

The historical avulsion of the Tista River, and its relationship to the Brahmaputra: Map and archive evidence from 1750 to 1835

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Alluvial fans are constructed when river deposition raises local elevations until the river “avulses” to an alternative lower elevation alignment. Avulsions may be triggered by exogenous events, such as floods that locally overtop the river’s banks; they may then cause extreme flooding on a fan and have major impacts. Rivers draining the Himalayas into the Gangetic plain have behaved historically in this way; for example, the Kosi River’s historical westward migration (1731–1963), and its recent eastward shift (1980). In the major fan-delta of the Bengal Basin, the Brahmaputra and its tributary, the Tista, have both undergone historical avulsions, with some suggestion that these may have been causally linked. Between the Rennell survey of Bengal (1765–77) and the partial re-survey by Wilcox and Ommanney (1828–35), the Brahmaputra River substantially changed its course. In Rennell’s time it turned south-east into the Sylhet Basin leaving the higher land of the Madhupur Tract on its right; by 1830, it flowed due south with the Tract on its left. One hypothesis for the timing and cause of this avulsion relates it to the impact of a major flood and avulsion in the River Tista in 1787. This paper examines the evidence of the Rennell maps, the East India Company archives of correspondence between District Collectors about flooding and avulsion in the Tista, and the diaries of Francis Hamilton Buchanan who travelled along the Tista in 1807–11. From these contemporary sources it is possible to reconstruct the changes in the River Tista in the late 18th century, and to conclude that its avulsion had little direct influence on that of the Brahmaputra, although it went through some radical rearrangements of its own.

KEYWORDS

Brahmaputra, East India Company, floods and avulsions, James Rennell, map evidence, Tista

1 | AVULSIONS ON ALLUVIAL FANS; THE TISTA AND THE BRAHMAPUTRA

Rivers emerging from a mountain front often construct alluvial fans. These sedimentary features have the general form of a segment of a low-angle cone, and avulsions of the river are natural, endogenous processes without which fans would not exist. The river deposits sediment along its path, raising its elevation locally, until it switches into an adjacent lower route; this process is then repeated. The timing of an avulsion depends on a conjunction of the gradual process of sedimentation with an exogenous event like a flood which causes the river to switch, often into a palaeo-channel it occupied earlier.

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Once a river on a fan has avulsed, its former course below the avulsion atrophies, and the channel shrinks. If a later avulsion re-occupies this reduced channel, severe flooding can occur, causing major impacts on settlement, infrastructure, and agriculture on the fan, and on people's livelihoods, and even lives. The development of alluvial fans, the processes of avulsion by rivers draining them, the reduced size of their abandoned channels, and the river management issues on fans are all discussed in Appendix S1, to provide background for the later sections of this paper, whose purpose is to interpret a major avulsion event on the fan of the Tista River, now a tributary of the Brahmaputra, in the late eighteenth century.

The Tista River (see Figures 1 and 2) is one of a series of rivers with large, compound alluvial fans, formed by and named after their rivers which emerge into the Gangetic Plain and the Bengal Basin from the Himalayan mountain front. From west to east these include the Ghagra, Gandhak, Kosi, Mahananda, Karatoya, Tista, and Dharla rivers and fans. The first five of these are tributaries of the Ganges, the Dharla joins the Brahmaputra, and the Tista has at various times been tributary to both major rivers. This paper outlines an avulsion history of the Tista River that has involved several changes in orientation, from being a tributary to the Brahmaputra, then the Ganges, then switching back again in 1787. This history is as significant as that of the much-studied Kosi River (Gole & Chitale, 1966; Wells & Dorr, 1987), known as “the sorrow of Bihar” for its major floods relating to extreme monsoons and frequent avulsions. Gole and Chitale (1966) described the Kosi's general westward migration in a series of avulsions between 1731 and 1963, although an eastward shift following the breach of an artificial embankment occurred in 1980, causing significant river engineering problems (Gupta et al., 2010; Sinha, 2009; see Appendix S1).

Perhaps the most significant change to the rivers of the sub-aerial Bengal fan-delta in the historical period¹ has been the avulsion of the Brahmaputra itself, from its former course to the east of the Madhupur² Tract and into the Sylhet Basin to its present, more direct southerly route (Figure 1). The former course is now known as the Old Brahmaputra River, and the present course is the Brahmaputra-Jamuna³ River, which joins the Ganges near Aricha. The avulsion of the Brahmaputra occurred in the late eighteenth or early nineteenth centuries, between the Rennell surveys of 1765–77 that show it in its

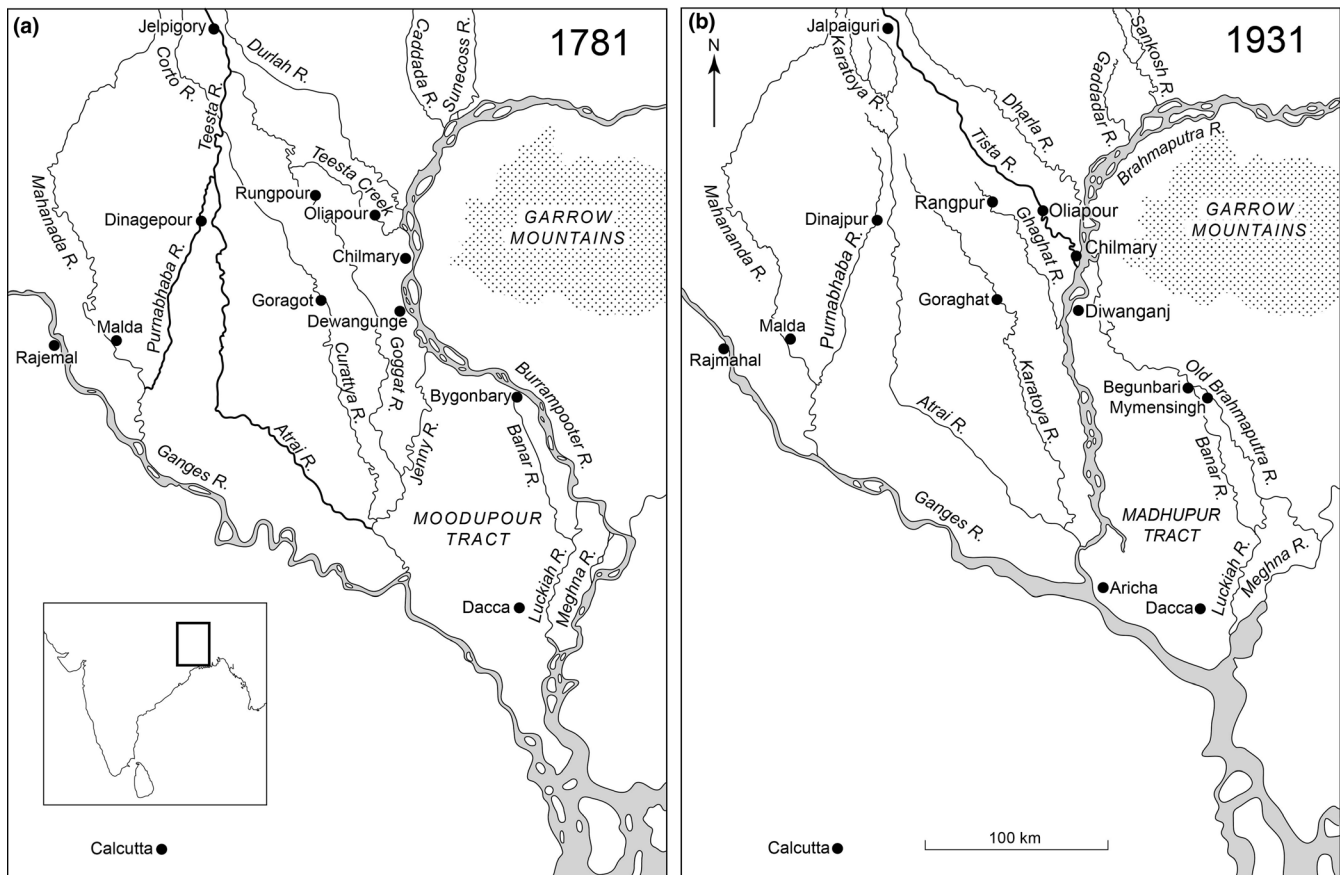


FIGURE 1 (a) The Burrampooter (Brahmaputra), and the Teesta (Tista) and other rivers to the west of the Burrampooter, at the time of the Rennell surveys from 1773 to 1777, based on *The Bengal Atlas* (Rennell, 1781); and (b) the present-day Tista, Brahmaputra-Jamuna, and other rivers, based on Survey of India map sheet 78 (Darjeeling), 5th Edition published in 1931.

