

Impacts of Tipaimukh projects on rivers and economy of Bangladesh

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Bangladesh is the largest delta of the world, created and shaped by the Himalayan orogeny initiated during the Cretaceous Age and the sediments carried and deposited by the numerous river systems. Among the river systems, the Ganges (also known as Padma), the Brahmaputra-Teesta, the Surma-Meghna, and the Karnaphuli are the most notable. These rivers and other numerous small rivers originate from India, China, and Myanmar and, unfortunately, the people of Bangladesh have no control over the river systems. The socio-cultural, economic, and political history of Bangladesh and greater Bengal are actually the history and geomorphology of these rivers. The rivers have been providing the people with food, shelter, transportation, trade, and prosperity by bringing new nutrition-rich sediments and sheltering a myriad of wildlife including fish, birds, aquatic plants, and fruits. The rivers have also cursed the lives of the people of Bangladesh by bringing sudden and catastrophic floods. Floods displaced people, washed away crops, and affected lives in every aspect. Floods also brought new nutrition-rich sediments, and washed away the toxic chemicals accumulated in the land during drier times, which renewed life and society.

The water flow of the Padma at Hardinge Bridge is 2,000,000 cubic feet per second (cfs). The flow of the Brahmaputra at Sirajganj is 2,500,000cfs while flow of the Meghna at Bhairab Bazaar is 420,000cfs. A combined flow of 4,900,000 cubic feet per second of water flows to the Bay of Bengal via these river systems. These rivers carry approximately 1,200,000,000 tonnes of sediments via the delta of Bangladesh. These flow of water and sediments shaped the physiographic, geomorphology of the country and as such influence the societal development and the economic activities. The landscape developed into

the largest delta in the world with almost flat slope with a gradient of one centimetre per kilometre. A slight variation is discernable near the bank of the rivers due to the formation of natural levee and the land called BarindTrack. The combined flow of Ganges (also known as Padma) and the Brahmaputra at Goalando Ghat is 4,200,000cfs and flow to the south-easterly direction towards Chandpur to cause widespread scour and erosion to the land on the eastern bank of the river. The flow of the Meghna upstream of Chandpur is 720,000cfs and flows south towards the Bay of Bengal. These two flow vectors meet at Chandpur in an angular way and the flow of Meghna diffuse the erosive force of the flow of the Padma to reduce the scour and river shifting. It is obvious that south-eastern flow of the Padma is impeded by the landmass east of Chandpur to continue flow towards Comilla-Noakhali. In addition, the flow momentum of the Meghna deflects the trajectory and forces the combined flow to go to the south. Due to their out of synch peak flow, some erosion and significant scour occur at Chandpur. This angular trajectory of the flow momentum has created a quasi-equilibrium condition. Any imbalance in this quasi-equilibrium will cause significant scour to the town of Chandpur and the river course may change its direction.

The rivers and the overall climate of the area have created a society which is bonded together like a family. They are used to farming together, fishing at the same time in same areas, harvesting the crops as a unit mass during harvesting time. Activities such as unique societal bond are as strong as the ionic bonds of metals and chemical compounds and the strong bonds among the people are a gift from the floods of the rivers. This unity swivels the political and morale flow of the country to the right direction like competent navigators pilot his vehicles during endless storms.

The perennial flow of the rivers together with the sediment provided the land with not only with water but also energy in the form of temperature and speed of water and sediments. The nutrients including phosphorous, nitrates, microbes, fungus are generally gathered in the sediments, especially in the finer sediments, are coated due to their electrical charge deficiency created by isomorphous substitution during the heavy and turbulent flow in the upstream. These micronutrients and trace metals are released by the decomposing leaf litters, detritus and dead animals including animal wastes in the upper watersheds of the rivers. During the receding floods and as the flow enters the flat slopes, the velocity of the water decrease to result in these nutrient coated sediments settle in the flood plain providing naturally rich soils for crops to thrive. This particular phenomenon plays significant part in the rivers of Bangladesh, especially the Meghna, as the Barak river flow through dense forests of the Tipara and Naga Hills. The kinematic thrust of the river flow also keep the intrusion of the sea water from getting inland and the groundwater is recharged continuously.

