CHAPTER 6

INITIAL STUDY ON BRIDGE LOCATION AND ROUTE ALIGNMENT

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6.1 Identification of Bridge Location and Route Alternatives

6.1.1 Planning Constraints

(1) Examination Viewpoint

There are several possible alternative means for crossing the Hugli River between Raichak and Kukrahati such as bridge, tunnel and car ferry development. There are not so many restraints on the crossing location for the tunnel and car ferry alternatives as there are for the bridge option. There are, however, other issues but mainly the matter of alignment of inland approach road development, which are raised in the bridge case as well. Owing to the conditions mentioned above, the crossing location alternatives for the bridge case are examined in this section as the first step prior to the discussion on the crossing means.

(2) Planning Constraints

a) Category

The planning of the crossing location for the bridge is constrained by the following factors:

- Social environment;
- Natural environment;
- Geography and geology;
- River and hydraulic engineering;
- Ship navigation;
- Traffic demand and road network condition; and
- Construction cost.

b) Social Environment

The scale of resettlement and relocation of facilities required for the project is an important factor to consider when examining the crossing location. The major land use features at the crossing location on the Raichak and Kukrahati sides are generally as follows:

- A ferry terminal facility is located on each side;
- There are some small shops and other service facilities around the ferry terminals on both sides;
- Ship navigation-aid facilities are built along the river bank on both sides;

- Large manufacturing factories and brick factories are located along the river bank on the Raichak side;
- The Radison Hotel and a large bio-factory are located beside the ferry terminal on the Raichak side;
- Except for the brick factories, no large manufacturing facilities have been observed on the Kukrahati side;
- The area is dotted with small villages and paddy fields on both sides; and
- Sarisha and Kukrahati are core villages in the local area.

It is a matter of course to avoid the large facilities mentioned above such as the ferry terminal facility, hotel and factories when selecting the crossing location. It is, however, inevitable that there will be, to some extent, infringement on land and housing. A key to success will be to minimize the negative impacts when examining the crossing location. In addition, sacred and symbolic facilities are to be avoided.

c) Natural Environment

As far as the natural environment is concerned, there is no serious constraint that needs to be examined for the crossing location though some countermeasures may be required to relieve negative impacts accruing from the implementation of the project.

d) Geography and Geology

Flat plains are the predominant geological and topographical feature of this area. Although no geotechnical information has been obtained so far, it seems that geographical and geological aspects have no affect on the crossing location.

e) River and Hydraulic Engineering

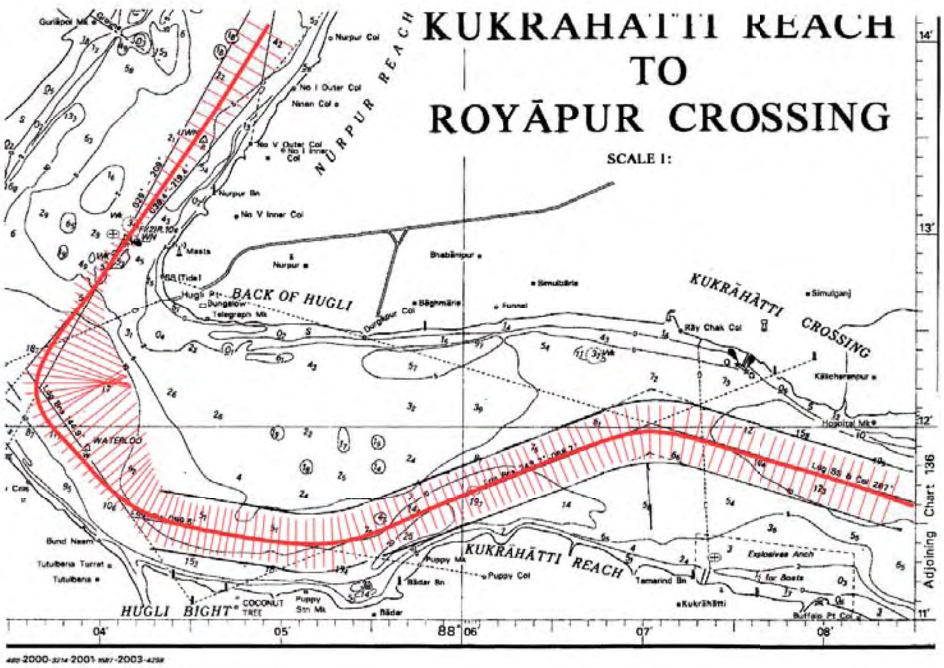
The Raichak and Kukrahati reach has salient river engineering features as follows:

- Confluence of Hugli River and River Purnarayan;
- Changing of tidal river flow ;
- Changing river width;
- Sharp bend at Nurpur;
- Continuous sedimentation; and
- Chronic erosion of the riverbank.

Although it is easily supposed that these circumstances may make the engineering examination complicated, the only countermeasure that needs to be considered is the protection of banks from erosion at the crossing location.

f) Ship Navigation

Tides, depth of river and the sharp bend make the channel between the Kukrahati reach and the Nurpur reach a difficult spot for ship navigation. There is no definite navigation channel identified by buoys and other navigation aids in the water. Ships can pass through any part of the channel depending on the judgement of the captain and pilot. There is, however, a course commonly used by ships, based on past experience, taking the depth of the river and the bend in the channel into consideration. Although there is no definite rule at this moment **Figure 6.1.1** shows the common course, obtained through interviews with relevant officials about current situation. Ships coming from (or going to) the Kolkata Dock System sharply turn at the confluence of Hugli River and River Purnarayan. After that, the ships pass over to the Kukrahati riverbank side, where there is deep water. Then the ships change course toward the opposite side of the river, the Raichak side, where it is also deeper along the bank before passing toward the offshore course of Diamond Harbour.