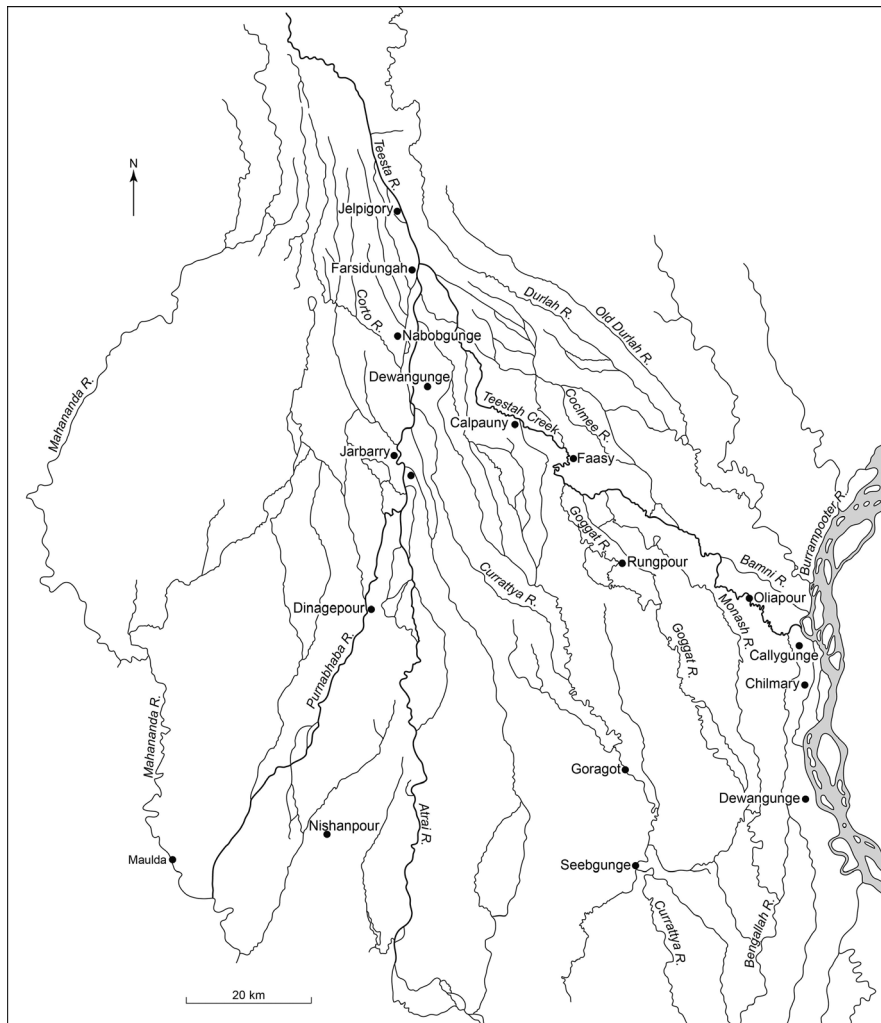


FIGURE 2 The Teesta (Tista) and other related rivers as mapped by Rennell, based on surveys between 1765 and 1777 in Rungpou district (map dated 1777), and surveys in 1767 and 1771 in Dinagepou and Goragot districts (map dated 1772). This figure is based on the Provincial Maps in the Companion to Rennell's *Bengal Atlas* maps, published in 1781 at a scale of 5 miles to an inch, and combines the two sheets for Rungpou and Dinagepou-Goragot. The Teestah Creek is shown with a heavier line than befits its size, for clarity.

easterly route, and the 1828–30 Wilcox survey (Wilcox, 1830) which was the first to show it in its southerly route. When the avulsion actually occurred between these dates and what its cause(s) might have been are less clear, notwithstanding several studies of the event, often using historical maps as evidence (Morgan & McIntyre, 1959; Coleman, 1969; Bristow, 1999). Map evidence can record historical change in river systems, but needs to be treated with care (see Section 2). The survey for the map captures the river's state at a particular date, but the dates of change remain ambiguous; and maps can only provide indirect evidence in support of hypotheses about the causes of change, for which other data are essential.

One such causal hypothesis invoked to explain the Brahmaputra avulsion is that it was triggered by a severe flood after a major avulsion in 1787 on its tributary, the Tista (Morgan & McIntyre, 1959, p. 331). Certainly, the Brahmaputra and Tista both underwent major changes after having been mapped by Rennell (Figure 1). The former “veered” through 35° from the south-easterly course into which it had turned, downstream from Chilmary (Figure 1), to its modern southerly course; while the Tista is seen in Rennell's maps to drain south towards Dinajpur and ultimately to the Ganges, but after Rennell (in 1787) it “backed” 40° into a south-easterly course passing to the north of Rangpur to join the Brahmaputra near Chilmary. These are major changes of alignment in large rivers; 100 km downstream from each of their avulsion sites, the old and new river courses were *c.* 75 km apart.

Perhaps these major and almost contemporaneous changes were indeed causally related. However, the discharge of the Tista (at Kaunia; 25°47'20"N, 89°26'13"E) contributes only about 10% to the flow of the Brahmaputra at Bahadurabad, downstream from its confluence with the Brahmaputra (for both mean annual and average peak flows). It thus seems

unlikely that the Tista would cause the much larger river to change course. But the Tista is flashier (Brammer, 2012, p. 80), peaking earlier in the monsoon than the Brahmaputra, and then providing more than 10% of the latter's flow. The Tista also has a steep, high-relief catchment susceptible to heavy monsoonal rainfall and frequent landslides, which may cause temporary dams whose eventual failure triggers dam-break floods, high sediment yields and delivery of debris, suggesting that it can be a highly active river whose geomorphological effects belie its size. The possibility that a 1787 flood and avulsion in the Tista may have influenced fluvial processes in the Brahmaputra, and even contributed to the latter's own avulsion, does therefore require detailed analysis. In this paper we assess map and archival evidence of the Tista avulsion to consider this possibility, and to illustrate the risks associated with river dynamics on alluvial fans.

2 | SOURCES, AND A CAUTIONARY NOTE ABOUT USING MAPS

The paper examines evidence for change in the River Tista provided by: (1) the Rennell maps based on surveys between 1765 and 1777, and Rennell's Journals as edited by de la Touche (1910); (2) archival evidence provided in the East India Company records of the effects of the 1787 flood on the Tista fan; and (3) the memoirs of Francis Buchanan Hamilton (edited by Martin, 1838) who travelled between 1807 and 1811 in several districts, including Rangpur, Dinajpur, and Purnea, to undertake a survey commissioned by the East India Company,⁴ in which he reported on changes in the Tista since the Rennell maps. In Appendix S2: Table S2.1 summarises the various relevant Rennell survey and map dates, distinguishing maps based on route surveys, "cursory," or "detailed" chain-and-compass surveys; and larger-scale "manuscript" maps from "published" maps at reduced scale (de La Touche, 1910). Later maps include that by Tassin (1841), which includes material surveyed by Wilcox in 1828–30 and Ommanney in 1831–5, but lacks re-survey of the Tista, and is therefore not reliable for the present purposes. Appendix S2 includes low-resolution versions of the Rennell maps used in the interpretation; in the text, redrawn versions of these are used for simplicity and clarity.

