CULTURAL ANTHROPOLOGY

"TOO MUCH" SAND, NOT WATER: A Geostory of Himalayan Riverine Sediments as "Problem"

SAUMYA PANDEY
Ghent University
Chr. Michelsen Institute
https://orcid.org/0000-0002-5649-8018

The year 2013 was catastrophic for the Nepal-India Himalayas. Floods, landslides, glacial lake outbursts, dam bursts, and debris flow prompted concerns about *what* really caused this destruction when clouds violently cracked up over Himalayan rivers. Was the catastrophe due to heavy riverbed sand or unruly water? One engineer I spoke with commented on this question as such:

> Every year millions of tons of sand, gravel and stones [SG&S] are eroded in the upstream Himalayan rivers, transported to midstream areas, and deposited in the downstream region. This poses a major risk of flood hazard for the people residing along the riverbanks. It is difficult to reduce the rate of erosion in the geologically active Himalayas. A potential solution then is to mine the sand from the riverbeds.[1]

In this excerpt the engineer is concerned about "millions of tons of sand, gravel and stone"—just some of the sedimentary particles that make up the Himalayan rivers. Sand has to be mined from its riverbeds, the engineer notes, to reduce hazardous floods in the *geologically active Himalayas*. What are the implications? My

CULTURAL ANTHROPOLOGY, Vol. 39, Issue 4, pp. 564–591, ISSN 0886-7356, online ISSN 1548-1360. Cultural Anthropology *is the journal of the Society of Cultural Anthropology, a section of the American Anthropological Association.*
DOI: 10.14506/ca39.4.04

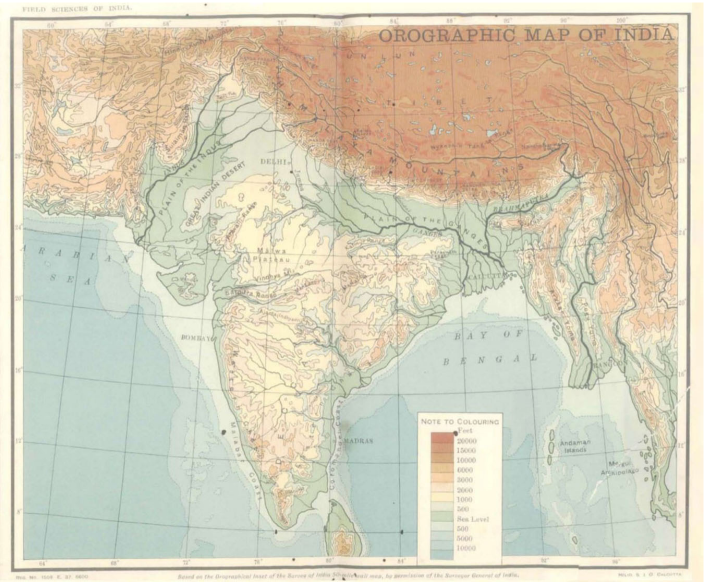

Figure 1. Orographic map of India. Credit: South Asia Archive Foundation (source of digitization), Coherent Digital (host) and Indian Science Congress Association 1937 (original publisher of the printed work).

research asks: Why do engineers propose sand extraction in the already geologically active Himalayas? In the present essay, I ethnographically examine the multiple modes of knowing the sedimentary conditions in the Himalayan rivers that create possibilities for sand extraction. Such modes of knowing in their *ideological implications* (see Ehrlich 2023) do not deny sand its place in the Himalayan rivers but naturalize its force as a "geological problem."

In what follows, I trace the reasonings that lie behind the extraction of Himalayan riverine sand. I am less concerned with the capitalist ends of sand mining. Rather, I am interested in the "epistemic conditions" (Daston and Galison 2007; Aronowsky 2021)—the engineering logics, concepts, and theories on sedimentary mechanisms—that inform mining. So far, sand mining has been studied as a process through which the informal economy, greed, and easy capital operate (Jeyaranjan 2019; Hoffmann 2021; Paul 2015; Binoy 2017; Rege 2015). Sediment dredging has also been analyzed as an ecologically destabilizing practice in service of infrastructural standards that work *against* nature (Rentier and Cammeraat 2022; Carse and Lewis 2017). In contrast, I show how engineers claim to work *with* nature to produce knowledge about sediment extraction.

Most discussion of Himalayan sediments with engineers used to begin with the deep erosional history of these sedimentary terrains that emerged from beneath the Tethys Sea when Indian plates collided with the Eurasian plates some 50 million years ago.[2] Engineers noted that, as young active mountains that are still forming, the Himalayas experience constant uplifting and thrusting forces, which makes them prone to mass sedimentary erosion to this day. Rivers of the Himalayas thus carry some of the highest sediment load in the world. The engineering of these rivers was built on a geologically distinct understanding that the sediments of the Himalayas are loosely tied, easily erodible, and actively trigger the rivers to overflow by the slightest movement. Engineers thus perceived the Himalayan rivers not as passive, ahistorical objects only to be dominated and exploited, as riverine scholarship on South Asia tends to posit (Simpson 2024). Rather, the engineers evidenced complex and perplexing concerns about Himalayan riverine conditions beyond domination and perceived the fluviatile sediments as historically active subjects acting on us. This *knowledge* about Himalayan sediments' agential ability gave evidential depth to their engineering logic of extraction.

In this essay, I focus on engineers trained in fluvial hydraulics—a branch of engineering concerned with water and sediment flows in rivers. Such engineers conduct civil, geoengineering, and hydrological research works on broadly three scales of the Himalayan rivers—mountains, floodplains, and the deltaic Bay of Bengal. These are by no means the only scales through which engineers studied sedimentary processes but they proved, in my research, historically relevant and revealing. For me, moving between Himalayan scales and "attending to the politics of scale-making" (Hecht 2018, 115) revealed complexities of engineering politics.

The Himalayan scales posed a challenge to nineteenth-century colonial scientific explorations (Fleetwood 2022). Comprehension of these high terrains proved exceptionally difficult, imprecise, and uncertain because of their "gigantic scales" (Khan 2019, 334), verticality, and grandiosity. I show how engineers also contributed to this scientific tension with significant political implications in the twentieth century. They argued that these sedimentary terrains are still growing, breaking down, and violently mobile across shifting scales such as upstream-downstream, mountains-floodplains, slope-plains, source-destination, and so on. Some of these sedimentary breakdowns experience sketchy landscapes, atmospheric pressures, and earthly forces that are not always known, much less understood. I draw on these engineering scalar links to extend insights on the scientific "ambivalence" (Latour 2015, 98), uncertainties, and paradoxes entailed in conceiving sedimentary knowledge across varying, and sometimes inconceivable Himalayan scales.

Following the archeologist Lindsay Bremner, I follow sediments as-they-moved in the Himalayan rivers for twelve months (2021–2022). I focused on sedimentary processes of erosion in the mountains, transportation to the floodplains, and deposition into the Bay of Bengal (though not in any chronological order). In the process, I spoke with engineers who manipulated the movement of sedimented layers beneath these riverbeds. In what follows, I narrate my engagement with engineers who produced fluvial knowledge on Himalayan rivers in Nepal and India in their capacity as current or former government officials or as technical experts on internationally commissioned river projects. This method entailed visiting river work sites, participating in workshops and conferences on fluvial hydraulics, having sustained conversations with key engineers, and reading the textual sources they suggested.[3] Much of their engineering expertise on sand extraction, I found, was in rhythm with the history of Himalayan sediments and the uneven topographies across which this geological history was scaled.

Additionally, I conducted four months of archival work on the river training works of later-colonial India as well as on Himalayan erosion theories of post–World War II Nepal.[4] Earth and water data in modern engineering sciences in the late nineteenth and twentieth centuries, historians show, rendered rain clouds and entire Himalayan river basins extractable through storing, harvesting, and channelizing (D'Souza 2006a; Roy 2016), in turn expanding "cartographies of capital" (Fujikane 2021). Colonial authorities puzzled over and speculated on the sandy, silty attributes of these rivers that made them meander and oscillate (Amrith 2018; Bhattacharyya 2018; Saikia 2015). Such colonial valuations insinuated an extractive regime of thinking that reflected a strong "water bias" (see Parrinello, Bizzi, and Surian 2021; Parrinello, and Kondolf 2021; de Micheaux, Mukherjee, and Kull 2018) and endorsed the removal of sediments from the Himalayan rivers. An engagement with this history grounds my ethnographic claims on how sediments came to feature as a problem of Himalayan geology.