Note: Bar shows the common navigation course

Figure 6.1.1 Current Common Navigation Course

g) Traffic Flow and Road Network Condition

The approach road of the bridge will be connected to NH 117, Diamond Harbour Road, on the Raichak side and NH 41 on the Kukrahati side. The project area has similar features throughout, in short, dotted with small villages and paddy fields. In other words, the hinterland of the bridge does not show any serious constraints on the route alignment of the approach road for the bridge. Any crossing location can provide the approach road to connect the bridge to NH 117 and NH41 without serious problems. However, a downstream crossing location looks slightly advantageous for traffic flow because future traffic over the bridge will be generated mainly from the Haldia Industrial Complex on the Kukrahati side. In addition, the easternmost (downstream) alternative has a shorter approach to Diamond Harbour Road on the Raichak side. However, this will be discussed in the evaluation stage.

h) Construction Cost

A low cost option for the crossing location is preferable. In this regard, it is an advantage to have the narrowest location and be perpendicular to the river.

i) Priority Factors

Of the above mentioned considerations for the location of the bridge, the most important is to avoid negative impacts on ship navigation in the river. The navigation channel between Kukrahati reach and Nurpur reach is a dangerous point for ships going to and coming from Kolkata Dock System. In addition, the social environment is mainly taken into consideration if the inland approach roads for the crossing location alternatives avoid existing large villages and facilities. Furthermore, the area where the crossing location of the bridge is planned has almost the same conditions throughout in terms of the natural environment, geographical and geological aspects. With regard to the river and hydraulic engineering, the erosion that can be observed along the riverbank is not a serious constraint on the crossing location. Consideration of how to protect the bank from erosion can be made after deciding on the crossing location.

The above preliminary examination comes to the conclusion that the first priority is to consider the crossing location for the bridge based on the requirements of ship navigation in the channel.

j) Current Ship Navigation Characteristics

The navigation characteristics apparently indicate the following:

- Ships sometimes lose manoeuvring control offshore near Nurpur;

- The above means that the crossing location should be far from the confluence of the rivers; and
- The bridge needs to squarely cross the navigation channel where there is no unexpected ship manoeuvring.

6.1.2 Alternative Crossing Locations

Based on the above factors, the following four different alternatives are identified for crossing locations taking the ease in connectivity to both sides into consideration and avoiding monuments such as temples, built-up areas and community settlements:

- Alternative-A: This alternative is located at the most upstream end of the Kukrahati reach crossing the river perpendicularly in a straight part of the navigation channel;
- Alternative-B: This alternative is located at about 2 km downstream of Alternative-A, crossing in the middle of the Kukrahati reach perpendicularly to a straight part of the navigation channel (this was once proposed in another study by JETRO);
- Alternative-C: This alternative is located more than 3 km further downstream of Alterative-B, crossing at the east end of the Kukrahati reach perpendicularly to a straight part of the navigation channel ; and
- Alternative-D: This alternative is about 0.5 km downstream of Alternative-C and also crossing the easternmost end of the Kukrahati reach perpendicularly to a straight part of the navigation channel.

Figure 6.1.2 shows the crossing location alternatives.

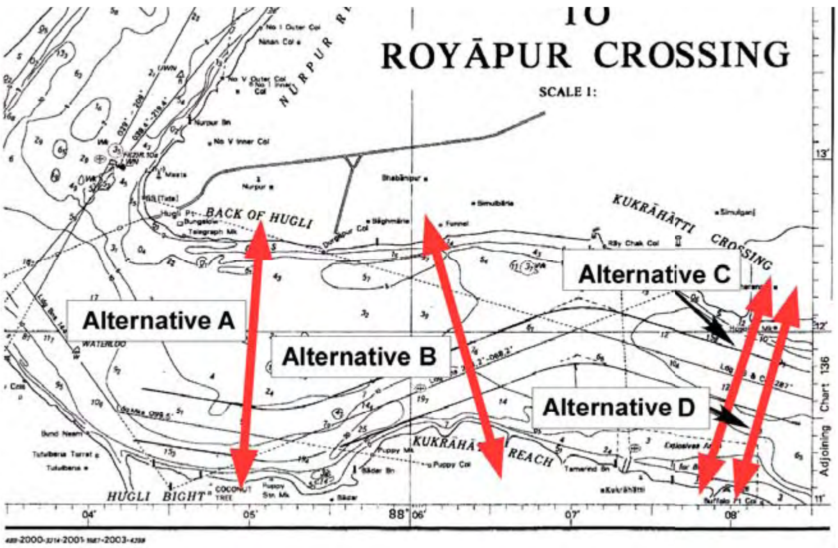


Figure 6.1.2 Crossing Location Alternatives

6.2 Engineering Evaluation on Each Alternative

6.2.1 River Engineering

The river engineering for a bridge location is based on a study of the river movement, flow direction and requirements for river protection works.

(1) Data Availability

Following data is available in this study.

- Chronological water depth near the alternative bridge sites from the Kolkata Port Trust
- Satellite image (6 April, 2005)
- Hydraulic study report at the JETRO proposed bridge site by the Kolkata Port Trust on August, 2003
- Flow direction survey prepared by the Kolkata Port Trust
- Tidal water level record by the Kolkata Port Trust

(2) River Movement

Charts around the alternative sites are collected from 1945 to 2006. **Figure 6.2.1** and **Figure 6.2.2** show 10m depth contour line and waterside line, respectively.