The use of map evidence to infer changes in river systems is well established (Hooke & Kain, 1982; Hooke & Redmond, 1989). However, it is important to add a cautionary note about the use of such evidence. Dated survey is critical for representing any change in the landscape, but only indicates change at some point in the period since a prior survey. Maps may be published at other dates, but if they did not involve re-survey, they do not provide evidence of change. For example, Chakraborty et al. (2010) trace migration of the Kosi River across its fan partly using the evidence of 28 historical maps dated between 1760 and 1960. However, several of these maps are derivative, and do not reflect new survey data; their differences may thus reflect changes of scale and cartographic licence as much as real channel change (or stability). Similar evidence is used by Chakraborty and Ghosh (2010) to consider channel dynamics on the Tista fan, and here again the cartographic evidence is not entirely reliable because of varying scales and cartographic approximations, and uncertainty about *survey* dates as opposed to *publication* dates.

Thus, simply comparing two maps to account for change in a river system is problematic. Scale differences mean differential cartographic approximations can produce apparent changes in channel position and geometry that bear no relation to real channel change; and differences between two maps are only meaningful if there was, between their publication dates, a new survey of the area of interest. The Wilcox survey of 1830 helps to identify the Brahmaputra avulsion, but cannot date it precisely; and it cannot provide information about the effects of change in the Tista because Wilcox did not survey west of the Brahmaputra-Jamuna. Map evidence therefore always requires complementary, and contemporary, archival support; the following sections seek to combine cartographic evidence with relevant interpretative material from archival sources.

3 | THE TISTA FAN IN THE PERIOD 1765–77: RENNELL

Figure 2 shows the Tista and its fan, according to surveys by Rennell, or commissioned by him, between 1765 and 1777 (Table S2.1). It is based mainly on the maps in Figures S2.1 and S2.2 in Appendix S1. Different parts of the Tista were surveyed at different times, and for simplicity the latest survey date – that of the upper Tista by Pringle in 1777 – is used in the following summary. Four rivers emerge from the mountain front very close together – the Mahananda, the Karatoya, the Tista, and the Dharla (from west to east). Given the avulsive nature of rivers on alluvial fans, and the low gradients of the fans of these rivers, it is unsurprising that they have had a history of interweaving with one another, and this is evident from the pattern of rivers in Figure 2, and the names attached to various stretches of river. Sometimes the name of a river that heads to the *west* of another (e.g., the Karatoya relative to the Tista) appears on a stretch of channel to the *east* of its neighbour. Frequently, there are names with the adjective "*huri*," or "*old*," or with the description "*Creek*" (such as examples of Teesta(h) Creeks at various locations), hinting at a former route now largely abandoned but occupied by an under-

fit meandering stream, whose flow may be derived from groundwater within the fan sediments, or that receives some minor over-flow at its head as a distributary of the present main channel.

The most important revelation from the Rennell maps summarised in Figure 2 (see Figures S2.1 and S2.2) is that the main channel of the River Tista in 1777 followed a southerly directed route after passing Jelpigory on its right bank, past the settlements of Farsidungah and Dewangunge⁵ to Dinagepour (Rennell's spellings). On this route, distributaries apportioned its flow into rivers with other names, causing the flow to diminish downstream. Upstream from Farsidungah, a small left-bank distributary led eventually into a "Teestah Creek," indicating that the Tista *before* c. 1770 had probably followed a more south-easterly course. This Teestah Creek can be traced along a meandering course, eventually joining the Brahmaputra both north and south of Chilmery (i.e., after splitting). The northern branch of the Teesta Creek close to the Brahmaputra had been mapped earlier by Rennell in 1765–6 (Figure 3 and Figure S2.4); the map shows it to be smaller than the adjacent Dharla (Dherla). The route of the Teesta Creek is close to that of the modern river, indicating that it has been reoccupied. Some of the flow from the main Tista to the Teesta Creek in 1777 was also diverted further to the south in a river called the Goggot or Goggat (Ghaghat today).

North of Jarbarry (Figure 2) and south of Dewangunge, a left-bank distributary from the main Tista flowed south-south-east into a stretch of river called the "Curratya," implying that the Karatoya had maintained a south-easterly route from its headwaters prior to a pre-1770s southerly avulsion of the Tista near Jelpigory. Above Dinagepour, the Tista split in 1777, and part of its flow followed a south-south-east route into the Atrai, which cut through the Barind region and eventually

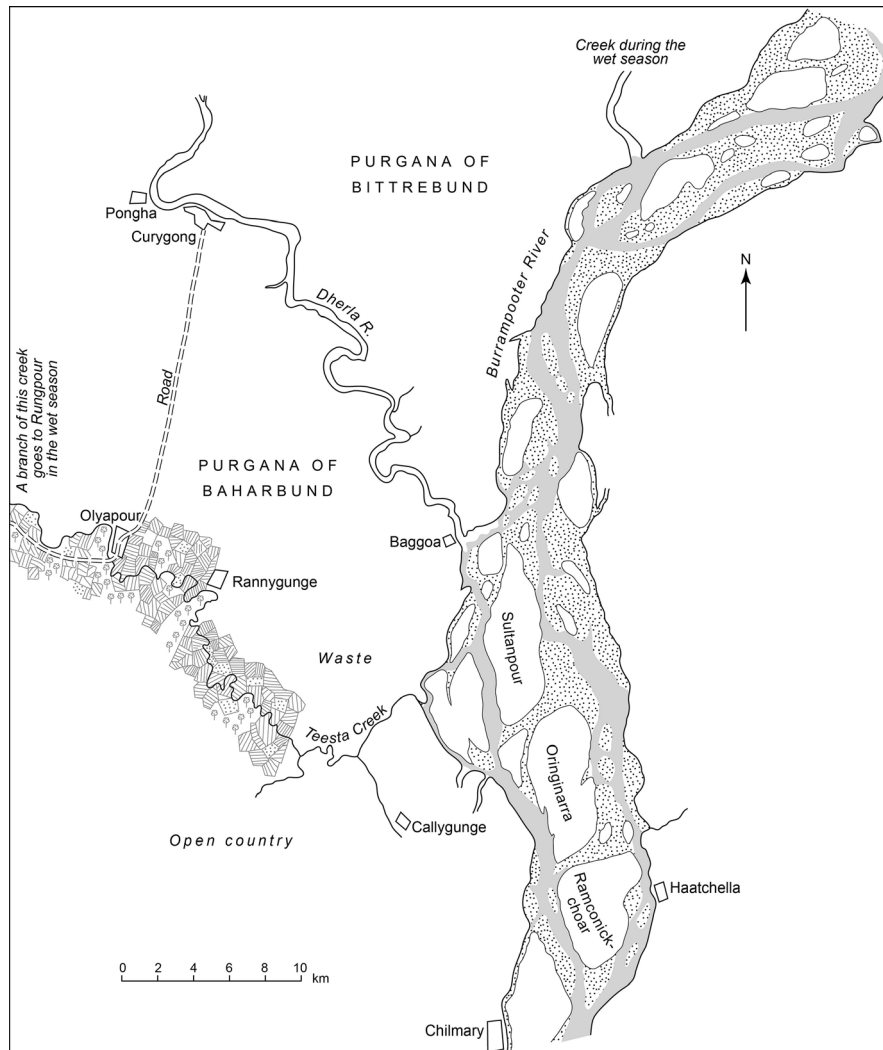


FIGURE 3 The junction of the Teesta (Tista) Creek with the Burrampooter (Brahmaputra) north of Chilmery as mapped by Rennell in 1765–6 (see Table S2.1); the Teesta Creek was mapped by “cursory survey,” more rapidly and with fewer survey points than for “detailed” surveys. The Dharla is shown as a more significant river than the Teesta Creek. The original is shown in Appendix S2: Figure S2.4.

joined the Ganges; a further part followed a south-south-west route named the Purnabhaba, to join a branch of the Mahananda. In 1777, therefore, the Tista had a southerly directed fan that cut across the former lower Karatoya, but had distributaries that radiated from Chilmary on the Brahmaputra to Malda, and from there to the Ganges.