I approach my ethnography on sediments as an anthropological inquiry into Himalayan geology. The relation between sediments and extraction does not constitute a normative case of geology. The Himalayas did not naturally become extractable. Rather, this is a story of the Earth, or a *geostory* (Latour 2014), about the naturalization of the Himalayas (Mathur 2013; Chakrabarti 2020). Engineers used a series of explanations for powerful sedimentary mechanisms to render Himalayan riverbeds extractable. As geological philosophy has it: the Earth tends to impose its own power and history in a geohistorical process of stratification and destratification (Deleuze and Guattari 1987). As such, the engineering knowledge claims about the asymmetrical and historical power relation of the Himalayan geology and the loose earth in its riverbeds made possible the political economy of sand extraction.

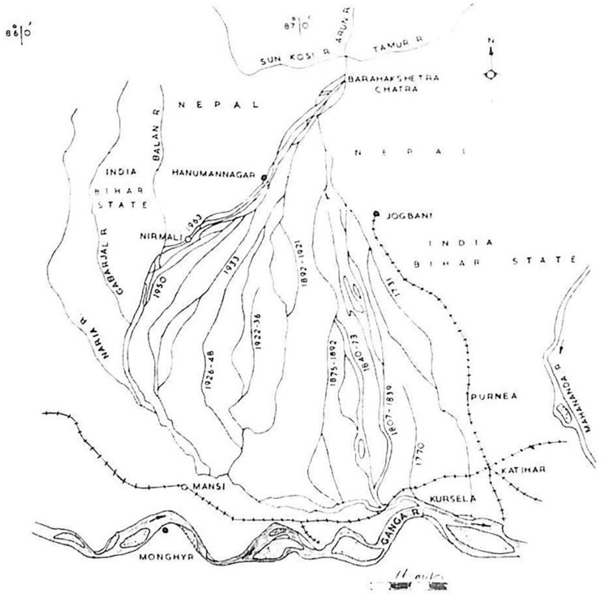

Figure 2. "Inland Delta Building Activity of Kosi River" in the Journal of the Hydraulics Division. With permission from ASCE.

"TOO MUCH" SAND, NOT WATER (FLOODPLAINS)

Roughly 6,000 rivers flow through the Nepal Himalayas to the floodplains of India.[5] The Kosi River Basin has concerned engineers the most. Kosi carries more than 100 million tons of sand to the floodplains each year. Engineers arrived at the conclusion that so much sand made Kosi swell up, meander, and spill over. A senior engineer in Nepal who prepared flood-mitigation reports once gave me a map of Kosi. It was a classic map that kept appearing in my fieldwork discussions to show how the Kosi had diverged some 112 kilometers westward in the past two hundred years. The map showed why, the engineer noted, sediments should be extracted. They would otherwise cause havoc in the floodplains. He explained the fluvial process to me as follows:

> When Himalayan rivers come down to the Indo-Gangetic floodplains, they slow down due to heavy sand load and low kinetic energy, so they deposit the sand because they cannot carry it anymore. It creates a fan-shaped deposition

> every year, and if it is not taken out, it will grow. We sometimes build embankments. But no matter what, the rivers keep depositing sand, and the riverbed keeps rising. The local settlements in both Nepal and India that are above riverbed levels slowly move below the bed. That’s dangerous. It will cause havoc.

For the reason of sediments rising above local settlements, engineers found the stretch of the Kosi River between the Nepal-India floodplains most dangerous. The unique geology and geomorphology of the Kosi indicated that the alpine and mountainous stretch—that is, the steep slopes from where the river rapidly gathered sediments—was in the Nepal Himalayas. On the other hand, the alluvial flat basin where the river deposited sediments was mostly in the Bihar floodplains of India. This geomorphology meant that when heavy rains hit the area, Kosi was already brimming with sand and silt from the mountains. Floods, therefore, were both predictable and unavoidable in this region, and engineers came to see their occurrence as a prototype of sedimentary catastrophe. On the careful examination of river mechanisms and monsoons over the years, most engineers had concluded that this stretch of Kosi, where it debouched into floodplains, was experiencing a tumultuous sedimentary life that made it shift paths, breach embankments, and cause frequent floodings. A concern lingering in their problem statement was: *Where would so much sand perennially flowing from the Himalayan mountains go if it is not removed from the rivers in a timely manner?* The bias against sediments was built into the problem statement.

The fluvial science on sediments hinged on two geological components: first, engineers noted that the Himalayas, as “tectonically active mountains,” were constantly rising and falling, making them prone to heavy “erosion.” Second, if the mobility logic of rivers were to be trusted, it indicated a correlation between the depletion and transportation of these sediments from “mountains to the floodplains” every year. Particularly during monsoons, when rains beat up these erodible Himalayan terrains, the sediment flows in rivers increased. In approaching this story, the engineers thus asked me to keep in mind the geological knowledge of the Himalayas as “easily erodible” terrains and flashy monsoonal patterns, which they usually called a “hydrological anomaly.” Indeed, known for tectonic movements and sudden intense rains, several parts of the Himalayas experienced regular landslides, heavy erosion, frequent floodings, cloudbursts, and glacial-lake outbursts. The engineers considered these major natural causes of sediment flow to the floodplains (Adhikari 2013). This knowledge about the topography, climate, and erosional history of the Himalayas thus induced *teleological conditions* (see Jamieson 2020) of geology, affecting the fluvial science on excess sediments.

This science should be read "critically and historically" (Galison 1994, 251). In a 1949 government report coinciding with engineers' planned training works to control paths of "sinuous" Himalayan rivers, it had made sense to quote a Dublin-born engineer under the British Empire, Claude Inglis, the director of the Indian Waterways Experiment Station in Poona. He claimed that "the main cause of meandering and high river levels is too much sand, rather than too much water" (GOI 1949, 206). This archival statement about *too much sand* has proved revelatory for me, since most anthropological and historical accounts on rivers fundamentally attribute meandering and catastrophic qualities to unruly water, not sand. According to Inglis, however, if we only had to deal with water in rivers, the problem would be simple. But sand bore weight; it caused rivers to rise and spill over. The spill of flood water over riverbanks concerned engineers. This is because spill represented "havoc." Engineers saw the rivers speedily debouching from the steep Himalayas into the Indo-Gangetic floodplains to be carrying heavy loads of sand and silt. An engineer reflected, "while the flooding of fertile silt for cultivable floodplains was desirable, excess coarse sand created blockage." As per engineering principles, excess sand "choked" smooth flows (Lacey 1958, 146).

What the excess-sand story lacked was a harmonic analysis of the phenomena. In particular, the engineers in the Indian Bihar floodplains asked me to be regionally attentive to the hazardous implications of the high sediment yield of Kosi for the downstream settlements in Bihar, because of which Kosi had garnered the reputation of being "the Sorrow of Bihar" (Mishra 2008a). An Indian engineer argued that "floodings were a political and governance-related matter," but also a result of "natural sediment yield from the Nepal Himalayas that caused the rivers in the Bihar plains to rise above the settlements." For Indian engineers, then, excess sediments entering from Nepal to India constituted a threat, even if the country was not. The Nepali engineers found this logic rather slanderous and ironic: a former government engineer noted that "neither the natural flow of sediment nor the topography is controllable." Further, he added, the "persistent framing of the flood problem by the successive governments of Bihar and the Indian news media hinted that the water and sand from Nepal mountains were intentionally causing floods in the Bihar plains." Nepali engineers often contended that such biased accounts ignored the geomorphology of the landscape and the role of infrastructures. An engineer, for instance, noted that such accounts "conveniently shielded the role of the Kosi Barrage," constructed by the Indian government in 1963, "which acted as a major barrier to the smooth flow of sediments from Nepal."

Here was a threat simultaneously physical and territorial: the sand, flowing from mountains to floodplains, from one country to another, causing turbulence in both, being projected as a catastrophe, and the engineering quest to explain this as a condition of sedimentary excess.

Technically speaking, there was nothing unusual about this engineering fascination with the *source* of the sedimentary problem. It ranged well within the spirit of scientific inquiry. Discovering truths about the physical world is intrinsic to the virtue of science, as the philosopher of science Sundar Sarukkai (2012) argues. And by investigating the truth about catastrophic floods, engineers forged knowledge about the physical world. "If excess sediments belonged to the Nepal Himalayas, as portrayed by India," a Nepali engineer rationally asked me, "by that logic the sand islands and territories forming in the rivers should also belong to Nepal." That the underlying task of science was an inquiry in logic, rationality, and reason was not lost on engineers. As technical expertise remained entrenched in seeking a supposed truth, with an impulse to explain *nature's truth*, another Nepali engineer asserted that, "had sediments from the Nepal Himalayas not flowed down and *settled* in the Nepal-India floodplains, what we know as Indo-Gangetic plains would not have *existed* as fertile lands for settlements." Engineering is often understood as an "applied science" (Latour 2015, 170–71), but here it becomes clear that as a key discipline about the physical world, engineering has a great deal to offer, not just in practice but also in theoretical principles about how it forges scientific knowledge (in this case, about fluvial sediments).

