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Environmental Safeguards in the Construction of Padma Bridge

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ABSTRACT

The Padma Bridge, being the largest infrastructure development project of Bangladesh, required extensive environmental safeguards to make the dream project of Bangladesh environmentally sound. Threat to biodiversity particularly breeding and migration of HIlsha (Tenualosa ilisha) fish, safe disposal of 50 million m3 of dredging spoils, disturbances and displacement of wildlife, conservation of biodiversity, plantation of trees lost to the project, control of construction related noise, air and water pollution, occupational health and safety of the workers were the main environmental impacts of the project. An Environmental Action Plan (EAP) with effective protective measures was successfully implemented. Environmental monitoring of quality of both surface and drinking water, ambient noise level, concentration of PM10, PM2.5, CO, ozone, oxides of nitrogen and sulfur in ambient air, disposal of domestic, construction and hazardous wastes, disposal of dredged spoils, use of personal protective equipment (PPE) and safety at work sites were conducted regularly by a team constituted for this purpose throughout the project period and protective measures were adopted as and when required. Increased flow, water level and temperature in Padma River due to climate change were considered in the design of the Bridge. A wildlife sanctuary has been established in the project area for flourishing of flora and fauna in the protected environment.

1. INTRODUCTION

In the regional context, Padma bridge is strategically located on the Asian Highway route AH-1 and Trans-Asian Railway Route. In the country context, it will provide a vital link in the transport network of Bangladesh by connecting southwestern region of Bangladesh, Mongla sea port and Beanpole land port located in this region with eastern region of the country and Chittagong Sea port. Padma Bridge will significantly boost economic and social uplift of the country, especially in the southwestern region of the country and function as a catalyst for poverty reduction. The construction of Padma Multipurpose Bridge will increase national GDP by 1.23 percent and southwest regional GDP by 2.30 percent and reduce poverty by 0.84 percent.

The people of Bangladesh had a long dream of having a bridge on the fiercely flowing Padma River for easy communication between eastern and south-western parts of country. But construction of Padma Multipurpose Bridge was the most complex and difficult project on the mighty river Padma, the second largest river of the world next to Amazon in respect of flow. The river Padma carries the combined flow of the two mighty rivers, the Ganges and the Brahmaputra with a peak discharge of 140,000 m^3/s and a peak velocity of 4 to 4.5 m/s and transport an estimated 1 billion ton of sediment to the Bay of Bengal (GoB, 2022a). Construction of Padma Bridge by taming such a turbulent river having enormous capacity of erosion of riverbank and bed was a big challenge.

Padma Bridge is the largest Infrastructure Development project in Bangladesh. The implementation of such a megaproject requires comprehensive Environmental

Impact Assessment (EIA) of the project, identification and quantification of environment impacts, development and implementation of environment management plan, and monitoring of environmental impacts of project activities and effectiveness of remedial measures adopted by the project. The environmental activities in the construction of Padma Bridge were planned to meet the co-financiers' requirements, Environmental Conservation Rules, 1997 of the Government of Bangladesh (Gob, 1997) and environmental compliance requirement of the contractors as mentioned in their contract specification. Although the co-financiers, the World Bank (WB), Asian Development Bank (ADB) Japan International Cooperation Agency (JICA) and Islamic Development Bank (IDB) withdrew their commitments to finance the project, the planned environmental activities were fully implemented. This paper describes the environmental safeguards adopted by BBA in the construction of Padma Multipurpose Project to make the project environmentally sound.

2. ENVIRONMENTAL IMPACT ASSESSMENT.

Bangladesh Bridge Authority (BBA) prepared the Environmental Impact Assessment (EIA) report and Environmental Action Plan (EAP) at the design stage of the project in 2009-2010 (Maunsell/AECOM,2010a). Based on the recommendation of the EIA report BBA carried out a follow-up study in 2015-2016 to enhance the baseline information covering seasonal variations, prepare a monitoring plan for the construction and operation stages.

A. Physical and Biological Resources

The project boundary for environmental impact assessment included 15km upstream, 7 Km downstream, and laterally 6km from riverbank at Mawa towards Dhaka and 4km from riverbank at Janjira side. The project site has a rich physical and biological resources that are mutually dependent and belong to a unique ecological system. The physical resources including homestead, agricultural and commercial lands, char land and water bodies as observed during the baseline survey in 2015-2017 (Agroconsulting S.p.A, and Sodev, 2017). These features change with the change of the flow of the mainstream of the Padma River and associated erosion and accretion of the bank and bed of the river. The main flow of the river moves from north bank to south bank at an interval of around 12-15 years causing enormous bank and bed erosion. The River Training Works (RTWs) were located along relatively stable bank lines allowing the river to continue its usual movement. Hence, no obstruction to natural flow of the river was made to induce additional change of physical environment within the Padma River influence area.