The Karatoya in 1777 thus appears to have been dismembered by the Tista before this date, reflecting the Tista's history of significant re-orientation of its own alignment, and diversion of flow in adjacent rivers (especially the Karatoya). The greater stability of the Karatoya, and its vulnerability to the predations of the Tista, is probably because its mountain catchment area is significantly smaller and its discharge lower, its fan head sediments have more frequent stabilising pebble beds, and the fan head is entrenched. The Karatoya is today a meandering river between the Mahananda and the Tista, flowing across a relatively stable land surface, in roughly the same channel as that mapped by Rennell in 1777. Its stability has led to it forming the boundary between adjacent districts (Rangpur and Dinajpur) and their preceding dominions (Martin, 1838, vol. 3, p. 359).

4 | THE 1787 FLOOD AND ITS CONSEQUENCES

It appears that monsoon rainfall began particularly early in 1787. In Dhaka, Medical Officer James Taylor noted that “[e]arly in the month of March, the rains set in, and continued incessant from this time up to the middle of July, when the rivers rose to an unprecedented height” (Taylor, 1840, p. 301). The whole year was notable for widespread heavy rain and flooding across Bengal, with reports from Sylhet, Assam, Benares, and Dhaka; reports of embankments breached on the Ganges; and the report by Reuben Burrow, travelling up the Brahmaputra in 1787 (published 1792) and describing Dewangunge (see endnote 5) in a “wretched condition in consequence of high floods that have covered much of the country with sand.” Records of both historic La Niña events that today tend to result in high monsoon rainfall and floods in Bengal (Gergis & Fowler, 2009), and historic cyclones (Alam & Dominey-Howes, 2015) do suggest events in 1787, although neither of these can be linked convincingly to the contemporary records.

Fortunately, however, this contemporary evidence of high rainfall and flooding in 1787 is quite detailed, because the severity of flooding led to requests for mitigation of taxes, and the East India Company archives provide accounts of these (edited by Firminger, 1914–28; see endnote 6). Flooding was widespread, and some of it may have been the result of exceptionally heavy rain falling on a low-gradient and poorly drained fan surface, with some levées or early agricultural embankments inhibiting drainage into the rivers. However, there are also reports of river flooding related to overtopping of the riverbanks; these floods may have had rather more severe but localised impacts. There are also references to “sudden” floods, which as explained below, relate to the occurrence in late August of the upstream avulsion of the Tista into a former channel too small to carry the diverted discharge.

On 2 September 1787, D.H. McDowall, the Collector of Rangpur District on the Tista fan, wrote^{6,7} to a military contact about “the repeated and before unheard of inundations with which these districts have been vested since the 26th of March last...,” which indicates the early date when flooding began. Earlier, on 18 June he wrote to the Bengal Revenue Board to report that a detachment sent to Jalpaiguri (Jelpigory) was delayed because the roads were impassable, and he was acquiring boat transport⁸; he wrote again on 19 June⁹ to anticipate losses in the *rabi* (first) crop because of the rains. Even in Rangpur itself, McDowall noted three overbank events on the Goggot River between 26 March and 15 June, destroying not only crops but houses and cattle. On 29 July, McDowell reported dealing with requests for suspension of revenue collection and indicated that he was being lenient because of the damage; however, he also noted that the rains had abated for about 10 days in mid-July,¹⁰ and that some recovery of crop production was possible. In August the rains returned, and flooding began again, as returning “with fresh violence the rivers again over flowed their banks and in a few days the Country exhibited a repetition of the same scenes of Distress which in the former part of the season had created so great an Alarm” (10 August¹¹). Through August 1787, McDowall wrote several letters to the Revenue Board about flood damage to crops, distress in the population, and reduced revenues.¹² The year continued to be characterised by unpredictable and extreme weather, and on 3 November¹³ a further letter reported “a most furious Hurricane” that tore up trees, unroofed “Gentleman’s bungalows”, caused considerable mortality in Rangpur, and flattened an *amman* rice crop that had promised to compensate for the earlier losses.

However, before then, in a letter dated 2 September,¹⁴ a different emphasis is apparent in McDowall’s explanation of the cause and severity of flooding, when he wrote that:

Multitudes of men women Children & Cattle have perished in the floods, and in many places whole villages have been so completely swept away as not to leave the smallest trace whereby to determine that the ground had been occupied ... the latest inundations, caused by the sudden and unaccountable shutting up of the

Channel of the great River Teister, the Water of which has spread itself over the whole of this District, leaving the Denagepore Rivers almost dry, has been attended with worst consequences than any of the former floods ...

This is the first report of the Tista avulsion, whose flooding and its consequential impact on a Rangpur population already experiencing famine because of crop failure became particular concerns for District Collector McDowall throughout September. On the 13 September he reported an attempt to obtain rice from Dinajpur had failed because of the impossibility of water transport in the former southward-draining Tista channel.¹⁵ District Collector Hatch in Dinajpur also wrote to the Revenue Board on 30 October¹⁶ about the causes and revenue implications of the Tista avulsion, which he described thus:

Much detriment will be apprehended to the Sayr Revenue of the Zemindarry¹⁷ of Dinagepore, if some measures be not speedily adopted to remove an embankment occasioned by a large quantity of Timbers being lodged by the violence of the Torrent from the Hills, at the Influx from the River Teesta; near to a place called Cantamarry about ten Miles below Jelpigory ...

On the 1 December¹⁸ he wrote to his Assistant Collector, William Hunter, indicating that the Board of Revenue had agreed to his request to depute Hunter:

To enquire into the nature of the obstructions which have contributed to close up the channel at the Influx from the River Teesta into the Rivers Attri & Purnabubba, you will be pleased to proceed to Contoomarry the spot where the embankment is formed and draw up a report of the state of it.

Later, in 1788, McDowall was required, by a Revenue Board that was not convinced by his explanations of lost revenue, to provide a report; in this (dated 7 May),¹⁹ he stressed the effect of the Tista avulsion after a season of especially heavy monsoonal rainfall:

The large river Teesta, a small branch of which formerly ran through this district in a south east direction, about the latter end of August, suddenly altered its course, and leaving the Dinagepore river almost dry, forced its way in a most astonishing manner into the small branch aforementioned, where, not meeting with a channel sufficiently large, it overflowed the whole of this district, carrying with irresistible violence everything before it, and involving the inhabitants, with their cattle and houses, in one general wreck.

This provides an explicit indication that the Tista had reoccupied the old “Teestah Creek” as mapped by Rennell (Figure 2), itself a vestige of a pre-1777 route of the Tista that had passed to the north of Rangpur. Later in May (26th),²⁰ McDowall wrote again to the Revenue Board to inform it of the potential risks:

... altho the rains have not yet set in, in this quarter the River Teestah, has since ... the end of last Month, been almost constantly full, and frequently for many days together, running over its banks into the country to the infinite destruction of their crops.

He continued by arguing for work to be undertaken at the Tista avulsion point to return it to its original channel:

If on enquiry it shall appear practicable to restore this River to its former Channel, through the District of Dinagepore, I would strongly recommend this attempt to be made, as from my late observations I am persuaded that so long as it shall continue to run in its present Course, this district must be subject to annual Inundations. If the Channel cannot be restored, it will be necessary to erect Pools [embankments] in a great many places the expense of which, from the inability of the Zemindars to perform such a work would ultimately I fear fall upon Government.

At almost the same time, the Assistant Collector at Dinajpur, William Hunter²¹, had submitted his report on visiting the avulsion site (Figure 4), writing on 31 May²² to his senior, Hatch, as follows:

In consequence of your order to proceed to Cantamarry to inquire into the nature of the obstructions which have contributed to the closure of the channel at the influx from the River Teesta into the rivers Atrie and Purnababba, I have the pleasure to inform you of my having been to the place where the Bar is formed about four miles above Cantamarry and near two miles from Mundelgot. It is formed of large pebbles and quick sand intermixed with timbers of 20 to 30 Feet long the property of merchants. The Bar appears to be three or four feet above the surface of the water. The depth of water in the River at the Bar from seven to ten feet, and about 600 yards wide. The force of the Current runs on the Mundelgot or Westerly side of the Teesta over to the opposite Shore on the Baccally side and down the Goggot River ...