For a brief shining moment this may seem like the engineering discipline's natural inclination toward the objective pursuit of fluvial science. But the engineers' knowledge of the laws of fluid motion did not emerge in a void. It boomed in the late nineteenth century, when interest grew in building permanent structures on the Himalayan rivers as part of development prospects. In 1847, the first engineering college, Thomason College, currently known as the Indian Institute of Technology, Roorkee, was established in a small Himalayan city under the British Empire in hopes of training local *elite* Indians in the science of engineering to meet the post-famine emergency call for technical know-how in the River Ganga canal.[6] At least the theoretical presentation of modern engineering practice, then, carried moral weight and social potentialities. An engineer building a reservoir, bridge, canal, or dam, while altering the chemical composition of water and sediments in the river or displacing large sections of local settlements or sidestepping the impact on a transboundary country, could skip scrutiny for ascribing energy, value, and social meaning to their design. In this sense, engineers were no ordinary builders; they were the primary contributors to a nationalist sovereign "visioning exercise" (Sekhsaria and Thayyil 2017, 1837) of how nature could be geared toward social purpose (Bolaños 2022; Mukerji 2022; Oğuz 2021). With the rush of hydropower development projects in the mid-1950s and 1960s, they came to play a central role in forging knowledge about the characteristics and scope of the Himalayan rivers, which always contained an element of these "sovereign anxieties" (Hayat 2022, 3). River valley development projects emerged in Nepal at nearly the same time, with US-AID involved in hydrological and river-training projects from 1960 onward.[7] Nepali engineers, too, trained at the Institute of Engineering (IOE) in Nepal to identify the water resource-potential of the Himalayan rivers for their own country.

In this amassing of knowledge, the neutrality of science cushioned sovereign claims to determine the source and destination of the purported sediment problem. The problem statement usually indicates *where* exactly the fault rested.[8] This idea lingered in the sovereign anxiety among Nepali-Indian engineers, and it's easy to see why. The shared floodplains of Nepal and India experience frequent floodings, so it made sense for engineers to use sovereign frames to scientifically identify the source of this problem across the border. To this end, in 1969, when India sponsored a research mission into the Nepal side of River Kosi, a certain bias became ensconced in the framing of the research question: the team wanted to determine the role of "upstream activities" in heavy siltation "downstream" (Eckholm 1976, 81). The research team went on to warn that Kosi, which geographically included most of eastern Nepal, was now "one of the worst eroded in the world" (Eckholm 1976, 82).

The anxiety on sediments, however, had not been growing in siloed binaries of Nepal-India expertise. The postwar humanitarian experts referenced the floodings in plains as well as plumes of sediment far in the Bay of Bengal as a crisis of Himalayan degradation (Curray and Moore 1971). Two key factors informed the degradation theory: The first relied on neo-Malthusian climate rationalities about "population explosion" in relation to pressure on mountain soil, which in turn, led to more sediment flows to the plains. Second came an attempt to understand the natural or geomorphological factors behind sediment mobility (Ives 1987, 190). Critiques of the Malthusian rationality are well documented (see Thompson and Gyawali 2007; Robertson 2006). Less explored is the concurrent emphasis on the erosion of Himalayan geology that played an equally important role.[9] This was evident in the GTZ-UNESCO Munich conference in 1974, which appealed for scientific answers to erosion from the mountains to the floodplains (UNESCO-MAB 1974).[10] Erik Eckholm's thoughts further summarized this trend: he noted that "Nepal was exporting the commodity that it could least afford to part with, namely topsoil, to India, in the form that India could least afford to receive" (Eckholm 1976, quoted in Ives 1987, 191). Eckholm's interest here were the fertile, silty sediments flowing down, which he deemed the Nepal Himalayas' "most precious export" to India, for which Nepal "received no compensation" (Eckholm 1976, 78). The sediment flows from the "Nepal mountains" to the "India plains" here evolved into a forceful geomorphological question: *If the sediments were indeed flowing down in abundance, then the formation of fertile Indo-Gangetic floodplains owed much to the Himalayas.*

It is difficult to tell the extent to which this link between mountain erosion and plains floodings informed sand-extraction works in this region. River management and extraction in the floodplains do not form a simplistic unitary project.[11] Embankments, dikes, levees, barrages, canals, and even rats feature in the discussion (GOI 1969, 54). I thus want to exercise caution in advancing the more familiar extraction scale framing to capture the political and capitalist sentiments on sediments. The measure to which engineers puzzled over dredging mechanisms remains unclear to me. Yet, evidently, the engineering philosophy was a geological philosophy in which the deep history of the Himalayas was nature's story about sedimentary excess.

Figure 3. Accumulation of sediments in a drying river in Bengal, as observed by me. Photo by Saumya Pandey.

RIVER IMPROVEMENT BY DREDGING (DELTAS)

Far below the 2,500 kilometer Himalayan stretch things looked different, however. Here, the ways in which capitalism implicates the history of sedimentary excess and extraction becomes more visible. It is here, before reluctantly merging with the Bay of Bengal Sea, that Himalayan rivers thicken with sediments. I sat by these rivers to observe how thick, voluminous lumps of sand and silt deeply soaked in and released water in rhythmic breath, pushing back against forward movement. And each time the rivers expanded their lungs, they moistened their banks by their touch. That's how the rivers spread and widen—by resisting forward movement. Engineers explicitly used terminologies such as *deterioration*, *siltation*, and *sedimentation* to explain these riverine conditions of thickening, resistance, and counter-movement. Pragmatically it made sense to the engineers to dredge rivers here: a long period of time after Himalayan rivers had debouched from mountains into plains, had accumulated sediments, and were making mega fans, sandbanks, and shoals, especially at the mouth of the Bay of Bengal Sea. This point was reemphasized throughout the course of my fieldwork. As an Indian engineer noted, "dredging was not good when rivers were young and flowing through steep Himalayan slopes with high velocity. But it was good when rivers had aged in the deltaic plains and had started to form sand and silt shoals and sandbanks." I will come to the link between sediment, extraction, and mountains in the following section, but first—why was dredging "good" in the deltas?

Archives on colonial river maintenance and training works show that merchant ships and vessels in the past had sunk deep in great piles of sand and silt that accumulated at the mouth of the deltaic rivers. In particular, historical records compiled by East India Company engineers told the story of the James and Mary Sands, named after the *Royal James and Mary* ship, which in 1694 sunk deep into the sandbanks. These sands had an "evil reputation for their peril to vessels making the passage of the [River] Hooghly" (Bengal Secretariat Press 1914, 5). Engineers observed that the James and Mary Sands posed "chief danger" to the navigation of the Hooghly as the vessels were sucked in the thickness of the shoals (Bengal Secretariat Press 1914, 5).

Counter and lateral movements confounded colonial engineers: "The cry that Hooghly is deteriorating [was] raised every now and then" (Bengal Secretariat Press 1914, 5). For engineers, this gave grounds for dredging mechanisms. When I started my fieldwork, I was likewise expected to accept the colonial logic that dredging helped rivers "improve" through the removal of silt, a process engineers described as "de-siltation." Somehow, it constituted an established truth that dredging sand made deltaic rivers better. Powerful suction dredgers became an important investment for port commissioners to carry out sand dredging operations in 1907 to "improve," for instance, the deltaic Hooghly River. Several experiments were undertaken in the tributaries and distributaries of rivers entering the Bay of Bengal. In fact, the first experiment with a modern dredger on the deltaic river Nadia took place in April 1902 with the Lindon Bates, a suction dredger named after its engineer (Bengal Secretariat Press 1906, 23). It was thus in the rich deltas that the colonial and economic place of sediments first became visible, much before the idea of dredging even reached the upstream Himalayan mountains. The scholars Ashley Carse and Joshua Lewis (2017) observe that technological exposition on the environment subtly modified vast ecologies in political and economic ways. Indeed, if rivers were to be made navigable, and shipwrecks avoided, the rivers had to be stripped of sediments. Dredging technologies made this ecological experiment possible. This imperialist logic had sweeping consequences, its power accepted with impunity. I rarely found engineers questioning the fundamental premise behind the idea of removing sand and thus improving rivers through dredging.

Clearly, engineers saw dredging as the alibi—not the root cause of any problem. Therefore, whether accumulated sand was causing catastrophe could only be decided based on the multiple ways in which engineers applied the logic of economy or cost-cutting in maintaining infrastructures such as bridges and canals. An Indian engineer explained this:

> Sandy rivers were shallow in depth and broad in width. If the sand is extracted from the water, rivers will increase in depth. The width too will shrink. Shorter bridges can be built on rivers. This will save cost.