An inventory of biological resources in the project area was made by conducting a baseline survey in 2015 (Agoconsulting S.p.A, and Sodev, 2017). A total of 311 species of Flora under 247 genera and 90 families was found in the PMBP area. Among the floral species 95 (31%) species were trees, 33 (11%) species were shrubs, 173 (56%) species were herbs and 10 (3%) species were climber. The study also revealed that 56 plant species were used as medicine in primary health care, 41 used as food and fruit, 57 as vegetables, 29 as fodder, 52 as construction material, 22 as timber, 11 as fuel wood, 9 as cash crop, 10 as culinary and 10 as decorative plants. The habitat-wise distribution of flora is shown in Figure 1. The wildlife recorded in the areas include 112 species of birds (86 resident and 26 migratory), 16 Amphibians, 35 reptile and 25 mammals. 89 species of fish were identified in the project area where Hilsha was the most dominant and important fish in the project area.

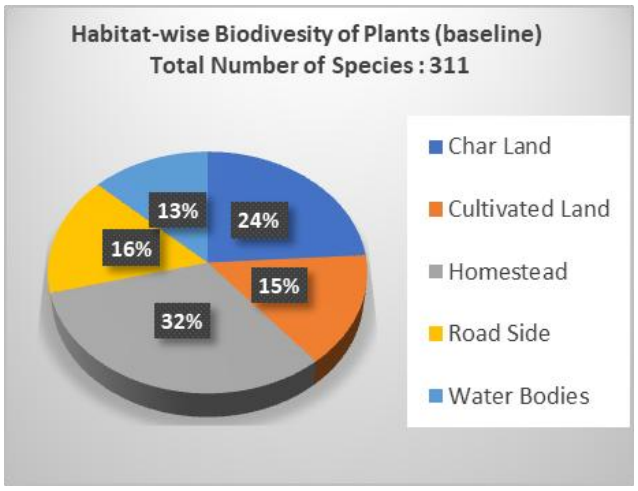

Figure 1: Habitat-wise Baseline Biodiversity in PMBP Area in 2015

B. Environmental Impacts

Comprehensive Environmental Impact Assessment was carried out for identification and quantification of major environmental impacts for mitigation. The major environmental impacts identified by comprehensive EIA of the project are given below:

- The Padma River is the migration route of Hilsha (*Tenualosa ilisha)* fish to upstream of the river and the bridge site is breeding ground for Hilsha and many fishes. The massive construction work in the river is likely to have adverse effect on breeding and migration and breeding of Hilsha and other fishes of Padma River.
- Construction work will disturb and displace wildlife and biodiversity in the project area may be adversely affected by massive construction work.
- Dredging of char land for construction work will destroy the breeding ground turtles.
- Disposal of huge quantity of dredging spoil on land or in water will affect the quality of land and river water. Presence of toxic substance in dredge spoils may pollute the environment.
- Disposal of wastewater and hazardous waste will also cause deterioration of river water quality.

- Destruction of trees from the areas acquired for the project will reduce tree cover in the project area.
- High noise level in water and ambient air due to driving of 3m diameter pile may have adverse impact on aquatic lives and hearing of workers and population around project site.
- Inadequate sanitation, solid and construction waste disposal will create a filthy environment.
- Construction related air, water, soil and noise pollution may create an unhealthy environment in the project site.
- Occupational health and safety of large number work force are of great concern.

C. Environmental Management Plan and Mitigation

Environmental management plans were made for all and components of the project to eliminate, reduce, compensate all adverse environmental impacts as well as enhancement of positive impacts of the project. The mitigation measures implemented by the project for adverse impacts are stated below.

i. Protection of Hilsha Fish

A study conducted under biodiversity baseline survey reported that the mother Hilsha migrate in deep water. So, a decision was taken to suspend all construction activities in the Padma River having depth greater than 7m in Hilsha breeding and migration season and the decision was implemented strictly. The high velocity of water prevented all activities in the main channel of the Padma River. Biodiversity monitoring program recorded an increase in Hilsha production in the construction period.

ii. Biodiversity Conservation

A biodiversity conservation program was conducted throughout the whole project period. An awareness of importance of biodiversity was raised among the workers, fishermen, local people and school children. All people around the project area were instructed not to disturb wildlife and destroy their breeding spots and nests. A wildlife sanctuary was established for conservation of biodiversity.

iii. Breeding of Hard Roofed Turtle

Construction of bridge and maintenance of channels for ferries and other watercrafts required dredging of char land used for breeding of turtles. An alternative char land was required to be protected for breeding of turtle. A wildlife sanctuary was established around the bridge which included char land for undisturbed breeding of turtles.

iv. Disposal of Dredging Spoils and hazardous wastes

Samples of soils to be dredged for RTW works were collected and tested in BUET Environmental Engineering Laboratories for concentration of lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), Manganese (Mn), Arsenic (As), Selenium (Se) and Mercury (Hg). Since, acceptable concentrations of these heavy metals in soil are not available in BDS, the results were compared with USEPA standards 2000. Trace amounts of Cr, Cu, Zn, Mn, As, Se, and Hg were found while concentrations of Pb and Cd were below minimum detection level (MDL). It was confirmed from the test results that no heavy metal accumulated in the bed of Padma River in bridge influenced area. But still disposal of dredging materials in water bodies having low dilution factor can deteriorate water quality (increased turbidity and total solids) and create artificial chars to obstruct water flow. On the other hand, disposal on agricultural lands reduces soil fertility. In the absence of lowlands or ditches for filling on both sides of river, some char lands were acquired by BBA for disposal of dredged soil. Discharge of dredged materials or effluent from deposits of dredged materials in agricultural land was strictly prohibited. The flow in the main channel of the Padma River is very high, about $140{,}000\ m^3/s$ in the monsoon period. The water becomes highly turbid and carries more than 1 billion tons of sediment per year. In this period, the discharge of some dredging materials was allowed in high flowing turbulent river in the monsoon, but no dredging material was discharged in river in dry season. In some locations, polythene bag and other materials were found that interfered with dredging operations.