Figure 4 is drawn from the map published as Map 5 in Rennell's *Bengal Atlas* (1781), to show the location of the 1787 avulsion site south of Jelpigory, between Mundelgot and Catamarry. The suggestion above is that the Teesta avulsed into a river called the Goggot. However, on the Rennell map (Figure 2, and Figure S2.2), the small distributary named "Teestah Creek," drains to the south-east from the avulsion site near Farsidungah, and retains this name to a point west of

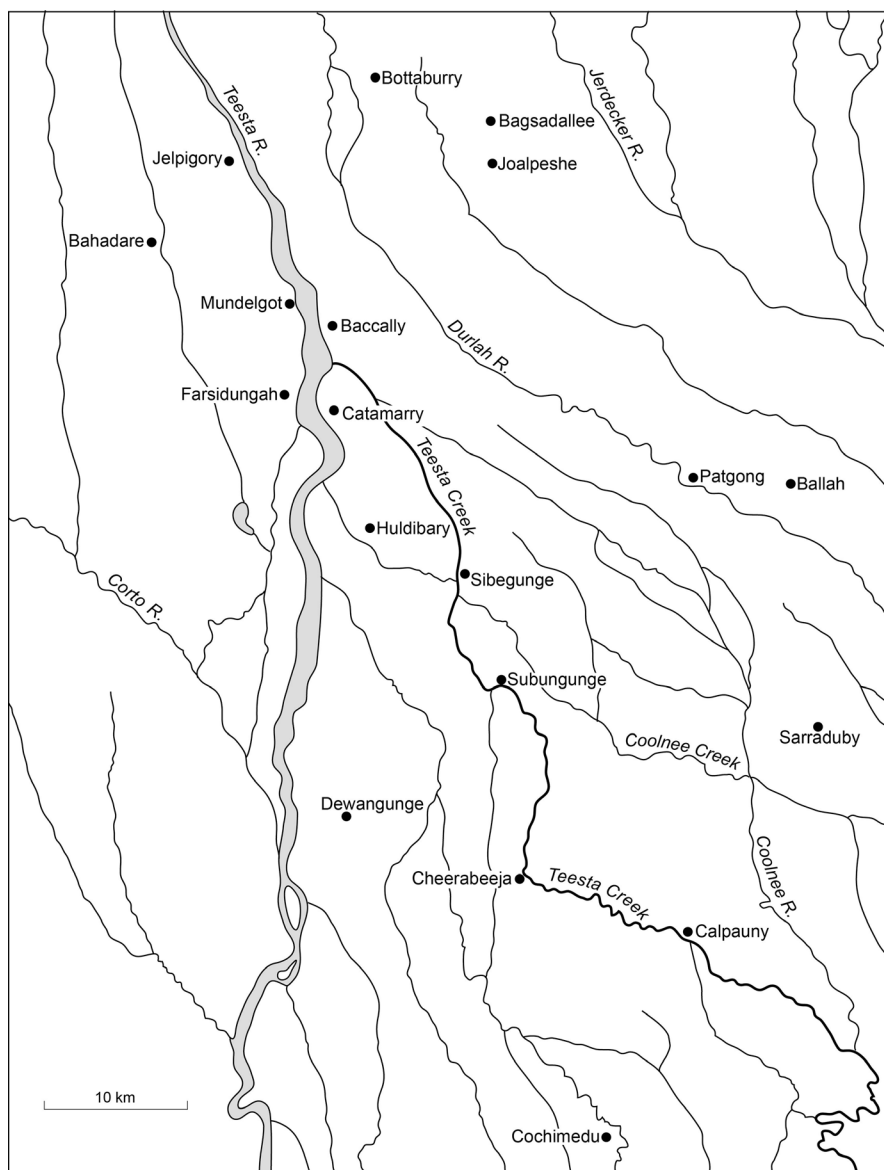


FIGURE 4 The site of the 1787 Teesta avulsion, between Mundelgot and Catamarry to the south of Jelpigory, showing the Teesta as mapped prior to the event by Rennell, and the Teesta Creek into which the avulsion took place. This extract is from the Rennell *Bengal Atlas* of 1781, and the Provincial Maps in its Companion Atlas.

a settlement called Fassy. Here, the river loops south, and is named the Goggot; this continues to Rangpur (Rungpour), after another easterly directed reach named “Teestah Creek” branches off.

Hunter continued in his report:

The inhabitants of Cantamarry and Mundelgot inform me that the Bar has been forming in a small degree these three or four years past, that an immense quantity of Sand and Pebbles, came down with the unexpected torrent from the Hills which meeting at a Resistance at those places, from the number of timber that were laying there ready to be transported upon the raising of the River, was the cause of the sudden forcing of the Bar, and stoppage of the River.

Local people at the Tista avulsion site had thus observed a bar developing during lower magnitude flood events from 1784 to 1787, but also reported a sudden “torrent from the hills” (perhaps arising when a landslide temporarily dammed the Tista in its mountain valley, forming a lake that released an outburst flood when the dam failed). But rather than trees uprooted by landslides in the hills,²³ they reported “large woody debris” (LWD) in the form of cut timber owned by merchants, washed from river-side storage while awaiting downstream flotation to Dinajpur. This timber presumably stalled on the bar, trapped more sediment, and helped the river to build the level of the bar up until the avulsion occurred. The role of LWD in contributing to bar construction in braided rivers is well known (see Appendix S1). It appears that commercial extraction of timber resources from the upper Teesta catchment was thus a factor contributing indirectly to the avulsion event, by creating a store of potential large woody debris. Timber extraction upstream may also have contributed to the generation of high flows by increasing runoff rates.

The Revenue Board Proceedings for 17 June 1788 record²⁴ decisions that the Collector of Dinajpur should assess the feasibility of cutting a channel through the bar in order to direct the Tista back into its southern course; and that the Collector of Rangpur should assess the cost of embankments along the “new” Tista. A scheme was proposed for re-directing the channel, involving a piled bank using the timber recovered from the bar.²⁵ McDowall emphasised the need for urgency, because Rangpur district was already flooded and it was necessary to build embankments before the 1789 monsoon.²⁶ By December in 1788 and into 1789, and after further investigation at the avulsion site, it was less clear that re-direction of the river would be feasible, apparent that it would be logistically difficult to obtain and support a workforce in the remote location, and evident that it would be costly (200,000 rupees).²⁷ Furthermore, the Collector of Dinajpur (Hatch) concluded that the impact of the diversion of the Tista was less severe in his District, and expenditure would be more appropriate on flood embankments in Rangpur.²⁸

Nevertheless, the Revenue Board’s Superintendent of Works, Thomas Lyon, visited the site and developed a detailed proposal, which Barlow, for the Board, communicated to Hatch.²⁹ Hatch then wrote to Lord Cornwallis, the Governor General, complaining about the commitment the plan imposed on him to raise the labour force, to the annoyance of McDowall.³⁰ However, not without difficulty, preparations to undertake the work continued, and Hunter (Assistant Collector, Dinajpur) was deputed to oversee the work, and together with a workforce and equipment he arrived at the site in November and began work. Lyon then re-visited the avulsion site when Hunter was ill in December, and decided that the Tista had altered its alignment in a manner that would lead it back naturally into its “natural course,” and wrote to the Governor General to explain this³¹:

I then sounded the River Teestah above the new Channel and found it much changed since January last, particularly ... a very large Barr being formed quite across the new channel, with small stones washed down the River. This Barr is near a quarter of a mile in thickness [*sic*: meaning extent?], over which there is not in any place more than five feet water. This Change in the Course of the River ... seems to indicate ... that the River Teestah will in a few years flow in the old Channel, and leave in part, if not wholly, the new channel; and this Change will I firmly believe happen in a few years if nothing is done to adjust it.