Similar accounts appeared in the river training reports: colonial engineers justified riverbed extraction as economically sound, as they estimated the cost of bridging the entire stretch of a river to exceed the sum of the costs of shorter bridge (Superintendent Government Press 1903). This revelation proved rather easy to implement given that the beds of river in question were loose, unstable, and not composed of solid, unerodable rock. It is therefore not in uniformity and stability that technical science saw nature. Laws of nature were unstable. Engineers recognized that.

Engineers tried to interpret sedimentary mechanisms as conditions to be recognized, not opposed. Inglis, who left a notable mark on Indian canal design models, for example, "preferred to enlist the forces of Nature rather than oppose them" (Thomas and Paton 1975, 380). Inglis's riverine knowledge and designs around removing sand while letting silt pass before they entered irrigation canals have often been projected as moral and honest, a task undertaken not with any compulsive obsession to control the natural, free-flowing river, but under the logic that trained rivers would flow more purposefully. According to Gerald Lacey, we might almost say that Inglis studied "river psychology": "He treated these alluvial rivers as though they were alive, not rigid, or dead. He asked himself the question 'What would I do if I were the river?' . . . He was concerned with the misinterpretation which he saw others making, particularly where an opportunity was being missed of making nature do most of the work" (Thomas and Paton 1975, 384).

The environmental *conditions* of sand's materiality such as siltation, sedimentation, and rising riverbed levels thus historically dominated the dredging hypothesis and gave it ecological legitimacy through colonial river management, training, and governance practices. These humanist processes by no means, however, translated into innocently studying nature. Rather, as the environmental historian Rohan D'Souza (2006b, 151) notes, the "logics and calculations for regulating the rivers" emphasized how the use-value form of deltas informed capitalist logic. To this end, colonial engineers used sediment behavior in the deltas as evidentiary knowledge about what sedimentation in rivers could do to the economy of infrastructures that came their way, a notion that dislodged a possible criticism of river dredging mechanisms per se.

In a twisted fate, these colonial ideologies informed the (post)colonial knowledge on sediments in the Bay of Bengal not just as excess to be dredged but also as legally claimed. To paraphrase the anthropologist Gisa Weszkalnys (2015), here we see the double logic of capitalist expansion, which makes for both a site of inherent failure and speculation. Excess sand in the form of mobile landscapes such as sand islands and shoals that brought grief to merchant vessels revealed new tensions about sovereign ownership and territorial rights over fluid geographies. India and Bangladesh have, for instance, claimed rights over mobile sand islands in the Bay of Bengal. As generative sites of colonial, legal, and economic power, sand islands find rich mention in the study of deltaic rivers. The historian Debjani Bhattacharyya (2021, 144) writes: "Silt and shoals emerge in European writing as sites of labor and exhaustion and as places that science passed over." One may extend this insight to the current descriptions of littoral spaces to read the counter-movement of rivers and the environmental crisis as a symptom of cartographic colonial power.

Prognostics of sand as disastrous were thus imbued with the colonial mentality of mapping flows and usually exceeded an engineering vision of linear flows (da Cunha 2018; Boyer and Vardy 2022; Lahiri-Dutt 2014). The invisible, slow forces of deeper timescales such as sedimentation and siltation—that made and unmade *land*—were brought to the surface as historically contingent products of disaster to reconstruct the more recent history of river dredging. As these rivers evaded the "logics of hydrology because they are too weighed down with sediment, and of strata, because they are too mobile" (Bremner 2020, 3), and fluidity "became a generative site of productive law making" (Bhattacharyya 2021, 145), dredging prompted vexing questions about the scientific, ecological, political, and economic contours of what value sand held in contemporary capitalist endeavors. If deltas, shoals, seabeds, and rivers were dredged and dried in service of capital accumulation, land speculation, and cartographic expansion (Khalili 2020; Carse 2022), what value did the loose sediment in the Himalayan rivers have?

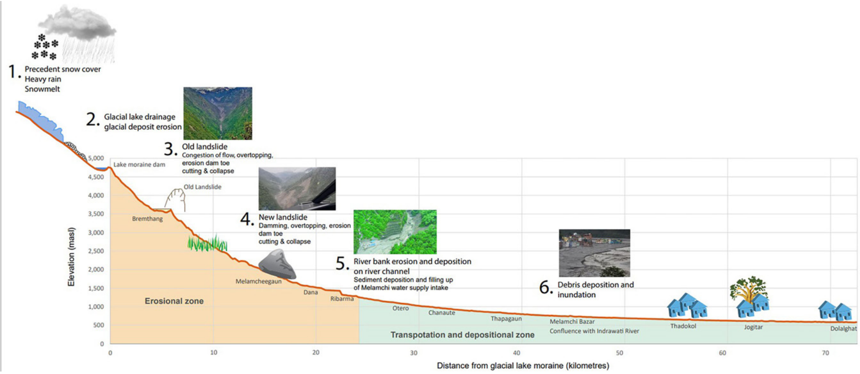

Figure 4. Melamchi floods. Credit: Sudan Bikash Maharjan | ICIMOD.

SAND FUTURES AS "PROBLEM" (MOUNTAINS)

In the June 2013 monsoons, the sediment ratio in River Mandakini, high up in the Indian Himalayas, was so elevated that the bed level rose to 1,640 m from 1,611 m (Sundriyal et al. 2015, 181). Water-laden clouds, bulging at the seams, had apparently meandered from their regular path toward northeast India. Instead, after absorbing moisture from the Bay of Bengal Sea, they headed straight up toward the low-pressure trough in the Himalayan region of northern India and western Nepal, bringing monsoons two weeks sooner than usual. The clouds violently burst at a moment when the region was already experiencing showers from westerlies, causing high-intensity, focused rainfalls. Around twenty-five Himalayan rivers and their tributaries swelled with "debris" (Sati and Gahalaut 2013, 193), which was basically the sediment and muck that had assembled during landslides, had been left behind by the receding glaciers, resulted from dam bursts, or all of these factors. *It is still hard to tell.*

Within months of starting my fieldwork in June 2021, a similar incident unfolded in Melamchi in Nepal, which had all the elements the engineers feared: dense clouds bursting; heavy showers; glacial lake outburst; earth flow; inundated banks; the destruction of life, infrastructure, and agricultural fields. The site of a village buried in sediments to me served as a reminder of what Nayanika Mathur's (2021, 159) Himalayan ethnography describes as *daivya apada* (disaster) and *prakriti ka prakop* (retribution of nature), both attributed to the power of the mountains and rivers that sought to reclaim their position from anthropogenic exploits. In our discussions, several engineers noted that, one, the Himalayas were still growing, with their movements unstable; and two, a late 1980s and 1990s neoliberal development trajectory—in the form of the heavy construction of roads, upstream dams, deforestation, and rampant sand mining—on the region's shoulders was weighing it down, leaving it to unravel its catastrophic fury on humans. This, in turn, made a pressing case for how "social and political agency emerges alongside earth forces" (Bremner 2021, 24). A Nepali engineer observed that the "frequency of sedimentary catastrophes has been increasing," and engineering knowledge on sedimentary conditions thus sat uncomfortably with what engineers unanimously believed had never been appliable to the Himalayan rivers.

As a general rule, engineers reflected that they were *not taught to think with sediments, but mostly water*. Hydro-engineers, for instance, argued that they were trained to study the "water-resource potential" of the rivers. Little importance was given to sediments. A hydro-engineer recalled after completing his training in Austria that "it was not until I moved back to Nepal and started thinking about sediment basins to trap excess sediments and operating expensive turbines that easily corroded from quartzite sediments that I realized that my design and training had not considered the behavior of these sediments." In fact, several Nepali and Indian hydrologists, who envisioned dams on rivers and witnessed enigmatic sedimentary mechanisms, felt strained by their learning, and often complained to me about how little Euro-American engineering models knew about the sediment-rich rivers flowing from the hyperactive Himalayas.