v. Tree Plantation

The inventory of environmental resources in EIA report indicated that about 366,886 trees from acquired land for the project were cleared during construction of the project in which 101,319 were bamboo trees and 109,095 were banana and the rest were wood and fruit trees. On the other hand, a lot of scope for plantation of trees was created in 7 resettlement sites, 2 service areas, roadsides and vacant areas acquired by BBA. About 1,73,200 trees have been planted so far in 100 hectares in resettlement sites, service areas and on sides of approach roads. Different varieties of sapling consisting of 80% timber, 10% fruit, 5% medicinal and 5% ornamental plants have been planted with assistance from the Department of Forest. PMBP has already received Prime Minister's National Award for tree plantation twice in recognition of best performance in tree plantation (GoB, 2022b). The ultimate target is to plant 3 trees against destruction of 1 tree by the project.

vi. Sound Level

The piers of bridge were constructed on 3m diameters steel piles driven to a maximum depth of 122m. The Menk hammers of 3500 kilojoules, 2400 kilojoule and 1900 kilojoule capacities, specially designed in Germany for this project were used for pile driving. The project made world records both in respect of depth of driven piles and capacity of hammer used for driving these piles. But it produced high sound in ambient air and higher sound in water that may be injurious for workers as well as aquatic lives.

The typical sound level in ambient air close to piling was found to be 115dB, which is not acceptable in any standard for humans. The workers engaged in pile driving were instructed to use air plug during pile driving. The sound intensity in water was measured at distances of 25m, 50m, 100m, 500m and 1000m from the piling locations at piers. The pattern of sound level in water is shown in Figure 2. The sound pressure level as shown in Figure 2 was very high and varied between the starting and ending of every stroke of the hammer. The sound generated during driving

of the top and bottom sections of the pile no.1 of pier No. 9 is recorded at distances from 50m to 1000m and shown in dB RMS in Figure 3. It is observed that the sound level reduced a little bit from beginning to end of driving of the pile and the rate reduction of sound with distance is very low. However, the sound level was lower than the injury threshold of peak 206 dB for fish and 190 dB RMS for pinnipeds. The fishermen fishing within 100m from piling location further confirmed that the sound of piling did not cause any harm to fishes (Nizam Uddin, 2018).

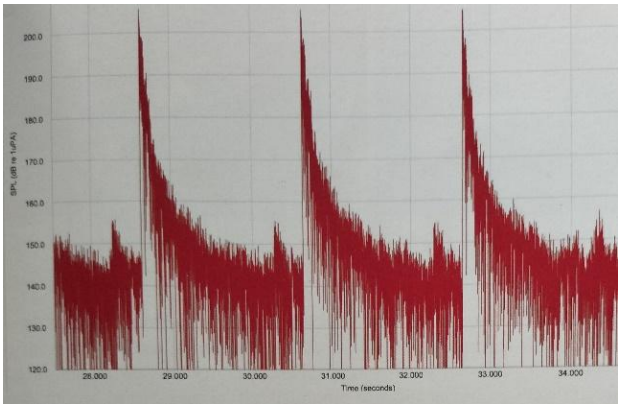

Figure 2: Pattern of Sound Level in Water

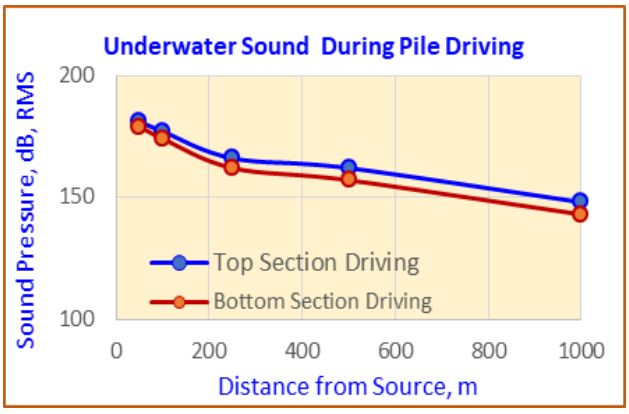

Figure 3: Variation of Sound with Distance

vii. Sanitation, solid and hazardous Waste

Safe sanitation and disposal of the solid waste, construction and hazardous waste was ensured in residential areas, accommodation of workers, construction yards and all workplaces by frequent monitoring. Safe sanitation was provided by installation of sanitary latrines for all. The solid waste was safely disposed in large concrete bins constructed in Mawa and Janjira sites. BBA has a plan to recycle the nutrient in solid waste by composting. Fuel, lubricant and chemicals used for construction were stored in safe containers at designated locations/warehouse as recommended monitoring team. Any leakage of fuel or chemicals was immediately reported, and remedial measures were adopted.