The lean period, or low flow, provides a higher temperature to accelerate growth of algae, phytoplankton, periphytons and other microbial organisms that provide the basis of nutrients for fish, mammals, and plants. The bank full discharge is the most efficient flow within the river channel which flushes and cleanses the river bed to provide shelter for fish and lay their egg to hatch. The overflow discharge or flood discharge provide nutrient rich sediment to the flood plain. Periodic large flood replenish the entire river basin. Therefore, for the river basin to act as beneficial to society, all these flow events including pulsating floods are essential.

As the population increases in this part of the world, including within the watersheds of our rivers and in our country, stress on the rivers, their productive nature, and their mending power also are affected negatively. This gives more frequent floods, environmental degradation, and ecological

downtrends. Unregulated, greedy, and profiteering industries have been discharging pollutants to the rivers starting from the sources, either knowingly or unknowingly. As such, the water quality, and aesthetics of the rivers are plunging downward while sediment toxicity is rising. The massive use of unplanned agro-chemicals, discharge from municipal solid wastes, human and animal remains, and erratic construction within active river channels (including unplanned dredging) have taken and are taking their toll. In this desperate situation a healthy year-round flow of rivers, including flood flow, has been playing a significant role in diluting and re-mediating the contaminants and flushing them out of the country to the Bay of Bengal. Any upstream control that will affect this sensitive situation of the flow of the rivers will have a tendency to affect the society's culture, economics, emotions, and ecological aspects.

Background of Surma trough/haor basin

Bengal Basin started to devolve during the late Jurassic to early Cretaceous period. The basin is a half graben Gondwana and moved to its present position after splitting from the Australia-Antarctica mass. As the Indian shield moved to its present position, it started colliding with the Euro-Asian Plate to create the Himalayas. It also interfered with the Burmese plate in the east. While in the north the collision gave rise to the Himalayas by thrust, in the eastern side, the Indian plate started subducting beneath the Burmese Plate. The thrust of Euro-Asian Plate created numerous thrust block faults and the east-west oriented mountain system in India and Tibetan Plateau. In the eastern portion, it created series of folded mountain system that are oriented north-south. The two complex movements together with the presence of Shilling Massif that started its east-west orientation from northeast Naga Hills to continue to west had also created a series of complex faults, oriented mainly east-west in the north and north-south in the eastern portion. Arakan Youma, Desang and Dauki Faults in the transitional location of Burmese and Indian Plate

are a few but very active faults that have produced catastrophic earthquakes in the past. Yarlong or Indus-Tsangpo Suture, Himalayan Main Thrust are a few but very active and dangerous east-west fault systems including Jianji Fault near the Namchi-Barwa area in eastern Himalaya. They are very active and determining their causative earthquake is also complex. In addition, no credible studies including collection of data on fault movement, or seismicity data are known. The subduction also created a fore-bay type depression in the north-eastern Bangladesh known as Surma trough which came to its present forms by receiving sediments from the Barak and other smaller rivers. As this land is locked in its present position due to the movement of the plate tectonics, the graben started filling with sediments shed from these mountain systems by the fluvial process.

One of the most important rivers that played and is playing the most significant economic, social and cultural shaping of the country is the Meghna. The Meghna is created by the joining of the Surma and the Kushiya in greater Sylhet. These two rivers are the result of the bifurcation of the Barak at the Bangladesh-India border near a place called Amalshid. The Barak originated from the Lusai Hills of eastern Tripura and Manipur states of India and passes through the folded hills and densely-vegetated, long, narrow valleys within this area. The Barak receives other smaller rivers that originated from the Naga Hills and the hills of Assam. The upper watershed of the Barak receives more than 2,000 millimetres of rainfall in an average year with some areas receiving more than 6,000mm a year. The landscape consisted of dense tropical rainforest and scattered villages or communities of the original inhabitants. However, since World War II and since the British left the subcontinent, encroachment by the people of plain land have been migrating and settling in this area resulting in isolated urban sprawls and denudation of the forest to destroy the existing climax community to establish agricultural lands. This has created another unwanted concern that the sediment yields from this portion of the catchment area increased with increased runoff. However, as

the leaf litters and the dead trees release essential nutrients to the runoff water and the forest floor, the destruction of the forests decreased the nutrient supply to the sediments to a minimum level only to generate sterile sediments. From some areas pollutants are also discharged from point and non-point sources such as agricultural practices, raw sewage, industries, manufacturing plants and cremations into the waters of the rivers.