As social thinkers, engineers wanted to protect the environment. A Nepali engineer critically noted that the "*curvy* Himalayan geology made it hard to implement Western-style river projects." To civil engineers, especially who inhabited and dealt with the geology of Nepal—a country that is 83 percent mountainous landmass—and seismic events on a day-to-day basis, it was even more important to bear in mind that much of the engineering expertise on rivers had been based on “grownup mountains” and river systems *elsewhere*. Indian engineers, too, believed in this theory. A concerned engineer explained that, “Europeans formulated solutions we have to use that best suited mature mountain regions such as the Alps, which are relatively more stable terrains and do not easily erode or have high sediment load like our Himalayas.” Another engineer explained that “unlike the neat chains of the Alps, the Himalayas have parallel terrains and complexly folded riverine paths that accumulate sediments by creating traps always on the verge of a disaster.” In a couple of engineering workshops on geohydrology in Nepal I attended, the engineers in smaller groups discussed how the sedimentary disasters further accentuated that recent bouts of intense heat were melting Himalayan glaciers—the third-largest glacial reserves (after the poles) in the world. The by-products of such melting were not just water but also moraine, as several engineers pointed out. Engineers often highlighted that several *less-known* ongoing geological factors were thus disrupting the logic of water, mobility, and flow at an “uncertain scale.” These complex, seemingly inexplicable shifts aggravated sediment flows in the rivers.

To the average engineer, then, sediment flows proved erratic, irregular, and unknowable, with one of their constitutive elements being that they ruined lives and infrastructures, without any *one* geological force clearly being at fault. As a result, the majority of engineers believed that, ideally, extraction works in the mountainous terrains should be avoided because these terrains were exceptionally “unstable,” and leading to disasters “unknown.” Yet this was also the *very* reason many believed that extraction made for an environmental “necessity”: for instance, one engineer argued that “if the sediment is not removed from time to time, it will keep piling up in the mountains, naturally dam the upstream river flow, and lead to more destruction at an unknown Himalayan scale.”

It is here in what Mathur (2015, 102) describes as the “unassailable potency” of climate narratives in the Himalayas that a blueprint for private extraction work finds impunity. Engineers have noted that at least for as long as extraction proves an environmental necessity, it is important to economize this opportunity. They have *always* reminded me that sand has an economic value for the construction industry to build roads, dams, bridges, and even embankments, and that local governments usually earn revenue/royalties by extending private mining leases. If a governing body does not capitalize on this extraction, it will cause revenue loss to them; and this is, as an engineer once sharply put it, a "windfall gain" for "mining and crushing *vyavasai* [businesses]." This has proven a common governance approach to extraction. Private companies are given mining leases by local governing authorities not for mere profitability but with the clear scientific motivation that extraction controls future sedimentary catastrophes.

Several flood-management reports from Nepal I read recognize the engineering approach to the extraction of sand, gravel, and stones for both flood control and as an important source of revenue for local governments. A senior engineer who always encouraged me to critically examine how sediments are treated in the technical sciences patiently explained the relevance of this:

> The local governments in Nepal can potentially issue permits to the private contractors to mine the sand, gravel, and stone in the riverbed. This is a flood-adaptation measure against the ongoing impacts of sedimentary disasters. It allows the government to maintain the riverbed levels without incurring costs on public money, while also ensuring revenue generation to promote infrastructural development.

Here, if governance claims and scientific knowledge do not differ from a form of social and economic organization of riverbed mining, it is because the social and economic position on extraction in the twenty-first century is one of science and governance. The narrative of economic-environmental balance is a scientific one in which sediments pose a futuristic challenge and private mining offers the engineering solution. This is where science, capital, and governance become entangled—historically, materially, conceptually, and epistemically. If one carefully reads the regular grounds on which mining permits are leased out to private companies in India, one sees traces of this engineering logic. For example, a lease from 2020 shows that the Ministry of Environment, Forest and Climate Change, Government of India, discussed a proposal seeking prior approval of the government under the 1980 Forest (Conservation) Act to renew the sand-mining lease in specific rivers in the Himalayan region of Uttarakhand. The proposal contained a brief note on the justification for locating the project in forest land by the proposing body, the Uttarakhand Forest Development Corporation, which stated the following (translated from Hindi to English by me):

> The sand, boulder, gravel, and other riverbed minerals that are brought by mountain rivers when it rains accumulate in the riverbed, which causes the

> river flow to change direction and acts as a potential threat to the population settled close by. If mining activities are not undertaken in these regions, the beds of rivers will be overwhelmed with sediment material, and there will always be a risk of rivers overflowing and flooding the settlements that are on the banks of these rivers. Therefore, to protect the lands surrounding the river and to control the flow of the direction of the river, the removal of these minerals is of absolute and *necessary* importance.
>
> Minerals, for geographical reasons are present in rivers, which fall under the forest department. This is the reason why there is no choice left but to seek mining permission from the Indian government.[12]

This scientific legitimation for private extraction aside, the sharp ontological distinction between scientific reasons for extraction and a neoliberal impulse to rampantly extract persists. A couple of news and land-research platforms in India, for example, have found it startling that environmental protection and disaster management laws on dredging for flood protection have been used for private exploitation (Joshi 2021). Within their framework, engineers, too, sometimes use the scientific phrase "sand harvesting" to distinguish their ethical principles on extraction from excessive "sand mining." Engineers believe that sand harvesting is environmentally friendly because it relies on the logic that the Himalayas will always erode, in which case if "moderate" amounts of sediment are extracted, they would be easily and "naturally" replenished each year. "The political economy of sand harvesting," an engineer noted in an online public discussion on sand mining in South Asia in 2020, "is very different from the political economy of sand mining": "If you forgive me for rather crude language, it's the difference between making love and rape. What the politics of harvesting implies is sustainability, whereas mining means extract whatever you can." Several engineers have thus expressed concern that private contractors work following the logic of profit, not science or sustainability, drawing clear theoretical distinctions between "scientific" and "private" extraction practices.

On the contrary, I want to argue that the link between the two is historically contingent and geologically profound. First, when it came to accounting for the credibility of using scientific methods for private mining, engineers asserted that scarcely any examples existed to offer at the present time. At least in my fieldwork sites, then, the link between science and private mining occupied *affective* registers. So, when the engineers anticipated sand exploitation, tensions arose as to the "appropriate ethical orientation" (Weszkalnys, 2014, 129) toward extractive futures. Second, even when the distinction between rampant mining and scientific mining attenuated, as in the context of extracting from "uncertain" mountainous rivers, engineers contended that the fundamental concern remained unresolved: *How could science and governance manage the sand problem in the erodible Himalayas?* This *positive feedback loop* (Clark and Szerszynski 2021) of prognostically identifying Himalayan sediments as a problem and finding engineering solutions ran deep in a wide range of *private* mining contracts.

But then again, we should not regard this as an unforeseen, sudden occurrence. At the heart of this scientific-private loop on sediment management lies the nineteenth-century European anxiety about the Himalayas' deep geological history: how the Himalayas broke, moved, and to what end. In particular, colonial foresters in British India were anxious about rapid sedimentary breakdowns in parts of the eastern Himalayas. They concluded that informal local grazing, tree-cutting, and small cultivation practices in the mountains were "unscientific"—that they caused the Himalayas to further denudate, leading to "deforestation" and "desertification." Yet, predictably, they found no fault with *private* tea estates on the hill slopes, which they believed were "well managed" (Sivaramakrishnan 1999, 199). Sediment governance has thus historically come to center on the idea that Himalayan erosion necessitates stricter "private" enclosure, "scientific" forestry, "sustainable" farming, and so on (Carson 2020; Malla 2001).

Third, the classification of sediments here seems to overlap with a more familiar industrial and economic classification of sand as a "construction aggregate." This is to say that the classification of fluvial earth as strictly sand, gravel, and stones (SG&S material) sustains the economistic appeal by claiming at once vagueness and specificity on the sediment matter, size, shape, form, origin, and purpose. I want to argue here that this vagueness is not a classic case of ignorance; neither the government permits mentioned above nor the engineering voices I unfold in this essay have ignored Himalayan complexities. In fact, as I have shown, engineers made value distinctions between silt/sand, desirable/catastrophic, stability/turmoil, mountains/plains, sediment/water, harvest/mine, sustainable/rampant, revenue/profit, even as the private businesses that scooped riverbeds did not. Rather, this is a form of denial, expressed in a manner that supports both science and governance (river maintenance and revenue-generation through extraction!) while retaining a deniability of scale and measure (the motivation behind extraction was to prevent catastrophe and save lives, not destabilize the Himalayas or profit!).

Such a premise can prove disquieting.[13] Such a "vision of the world" (Yusoff 2009, 1021) can exceed its mechanistic claim and have destructive implications. Extraction as a supposed necessity persists even as engineers have meant no harm to the Himalayas and its rivers. On the contrary, engineers are mindful and not in denial about the fluvial sedimentary conditions in the context of the limitations of a technical training steeped in non-Himalayan visions. To the engineers, then, the technical science is questionable. Yet that has not dented the appeal of seeing too much sediment as problem.

What, then, was applicable to the Himalayan rivers?