viii. Health and Safety

Occupational health and safety of the workers were given top priority in the construction of Padma Bridge. Safety at the workplaces and use of Personal Protective Equipment (PPE) were regularly inspected by the Environmental Team (ET) of Consultant Supervision Consultant-2 (CSC-2). Health centres, one in Service Area-1(SA-1) at Mawa and one in Service Area-2 at Janjira with doctors, nurses and word boy were established with all facilities and lifesaving medicines. Covid-19 isolated units were also established at health centres to monitor health condition and provide Corona related emergency health services. Speed boat and field ambulance were kept ready for transfer and transport of injured workers.

D. Environmental Monitoring

Environmental monitoring was conducted at regular intervals to observe the effectiveness of the environmental protection measures in reducing impacts and overall impact of the project activities on environmental quality of project area. Biodiversity within the project area was monitored by a consulting firm engaged for this purpose. Environmental monitoring was conducted by physical inspection, visual and instrumental methods. A team comprised of Environmental unit of PMBP, Environmental specialist of CSC, MSC and representatives of contractors was constituted to conduct monitoring. The main tasks of the team were to inspect environmental and occupational health aspects such dredging spoil disposal, solid and liquid waste management, dust and noise control, safety of water and sanitation provisions, as well as occupational health and safety related matters like safety at construction sites, use of appropriate personal protective equipment (PPE), fire safety etc. To comply with Environmental Quality Standards (EQS) as proposed in Environmental Management Plan (EMP) the following environmental quality parameters were monitored at prescribed interval:

- River water quality
- Drinking water quality
- Ambient air quality
- Effluent from dredging spoil
- Noise level

i. Surface water quality

Surface water quality was monitored at regular interval to observe the change in surface water quality during construction period. The water quality parameters monitored were pH, Turbidity, Total Dissolved Solids (TDS), Total suspended Solids (TSS), Electrical Conductivity (EC), Chloride (Cl), Ammonia Nitrogen (NH3-N), Iron (Fe), Arsenic (As), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Oil and Grese. The surface water quality was measured quarterly from 6 strategically located points fixed by GPS around the work area. The water quality parameters measured in May 2018 are shown in Table 1. The test results on quality of water of Padma River is generally good. Pollution assimilation capacity of Padma River is very high due the high discharge and turbulent nature of the flow. High Dissolved Oxygen and Low Biochemical Oxygen Demand as compared to baseline values indicate an improvement of water quality during the period of study. Very low chloride content of water indicates that influence of salinity does not reach up to Padma Bridge.

Table 1
Surface Water Quality of Padma River Water at 5 locations

Sl. No.	WQ Para-meters, Unit	Sample ID						BDS	Baseline Value
		SW 1	SW 2	SW 3	SW 4	SW 5	SW 6		
1	pH	7.33	7.58	7.70	7.86	7.91	7.93	6.5-8.5	7.76
2	Turbidity, NTU	107	91.6	101	86.1	118	84.1	-	-
3	TDS, mg/L	93	82	97	89	102	101	-	93
4	TSS, mg/L	69	45	82	64	73	67	-	96
5	EC, µS/cm	148	139	148	140	179	115	-	131
6	Cl, mg/L	6	4	5	6	8	8	-	6
7	NH3-N, mg/L	0.18	0.12	0.18	0.95	0.23	0.22	-	0.58
8	Fe, mg/L	1.6	1.4	1.6	1.2	1.2	1.0	-	0.5
9	As, µg/L	1.5	2.0	<MDL	2.3	2.7	1.5	-	2.0
10	DO, mg/L	6.97	6.81	6.82	6.78	6.63	6.52	≥ 5	4.83
11	BOD, mg/L	0.2	0.4	0.4	0.2	0.2	0.2	≤ 6	1
12	COD, mg/L	3	7	7	4	4	3	-	6

ii. Drinking water

Safe water was ensured by regular monitoring of some essential parameter of drinking water quality. Deep tubewells were the main source of drinking water in residential areas, resettlement sites and works areas. Water samples collected from 9 deep tube wells used as source of drinking water in project site were tested quarterly in laboratory. Out of 9 water quality parameters shown in Table 2, Mn, As, TC and FC are related to health and others are related to aesthetic quality and taste. The test results of all 9 tubewell water samples in Table 2 show that the water supplied for drinking and other domestic purposes was very clear (low turbidity), contained very low hazardous chemicals (Mn and As) and free from microbial contamination. Close examination shows that 2 samples exceed Bangladesh standard for manganese but the allowable concentration of Mn in drinking water has been increased to 0.4 mg/L by World Health Organization (WHO 2011), whereas BDS maintained a strict standard of 0.1 mg/L set in 1991 and enforced by gazette notification in 1997. The Department of Environment (DoE) has recently taken an initiative to update EQS for drinking water. Although presence of microbial contamination was found in baseline samples, no such contamination is found in any of the samples examined later. The deep tube well water used as drinking water in the project area, as compared to acceptable levels in Bangladesh Standards (BDS), was of excellent quality.