The quality of water within the Barak-Meghna used to be one of the cleanest in the world. Natural cleaning of water would occur due to the presence of the Surma trough created by the plate tectonic of the area. The Surma trough, a fore-bay depression of the subduction zone of the Indian Plate into the Burmese Plate, houses a myriad of small and medium sized natural lakes locally known as haors. These haors allow varieties of phreatic plants, floating vegetation, periphytons, algal mats, fungi, bacteria and other micro-organism to grow which ultimately clean the river water. The haors also provide habitat for more than 53 resident water fowls with 160 species of migratory and resident birds, 260 species of fish. In addition, during lean months, as the haors start drying, the dried portions are utilised to grow boro rice. The topography of the lands in and around the haors is such that they have less than 0.001 per cent slope. The slopes are usually towards the deeper portions of haors and the banks of the rivers are slightly higher than the surrounding lands due to the formation of natural levee. This typical topography allows vast areas around the haors to be utilised to grow boro rice during winter season. Due to its almost flat slope, it is easy to irrigate the boro crops continuously by lifting water from the haors or the rivers without using massive lift. In fact, the irrigation used to be done manually by lifting water from the channels of the Surma, the Kushiya, the Manu and other rivers that cross through these haors.

The entire haor basin and most of the Surma trough is inundated every year during the monsoon and flooding seasons. As such, people have built their homes in artificially filled higher ground along

the natural levees and natural higher ground known as kandas. The haor system also united the people to a cohesive cultural society to utilise the resources. They face the natural calamities such as high floods, erosion of their villages as a one unit and do farming as a unit giving rise to especial social order which is very unique for this area.

According to the Bangladesh Bureau of Statistics, in 2008-2009, approximately 17 million tonnes of boro rice was grown in Bangladesh. Out of this 30 per cent of the boro rice was grown in Surma trough and along the floodplain of the Meghna which equates to about 5 million tonnes. A loss of 25 per cent of the boro crops due to inundation of the haor basins will cause loss of more than 1.25 million tonnes of rice in Bangladesh. In present-day market price of 500 dollar per ton, total direct economic impact on food could be as high as 625 million dollar. With increasing population or more mouths to feed coupled with loss of arable land due to increase in population will devastate the country. It may require a few billion dollar to be allocated to import rice to feed future projected population. In addition, the existing economic condition of the world, floods in Thailand, draught in Africa, and the unyielding mentality of rice exporting countries have created a volatile market of food grain. Anything but price of commodities are stable in international market. Surma Trough also grows winter crop such as mustard, beats, cabbages, and other crops.

Unique climatic and geomorphic/hydrologic features of the boro rice include continuous irrigation or inundation of land during growing season. On the contrary, during maturing stage, the boro crops require the land to be dry so that the paddy stalks carrying maturing rice do not get rotten. Generally boro crops are harvested in mid to late April. March to May is most likely three of the drier and hotter months of the year in Bangladesh and this natural dryness and hot weather help the rice to mature properly. The other feature of the area is that flash floods during mid to late April and May due to downpour in the Shillong Plateau causes widespread damage of the boro

crops. As mentioned above, a one foot rise in the water depth in the rivers generally inundates approximately 10 per cent of the rice crops. A one meter rise in depth of water could inundate 25 to 30 per cent of the boro crops completely under water. To prevent these damages, the farmers congregate together in a commune manner to harvest the crops. Migrant rice worker from lower Meghna such as greater Comilla, Dhaka, Noakhali, Faridpur and even from Barisal area come to this Haor areas to work on harvesting and processing this boro rice. These workers work as exchange worker in which cash is not transacted rather these migrant workers get share of the rice harvested from the farmers.