CONCLUSION

The reasons for extraction are "ethically" crafted. The Himalayas' own history was summoned forth in engineering to voice the ethics of extraction. The geological conditions of the Himalayan sediment rising, breaking, eroding, transporting, settling, and accumulating at the Bay of Bengal Sea gained political traction and epistemic legitimacy in extraction reasonings. Sediment unsettled the disciplinary boundary of river engineering. It was shown to be a loose substance wandering in the Himalayan rivers in excess, obstructing shipping paths, preventing the forward movement of rivers, destroying infrastructure, causing inundation and, most important, risking lives. All this made extraction possible, ethical, and justifiable in the first place.[14]

The extraction reasoning will continue to be enacted as an ethical imperative. This is because it is made legible on environmental and humanitarian concerns—not just capitalist pursuits. One also finds the ethical imperative of extraction forged in international climate science and policy discourse, which proposes sediment extraction in the Greenland Arctic's warming sea ice as a response to the challenges of climate change. The proposed climate events that drive this approach are "melting glaciers" and "rising sea levels" (Bendixen et al. 2019, 99). One might appreciate this extractive approach in science for its ability to supply solutions during climate catastrophes. However, it's hard to ignore that the "abundance" of these sediments melting from Greenland glaciers is proposed to meet the purported scarcity of sand for the construction industry—ironically, the largest emitter of climate-altering greenhouse gases.[15]

Ideas of scarcity, abundance, and those around the world running out of a resource, often justify exploitative capitalist ambitions (Kirsch 2020). It is also not enough to say that sand extraction mobilized under the imprint of colonial dredging innovations thereby makes way for capitalist expansion. Presenting extraction in capitalist-scale terms (measurable value), although important, certainly underrepresents the role of knowledge and epistemological frameworks in their inconsistent, unmeasurable, and intangible politics and ideology (see Navaro-Yashin 2020). For this reason, I have considered the sedimentary knowledge in history, geology, and related fluvial sciences that serve multiple, and often ambiguous, ideational claims across different scales (floodplains/deltas/mountains) and periods (postwar/colonial/neoliberal). Such political ambiguities do not necessarily lead to a dismissal of sand extraction as a geologically unstable way of conditioning the Himalayan rivers. Rather, geological instability itself serves an epistemic position in the extraction discourse, in which the exclusion of sand from Himalayan rivers occupies a valid place in the environment.

ABSTRACT

This article examines how a future about surplus sand entered river-engineering vocabulary as an obstruction to the free flow of Himalayan river systems. It is a historical and ethnographic analysis of sand's conceptualization as a catastrophic material that caused rivers to spill over, which became conducive to its removal from rivers for economic endeavors. Sand holds a unique place in society, it's the foundation on which roads, bridges, and buildings are built. Today, a shortage of these sediment particles has been described as a moment of economic and environmental crisis. Against the grain of sand's desirability and shortage as a resource material, I pay close attention to the destructive articulations of the Himalayan earthly forces that made the political economy of extracting excess sand possible. [catastrophe; economy; engineering; geology; Himalayan rivers; politics; sediments]

सार

यह लेख इस बात की जाँच करता है कि कैसे इंजीनियरिंग शब्दावली में अधिक रेत का भविष्य हिमालय नदी में बाधा के रूप में बताया गया । यह एक ऐतिहासिक और नृवंशविज्ञान विश्लेषण है जो दिखाता है की रेत को कैसे विनाशकारी सामग्री बताया गया । यहाँ हम बताते हैं की बाढ़ के कारन नदियों से रेत को हटाने के लिए क्यों अनुकूल समझा गया । रेत समाज में एक अद्वितीय स्थान रखती है । यह वह सामग्री है जिस पर सड़कें, पुल और इमारतें बनाई जाती हैं। आज रेत की कमी को आर्थिक और पर्यावरणीय संकट का श्रोत बताया गया है। किन्तु हम यहाँ रेत के अधिकता और कमी पर तर्क नहीं करेंगे। बजााय हम इंजीनियरिंग में हिमालय की ताकतों की विनाशकारी अभिव्यक्ति पर बारीकी से ध्यान देंगे जिसने अधिक रेत निकालने की राजनीतिक अर्थव्यवस्था को संभव बनाया है।

[विनाश; अर्थव्यवस्था; इंजीनियरिंग; भूविज्ञान; हिमालय नदी; राजनीति; रेत]

NOTES

Acknowledgments This essay has greatly benefited from the close reading and incisive comments of engineers, my anonymous reviewers, as well as the *Cultural Anthropology* editors

AbdouMaliq T. Simone and Julia Elyachar. Versions of the longer chapter from which this essay was developed were presented at ESEH Bern (2023), "Mountains and Plains: Past, Present, and Future Environmental and Climatic Entanglements"; Shiv Nadar University (2022), "Approaches to Mobility: Thinking through Space and Time"; and Cornell University (2022), "Writing the History of the Built Environments of Asia: Materiality, Translations, and Colonialism." I am deeply grateful to Debjani Bhattacharyya, Giacomo Parrinello, Santiago Gorostiza, Hari Krishna Srestha, Dipak Gyawali, Dinesh Mishra, Siddharth Agarwal, Saloni Verma, Edyta Roszko, Kari Telle, Xuefei Shi, and Hang Zhou for their time, encouragement, and thoughtful discussions. My doctoral research on Himalayan riverine sediments is funded by the Research Council of Norway (300875).

1. Nepali engineer interviewed by Saumya Pandey, April 2021, Kathmandu, Nepal.
2. To learn more about the history of Himalayan geology, see Gansser 1964.
3. Sand mining implicates the lives of those who work on it in Nepal and India. I identified rivers and experts very broadly to protect people in my field sites. I used specific names when it was necessary to describe the history and topography of a region and only quoted from documents that are publicly available. This is a serious matter. So, in organizing my research, my intention has been to counter Anglocentric epistemological hierarchies that claim fieldwork truth in heroic descriptions.
4. Nepal was not colonized by the British Empire, but colonial river works reached Nepal because of Nepal-India transboundary connections.
5. The rivers eventually merge with the Ganga Basin.
6. See the anthropologist Ajantha Subramanian's (2019) work on caste elitism in engineering in India. For a thoughtful discussion of the history of caste elitism in science in general, see Prashant Kumar 2022 and Prakash 1999.
7. US-AID is an acronym for the United States Agency for International Development. In 1962, US-AID–sponsored Tennessee River Valley development models were forged onto the Rapti River in Nepal; see Robertson 2016. For Nepal's development roadmap, read Sharma 2021. To understand how international organizations take an "eagle's eye science" view instead of a "toad's eye science" view, read Gyawali and Thompson 2016.
8. By thinking of mobility with notions such as source and destination, the technical sciences erased possibilities to reconsider the relationship between moving and being still, to rethink why *things* moved or "what mobility is for" (Clark and Szerszynski 2021, 143).
9. The anthropologist Nayanika Mathur (2015, 102) has in fact questioned this tendency to show the "Himalayas as forever on the brink of environmental disaster."
10. GTZ-UNESCO is an acronym for German Agency for Technical Cooperation–United Nations Educational, Scientific and Technical Organization.
11. For a rich analysis of these hydrological complexities and sovereign tensions, see Mishra 2008a; 2008b, as well as Gyawali 2021.
12. In the archives of the Ministry of Environment, Forest and Climate Change Government of India 2021; accessed on July 27, 2021.
13. The scientific double-talk can leave one paralyzed, Bruno Latour (2015, 98) reflects.
14. These forms of mobility—drifting, meandering, floating, and the like—are not only geographical, temporal, and political; they also express a sense of purposelessness and are thick with value judgments. To learn more about mobility logics, see Adey 2006; Dixon 2021; Peters 2015. Read Welland 2010 to learn more about sediment's accumulative power.
15. For more information on the impact of construction material on the environment see UNEP 2023.

REFERENCES

Adey, Peter

2006 "If Mobility Is Everything Then It Is Nothing: Towards a Relational Politics of (Im)Mobilities." *Mobilities* 1, no. 1: 75–94. https://doi.org/10.1080/17450100500489080

Adhikari, Basistha Raj

2013 "Flooding and Inundation in Nepal Terai: Issues and Concerns." *Hydro Nepal: Journal of Water, Energy, and Environment* 12: 59–65. https://doi.org/10.3126/hn.v12i0.9034

Amrith, Sunil

2018 *Unruly Waters: How Mountain Rivers and Monsoons Have Shaped South Asia's History*. New York: Basic Books.