Table 2
Quality of 9 Deep Tube wells (DW) Water Used as Source of Drinking Water

WQ Para-meters, Unit	Sample ID									BDS	Base-line Value
	DW1	DW2	DW3	DW 4	DW 5	DW 6	DW 7	DW 8	DW 9		
pH	6.64	6.60	6.68	7.34	7.05	6.45	7.23	8.12	6.47	6.5-8.5	7.76
Turbidity, NTU	1.73	0.87	2.85	0.88	3.14	0.66	7.67	0.71	0.59	10	-
TDS, mg/L	32	259	75	219	461	140	369	49	72	1000	-
Cl, mg/L	14	104	26	50	136	9	86	5	12	150-600	103
Fe, mg/ L	<MDL	<MDL	0.15	<MDL	0.18	<MDL	0.55	<MDL	<MDL	0.3-1.0	0.40
Mn, mg/L	<MDL	<MDL	<MDL	<MDL	0.25	<MDL	0.17	<MDL	<MDL	0.1	0.17
As, µg/L	<MDL	<MDL	<MDL	1.4	6	<MDL	4	<MDL	<MDL	50	2
TC, No./100ml	0	0	0	0	0	0	0	0	0	Nil	10
FC, No./100ml	0	0	0	0	0	0	0	0	0	Nil	2

iii. Dredging Effluent Quality

The dredging material, a mixture of water and soil, when deposited on land, the excess water after depositing solids comes out as effluent. The solid contents of the effluent often remain very high to silt up drainage channels, and khals carrying effluent and pollute receiving water. TDS, TSS, and Turbidity of the effluent from dredged soil were measured. In case of high solid content, the dredger was instructed to increase retention time within embanked area used for discharge of dredged materials. Long detention time in the embank area allows settling of more solid and clarify the effluent for disposal in natural water.

iv. Ambient noise level.

The main bridge contractor, Major Bridge Engineering Company (MBEC) of China, carried out regular ambient noise measurement at construction sites by digital sound level meter. Noise levels in ambient air were measured at different locations and distances from the sources. The results were reported in monthly, quarterly and annual reports of the Construction Supervision Consultants-2 throughout the project period of construction and protective measures were adopted as and when required (CSC-2, 2015-2022).

The baseline sound in Mawa roundabout was found to be 61.5 dB, which is the typical sound level in commercial areas of Bangladesh. The ferry ghat, river and road traffic were the main sources of sound. The main work stations were in the river, far away from residential and commercial areas. The noise from the construction hardly reached the populated areas. The noise level in the residential area varied from 53 dB to 68 dB. The maximum acceptable levels for residential and commercial areas are 55 dB and 70 dB respectively. However, the highest ambient sound of 115 dB was measured at 20m from pile driving and high sound was also measured in workshops exceeding Bangladesh standard of 75dB for industrial area. The contractors were instructed to provide air plug/air muffles to workers exposed to higher sound level and ensure its use.

v. V. Ambient air Quality

Deterioration of air quality at construction sites is common due to dust and burning fuel etc. The air quality parameters selected for monitoring include Particulate Matter PM10, and PM2.5, Oxides of Sulphur (SOx), Oxides of Nitrogen (NOx), Carbon Monoxide (CO) and Ozone (O3). Quality of air was quarterly monitored at Mawa and Janjira sides of the river and compared against Bangladesh Standards (BDS) and baseline values established in November 2009. It is observed that the air quality parameters measured during the period were well within the acceptable limits and the concentrations of most of the air pollutants were lower than the baseline values.

Table 3
Results of Air Quality Monitoring during 2nd Quarter of 2022 in the project Area

Sl. No.	Parameters	Unit	Concentrations at		BDS	Baseline Values	
			Mawa	Janjira		Mawa	Janjira
1	$PM_{2.5}$	µg/m³	3.11	2.85	65 for 24 hrs	<1	6.12
2	PM_{10}	µg/m³	5.39	8.26	150 for 24 hrs,	112.5	41.14
3	SOx	µg/m³	30.43	0.57	365 for 24 hrs	15.46	7.66
4	NOx	µg/m³	0.93	0.72	100 for 365 days	6.40	3.37
5	CO	ppm	0.52	0.38	10 for 8 hrs	-	-
6	O_3	µg/m³	47.70	48.57	157 for 8 hrs	-	-

vi. Corrosion of Steel Members of the Bridge

The steel members of the bridge are exposed to corrosion. The steel piles supporting the piers are exposed to water and soils have no protection against corrosion. It has been assumed that 10mm out of 60 mm total thickness of exposed steel pile will be lost due to corrosion and erosion in 100 years' lifespan of the bridge. The remaining thickness of the piles would be enough to carry the load of the bridge. Low salinity of water and soil as mentioned in section 2(i) will reduce the rate of corrosion of steel piles. Both inside and outside of the hollow members of steel truss of the bridge superstructure exposed to air are painted applying 3 coats of high quality paints. This will protect the members of steel truss against corrosion for long, but the paint will deteriorate with time. The outside of the truss members can be painted again but the inside of the truss member will remain inaccessible. It has been decided that dehumidifiers will be installed to dehumidify air inside the truss member to protect the inside of the truss members from corrosion.

