IMPACTS OF TIPAIMUKH MULTIPURPOSE PROJECTS ON RIVERS AND ECONOMY OF BANGLADESH

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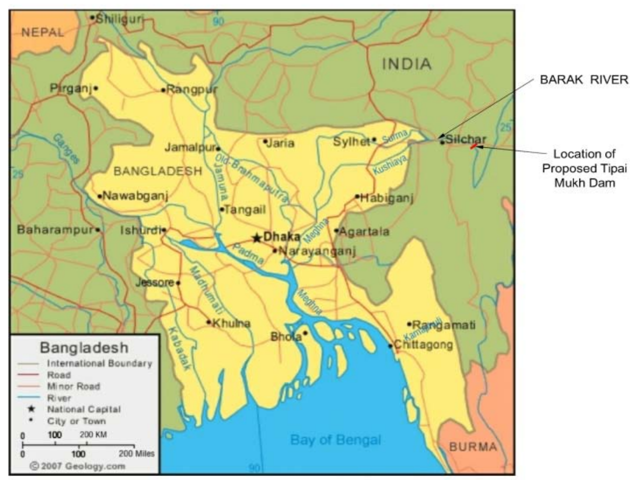
Introduction:

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 Karnafuli 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.



General Map of Bangladesh with Major Rivers.
(Data from http://geology.com/world/bangladesh-satellite-image.shtml)

Figure 1 General Map of Bangladesh with Major Rivers

The water flow of the Padma River at Hardinge Bridge is 2,000,000 cubic feet per second (cfs). The flow of Brahmaputra at Sirajganj is 2,500,000 cfs while flow of Meghna River at Bhairab Bazaar is 420,000 cfs. A combined flow of 4,900, 000 cubic feet per second of water flow to the Bay of Bengal via these river systems. These rivers carry approximately 1,200,000,000 tons 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 centimeter per kilometer distance. A slight variation is discernable near the bank of the rivers due to the formation of natural levee and the land called Barind Track. The combined flow of Ganges (also known as Padma) and the Brahmaputra at Goalando Ghat is 4,200,000 cfs and flow to the southeasterly direction towards Chandpur to cause widespread scour and erosion to the land on the eastern bank of the river. The flow of Meghna upstream of Chandpur is 720,000 cfs and flows south towards the Bay of Bengal. These two flow vectors meet at the Chandpur in angular way and the flow of Meghna diffuse the erosive force of the flow of the Padma to reduce the scour and river shifting. From the diagram presented in Figure 2, it is obvious that southeastern 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 River deflects the trajectory and forces the combined flow to go to south. Due to their out of synch peak flow, some erosion and significant scour occur at Chandpur. This angular trajectory of the flow momentum had created a quasi-equilibrium condition. Any imbalance in this qausi-equilibrium condition will cause significant scour to the town of Chandpur and the river course may change its direction.

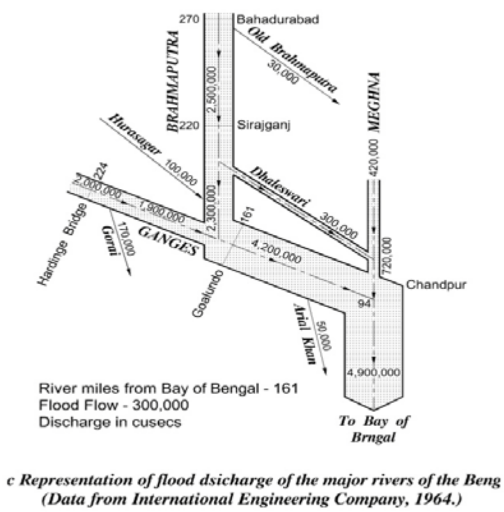


Figure 2 Flow of the Major River Systems of Bangladesh

The rivers and the overall climate of the area have created a society which is bonded together like a family. They used to go 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 is as strong as the atomic 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 perenial 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 phosporous, nitrates, microbes, fungus are generally gathered in the sediments espcially 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 recedinbg floods and as the flow enters the flat slopes, the velocity of the water decrease to result in these nutrient coated sediments settling 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 alo keep the intrusion of the sea water from getting inland and the ground water is recharged continuouesly.