Aronowsky, Leah

2021 "Gas Guzzling Gaia, or: A Prehistory of Climate Change Denialism." *Critical Inquiry* 47, no. 2: 306–27. https://doi.org/10.1086/712129

Bendixen, Mette, Irina Overeem, Minik T. Rosing, Anders Anker Bjørk, Kurt H. Kjær, Aart Kroon, Gavin Zeitz, and Lars Lønsmann Iversen

2019 "Promises and Perils of Sand Exploitation in Greenland." *Nature Sustainability* 2, no. 2: 98–104. https://doi.org/10.1038/s41893-018-0218-6

Bengal Secretariat Press

1906 "Waterways in Bengal:Their Economic Value and the Methods Employed for Their Improvement. Six Lectures Delivered During March 1906 by O.C. Lees." Calcutta, India: Bengal Secretariat Press. https://southasiacommons.net/artifacts/2360216/waterways-in-bengal/3358164/

1914 "Bengal District Gazetteers 24 Parganas." India: Bengal Secretariat Press. COI: 20.500.12592/9dg3v9. https://coilink.org/20.500.12592/9dg3v9

Bhattacharyya, Debjani

2018 *Empire and Ecology in the Bengal Delta: The Making of Calcutta*. Cambridge: Cambridge University Press.

2021 "A River Is Not a Pendulum: Sediments of Science in the World of Tides." *Isis* 112, no. 1: 141–49. https://doi.org/10.1086/713567

Binoy, Parvathy

2017 "Darly and Her Battle with the Sand-Mining Mafia: Tracing a Feminist Geopolitics of Fear in the Production of Nature." *Human Geography* 10, no. 2: 37–53. https://doi.org/10.1177/194277861701000203

Bolaños, Isacar

2022 "Water, Engineers, and French Environmental Imaginaries of Ottoman Iraq, 1868–1908." *Environmental History* 27, no. 4: 772–98. https://doi.org/10.1086/721180

Boyer, Dominic, and Mark Vardy

2022 "Flooded City: Affects of (Slow) Catastrophe in Post-Harvey Houston." *Current Anthropology* 63, no. 6: 615–36. https://doi.org/10.1086/722270

Bremner, Lindsay

2020 "Sedimentary Logics and the Rohingya Refugee Camps in Bangladesh." *Political Geography* 77: 102109. https://doi.org/10.1016/j.polgeo.2019.102109

2021 "Sedimentary Ways." *GeoHumanities* 7, no. 1: 24–43. https://doi.org/10.1080/2373566X.2020.1799718

Carse, Ashley

2022 "The Dredger." *History and Anthropology* 33, no. 2: 208–13. https://doi.org/10.1080/02757206.2022.2066096

Carse, Ashley, and Joshua A. Lewis

2017 "Toward a Political Ecology of Infrastructure Standards: Or, How to Think about Ships, Waterways, Sediment, and Communities Together." *Environment and Planning A: Economy and Space* 49, no. 1: 9–28. https://doi.org/10.1177/0308518X16663015

Carson, Sarah
2020 "Atmospheric Happening and Weather Reasoning: Climate History in South Asia." *History Compass* 18, no. 12. https://doi.org/10.1111/hic3.12640

Chakrabarti, Pratik
2020 *Inscriptions of Nature: Geology and the Naturalization of Antiquity*. Baltimore, Md.: Johns Hopkins University Press.

Clark, Nigel, and Bronislaw Szerszynski
2021 *Planetary Social Thought: The Anthropocene Challenge to the Social Sciences*. London: Polity Press.

Curray, Joseph R., and David G. Moore
1971 "Growth of the Bengal Deep-Sea Fan and Denudation in the Himalayas." *Geological Society of America Bulletin* 82, no. 3: 563–72.

da Cunha, Dilip
2018 *The Invention of Rivers: Alexander's Eye and Ganga's Descent*. Philadelphia: University of Pennsylvania Press.

Daston, Lorraine, and Peter Galison
2007 *Objectivity*. New York: Zone Books.

Deleuze, Gilles, and Félix Guattari
1987 *A Thousand Plateaus: Capitalism and Schizophrenia*. Translated by Brian Massumi. Minneapolis: University of Minnesota Press.

Dixon, Deborah P.
2021 "Drift in an Anthropocene: On the Work of Terrain." *Dialogues in Human Geography* 11, no. 2: 203–7. https://doi.org/10.1177/20438206211001034

D'Souza, Rohan
2006a *Drowned and Dammed: Colonial Capitalism and Flood Control in Eastern India*. New York: Oxford University Press.
2006b "Water in British India: The Making of a 'Colonial Hydrology.'" *History Compass* 4, no. 4: 621–28. https://doi.org/10.1111/j.1478-0542.2006.00336.x

Eckholm, Erik P.
1976 *Losing Ground: Environmental Stress and World Food Prospects*. New York: W. W. Norton.

Ehrlich, Joshua
2023 *The East India Company and the Politics of Knowledge*. New York: Cambridge University Press.

Fleetwood, Lachlan
2022 *Science on the Roof of the World: Empire and the Remaking of the Himalaya*. New York: Cambridge University Press.

Fujikane, Candace
2021 *Mapping Abundance for a Planetary Future: Kanaka Maoli and Critical Settler Cartographies in Hawai'i*. Durham, N.C.: Duke University Press.

Galison, Peter
1994 "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision." *Critical Inquiry* 21, no. 1: 228–66. https://doi.org/10.1086/448747

Gansser, Augusto
1964 *The Geology of the Himalayas*. Regional Geology Series, edited by L. U. de Sitter. Wiley: New York. https://archive.org/details/GeologyOfTheHimalayas-Gansser-A

Gyawali, Dipak, and Michael Thompson
2016 "Restoring Development Dharma with Toad's Eye Science." *IDS Bulletin* 47, no. 2A:179–90. https://doi.org/10.19088/1968-2016.173192

Government of India (GOI)
1949 "Government of India. Central Waterpower Irrigation & Navigation Research Station Poona. Research Publication No. 13 'The Behaviour and Control of Rivers and Canals (with the Aid of Models).'" India: Yeravda Prison Press. South

Asia Commons, CID: 20.500.12592/2p90fm. https://southasiacommons.net/artifacts/2362267/government-of-india/

1969 "Estimate Committee: Kosi Project." E.C. No. 573. https://eparlib.nic.in/bitstream/123456789/57954/1/ec_04_117_1969.pdf

Hayat, Maira

2022 "Storage as Security: Damming Water in Pakistan." *Political Geography* 97: 102629. https://doi.org/10.1016/j.polgeo.2022.102629

Hecht, Gabrielle

2018 "Interscalar Vehicles for an African Anthropocene: On Waste, Temporality, and Violence." *Cultural Anthropology* 33, no. 1: 109–41. https://doi.org/10.14506/ca33.1.05

Hoffmann, Michael Peter

2021 "Digging for Sand after the Revolution: Mafia, Labor, and Shamanism in a Nepali Sand Mine." *Dialectical Anthropology* 45, no. 2: 117–33. https://doi.org/10.1007/s10624-020-09615-0

Ives, Jack D.

1987 "The Theory of Himalayan Environmental Degradation: Its Validity and Application Challenged by Recent Research." *Mountain Research and Development* 7, no. 3: 189. https://doi.org/10.2307/3673192

Jamieson, William

2020 "For Granular Geography." *Dialogues in Human Geography* 11, no. 2: 1–19. https://doi.org/10.1177/2043820620950053

Jeyaranjan, J.

2019 "Sand and the Politics of Plunder in Tamil Nadu." In *The Wild East: Criminal Political Economies in South Asia*, edited by Barbara Harriss-White and Lucia Michelutti, 92–114. Chicago: University of Chicago Press.

Joshi, Mukta

2021 "Is Uttarakhand Abusing Disaster Management Laws to Allow Rampant Riverbed Mining?" *Newslaundry*, June 17.

Khalili, Laleh

2020 *Sinews of War and Trade: Shipping and Capitalism in the Arabian Peninsula*. London: Verso Books.

Khan, Naveeda

2019 "At Play with the Giants: Between the Patchy Anthropocene and Romantic Geology." *Current Anthropology* 60, S20: S333–41. https://doi.org/10.1086/702756

Kirsch, Stuart

2020 "Running Out? Rethinking Resource Depletion." *The Extractive Industries and Society* 7, no. 3: 838–40. https://doi.org/10.1016/j.exis.2020.06.002

Lacey, G.

1958 "Flow in Alluvial Channels with Sandy Mobile Beds." *Proceedings of the Institution of Civil Engineers* 9, no. 2: 145–64. https://doi.org/10.1680/iicep.1958.2283

Lahiri-Dutt, Kuntala

2014 "Chars: Islands That Float within Rivers." *Shima* 8, no. 2: 22–38.