vii. Biodiversity

Biodiversity is the most precious gift of nature, the value of which in the life of all organisms including humans is enormous. Biodiversity is globally recognized as a cornerstone of healthy ecosystem. Wildlife biodiversity in Bangladesh is under severe threat due to rapid development and related pressure like construction of infrastructure, industrialization, urbanization, deforestation, pollution, overexploitation of resources etc. Hence, biodiversity conservation was one of the important components of environmental management. Padma Multipurpose Bridge, being the largest infrastructure development project, biodiversity conservation has been given high priority. After preparing a comprehensive inventory of wildlife in the project area during project preparation, Sodev Consult International was given the responsibly of monitoring and conservation of biodiversity during construction phase of the project which will continue even after the construction of the project (Sodev, 2017-2022). Since all the species cannot be closely monitored 22 indicator species were selected for close monitoring along with quarterly monitoring of biodiversity of all flora and fauna in selected locations of the project area. The indicator species comprised of 11 wildlife species, 5 plant species and 6 species of fish are shown in Table 4.

Table 4
Fauna and Floral Indicator Species for Close Monitoring (Sodev, 2017-2022)

Wildlife Species, Local/English (*Scientific*) Name	Floral Species, Local/ English (*Scientific*) Name	Fish Species, Local (*Scientific*) Name
Amphibia 1. Sona Beng/Bull Frog (*Hoplobatrachus tigerinus* **Reptile** 2. Kori Kaittha/Roofed Turtle *(Pangshura tecta*) 3. Maita Guisap/Bengal Monitor (*Varanus bengalensis*) **Bird** 4. Katua Chil/Black-winged Kite (*Elanus caeruleus*) 5. Pakra Machranga/Pied Kingfisher (*Ceryle rudis*) 6. Hot-titi/Red-wattled Lapwing (*Venellus indicus*) 7. Choto Pankor/Little Cormorant (*Microcarbo niger*) 8. Gang Shalik/Bank Myna (*Acridotheris gingianus*) 9. Bhomra Soton/ Zitting Cisticola (*Cisticola juccidis*) **Mammal** 10. Shishu (shusuk)/ Ganges River Dolphin (*Platanista gangetica*) 11. Shial/Golden Jackal (*Canis aureus)*	1. Kash/Thatch Grass (*Saccharam spontanium L*) 2. Nal/Tropical Reed (*Phragmites karka(Rtz)Tnn*) 3. Hogla/Cat Trail (*Typha elephantina Roelephantina Roxb.*) 4. Panijoma/Indian Willow (*Salix tetrasperma Roxb.)* 5. Nona Jhau/Indian Tamarisk (*Tamarsik Indica L)*	1. Hilsha or Ilish (*Tenualosa ilisha*) 2. Rui (*Labio rohita*) 3. Aire (Mystusaor) 4. Chitol (*Chitala chitala)* 5. Baim (*Macrognathus - aculeatus*) 6. Baila (*Glosoglobius guris)*

The methods of monitoring followed for flora and fauna are (i) Field Diary Method (ii) Photo Documentation Method (iii) Transect Walk Method and (iv) Focused Group Discussion Method. A total of 324 plant species have been identified and recorded in Padma Bridge wildlife sanctuary area including landscape zone. Habitat-wise distribution of the plant species are shown in Figure 4 (Sodev, 2022). A total of 13 numbers of additional floral species is reported as compared to baseline species recorded in Biodiversity Baseline Survey conducted in 2015. A similar habitat-wise distribution of plant biodiversity shown in Figures 1 and Figure 4 indicates no significant change in plant biodiversity due to construction of Padma Bridge. The increase of 13 new species may be due to more intensive search for species during long monitoring period.

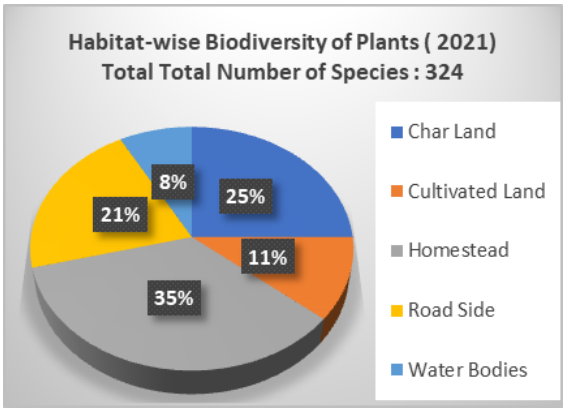

Figure 4: Habitat-wise Biodiversity of Plant in PMBP Area in 2021

Wildlife species diversity recorded in the Padma bridge influence area in 2019, 2020, and 2021 has been presented in Figure 5. A small variation in observed amphibians, reptiles, birds and mammals were recorded in the intensive construction period of the bridge, while total species variation shows decreasing trend. The observed decrease in biodiversity in 3 years of construction period is less than 4 percent. It is expected that the species diversity will be restored to normal after the construction of the bridge is over. The indicator species were visible almost every quarter indicating no disappearance of species from the Padma Bridge influence area.