The floods in Surma Basins or the Haor Basins come in two stages. One flood comes during the early summer or late spring during the months of April to May. This flood is exclusively due to the sudden and high intensity micro-burst related rainfall in the southern slopes of the Tura Range. This rainfall is basically orographic and damages the boro rice and winter crops. Even though this weather pattern exists within the upper watershed of the Barak, due to the dense forests and high water holding capacity of the under hedges including leaf litters in that regions, runoff from the upper Barak does not contribute to the early flood. The second flood arrives during the monsoon time. Due to high frequency sustained rainfall of more than 6,000mm within the southern slopes of the Tura Range, the contribution to the damaging flood is mostly due to this rainfall in Meghalaya. Any development and watershed modelling should consider this fact.

The Surma trough's other uniqueness is that the haors and the arable lands around haor areas require full flood and drying of the land to maintain the ecological and hydrological balance. The flooding generally remove the undesirable and toxic chemicals left over by the farming, fish droppings and the natural wastes left over by the millions of migratory birds. In addition, the aquatic plants, periphytons, bacteria, fungus and algae or other microbes require flushing every year. The flooding

especially the early flood cleans the river beds and banks to a level so that the fish fries and spawning fish can make their nest for the hatchlings. The flooding also provides the young fish ample space for play and movement including their uninterrupted travel during their migration downstream. In winter or dry months it is also essential that the land remain dry for a period of time and the lake water level go below certain depth so that water temperature rises for some photobioreaction to occur.

Tipaimukh dam

India has initiated study from 1952 to formulate flood control in Cachar Valley and to build a dam on the Barak which will provide power and water for irrigation during lean months. Until the early 1990s India could not find any suitable location for the dam. In 1995, the then prime minister Atal Behari Vajpayee, during his visit to north-eastern India, declared that 50,000 megawatts of hydro-electricity should be generated in the north-eastern states. The Tipaimukh dam project gained new momentum. In the 14th Joint River Commission meeting, India brought the issue of the dam all of a sudden. In fact, in a Joint River Commission record of decision contained the following text: 'With regard to the flood problem of Sylhet, Cachar and adjoining areas, the Commission should jointly examine the scope of the Indian scheme of storage dam on Barak River at Tipaimukh and study expeditiously the potential flood control and other benefits in Bangladesh and report the progress to the Commission at its next meeting.' This text was not recommended by the joint technical committee constituted by the commission. It is not clear whether the committee ever studied the flood benefits of the project for Bangladesh because the Tipaimukh issue completely disappeared from the agenda of the subsequent JRC meetings. As mentioned earlier, flood control in Bangladesh due to this dam will be minimal due to the fact that majority of the flood flow comes from Meghalaya.

Tipaimukh Dam as proposed will have the following facts:

Location : Lat 24°14'N, Long 93°1'E
Height : 161m
Length : 390m
Area : 29,150 hectare
Design flood discharge : 16,964 m³/sec
Average annual yield : 12.5 billion m³
Dependable yield (90%) : 8.1 billion m³
Power generation : 1500 MW but dependable is 412 MW

The approximate location of the dam is about 500 metre downstream of the confluence of the Barak and the Tuvai and 190 kilometres upstream of the Bangladesh border. The dam is planned to be a rock-fill dam with a central clay core to act as impermeable barrier to water seepage. The height and capacity of the spillway(s) are also not known.

No data has been provided to Bangladesh to assess the construction time schedule and reservoir filling process. It is estimated that this dam may require five to seven years to build. During this time, it is not clear how the floodwater will be diverted, i.e. whether there will be a diversion channel to connect to the Barak downstream of the dam or the water will be diverted to Assam for irrigation. Should India decide to fill the reservoir without releasing water, Bangladesh will not get a drop of water during the two years of reservoir filling times. The reservoir filling time may run from one and a half to two years' timeframe depending on the weather conditions at those times. This may bring catastrophic economic disaster to Bangladesh.

