIDP 2011; Guragain 2012).

*Difficult to divert water:* Due to deepening of the riverbed of the Tinau, difficulty was faced in diverting water for irrigation by employing the traditional practice of boulder/brushwood dam. Hence the Department of Irrigation (DOI) constructed a semi-permanent diversion structure (cutoff wall) to divert the Tinau water to SCMIS. The same case was with CTIS where DOI constructed a permanent headworks in the Danao too (DOI 2011). Thus four numbers of bed-bars were constructed in the Tinau to divert water into the SCMIS and also CTIS.

*Negative effects on aquatic life:* In general, riverbed extraction causes the destruction of fish habitat. In the Tinau, the pools have been destructed, and spawning sands, gravels, cobbles, pebbles have been excavated in a massive way. Thus the habitat has been destructed and it has adversely affected the fish habitat in the Tinau (Dahal 2002).

*Lowering of ground water table:* The extraction activity has lowered the ground water table in the vicinity of the Tinau River. The effects can be seen in many dug wells and shallow tube wells in and around the Butwal area. Many low depth shallows have failed to yield water in the dry season. They yield water only in the rainy season (NEM 2011).

*Cost externalisation:* The extraction activities have induced lowering of the river bed which has incurred increased cost for the additional maintenance of SCMIS and CTIS Canal, resulting in cost externalization.

All the aforesaid effects of riverbed extraction in the Tinau River need to be researched and proved scientifically in a broad perspective.

## Conclusion

Riverbed extraction can cause the destruction of the whole ecosystem of a river. The extraction activities

lower the groundwater table and cause the depletion of productivity. Ultimately, it causes an increase in pollution and causes nuisance to the aesthetic beauty. Extraction of riverbed materials directly affects the hydraulic structures like bridges, dams and weirs. The river morphology also changes and incision takes place. Other impacts include the destruction of the aquatic habitat, disappearance of native fish species and invasion of exotic species. As the species and abundance of fish reduces, it affects the livelihood of the people (fishermen). The extraction of riverbed materials benefits the industrialists but it raises the external cost for the general people. More resources need to be made available to save the environment and repair the damaged infrastructures caused by extraction activities.

As river bed extraction is a very good source of income for the local bodies, it is recommended to exploit the resources in a controlled (environmentally sound) manner.

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## Hydro Nepal Excellence Award

This journal has been awarding HYDRO Nepal Excellence Award each year to anyone who has rendered outstanding services in the field of water, energy and/or environment sector. For 2012 award, we had called for suitable nomination for the probable candidates in the HN Journal issue no. 10 (January Issue). However, we have not received any nomination and also the Evaluation and Selection Committee could not find a suitable person/institution for this Award. Hence, no Award has been announced for the year 2012.

**-Editors**