The lean period, or low flow, provides a higher temperature to accelerate growth of algae, phytoplankton, 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 the 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 increases. 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 remediating 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 was 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 Australia-Antarctica mass. As the Indian shield moved to its present position, it started colliding with the Euro-Asian Plate to create the Himalaya. It also interfered with the Burmese plate in the east. While in the north the collision gave rise to the Himalaya 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 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 very active faults that have produced catastrophic earthquakes in the past. Yarlong or Indus-Tsangpo Suture,

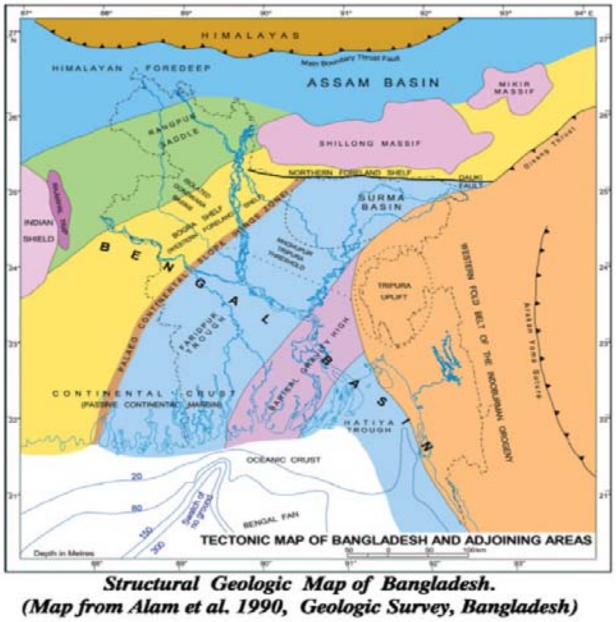


Figure 3 Geology of Bangladesh

Himalayan Main Thrust are 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 northeastern Bangladesh known as Surma Trough which came to its present forms by receiving sediments from the Barak River 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 River. The Meghna River is created by the joining of the Surma and the Kushiyara Rivers in the greater Sylhet District. These two rivers are the result of the bifurcation of the Barak River at the Bangladesh-India border near place called Amalshid. The Barak River 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. Barak River receives other smaller rivers that originated from the Naga Hills, and hills of Assam Provinces as well. The upper watershed of the Barak River receives more than 2000 millimeter rainfall in an average year with some areas receiving more than 6000 mm a year. The landscape consisted of dense tropical rainforest and scattered villages or communities of the original

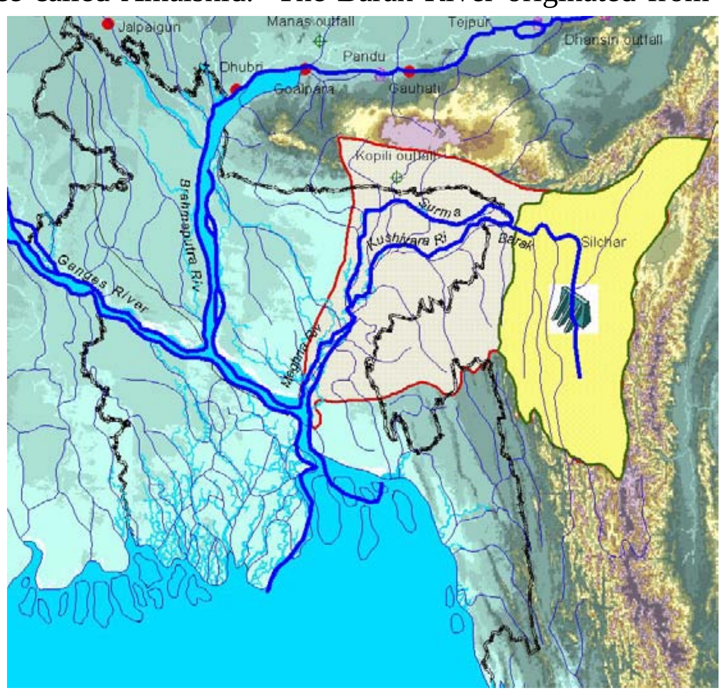


Figure 4 Meghna Basin and Location of Tipaimukh Dam

inhabitants. However, since the World War II and since the British had left the subcontinent, encroachment by the people of plain land had been migrating and settling in this area resulting in isolated urban sprawling and denudating 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 River used to be one of the most clean 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 microorganism 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 started drying, the dried portions are utilized to grow boro rice. The topography of the lands in and around the Haors is such that they have less than 0.001 percent 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 utilized to grow boro rice during winter season. Due to its almost flat slope, it is easy to irrigate the boro cops 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 Kushiyara, 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 had built their homes in artificially filled higher ground along the natural levees and natural higher ground known a Kandas. The Haor system also united the people to a cohesive cultural society to utilize 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 tons of boro rice was grown in Bangladesh. Out of this 30 percent of the boro rice was grown in Surma Trough and along the