The location of the dam is in seismically active area that includes a fault named Taithu Fault. The dam is located adjacent to and near the location of the meeting point of the Eurasian Plate, Indian Plate, and Burmese Plate. There are complex movements of plates at this site due to differential movement of these plates. The plate movement includes subsidence, lateral movement, and thrusts. These complex movements have created a mosaic of active, yet shallow faults that can and have triggered very large catastrophic earthquakes. The faults include the Arakan-Youma, Dauki, and

Disang Faults. The mountains and sharp turns of the stream channels in this part of the subcontinent carry the telltale signs of these complex phenomena. The likelihood of occurrence of a major earthquake of magnitude 7.6 in next 25 to 30 years in this the region is between 40 and 60 per cent. Probability of occurrence of Magnitude 8.7 earthquake with its epicentre at the Shillong Plateau is perhaps 2 to 5 per cent within next 200 years, assuming the events are random and can be described with a simple binomial probability model. Any major or significant earthquake can cause dam burst. In such case, river channels and sedimentation patterns in the northeast region may be subject to major disruptions following a severe seismic event. During past earthquakes, instances of ground liquefaction, landslides, rapid subsidence, collapse of river banks, and changes to river courses have been documented (District Gazetteer, 1917).

Recently the Manipur government of India signed a contract to build this dam and the hydroelectric project. The original design called for a barrage at Phulertal to divert water to Assam for irrigation purpose. At this point no information has been delineated to the people of Bangladesh. Bangladesh Government also not disclosing any information that might have been given to the respective Ministry. Only a senior level team of Bangladeshi legislators and few hand-picked experts made a helicopter tour of the site of the dam but they could not land at the site due to prevailing weather conditions. No report of the team except interviews of some participants was available at this time. Another development that worth mentioning here that during a prime minister-level meeting in Bangladesh, Manmohan Singh mentioned that India would not do anything at the Tipaimukh dam that will harm Bangladesh. This statement, however, does not assure that India will not build this dam without talking to Bangladesh. Besides, there is no mention of who is going to study the adverse effect and benefit ratio due to the dam. It is now a known fact, based on worldwide data, that there is not a single large dam that does not do significant harm to the downstream. In fact, most dams failed to fulfil the

long-term benefit and brought environmental and economic disaster to the riparian citizens. In the north-western US and other parts, the US government has initiated a decommissioning of dams to revive the original environmental and ecological conditions.

Bangladesh is worried whether the Tipaimukh project will become another havoc and economic devastation like the Farakka Barrage (Asafuddowlah, 1994) in bilateral relations between the two countries. There had been strains in relations between the two neighbours for 30 years over the sharing of the waters of the Ganges River (Khondker, 2003). 'Bangladesh's concern is magnified due to the fact that the concern expressed by the indigenous people of the Manipur were sidelined, the government of Bangladesh was not informed about the project despite international norms requiring consultation with lower riparian countries. India had earlier promised to provide Bangladesh with the Detailed Project Report (DPR) and Environmental Impact Study of the Downstream area due to the construction and operation of the Tipaimukh Project before going for its implementation. This information could be used to review the project to verify and mitigate any ill effect and dispel the lower riparian neighbour's concern. But unfortunately, NEEPCO completed the DPR, solicited international bids, prepared short list and proceeded with the construction, but yet to provide Bangladesh with the promised DPR' (Khondker, 2009). It appears that India is playing hard with arrogance to sideline the issues of Bangladesh and the indigenous communities in Manipur and Mizoram while conceiving the project.

It is also understood that India may build a barrage at Phulertal to divert water to Assam for irrigation. The detailed of the diversion barrage is also unknown to Bangladesh. Other unknowns that could impact in adverse manner with regard to proposed Tipaimukh Dam to Bangladesh included the following:

Reservoir operation rules

Rate of dam impoundment in the first two years

Rate of flow impoundment in a normal flooding year

Release of water through spillway in an sudden flood event

Water to be released through the turbine outlets

Water diversion plans through barrage(s) and other means

Dam risks and Safety

Preliminary reports indicate that in full operation, the dam will release water during winter time to raise the water surface by about 1.5 to 2.0 metre at location downstream of Amalshid. This rise in water level will cause widespread inundation of boro rice within the haor basin and along the Meghna floodplain. Approximately 30 percent of the arable land will undergo permanent inundation giving rise to unhealthy and ecologically disastrous swamps. This effect assumes that India will not divert any water out of the Tipaimukh dam or its reservoirs in upstream of the dam or immediately downstream of the dam. During the flooding time or monsoon time unpredictable flood an inundation of the land will occur frequently.