Latour, Bruno

2014 "Agency at the Time of the Anthropocene." *New Literary History* 45, no. 1: 1–18. https://doi.org/10.1353/nlh.2014.0003

2015 *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, Mass.: Harvard University Press.

Malla, Y. B.

2001 "Changing Policies and the Persistence of Patron-Client Relations in Nepal: Stakeholders' Responses to Changes in Forest Policies." *Environmental History* 6, no. 2: 287–307. https://doi.org/10.2307/3985088

Mathur, Nayanika

2013 "Naturalizing the Himalaya-as-Border in Uttarakhand." In *Borderland Lives in Northern South Asia*, edited by David N. Gellner, 72–93. Durham, N.C.: Duke University Press. https://doi.org/10.1215/9780822377306-004

2015 "'It's a Conspiracy Theory and Climate Change': Of Beastly Encounters and Cervine Disappearances in Himalayan India." *HAU: Journal of Ethnographic Theory* 5, no. 1: 87–111. https://doi.org/10.14318/hau5.1.005

2021 *Crooked Cats: Beastly Encounters in the Anthropocene*. Chicago: University of Chicago Press.

Micheaux, Flore Lafaye de, Jenia Mukherjee, and Christian A. Kull

2018 "When Hydrosociality Encounters Sediments: Transformed Lives and Livelihoods in the Lower Basin of the Ganges River." *Environment and Planning E: Nature and Space* 1, no. 4: 641–63. https://doi.org/10.1177/2514848618813768

Mishra, Dinesh Kumar

2008a "Bihar Floods: The Inevitable Has Happened." *Economic and Political Weekly*, 43, no. 36: 8-12. http://www.jstor.org/stable/40277917

2008b "The Kosi and the Embankment Story." *Economic and Political Weekly* 43, no. 46: 47–52. https://www.jstor.org/stable/40278181

Mukerji, Chandra

2022 "The Agency of Water and the Canal du Midi." In *Hydrohumanities: Water Discourse and Environmental Futures*, edited by Kim De Wolff, Rina C. Faletti, and Ignacio López-Calvo: 23–41. Berkeley: University of California Press.

Navaro, Yael

2020 "The Aftermath of Mass Violence: A Negative Methodology." *Annual Review of Anthropology* 49: 161–73. https://doi.org/10.1146/annurev-anthro-010220-075549

Oğuz, Zeynep

2021 "Looking at STS through the Lens of Geological Anthropology: Interview with Zeynep Oğuz." *IstanbuLab* (blog), March 19.

Parrinello, Giacomo, Simone Bizzi, and Nicola Surian

2021 "The Retreat of the Delta: A Geomorphological History of the Po River Basin during the Twentieth Century." *Water History* 13, no. 1: 117–36. https://doi.org/10.1007/s12685-021-00279-3

Parrinello, Giacomo, and G. Mathias Kondolf

2021 "The Social Life of Sediment." *Water History* 13, no. 1: 1–12. https://doi.org/10.1007/s12685-021-00280-w

Paul, Sonia

2015 "How India's 'Sand Mafia' Pillages Land, Terrorizes People, and Gets Away with It." VICE, October 7.

Peters, Kimberley

2015 "Drifting: Towards Mobilities at Sea." *Transactions of the Institute of British Geographers* 40, no. 2: 262–72. https://doi.org/10.1111/tran.12074

Prakash, Gyan

1999 *Another Reason: Science and the Imagination of Modern India*. Princeton, N.J.: Princeton University Press.

Prashant Kumar, S.

2022 "The Instrumental Brahmin and the 'Half-Caste' Computer: Astronomy and Colonial Rule in Madras, 1791–1835." *History of Science* 61, no. 3: 308-37. https://doi.org/10.1177/00732753221090435

Rege, Aunshul

2015 "Not Biting the Dust: Using a Tripartite Model of Organized Crime to Examine India's Sand Mafia." *International Journal of Comparative and Applied Criminal Justice* 40, no. 2: 101–21. https://doi.org/10.1080/01924036.2015.1082486

Rentier, E. S., and L. H. Cammeraat

2022 "The Environmental Impacts of River Sand Mining." *Science of the Total Environment* 838: 155877. https://doi.org/10.1016/j.scitotenv.2022.155877

Robertson, Thomas

2016 "Cold War Landscapes: Towards an Environmental History of US Development Programmes in the 1950s and 1960s." *Cold War History* 16, no. 4: 417–41. https://doi.org/10.1080/14682745.2014.950238

Robertson, Tom

2006 "Malthusian Thinking Among Foreigners and Nepalis in Nepal." *HIMALAYA* 26, no. 1.

Roy, Tirthankar

2016 "The Monsoon and the Market for Money in Late-Colonial India." *Enterprise and Society* 17, no. 2: 324–57. https://doi.org/10.1017/eso.2015.84

Saikia, Arupjyoti

2015 "Jute in the Brahmaputra Valley: The Making of Flood Control in Twentieth-Century Assam." *Modern Asian Studies* 49, no. 5: 1405–41. https://doi.org/10.1017/S0026749X14000201

Sarukkai, Sundar

2012 *What Is Science?* New Delhi: National Book Trust.

Sati, S. P., and V. K. Gahalaut

2013 "The Fury of the Floods in the North-West Himalayan Region: The Kedarnath Tragedy." *Geomatics, Natural Hazards, and Risk* 4, no. 3: 193–201. https://doi.org/10.1080/19475705.2013.827135

Sekhsaria, Pankaj, and Naveen Thayyil

2017 "Visions for India: Public Participation, Debate and the S&T Community." *Current Science* 113, no. 10: 1835–40. https://doi.org/10.18520/cs/v113/i10/1835-1840

Sharma, Jeevan

2021 *Political Economy of Social Change and Development in Nepal*. London: Bloomsbury Publishing.

Simpson, Thomas

2024 "Find the River: Discovering the Tsangpo-Brahmaputra in the Age of Empire." *Modern Asian Studies* 58, no. 1: 127–162. https://doi.org/10.1017/S0026749X23000288

Sivaramakrishnan, K.

1999 *Modern Forests: Statemaking and Environmental Change in Colonial Eastern India*. Stanford, Calif: Stanford University Press.

Subramanian, Ajantha

2019 *The Caste of Merit: Engineering Education in India*. Cambridge, Mass.: Harvard University Press.

Sundriyal, Y. P., Anil D. Shukla, Naresh Rana, R. Jayangondaperumal, Pradeep Srivastava, L. S. Chamyal, S. P. Sati, and Navin Juyal

2015 "Terrain Response to the Extreme Rainfall Event of June 2013: Evidence from the Alaknanda and Mandakini River Valleys, Garhwal Himalaya, India." *Episodes: Journal of International Geoscience* 38, no. 3: 179–88.

Superintendent Government Press

1903 "River Training and Control- Being a Description of the Theory and Practice of the Modern System Entitled the Guide Bank System Used in India for the Control and Guidance of Great Alluvial River." India: Superintendent. Government Press. https://southasiacommons.net/artifacts/2360498/river-training-and-control/3364185/

Thomas, A. Rylands, and Thomas Angus Lyall Paton

1975 "Claude Cavendish Inglis. 3 March 1883–29 August 1974." *Royal Society* 21: 366–88. https://doi.org/10.1098/rsbm.1975.0010

Thompson, Michael, and Dipak Gyawali

2007 "Uncertainty Revisited; or, The Triumph of Hype over Experience." Introduction to *Uncertainty: On a Himalayan Scale*, by Michael Thompson, Michael Warburton, and Tom Hatley, iv–xxxviii. Kathmandu, Nepal: Himal Books.

United Nations Environment Programme (UNEP)
2023 "Building Materials and the Climate: Constructing a New Future." Paris: United Nations Environment Programme. https://wedocs.unep.org/20.500.11822/43293

UNESCO-MAB
1974 *Working Group on Project 6—Impact of Human Activities on Mountain Ecosystems: Final Report*. MAB Report Series No. 14. Paris, UNESCO.

Welland, Michael
2010 *Sand: The Never-Ending Story*. Berkeley: University of California Press.

Weszkalnys, Gisa
2014 "Anticipating Oil: The Temporal Politics of a Disaster Yet to Come." *Sociological Review* 62, no. 1: 211–35. https://doi.org/10.1111/1467-954X.12130
2015 "Geology, Potentiality, Speculation: On the Indeterminacy of First Oil." *Cultural Anthropology* 30, no. 4: 611–39. https://doi.org/10.14506/ca30.4.08

Yusoff, Kathryn
2009 "Excess, Catastrophe, and Climate Change." *Environment and Planning D: Society and Space* 27, no. 6: 1010–29. https://doi.org/10.1068/d7407