The Hugli River meanders from the confluence with the Rapunarayan River to Diamond Harbour. The alternative sites are located at a part of the meandering portion. The lowest riverbed elevation in this area shifts from the right bank side upstream near the Puppy Column to the left bank side downstream near the Hospital PT Column. Vessels follow the deep water through the waterway.

River movement is checked from the riverbank, waterside depth and deep-water depth.

a) Riverbank

Riverbank movement is not significant. However, the riverbanks in front of the Buffalo PT Column and near the Kalicharanpur River are eroded.

b) Waterside

Movement of the waterside line is not significant except around Hospital PT Mark. The waterside line around the Hospital PT Mark has moved out about 190 m during 60 years.

c) Deep-water depth (more than 10m)

The deep-water area is most important to the waterway for vessels. The deep-water area at the downstream of the left bank has moved about 140 m towards the bank side due to erosion of waterside. Therefore, the maximum 10 m deep area at alternatives B and C is about 980m and 940 m, respectively.

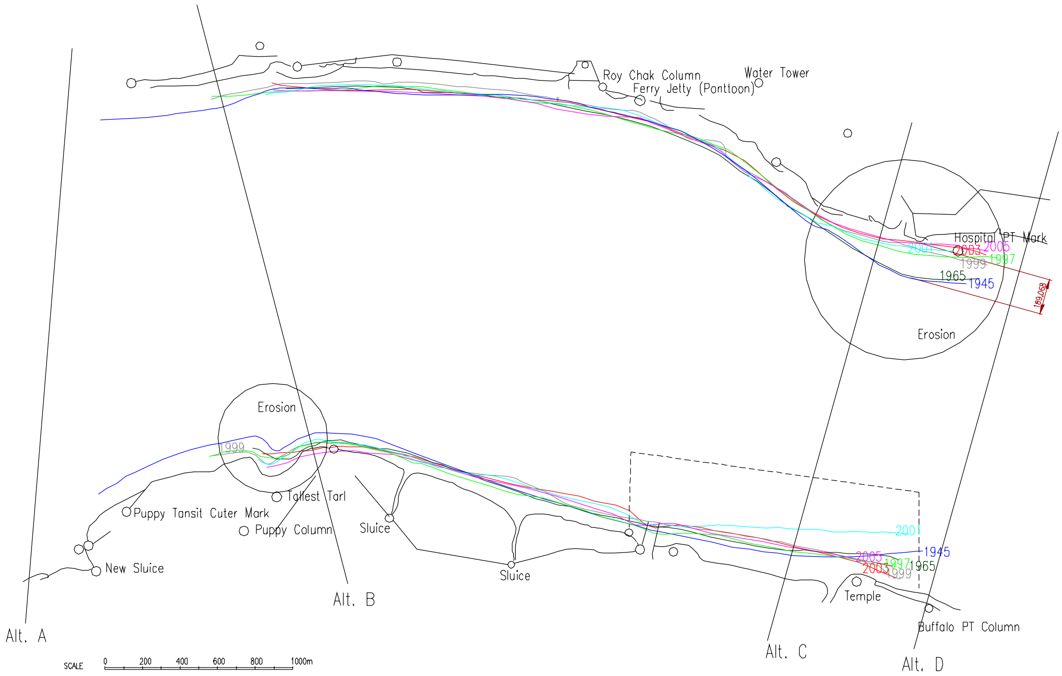


Figure 6.2.1 Chronological Waterside Line from 1945 to 2005

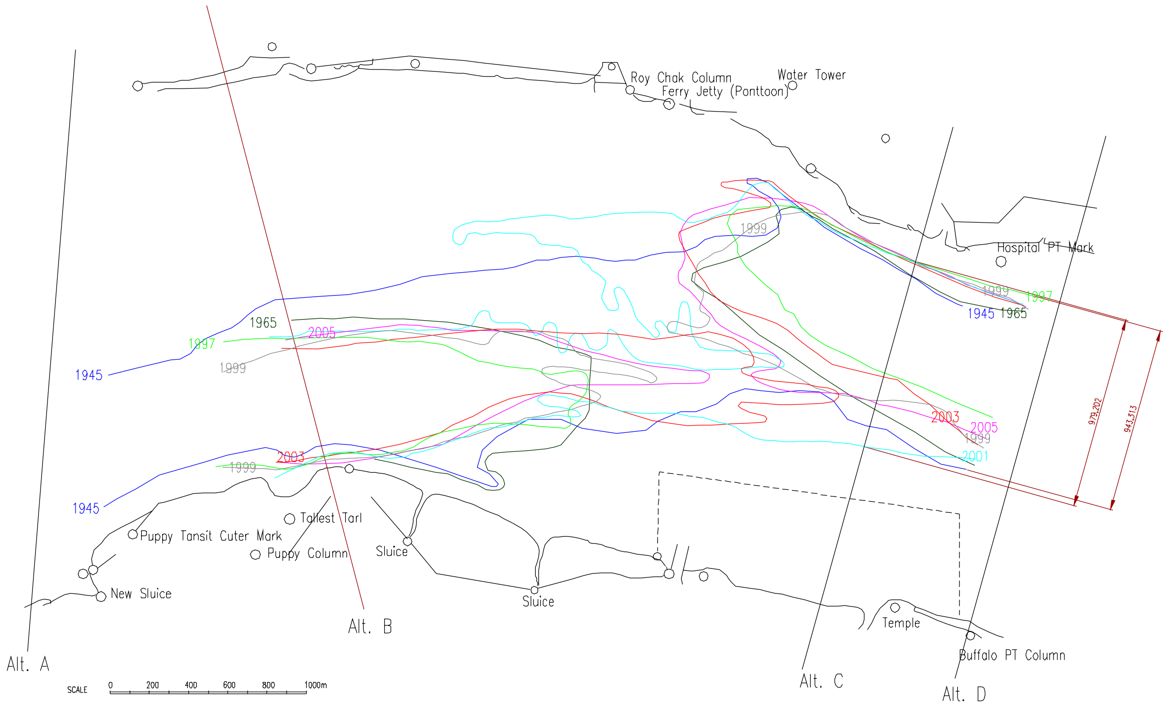


Figure 6.2.2 Chronological Water Depth (10m) from 1945 to 2005

(3) Flow direction