The potential impacts of the Tipaimukh Project have been studied by the government of Bangladesh under its Flood Action Plan 6 (FPCO, 1994) for North Eastern Regional Water Management Plan of Bangladesh. During an average flow year these impacts would include (first three items are from Sufian, 2009 with modifications):

* Flood flows on the Barak River will be moderated, with peak flows at Amalshid in Bangladesh reduced by about 30% from 5,250 m³/s to 3,500 m³/s. The corresponding water level will be reduced by about 1.6m, which will mitigate the impacts of floods.

* Dry season flows will double or triple from 170m³/s and 250m³/s to 500 m³/s. The corresponding increase in water levels at Amalshid will be 1.7m (Figure 1). The increased dry season flows will provide benefits for navigation, irrigation, and fisheries.

* The risk of dam failure is a significant issue. A dam-break is a catastrophic failure which results

in the sudden draining of the reservoir and a severe flood wave that causes destruction and deaths downstream. The most famous Teton Dam in the United States was a 90 m high earth-fill dam which failed in 1.25 hours and released a peak discharge of 65,000 m³/s, resulting in a wave height of 20 m in the downstream canyon. The Huaccoto Dam in Peru was 170 m high, similar to the Tipaimukh Dam, it failed over 48 hours due to a natural landslide in the reservoir. Generally, a dam-break wave travels at a minimum velocity of 10 km/hour and will reach Bangladesh in about 20 hours after the failure of the Tipaimukh Dam.

* A dam break analysis using computer modelling MIKE II Software by Central Water Commission indicates that at Dam Break, the wave height at Bangladesh border town of Bhanga would be 5.5m high with an inundation of about 2,000 square kilometres. Assuming a release volume of 0.3 million m³ per second or more, the depth of flooding inside Bangladesh at stabilized condition could be an average of 2.0 metre or more above normal flood level, which would cause increased inundation, property damage, erosion of the Kandas and loss of fisheries. However, as the first flow of the dm break analysis will be encompassed in a small chute type geometric configuration, at the instant of wave movement inundation will be much higher and more devastating.

* Increased dry season flow will result in water-logging in the Meghna Basin, duration of inundation will increase affecting boro agriculture will be severely affected.

* Supply of increased water during winter months would cause inundation of existing arable boro land thus affecting food security of Bangladesh

* Increased dry season flow will also alter ecosystem

* Increased dry season flow will enhance navigation but will complicate the extraction of construction materials from upper Kushiya area. In case of diversion of water, extraction of construction rocks will require surface and inter-modal transportation thus making it very expensive.

* Sediment will enhance bed scour and bank erosion in the upstream but in the downstream sediment concentration will increase due to the fact that the tributaries of Meghna from Meghalaya and Tripura will carry more sediment because of massive deforestation. As a result, serious siltation will take place in the downstream and lower Haors may ultimately be completely obliterated.

* In a normal flood year, due to lack of water, fragile ecosystem of the Meghna basin will be severely affected.

* Impoundment of water will result in impoundment of silt, which very much important for soil nutrient and annual silt deposition.

* Biodiversity will be seriously affected; especially some fish species will be destroyed.

* Fish species such as Ruhu, Katal, Chital, and Catfish spawn upstream within the valleys of Manipur, Assam, and northern Tripura. Dam construction will eliminate the spawning ground and species will be obliterated. These fish species are like the lifeblood of the Bangladesh economy.

Conclusions

The people of Bangladesh had been resilient to improve their lives since independence. Amid myriads of international and national problems, the country has achieved significant progress. According to Jeffrey Sachs, Bangladesh has achieved economic growth and improvements of education and health through its heroic efforts that deserves attention, care and development assistance. The decline in child mortality, increase in per capita income from 80 dollar per year per person to almost 700 dollar, food grain or rice production has increased from 11.8 million tons per year during 1971 through 1975 to more than 33 million tons per year in recent times is indicative of the fact that we are moving towards meeting the Millennium Development Goals. The hard working people especially the farmers, the garment industries, and Bangladeshi workers in foreign countries played significant role. Approximately 70 percent of the GDP is contributed by agricultural products. To keep this progress and to move forward, Bangladesh will require assured supply of water and control of floods. As such Tipaimukh

dam, Teesta River Treaty, and treaty of other rivers in a win-win terms is essentials. While it is important to continue talk and exchange data of rivers with India, Bangladeshi leaders and bureaucrats also need to act in unison to address these issues of national interests. We also should be mindful that India is building dams in other rivers that are essentials to Bangladesh economy and ecology.