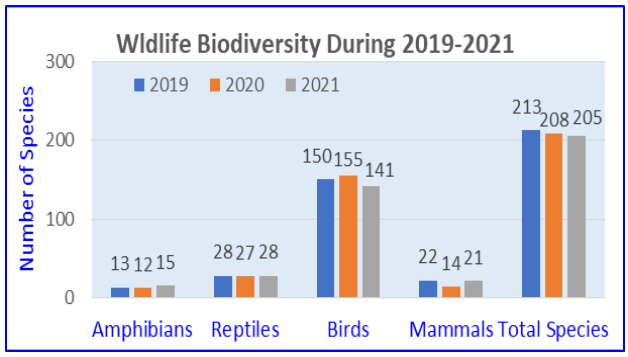

Figure 5: Variation of Wildlife Biodiversity in Last 3 Years

viii. Padma Bridge Wildlife Sanctuary

Padma Multipurpose Bridge Project for the first time in Bangladesh has ventured into a natural biological resources management through establishment of a wildlife sanctuary in an infrastructure development project area under biodiversity conservation program. The Government of Bangladesh established the Padma Bridge Wildlife Sanctuary (PBWS) by Gazette notification on 26 November 2020 under the Bangladesh Wildlife (Conservation and Security) Act 2012. Padma Bridge Wildlife Sanctuary (PBWS) is spread over 4 district, 5 Upazilas and 16 unions as shown in Figure 6. The total area of PBWS is 11,773 ha of which 8,143 ha is core area and 3,630 ha is buffer area, The sanctuary will be managed

in compliance of the Protection and Conservation of Fish Rules, 1985 and Protected Area Management Rule 2017. The sanctuary when fully operational will enhance riverine and adjacent terrestrial biodiversity for the overall benefit of the local community in the project area.

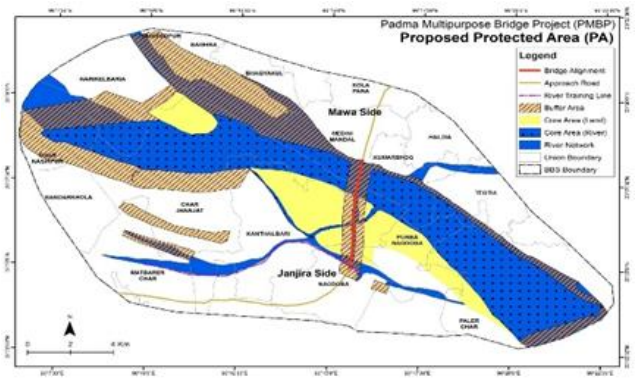

Figure 6: Padma Bridge Wildlife Sanctuary Area

ix. Wildlife Museum

BBA has established a wildlife museum in Service Area-1 (SA-1) with assistance from Department of Zoology, University of Dhaka. The primary objectives of establishing wildlife museum were to create people's awareness about wildlife biodiversity in the area, enhance knowledge of the students and researchers about animal diversity and conservation. The museum has collected and preserved 2353 wildlife specimen from Padma Bridge area up to May 2022 and arranged for public display. The museum has rich collection of amphibians, fishes, reptile, birds and mammals. In addition, replicas of several endangered species, fishing gears and bird nests have been collected and displayed. The museum is getting richer every month with more and more specimen. The wildlife museum has attracted many visitors and will continue to attract more visitors when the museum will be permanently located in the Padma Bridge Museum building under construction. The wildlife museum will be used for educational purpose for school children.

Figure 7: Some Bird Species in Padma Bridge Wildlife Museum

x. (viii) Death on Road

The frequent death of wildlife on the Dhaka-Bhanga expressway due to vehicle-wildlife collision is a great concern for the wildlife conservation. The wildlife monitoring team of PMBP has found 6 Golden Jackal (Canis aureus) dead during April-June 2022 and 14 wildlife during July-September 2022 on the Padma Bridge approach road. It is now clear that large number of wildlife used to cross the Dhaka-Mawa road at night. The conversion of this road into expressway, the geometric design has been changed, the design speed has increased to 80km/hr but most of the drivers drive vehicles at a speed around 100 km/hr. The expressway has under pass for crossing local vehicles and pedestrians but it appears that the wildlife hardly uses the underpass. The wildlife as usual enter into the road through the opening under the side barrier for crossing but in most cases cannot cross the high median and get trapped in the road. Welding of 1 or 2 horizontal bar below the side barrier may prevent entry of wildlife into the expressway.

3. ADAPTATION TO CLIMATE CHANGE

Bangladesh is the one of worst affected countries of the world due to climate change. All major structures are required to be adapted to the impacts caused by climate change. The lifespan of the bridge is 100 years. So, the predicted changes in sea level rise, rainfall, temperature, wind speed in 100 years due to climate change are considered in the design of the bridge. The upper range, mid-range and lower range of sea level rise of 0.98m, 0.60m and 0.26m respectively as projected by IPCC 2007b where the estimated ice sheet contribution were considered in upper and mid-range projection of IPCC. The Padma bridge is located 240 km upstream of the Bay of Bengal coastline. The net sea-level rise of 4 scenarios, 1.00m, 0.88m, 0.60m, and 0.26m were projected to cause water level rise at bridge site by 0.47m, 0.42m, 0.27m, and 0.09m respectively as shown in Table 5.