An observation of river flow was carried out between Raichak and Kukulahati on June 25, 2003. A hydraulic model test was carried out, by the Kolkata Port Trust in 2003, to check hydraulic phenomena after construction of a bridge.

Saltwater affects the alternative bridge sites in the Hugli River. River water flows upstream to downstream during low tide and downstream to upstream during high tide because the difference between the low and high tidal level is about 5m and riverbed slope is very gentle.

a) River flow observation (see Figure 6.2.3)

Though the discharge is unknown during the observation, the flow direction is south-west to north-east at low tide and south-east to north-west during high tide. The velocity at the centre of the river to left bank side is faster than the right bank side at the low tidal level (Vmax=0.87m/s) and center of the river to right bank is faster than the left bank during the high tidal level (Vmax=1.87m/s)

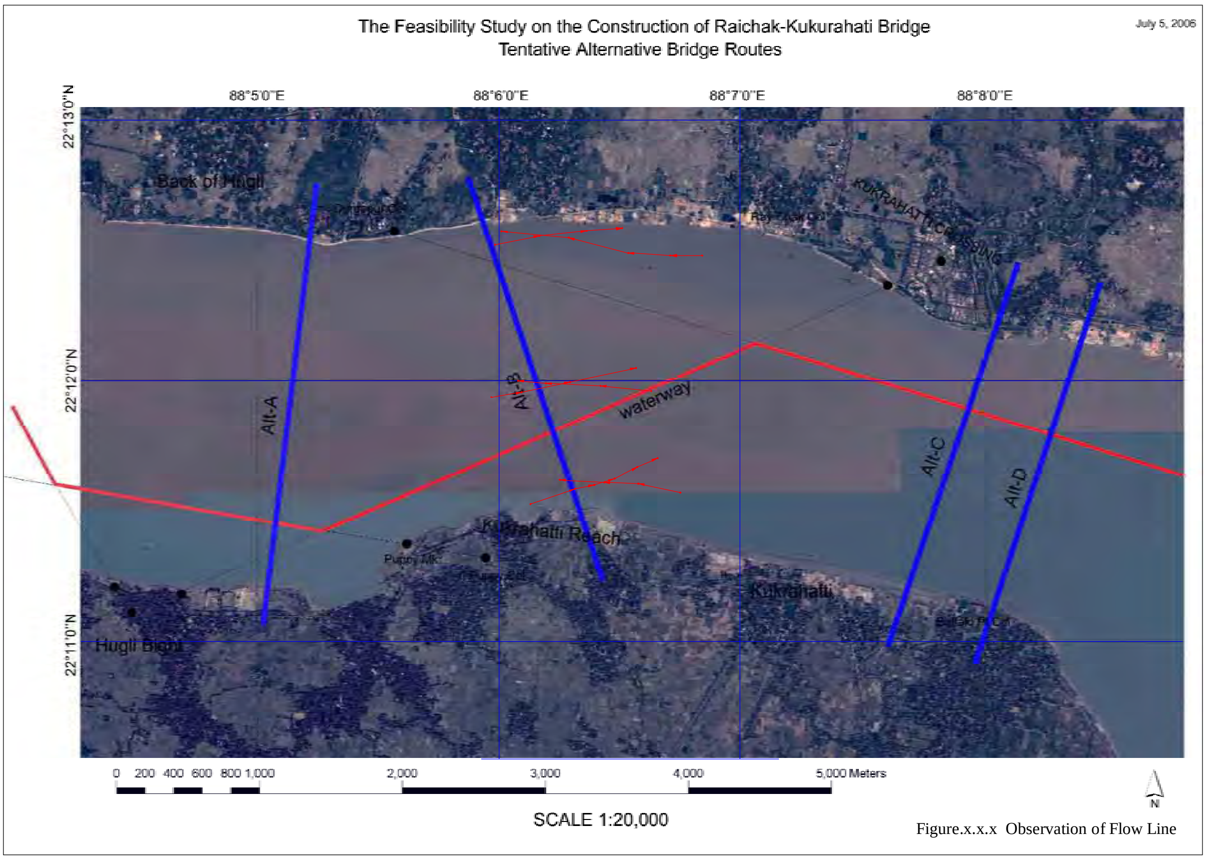


Figure 6.2.3 Observation of Flow Line

b) Result of Hydraulic Model Test (see Figure 6.2.4)

The results indicate that the:

- Flow direction at alternative A is west-southwest to east-northeast,
- Flow direction at alternative B is southeast to northwest during low tide and east to west during high tide
- Flow direction at alternatives C and D is west-northwest to east-southeast.
- Flow lines of alternatives A, C, D are the same line from upstream to downstream during low tide and downstream to upstream during high tide.