The following conclusions are drawn based on the above discussions:

* The increased flow may rise the water surface depth by 1.5 meter or more. The increased winter season flow of the proposed Tipaimukh Dam will inundate a significant amount of arable boro crops within the Haor and Beel Basins of the Greater Sylhet, Greater Mymensing, and Northern Brahmanbaria Districts. This inundation will cause a loss of a significant amount of rice and has the potential to impact the food security of Bangladesh. Inundation also has the potential to displace traditional families and landowners. Loss of boro rice alone could be around 500 dollar M. Loss of wetland and fish resources may run additional millions of dollar.

* The dam will detain and retain the basic ingredients of nutrition of sediments that come out of the leaf and woody litters that fell off the trees in the dense forests of the folded hills of Tripura, Manipur, Nagaland, and Myanmar, the source of the Barack River. A lack of natural replenishment of organic nutrition will require the use of chemical fertilizers that will impact ecology and are expensive.

* The possible higher post-spring flow through the dam (to prepare for reservoir for flood flow during monsoon rains) will further complicate harvesting boro rice as boro rice requires three to four weeks of dry land for the rice grain to mature and ripen.

* The increased dry season flow will inundate the areas from where sand, gravel, and cobbles are extracted for use as construction material from Chunaroghat, Tamabil, and other areas. This process will cost more than what it is now.

* The dam will reduce flood flow by 30%, which may have an apparent beneficial impact. However, it will not flush all the chemicals/contaminants out

of the stream corridor, which is causing environmental degradation.

* The reduced flood flow will affect the flow vector of Padma-Meghna at Chandpur and has the potential to have Padma flow wipe out Chandpur and adjacent valuable and highly productive irrigated lands within the Chandpur Irrigation Project.

* It is possible that reduced flood flow may not also flush all the sediments coming to the Haor Basins from the Meghalaya and Tripura Hills as they have undergone massive deforestation thus causing massive siltation and blockages of river flow..

* The reduced flood flow and increased winter flow will improve navigation and irrigation in some areas and have the potential for flushing salt water intrusion from the Bay of Bengal into the Meghna River.

* The project could be turned into a win-win project if the above conditions are researched and a baseline survey is made.

* It is also recommended that instead of a major dam, some small dams in upstream areas to generate power and develop pisciculture could minimise the impact on Bangladesh.

In the mean time Bangladesh should initiate data collection regarding the impact of this dam. Data collection must include, at a minimum:

1. Hydrologic data such as discharge-stage curve for all its rivers within the Surma Basin at a network of stations including Netrakona, Sunamganj, Amalshid, Sylhet, Moulvibazar, Chatak, Itna, Mitamine, Azabpur, Habiganj, Astagram, Bhairab, and other areas within Haors.

2. Geomorphic Data such as sediment data must be collected at those stations and at the entry point of all streams along the border of Bangladesh.

3. Economic, Ecologic and Social Data such as total arable land and dry season areas of Haors, including depth of water of Haors, should be made. An inventory of boro rice, aquatic plants, fish, birds, migratory birds, trees/bushes of swamp forests, insects, mammals, etc., should be taken. Social and economic structure data on the people of the basin should also be compiled.

4. Water Quality Data should be collected, including water temperature, alkalinity, pH, COD, DO, BOD, and nutrient content, and soil data and soil chemistry data including microphytes. Water salinity data long the coastal areas should be collected to determine and continuously update the amount of seawater intrusion.

Recommendations

Based on a presentation by this author, the following recommendations are chalked out. These recommendations were also forwarded to the office of Honorable Prime Minister of Bangladesh in 2010 under the auspices of the American Association of Bangladeshi Engineers and Architects.