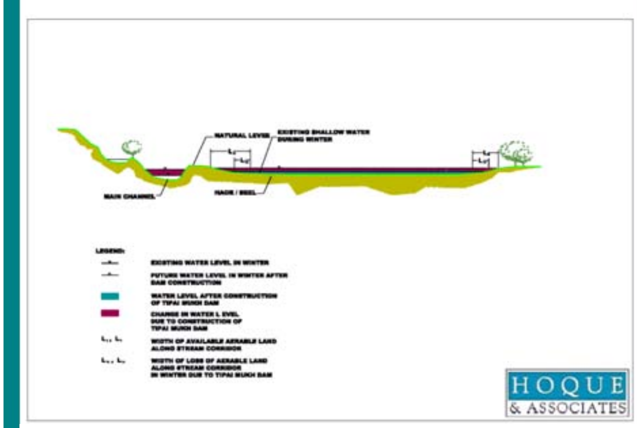


Figure 5 Conceptual Land Slope around Haor Basins

floodplain of the Meghna River which equates to about 5 million tons. A loss of 25 percent of the boro crops due to inundation of the Haor basins will cause loss of more than 1.25 million tons of rice in Bangladesh. In present day market price of $500 per ton, total direct economic impact on food could be as high as $625 Million. 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 few billion dollars to be allocated to import rice to feed future projected population. In addition, the exiting economic condition of the world, floods in Thailand, draught in Africa, and the unyielding mentality of rice exporting countries has 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 mustered, beats, cabbages, and other crops.

Two unique climatic and geomorphic/hydrologic features of the boro rice include a 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 two 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 percent of the rice crops. A one meter rise in depth of water could inundate 25 to 30 percent 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 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 initiated study from 1952 to formulate Flood Control in Cachar Valley and to build a Dam on Barak which will provide power and water for irrigation during lean months.

Until early nineties India could not find any suitable location for the Dam. In 1995, the then Indian Prime Minister Atal Behari Bajpayee during his visit to North-Eastern India declared that 50,000 Megawatt hydro-electricity should be generated in the Northeastern states. The Tipaimukh Dam Project has gained new momentum. In 14^{th} Joint River Commission meeting India brought the issue of the Dam all of a sudden. In fact, in a Joint River Commission (JRC) Record of Decision or ROD appeared 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 JRC. 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.

The location of the dam is seismically active area. 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 occurring in next 25 to 30 years of a major earthquake (earthquake of magnitude 7.6) in this the region is between 40 and 60%. Probability of occurance of Magnitude 8.7 earthquake with its epicenter at the Shillong Plateau is perhaps 2 to 5%, assuming the events are random and can be described with a simple binomial probability model. Any major or significnt earthquake ca 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 Central Government of India signed a contract to build this dam an the hydro-electric 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 public domain. Another development that worth mentioning here that during a Prime Ministry level meeting Indian Prime Minister Dr. Manmohan Singh had mentioned that India will not do anything at 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 regarding who is going to study the adverse effect and benefit ration sue to the dam. It is now a known fact based on world wide data that there is not a single large dam that does not harm significantly to the downstream. In fact, mot dam failed to fulfill the long term benefit and brought environmental and economic disaster to the riparian citizens.

Tipaimukh Dam as proposed will have the following facts:

- Location : Lat 24^o14'N, Long 93^o1'E
- Height : 161 m
- Length : 390 m
- Area : 29,150 hectare
- Design flood discharge : 16964 m^3/sec
- Average annual yield : 12.5 billion m^3
- Dependable yield (90%) : 8.1 billion m^3
- Power generation : 1500 MW but dependable is 412 MW

The approximate location of the dam is about 500 meter downstream of the confluence of Barak and Tuvai Rivers and 190 kilometer upstream of Bangladesh border. 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 sure how the flood water will be diverted such as via a diversion channel to connect to the Barak River 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. This may bring catastrophic economic disaster to Bangladesh.

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.

The unknowns 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 meter 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 River 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:

- Flood flows on the Barak River will be moderated, with peak flows at Amalshid in Bangladesh reduced by about 30% from 5,250 m^3/s to 3,500 m^3/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 170m^3/s and 250m^3/s to 500 m^3/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 90m high earth-fill dam which failed in 1.25 hours and released a peak discharge of 65,000 m^3/s, resulting in a wave height of 20m in the downstream canyon. The Huaccoto Dam in Peru was 170m 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. Assuming a release volume of 10 million m^3 and a ponded area of 100km^2, the depth of flooding at stabilized condition would be an average of 1.0m 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 mosre 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 Kushiyara area. In case of diversion of water, extraction of construction rocks will require surface and intermodal transportation thus making it very expensive.
- Sediment will enhance bed scour and bank erosion in the upstream but in the down stream sediment conc. will increase due to the fact that the tributaries of Meghna from Megalaya 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
- Bio-Diversity will be seriously affected, specially some fish species will be destroyed
- Fish species such as Ruhu, Katla, 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.