He also noted a bar with shallow water in the new channel, which he thought likely to encourage abandonment of the new channel, and for a while, directed the workers to create a channel in the Teesta that would encourage reversion to the old southerly route as he predicted. But then shortly after, he discharged the workers. In fact, of course, the reversion he predicted did not happen, and the Tista has since then followed its more south-easterly post-avulsion route to the north of Rangpur.

5 | POST-RENNELL CHANGES TO THE TISTA FAN AND IMPACTS ON THE BRAHMAPUTRA: BUCHANAN HAMILTON

Francis Buchanan Hamilton (Watson & Henry, 2016; Vicziany, 1986) travelled widely in the Rangpur and Dinajpur Districts between 1807 and 1811, with an extensive brief (see endnote 4). In 1814 he produced a series of manuscript maps from his field notes, at a scale of 1:728,640 (11.5 miles to the inch), using Rennell's map as a base (Figure 5). His extensive hand-written manuscripts were subsequently edited and published by Montgomery Martin in 1838; the summary map is shown as Figure S2.5. Buchanan Hamilton provided very detailed accounts of the routes followed by the rivers, beginning near the head of each and working downstream. Close attention is needed to his text, the Rennell maps, and his own sketch map to follow his descriptions. The main conclusions relating to the Tista are given below, with a somewhat more detailed summary in Appendix S2. Using Buchanan Hamilton's descriptions, it is possible to determine whether the avulsion of the Tista could have impacted on the Brahmaputra and also have influenced its avulsion.

Martin's (1838) edited text details the many river channel changes that occurred in the two Districts during and after the 1787 flood, providing a vivid picture of the catastrophic changes that can occur on a dynamic alluvial fan. Buchanan

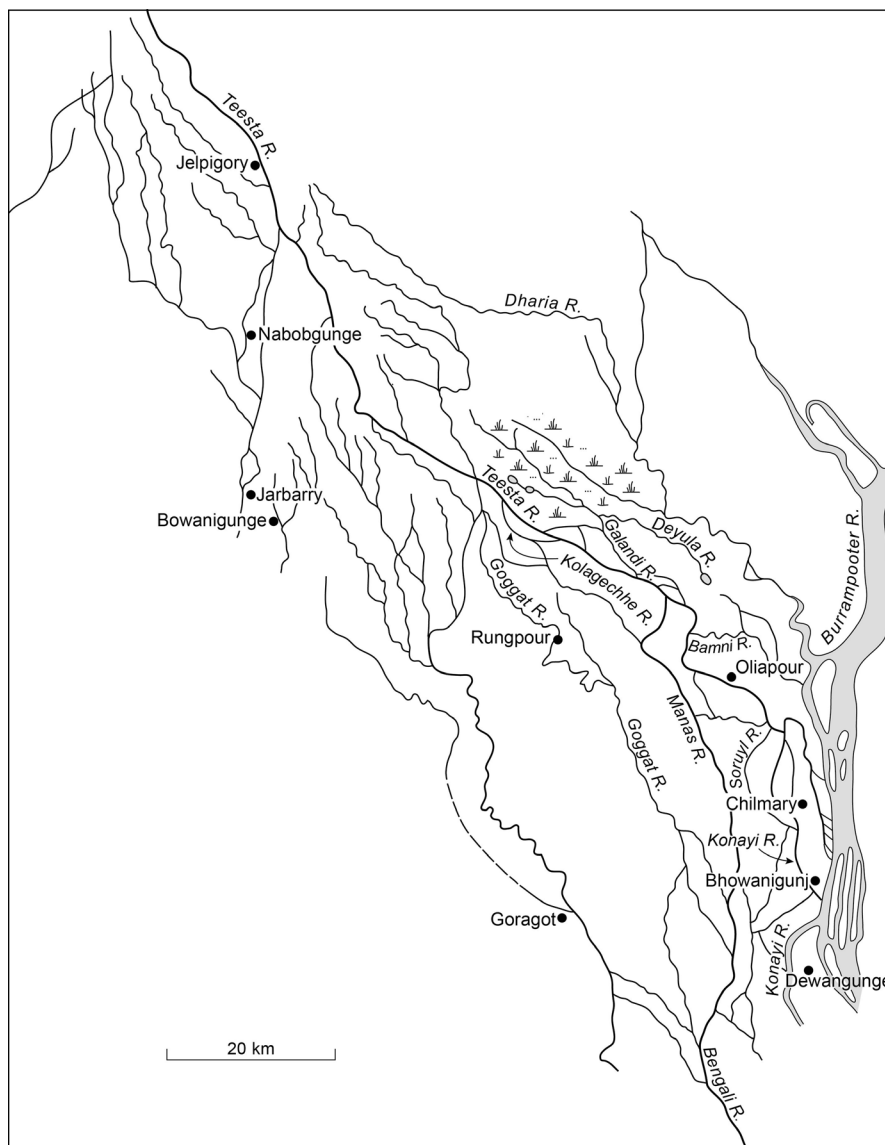


FIGURE 5 A simplified version of the sketch map of rivers on the Teesta fan as mapped onto Rennell's Companion Atlas Rungpour sheet (Figure S2.2) by Buchanan Hamilton (1814), following his travels in Rungpour and Dinagepour Districts between 1807 and 1811. This map is best read in conjunction with Figure 2, and with the adjacent text, and the text in Martin (1838). Martin's (1838) version of this map is in Appendix S2: Figure S2.5.

Hamilton often referred to *buri* (old) and *mara* (dead) channels, including at least two originally formed by the Tista; he also notes cases of a seemingly continuous river changing its name between different reaches. His description of rivers in Rangpur District opens as follows:

Since the survey was made by Major Rennell, the rivers of this district have undergone such changes that I find the utmost difficulty in tracing them. The soil is so light, and the rivers ... have acquired such force, that frequent and great changes are unavoidable ... whole channels have been swept away by others and new ones are constantly forming. The nomenclature is therefore exceedingly difficult. After tracing the name of a river for some distance you all of a sudden lose it, and perhaps recover the same name at a distance of 20 miles ... (Martin, 1838, vol. 3, p. 358)

This was written some 30 years after the 1787 flood resulting from the avulsion of the Tista, by which time the Tista had reoccupied and widened Rennell's "Teestah Creek" so that it could once more take the Tista's full flow.

In describing the Karatoya, Buchanan Hamilton follows its south-easterly route as it leaves the hills, until it joins the channel which was the main Tista in Rennell's time before the 1787 avulsion. He states that "... in the destructive floods which happened in the Bengal year 1194 [1787], the greater part of the water of the Tista *returned to its ancient bed* [our italics], and has left this immense channel almost dry" (Martin, 1838, vol. 3, p. 361). This recognises that the avulsion of the Tista in 1787 caused this river to return to a former south-easterly route, also therefore implying that it had avulsed at an earlier date into the pre-1787 southerly course.

Then, following the Tista from its mountain reaches, Buchanan Hamilton describes it in 1808–9 as "an exceedingly large channel, from 600 to 800 yards wide, and at all seasons contain[ing] a great deal of water ..." (Martin, 1835, vol. 3, p. 369). He identifies the 1787 avulsion location as the distributary labelled Teestah Creek on Rennell's 1777 Manuscript map (sheet 12, Bettoriah), leaving the then main river between the settlements of Mundelgot and Catamarry. The avulsed Tista then flowed south-south-east to Cheerabeeja (or Chirabhija; see Figure 4 and Figure S2; Martin, 1838, vol. 3, p. 371). Following its 1787 avulsion, the Tista must have occupied the vestigial and sinuous Teesta Creek, enlarged it, overtopped its banks, straightened it, and crossed some existing smaller channels, such as the Goggot, whose upper reaches are named the Coolnee (see Figures 4 and 5, and Figure S2). In Rennell's time, the Teestah Creek looped south just before a settlement called Faasy (Figure 2), but Buchanan Hamilton describes the Tista in the early 1800s as following a more direct route to the south-east; the village of Faasy is no longer present (it may have been a village destroyed as McDowell describes, in his letter of 2 September, 1787; see p. 6).