1. The Tipaimukh project should not be constructed without a full treaty with Bangladesh.

2. The treaty should be modelled like the Indus Water Treaty under the auspices of the World Bank or the United Nations and the treaty must assure that no water will be diverted by India from the Barak.

3. The treaty should spell out the operational aspects of the dam. The operation of the dam shall not cause widespread inundation of boro crop and release of the water from dam shall not inundate boro crop during maturing time of boro crop. In this regard, the existing Joint River Commission and Joint Technical Committee should have the opportunity to participate in flood and watershed modelling to determine the expected runoff of each year and each month which could be utilised to plan the operation of the reservoir to minimise impact on Bangladesh.

4. In addition, an operational aspect of artificial flooding by pulsating flood of the Sylhet/Mymensingh area to create artificial but controlled flood during rainy season to flush the Haor Basin should be included. The frequency and amount of the pulsating flood should be determined by full hydrologic study of the area by the Bangladeshi experts.

5. India shall not construct Phulertal Barrage ever to divert water.

6. India shall sell power to Bangladesh from this project on a long term agreement basis.

7. Bangladesh should use technical review irrespective of any political pressure and should set up commissions, comprised of national and international experts to review the project from technical, socio-economical, ecological, and environmental aspects.

8. Bangladesh government should take lessons from impacts of large international projects throughout the world (impacts before and after) to have first-hand knowledge on consequences of such projects.

9. Consideration should be given to develop small hydro-electrical projects whose impacts are minimum rather large mega projects.

In addition, a commission to review the dam design and construction should be set up by Bangladesh. The commission should consist of the following experts:

- * Hydrologists
- * Geologists
- * Geotechnical engineers
- * Hydraulic engineers
- * Electrical and mechanical engineers
- * Floodplain managers
- * Geomorphologist
- * Seismic experts
- * Wildlife biologists
- * Fishery experts
- * Ecologists
- * Environmentalists
- * Agriculturists

The commission should also include at least two farmers from the Surma basin, and two traditional fishermen who are intimately familiar with the area and its environment. If necessary, expatriate Bangladeshi engineers with this expertise could be pulled into the resources. Academic and political experts are needed. In addition the commission should include Bangladeshi born engineering experts practicing in foreign countries that can and will help the situation better.

The author strongly believes that this dam and other water resource projects, if developed in concerted effort jointly by Bangladesh, India, China, Nepal, Myanmar, Bhutan with objectives to utilise the water for beneficial purpose would be a winning project.

References:

1. Agricultural Finance Corporation Ltd, 2007, 'Environmental Management Plan', a Comprehensive Environmental Studies on Tipaimukh Hydro-Electric (Multipurpose) Project, Prepared for North Eastern Electrical Power Corporation Limited, Shillong, Meghalaya.
2. Hoque, Enamul, 2009, 'Impacts of Tipaimukh Multipurpose Dam on Rivers of Bangladesh', a paper presented at the silver jubilee celebration of the American Association of Bangladeshi Engineers and Architects, Maryland.
3. Khondker, SA, 2009, 'Tipaimukh Multipurpose Project and Potential Interstate and International Disputes', a paper presented at the Delhi Conference on Water Resources.
4. Asafuddowlah, M and Khondker, SA, 1994, 'Farakka Barrage: Its Impacts and Possible Mitigations', Proceedings of the 1994 ASCE Conference on Hydraulics.
5. FPCO (1994), Northeast Regional Water Management Project (FAP 6), Initial Environmental Evaluation, CIDA.
6. ANH Akhter Hossain, 2009, 'Effects of Tipaimukh Multipurpose Dam', Dhaka.
7. Coleman, James, M, 1969, 'Brahmaputra River: Channel Processes and Sedimentation', Sedimentary Geology, Elsevier Publishing Company, The Netherlands.
8. Khan, M Salar, Haq, Enamul, Huq, Salemul, Rahman, A Atiq, Rashid, SMA, and Ahmed, Helal, 1994, 'Wetlands of Bangladesh', Bangladesh Centre for Advanced Studies in Association with Conservation Movement, Dhaka, Bangladesh.
9. Personal Communications with Hares Sayed.

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