The following conclusions is 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 M. Loss of wetland and fish resources may run additional millions of dollars.
- 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.

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, Sunamgarj, 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 Haros, 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

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

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

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. 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.

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

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

6. 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, socioeconomical, ecological, and environmental aspects.

7. Bangladesh government should take lessons from impacts of large international projects throughout the world (impacts before and after) to have a first-hand knowledge on consequences of such 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
- Flood Plain Managers
- Geomorphologists
- Seismic Experts
- Wildlife Biologists
- Fishery Experts
- Ecologists
- Environmentalists
- Agriculturists

The commission should also include at least two farmers from 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 but practical engineers can and will help the situation better.

[1] *Mr. Enamul Hoque, P.E., D.GE, F.ASCE is a civil engineer currently resides in Chandler, Arizona, USA. He owns a civil engineering consulting company and provides services in geotechnical, environmental, materials testing and land and river restoration work. Mr. Hoque is also President of American association of Bangladeshi Engineers and Architects. He has been awarded numerous social and professional achievement awards including* ***prestigious ASCE's John C. Park Award for his outstanding contribution to advance the profession of civil engineering****. His notable work includes restoration of the Salt River, Construction of Deep Water Port for US Navy at Umm Qasr, Iraq, and development of regional marketplace on landfill in Tempe, Arizona. He is a graduate of Bangladesh University of Engineering and Technology and has been in the USA since 1981. Mr. Hoque is a Freedom Fighter and*

fought the War of Liberation as a soldier under the command of General Nasim during the very early stage and later he fought in western Brahmanbaria with Bangladesh Navy's Frogman to destroy gunboats and camps in Ashuganj area. He also established a Girls College near his village in Raipura Upzilla which houses 250 students with astounding performances. He also actively participated and worked as a volunteer in Bangladesh with other engineering students and with Mother Teresa's organization. He has won numerous awards from the state of Arizona and US Department of Housing some of which was broadcasted in Public Broadcasting System Television especially his technical innovation and philanthropic work. He is the first Bangladeshi in USA after whom a state land grant university, Arizona State University named geotechnical laboratory ***"EM Hoque Geotechnical Laboratory"****. His work on river restoration and utilization of appropriate technology to solve complex engineering problem earned him excellent reputation in his field.*