The Goggot is by 1807 a distributary of the Tista, diverting some of its flow as it continues to the south-east through Rangpur town (which is why Rangpur was flooded often in 1787, as Hunter reported on 31 May 1788; see p. 9). In Buchanan Hamilton's description, the Goggot (which he spells Ghaghot) is in 1807 a branch from the much enlarged Tista and is not navigable in the dry season. Both Rennell (Figure 2) and Buchanan Hamilton (Figure 5) also show a river named the Monash (Rennell) or Manas (Buchanan Hamilton), branching to the south and carrying significant flow ("a very considerable river": Martin, 1838, vol. 3, p. 374). Both the Goggot and the Manas thus appear to have diverted significant amounts of the avulsed Tista's flow further to the south, west of Oliapur, Calligunj, and Chilmaly (see Figure 2). These two distributaries eventually combine to form the Bengali River, as is apparent from Buchanan Hamilton's map (Figure 5). This river continues due south to be joined eventually by the Karatoya. If the Bengali River joined any river to its east in 1808–9, it was most likely to have been the Konayi (Kornayi in Martin, 1838), not the Brahmaputra.

After supplying flow to the Goggot and the Manas, the Tista itself begins to diminish, and its flow is diverted to several distributaries, some of which lead to marshes and lakes. At the distal end of the Tista fan, Buchanan Hamilton describes a northern channel called the Galandi (Figure 5) linking to what he calls a "very large channel... [which] ... ends in a large marsh of the Boro Vari division, which is named Deyula. This large channel ... seems to me to be an old channel of the Tista" (Martin, 1838, vol. 3, p. 375). This channel is traceable westwards to other marshes, over a distance of about 15 miles. It implies another Tista alignment that pre-dates Rennell's Teestah Creek, but that parallels it to the north; and also therefore pre-dates the Tista route south from Jalpaiguri to Dinajpur.

Many of the streams Buchanan Hamilton describes here are underfit, seasonal, and lose water through evaporation and infiltration during the dry season, especially in the wetlands that they supply. The post-1787 Tista is "diminished" in these lower reaches at the time of his observations in 1808–9, and has a number of small distributaries that branch eastwards, like the Bamni (Figure 5), "a dirty crooked branch, which after a course of about 15 miles joins the Brohmoputra" (Martin, 1838, vol. 3, p. 376); other, similar channels are evident in Figure 5 crossing the narrow strip of land between the Tista and the Brahmaputra on which the town of Chilmaly was then located.

The conclusion of Buchanan Hamilton's description of the Tista is that he is "persuaded, that formerly the channel of the Tista in this part of its course ran considerably more to the south; for very numerous large channels remain in that direction..." (Martin, 1838, vol. 3, p. 376). His last paragraph on the Tista is worth quoting in full:

Farther down the old Tista is separated from the Brohmoputro by an inhabited island, and sands, through which there are several openings, and at its lower extremity received the Soruyi... Immediately after the junction with the Burail, the Soruyi sends off a large branch called the Konayi, which is of great size, and formerly went with a winding course into the Nator district; but between the towns of Bhowanigunj³² and Dewanigunj the Brohmoputro has made an irruption, and has carried away a great part of its channel. In return the Brohmoputro gives a large supply of water to the lower part of the Konayi, which now passes behind Dewanigunj scarcely inferior to the mighty river, and threatens to sweep across the whole intermediate country. (Martin, 1838, vol. 3, p. 377)

This quotation about the role of the Konayi River, together with the evidence of Figure 5 that draws attention to the sand spreads and bars in the Brahmaputra, indicate that where the Brahmaputra at the time of Rennell's survey was turning to the south-east with Dewangunge on its western (right) bank (Figure 1a), a significant portion of its flow was, in about 1810, flowing south with Dewangunge on its eastern (left) bank – where it is still located to this day (Figure 1b). The southward avulsion of the Brahmaputra was at least beginning, if not completed, at around this date, and probably arose from lateral erosion of its right (west) bank until it was close to the Konayi and could spill into it.

6 | REVIEW AND DISCUSSION

The combined evidence of historical maps and archives provides several conclusions about the Tista, its fan, and their relationship to the Brahmaputra in the period 1773–1830. First, it appears that at least four different phases of occupation by the Tista of its fan can be recovered: (1) the alignment to the north of the post-1787 channel recorded in a series of marshes, and identified by Buchanan Hamilton; (2) the more central route of the Teestah Creek mapped by Rennell in 1777, but at that time no longer forming the main channel (Figure 2); (3) the southerly route of the main Tista from Jalpaiguri to Dinajpur as mapped by Rennell in 1777, and more recent than the previous two alignments; and (4) the post-1787 route described by Buchanan Hamilton which reoccupied Rennell's Teestah Creek, but then deflected most of its flow south into the Goggot/Ghaghot and the Monash/Manas. The Tista first migrated in a clockwise direction, from the northern route marked by marshes, to a route similar to the modern alignment (the Teestah Creek), then to the southern route to Dinajpur;³³ then in 1787 it returned in mid-fan to a route similar to route (b), completing this anti-clockwise shift in its lower reaches at a later date to create the route seen today.

Second, Buchanan Hamilton's observations suggest that a significant proportion of flow in the Tista after its 1787 avulsion was lost before the river reached the Brahmaputra. This is evident in the existence of low-lying marshy areas from which evaporative and infiltration losses would have been high; in lengthy periods of overbank water storage as the flood reoccupied the contracted Teestah Creek's channel; in the existence of large southerly directed distributary channels at the distal end of the fan, diverting flows to the Goggot/Ghaghat and Monash/Manas and thence to the Bengali River. These would all have reduced the impact of the Tista on the Brahmaputra. The more direct route of the modern Tista to the Brahmaputra in the lower part of its fan, south of Uliapur and Chilmary (which have moved west of their early nineteenth century positions), is a more recent adjustment.

Third, the sources of flooding on the Tista fan are quite diverse and have differing consequences (and management implications). Spatially extensive clear-water flooding caused by heavy monsoonal rain (responsible for the early flooding in 1787, as well as in, e.g., 1987; Brammer, 2012, Chapter 8 Annexe) may occur together with or separately from overbank flow by rivers in spate because of precipitation in the mountain headwaters. Flood hydrographs thus vary with the spatial distribution and intensity of precipitation input and may be compounded by other events caused by landslide dam breaks. Different types of flood have very different sediment signatures, and both hydrograph and sediment transport are attenuated downstream by dispersal over the fan. Any presumption that the 1787 flood might have delivered large volumes of sediment to the Brahmaputra is thus challenged by the evidence of the convoluted drainage system in the distal part of the fan described by Buchanan Hamilton.

7 | CONCLUSION

Survey evidence from the 1770s to the 1810s brackets the dates of major changes in the Tista, but it is written archival evidence that enables detailed interpretation of timings and processes. It also provides a rich source of material on the Tista's behaviour on its fan, the consequences for people, and both the potential indirect culpability of, and the subsequent (fruitless) attempts at a river management response by, the East India Company. The maps and the archival evidence show the Tista has a history of avulsion and river migration to rival the Kosi that continues to provide potential risks and challenges for river management. They also reveal that a river avulsion of major scale was the consequence, at least in part, of some poorly located and inadequately secured cut timber that became "large woody debris"; not something that could readily be modelled, except as a stochastic event.

Discussion of the contemporary evidence also leads to a Popperian falsification of the hypothesis that the almost contemporaneous Brahmaputra avulsion could have been caused by that of the Tista in 1787. Buchanan Hamilton focuses much more on the Brahmaputra itself encroaching on the lower Tista fan, as westward lateral migration by bank erosion in this much larger river caused "an irruption" into the Konayi. This requires closer examination of other map and archival evidence of the behaviour of the Brahmaputra at the site of its own avulsion node, between Dewangunge and Chilmay, and in the region to their south. The former of these settlements seems to have remained in its same location since 1765, although soon after 1810 and certainly by 1830 (Wilcox's survey) it found itself on the left rather than the right bank of the Brahmaputra. Chilmay, however, is known to have been successively re-located westwards as the Brahmaputra right bank eroded westwards. The timings and processes of this need further investigation, and consideration of other exogenous influences (including tectonics and earthquakes); but this has to be another story.