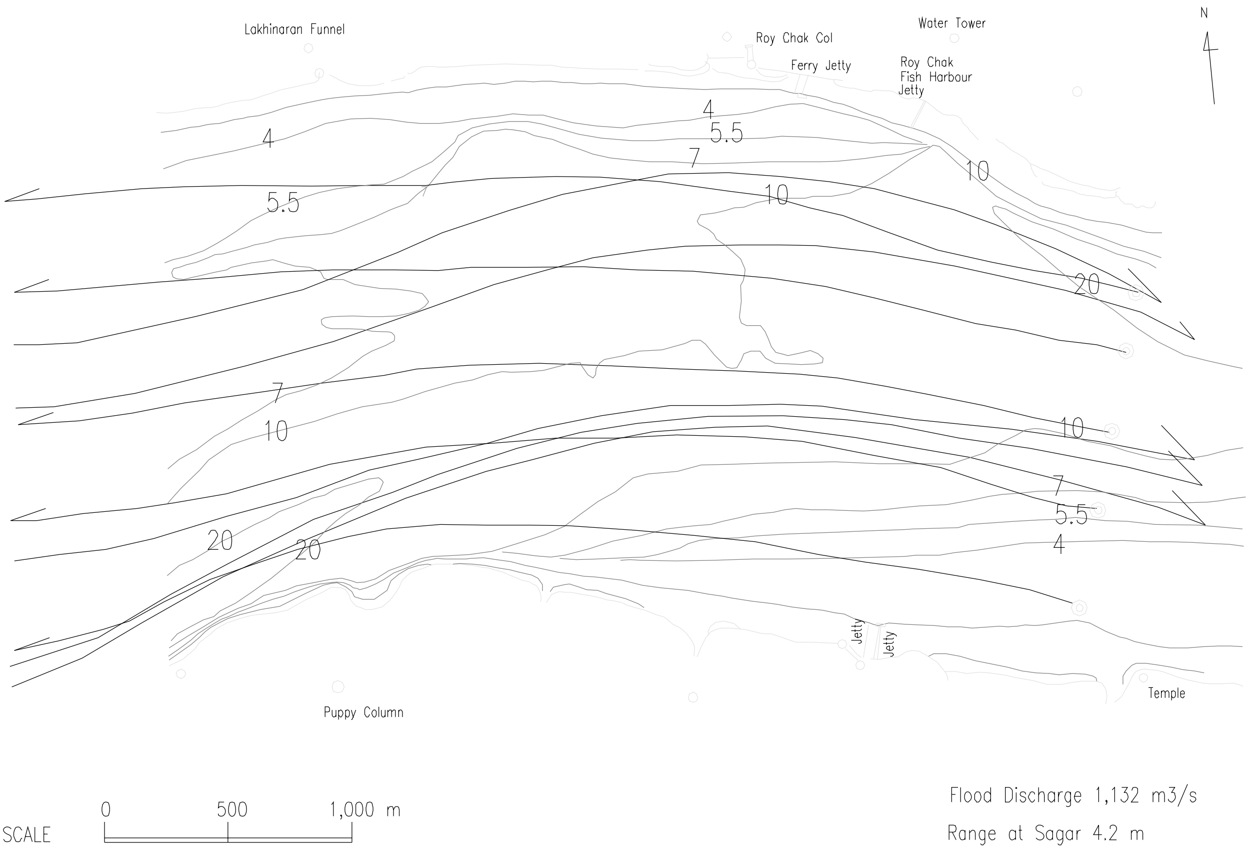


Figure 6.2.4 Flow Line of Hydraulic Model Test on August, 2003

(4) Present Riverbank Protection

The site reconnaissance was carried out on 24, 25 June and 1, 2 July. Visual inspection results are explained as follows.

The riverbank protection works are classified as five types in the study area.

- Masonry (Brick)
- Wet masonry (Brick)
- Stone masonry and gabion mattress
- Bamboo fence and sand bags
- Plastic bag

According to the Central Design Office in the Irrigation and Waterways Department, the protection method is decided from the site condition, availability of material and construction cost.

a) Right bank (Kukrahati Side) (see Figure 6.2.5 (1)-(5))

The study area of the right bank is divided into four (4) locations, which are:

1) About 4km downstream of the water treatment plant to inlet (about 2km),

2) Inlet to brick factory near the Kukrahati ferry port (about 2.5 km)

3) In front of the Kukrahati ferry port (about 1km), and

4) Kukrahati ferry port to around Buffalo PT. Column.

i) About 4km downstream of the water treatment plant to inlet (around 2km),

The waterside at this area is about 50m from the bank at the low tide. There are some boats along this area.

Wet brick masonry upstream collapsed by sliding due to movement of the soil layer from the back and erosion at the foot of the bank protection. Some parts of this area are not protected as shown in **Figure 6.2.5**. In this area, bank erosion has occurred due to waves.