Table 5
Water level rise at Padma Bridge site due to Sea-level Rise

Distance from Outer Boundary of SLR in Estuary, km	Sea Level Rise (SLR) in m			
	1.00	0.88	0.60	0.26
26	0.96	0.85	0.55	0.19
105	0.90	0.80	0.52	0.18
131	0.73	0.65	0.42	0.15
149	0.68	0.60	0.39	0.14
168 (Chandpur)	0.56	0.50	0.33	0.11
240 (Padma Bridge Site)	0.47	0.42	0.27	0.09

The global circulation model predicted that the rainfall in the catchment area of the Padma Bridge will increase by 26%, which may cause an increase of 16% water flow and 0.16m increase in water level in the Padma river. The total increase in water level would be 0.62m by adding 0.47m water level rise for 1.00m sea-level rise and 0.16m for excess rainfall. This was added to highest flood level in 100 years return period to arrive at the highest design flood level of 7.44m PWD. Since, Padma River is a busy waterway, a navigation clearance of 18.3m was added to

highest design flood level to fix the bottom level of the bridge.

The design discharge of $151{,}100\ m^3/s$ and design velocity of 5 m/s were estimated by considering additional flow caused by excess rainfall in the Padma Bridge catchment area due to climate change. The Maximum temperature of 46.6 0C and minimum temperature of 9.3 0C were considered in the design of the bridge (Maunsell/AECOM, 2010b). The change in temperature is important in the design of expansion joints provided between the modules of the bridge.

4. CONCLUSIONS

Padma Multipurpose Bridge Project is the most successful project having minimum impact on natural environment. The world's largest river training works have been erected to tame the river without affecting the natural flow of the river. Construction related impacts of such a megaproject such as disposal of 30 million m3 of dredging spoils, threat to Hilsha breeding and migration, disturbances and displacement wildlife, water, air and noise pollution have been managed successfully. The increased rainfall, water flow, water level and temperature due to climate change have been incorporated in the design of the bridge. A team comprised of environmental experts of BBA and Consultants and representative of contractors regularly monitored the implementation of EAP and compliance of environmental guidelines. All facilities developed for Implementation of the project are well planned and environment friendly. A wildlife museum has been established collecting and preserving wildlife from the Padma Bridge areas which will attract the visitors and be used for education of the school children. Padma Multipurpose Bridge Project for the first time in Bangladesh has ventured into a natural biological resources management initiative through establishment of a wildlife sanctuary in an infrastructure development project area under biodiversity conservation program. Government of Bangladesh supported the initiative of PMBP and declared 11,773 ha of char and wetland of Padma Bridge area as Padma Bridge Wildlife Sanctuary (PBWS) for breeding and preservation of wildlife and plant biodiversity.

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REFERENCES

Agroconsulting S.p.A, and Sodev, (2017) *Final Report, Biodiversity Baseline Survey*, Agroconsulting S.p.A. Rome, Italy and Sodev Consult International Ltd, Dhaka, Bangladesh.

GoB (2022a) *The Bridge of Pride at a Glance*, Bangladesh Bridge Authority (BBA), Ministry of Road Transport and Bridges, Government of Bangladesh.

GoB (2022b) *Safeguard Activities*, Bangladesh Bridge Authority (BBA), Ministry of Road Transport and Bridges, Government of Bangladesh.

GoB (1997) *Environmental Conservation Rule 1997*, Ministry of Environment, Forest and Climate Change, Government of Bangladesh.

CSC-2 (2015-2022) *Monthly, Quarterly and Annual Progress Reports*, Korean Expressway Corporation in Joint Venture with PEC, KECC,Sunjin ACE and in association with DevCon.

Maunsell/AECOM (2010a) *Final Report, Environmental Action Plan, Vol.1, Environmental Impact Assessment Report,* Maunsell/AECOM New Zealand in association with nhc, SMEC International, ACE Consultants

Maunsell/AECOM (2010b) *Final Report, Environmental Action Plan, Vol. 5, Factoring Climate Change Considerations in the Design of Padma Bridge*, Maunsell/AECOM New Zealand in association with nhc, SMEC International, ACE Consultants.

Nizam Uddin (2018) *Environmental Quality Survey for Padma Multipurpose Bridge Project During Construction*, Technical Journal, Retired Road Engineer's Association. P 46-63.

Sodev (2022), *Management Plan, Padma Bridge Wildlife Sanctuary*, Sodev Consult International Ltd. Bangladesh

Sodev (2017-2022), *Quarterly Biodiversity Monitoring Report*, Sodev Consult International Ltd. Bangladesh.

WHO (2011) *Guidelines for Drinking-water Quality*, Volume 4, World Health Organization, Geneva.