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DATA AVAILABILITY STATEMENT

All sources of data are cited in the main text or supplementary materials.

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ENDNOTES

- ¹ Borehole data and stratigraphic evidence suggest that proto-Brahmaputra alignments may have switched between these two courses on previous occasions in the post-glacial geological record (Goodbred and Kuehl, 2000).
- ² Toponyms (places, rivers, features) are usually given in a modern spelling in the text. In figures based on historical maps, and in text discussing them, the original spelling is used. This spelling is usually a transliteration into English from the original name, and the equivalence to the modern name is usually obvious when spoken (e.g., Dinajpur and Dinagepour).
- ³ The Jamuna was one of the existing south-flowing rivers into whose course the Brahmaputra avulsed.
- ⁴ The terms of reference for Buchanan Hamilton's journey were issued by the Governor General on 11 September 1807, and ran to five pages, including: A Topographical Account of Each District; The Condition of the Inhabitants; Religion; The Natural Productions of the Country; Agriculture; Arts and Crafts; and Commerce.

- ⁵ Note that there are two settlements with very similar, if not identical, names: a Dewangunge south of Jalpaiguri on the southerly directed 1777 route of the Tista; and the Dewangunge/Dewanganj south of Chilmary and on the right bank of the Brahmaputra in Rennell's time, but the left bank today.
- ⁶ Archival sources used are the correspondence of East India Company staff edited by W.K. Firminger (1914–1928), as detailed below; and A Report on the Famine in Rungpore by E.G. Glazier (1875).
Firminger, W. K. (ed.) 1914. Bengal District Records: Rangpur, Shillong, Calcutta: East India Company Record Office. Vol 1. Rangpur 1914 for 1770-79; Vol. 2. Rangpur 1920 for 1779-82; Vol. 3 Rangpur 1920 for 1783-85; Vol. 4. Rangpur 1921 for 1779-85; Vol. 5 Rangpur 1927 for 1786-87 (Letters Received); Vol. 6 Rangpur 1928 for 1786-87 (Letters Issued).
Firminger, W. K. 1914. Bengal District Records: Dinajpur, East India Company Record Office, Shillong; Calcutta. Volume 1, 1914 covers 1787–9; Volume 2, 1924 covers additional material for 1786–1788.
References to Firminger's editions are given as endnote references within the text, and the endnotes themselves give the date, place, volume number, an asterisk followed by the number of the entry/page number; e.g., Firminger 1928 Rangpur [6] *234/p. 232–3 (as below).
- ⁷ Firminger 1928 Rangpur (6) *242/p. 239–40.
- ⁸ Firminger 1928 Rangpur[6] *188/p. 193–4.
- ⁹ Firminger 1928 Rangpur (6) *189/p. 194–7.
- ¹⁰ Firminger 1928 Rangpur (6) *219/p. 217–19.
- ¹¹ Firminger 1928 Rangpur (6) *230/p. 227–8.
- ¹² Firminger 1924 Dinajpur (2) *180/p. 116–17; Firminger 1924 Rangpur [6] *234/p. 232; Firminger 1927 (5) *370/p. 237–8; Firminger 1928 Rangpur (5) *346/p. 221; Firminger 1914 [2] *188/p. 122.3; Firminger 1924 Dinajpur (2) *186/p. 120–1.
- ¹³ Firminger 1928 Rangpur (6) *270/p. 256–7.
- ¹⁴ Firminger 1928 Rangpur (6) *242/p. 239–40.
- ¹⁵ Firminger 1928 Rangpur (6) *244/p. 240–2; Firminger 1928 Rangpur (6) *244/p. 240–2; Firminger 1928, Rangpur (6): *246/p. 243–4.
- ¹⁶ Firminger 1924 Dinajpur (2)*226/p. 145.
- ¹⁷ Zemindars were local land-owning rulers.
- ¹⁸ Firminger 1924 Dinajpur (1)*248/p. 156.
- ¹⁹ Glazier 1875, A Report on the District of Rungpore: p. 77–84.
- ²⁰ Firminger 1928 Rangpur (6) *359/p. 222.
- ²¹ In a Gazette published much later, in 1875, Hunter provided a compressed account of the 1787 Tista flood: “Suddenly the main branch of the Tista, swelled by the incessant rains, swept down from the hills such vast masses of sand as to form a bar in its course, and, bursting its banks, the Tista forced its way into the Ghaghat” (Hunter, 1875, p. 296).
- ²² Firminger 1924 Dinajpur (2) *350/p. 222.
- ²³ Rennell's *Journals* observed “large woody debris” on a journey to the Tista near Farsidungah: “We perceived pieces of different kinds of Trees lying on the Sands in the River: these the Country People informed me are brought down from the Boutan Mountains by the Freshes: amongst many other kinds of fine Timber we perceived the stump of a Firr Tree of which I brought away several pieces” (de la Touche, 1910).
- ²⁴ Firminger 1914 Dinajpur (1) *168/p. 119.
- ²⁵ 24 August 1788: Dinajpur, from Hatch (Collector, Dinajpur) to the Revenue Board; Firminger 1924, Dinajpur (2) *427/p. 265.
- ²⁶ 2 July 1788, Rungpore: McDowall (Collector, Rangpur) to Hatch (Collector, Dinajpur); Firminger 1914 Dinajpur (1) *168/p. 119.
- ²⁷ 8 December 1788, Dinajpur: from Hatch (Collector, Dinajpur) to the Revenue Board; Firminger 1914 Dinajpur (1) *277/p. 181. 19 June, 1789, Calcutta: Barlow (Revenue Board) to Hatch; Firminger 1914, Dinajpur (1) 371/p. 236.
- ²⁸ 26 June, 1789, Dinajpur: Hatch (Collector Dinajpur) to Barlow (Revenue Board); Firminger 1914 Dinajpur (1) *376/p. 241–2. 1 July, 1789, Dinajpur: Hatch (CD) to McDowall (CR); Firminger 1914 Dinajpur (1) *382/p. 245.
- ²⁹ 16 September, 1789: Dinajpur, from Thomas Lyon (Superintendent of Works) to G H Barlow (Revenue Board); Firminger 1914 Dinajpur (1) *419/p. 269–71. 23 September, 1789: Barlow [Revenue Board] to Hatch [Collector Dinajpur]; Firminger 1914 Dinajpur (1) *421/p. 273.
- ³⁰ 1–2 October, 1789, Dinajpur: from Hatch (Collector, Dinajpur) to Lord Cornwallis [Governor General]; Firminger 1914 Dinajpur (1) *427/p. 276–8. 3 October, 1789, Rangpur: McDowall (Collector, Rangpur) to Hatch (Collector, Dinajpur); Firminger 1914 Dinajpur (1) 429/p. 279.
- ³¹ 17 December 1789, Cantamarry: From Lyon (Superintendent of Works) to Lord Cornwallis (Governor General); Firminger 1914 Dinajpur (1) *497/p. 325.³²
- ³² Note that, as with Dewangunge (endnote 5), there are two settlements with names similar to Bhowanigunj, and both are shown in Figure 5. One is near Jarbarry close to the pre-1787 route of the Tista, and is visible on Figure SI2.1. The one referred to here by Buchanan Hamilton was between Dewangunge and Chilmary, on the right bank of the Brahmaputra, and seems not to have survived the avulsion of the Brahmaputra.
- ³³ There is at least one other Tista route evident on Rennell's maps. On the Dinagepour District sheet (Supporting information SI2, Figure SI2.1), to the west of Rungpour and south of Buddlegun, an apparently relatively large left-bank tributary of the Currattya (which further upstream is named the Curtya; both suggestive of a former route of the Karatoya) is named the Teestah River. This could therefore be an additional step in the clockwise (western) migration of the Tista coming between (b) and (c). However, there is no dating evidence to confirm that there was a systematic westward movement between (a) and (c).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. A note on channel dynamics on alluvial fans.

Appendix S2. Historic maps of the Tista and its fan.

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