Brick masonry was constructed but some parts are broken due to erosion. Brick masonry is under construction with clay or silt backfill material.

ii) Inlet to brick factory near the Kukrahati ferry port (about 2.5 km)

Land use near the river is paddy field, cropland and housing. Applied stone masonry with gabion mattress has been used for slope protection of the access road near the river. Some parts of the access road functions as riverbank protection and access road.

iii) In front of the Kukrahati ferry port (about 1km)

The road parts from the river and a dyke is located along the river. Wet masonry protection has been constructed near the ferry port and the bank protection in front of the kilns has been constructed in brick masonry.

iv) Downstream of the Kukrahati ferry port to the Buffalo PT Column

The road parts from the river and a natural dyke is located along the river. The waterside line is about 150 m distant from the natural dyke except in front of the temple. Wave erosion has broken some parts of the natural dyke. At the brick kilns there is riverbank protection of brick masonry.

v) Evaluation

The riverbank condition is evaluated based on the above reconnaissance results as follows:

Alternative	Alt-A	Alt-B	Alt-C	Alt-D
Evaluation	A	A	C	B

Note: A: Excellent, B: Good, C: Fair

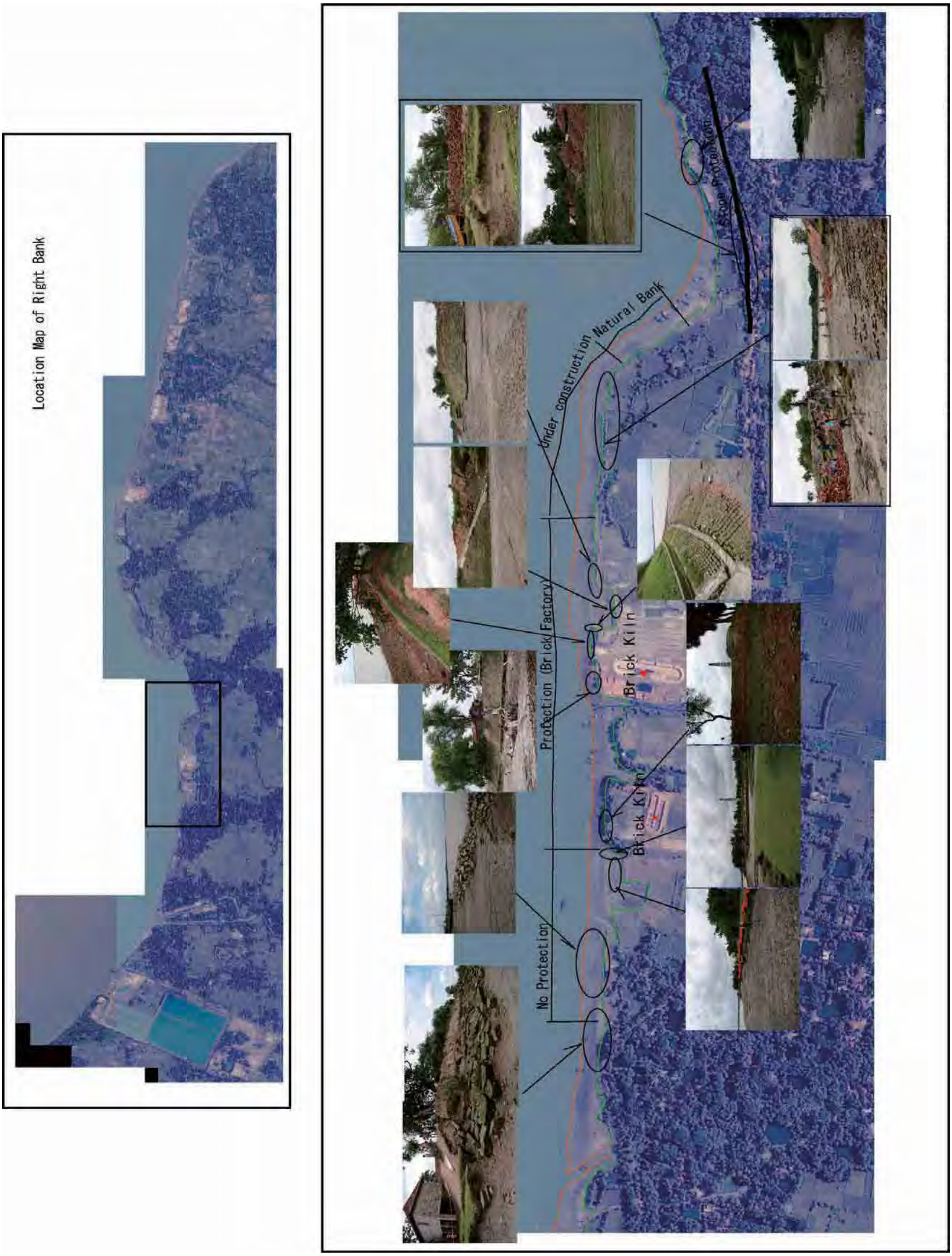


Figure 6.2.5 River Bank Protection Works at Right Bank (1/5)