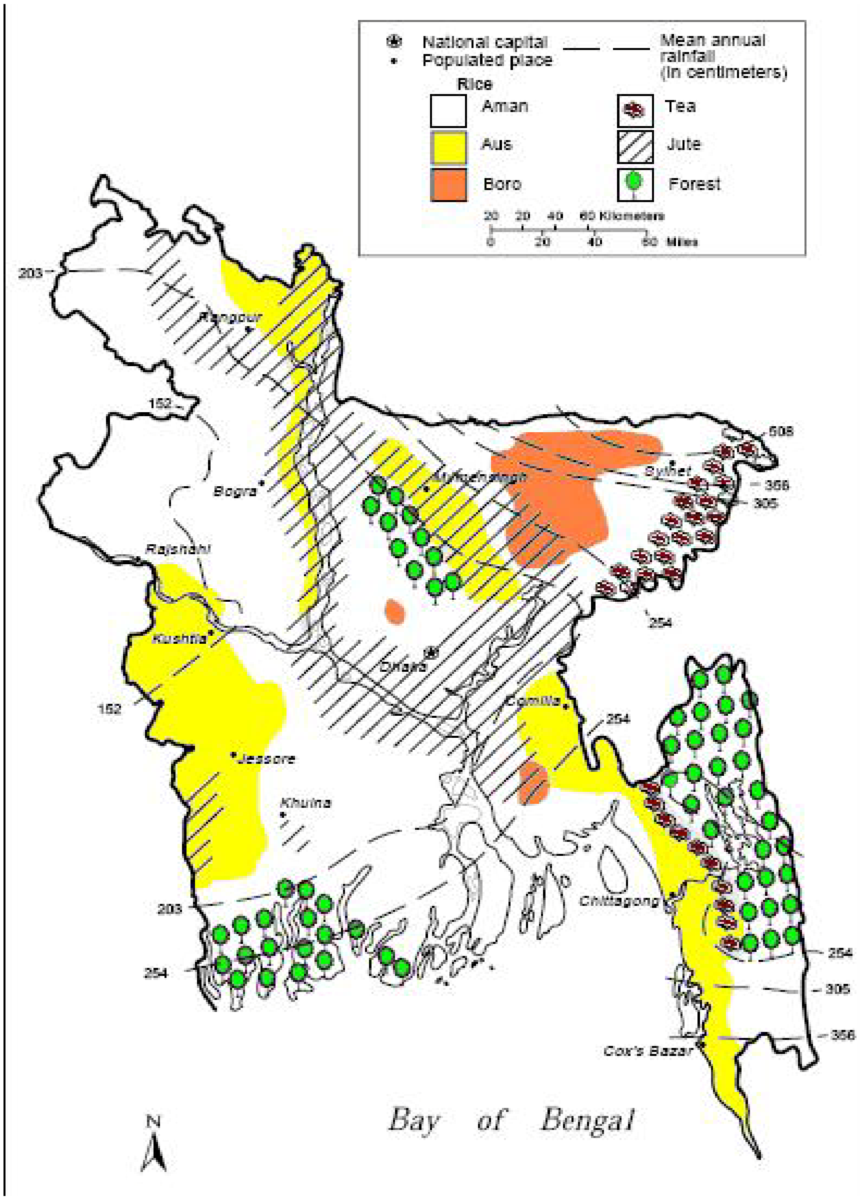


Figure 6 Map of Bangladesh Showing Boro Rice and Other Food Crops Growing Areas in 1950's and 1960's

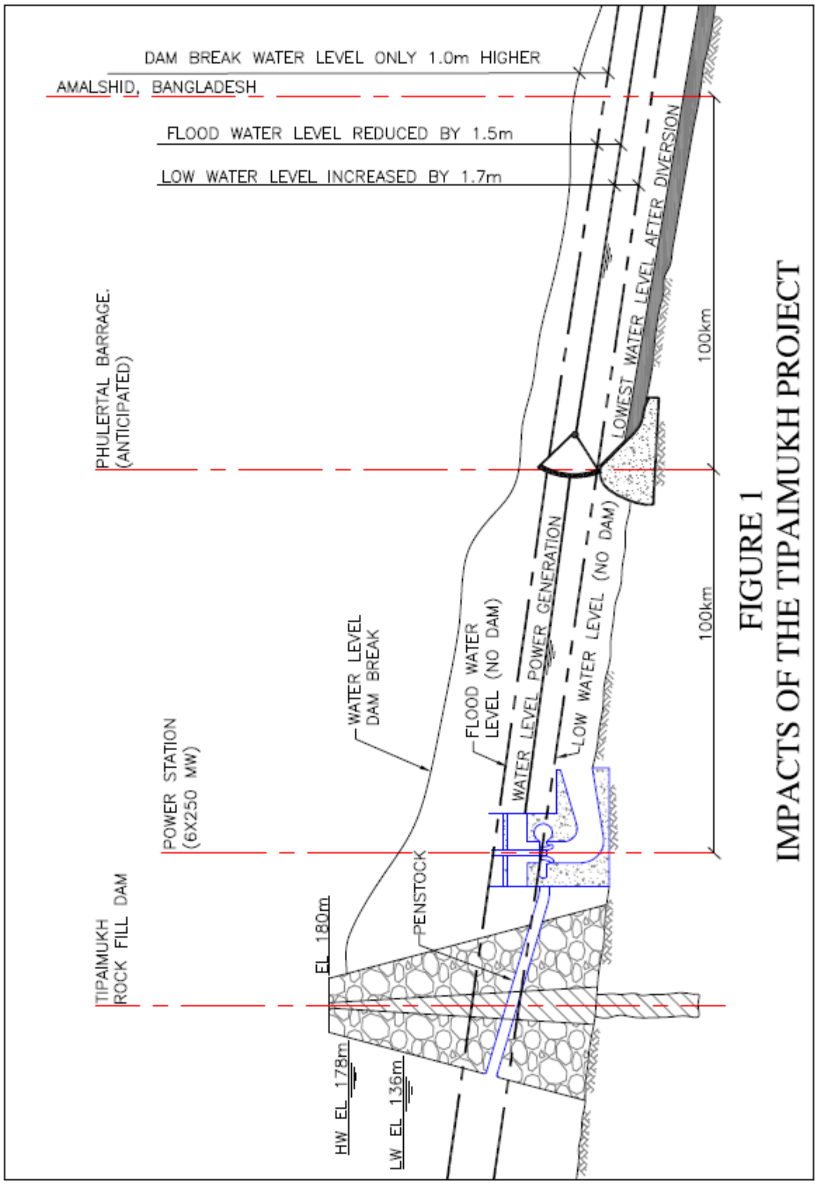


Figure 7 Copied from Presentation by Dr. Sufian Khondker