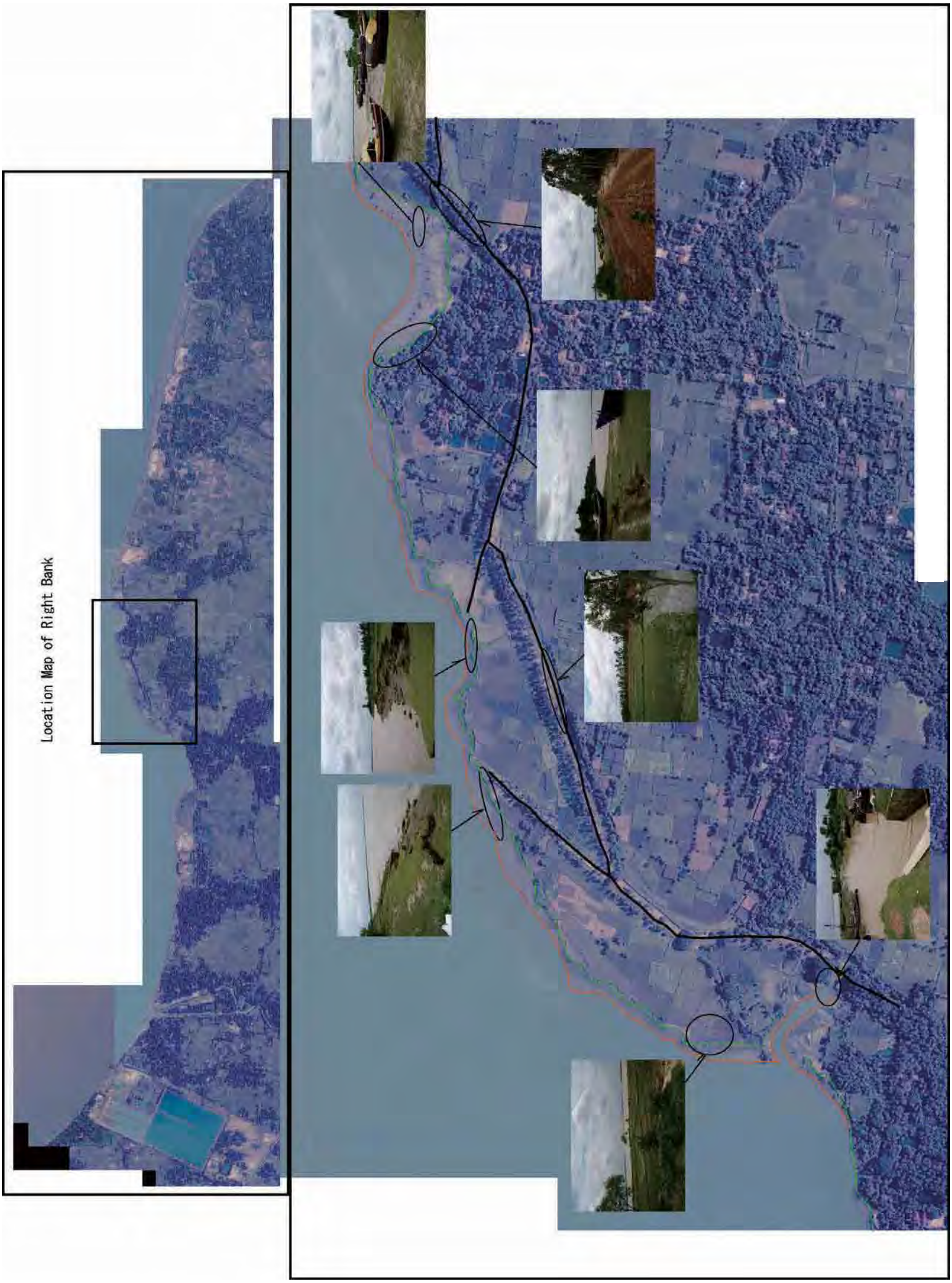


Figure 6.2.5 River Bank Protection Works at Right Bank (2/5)

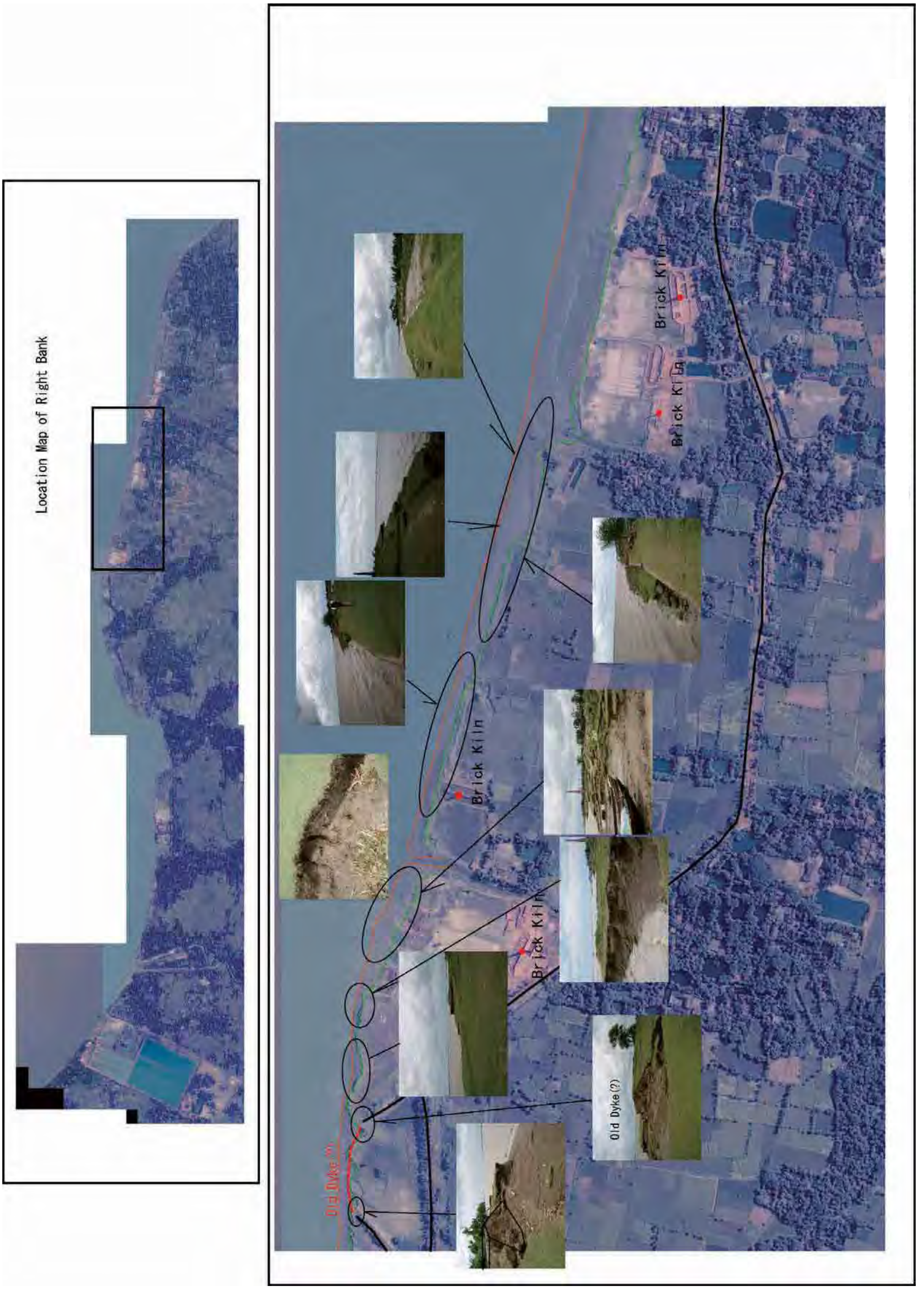


Figure 6.2.5 River Bank Protection Works at Right Bank (3/5)

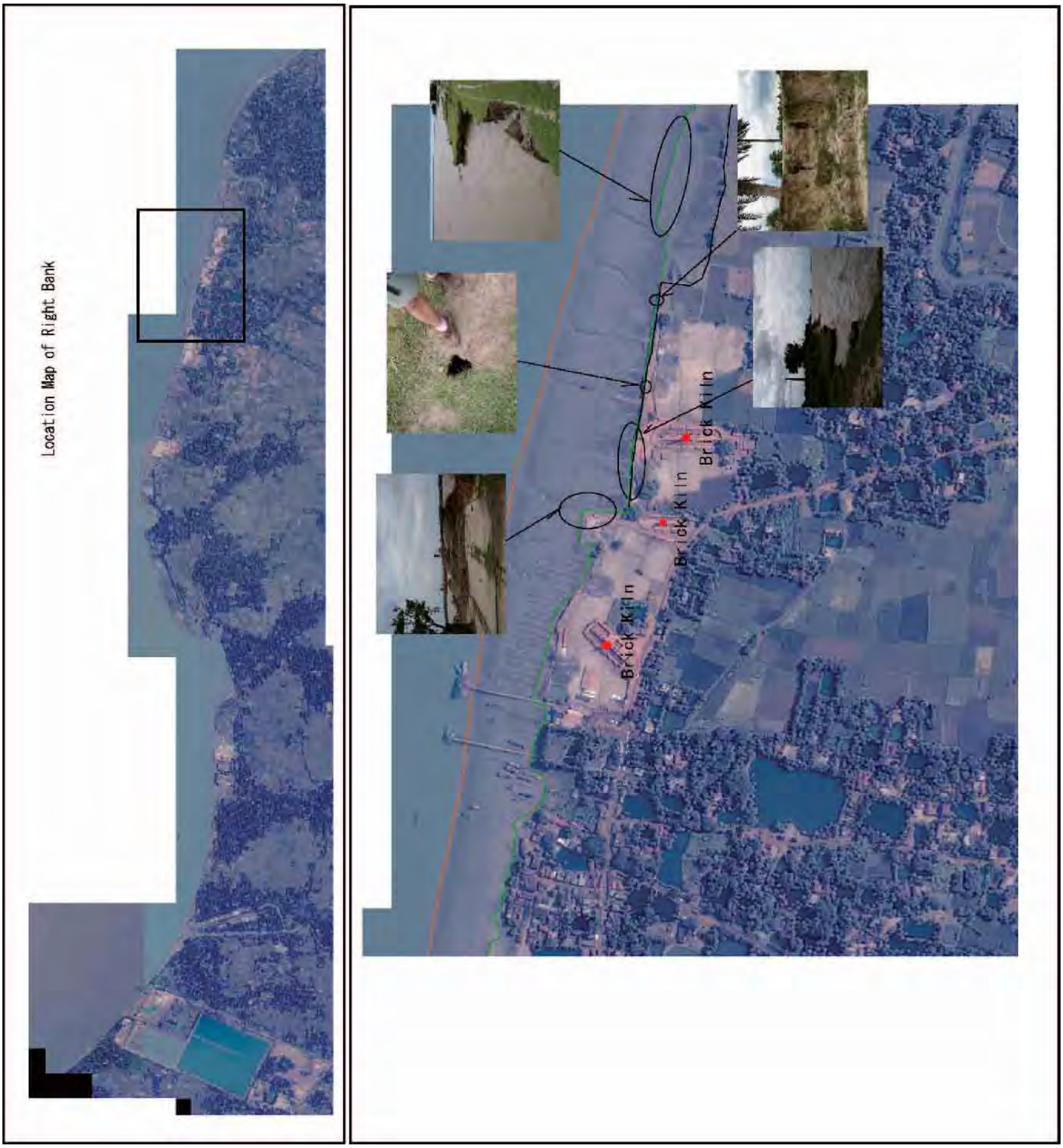


Figure 6.2.5 River Bank Protection Works at Right Bank (4/5)

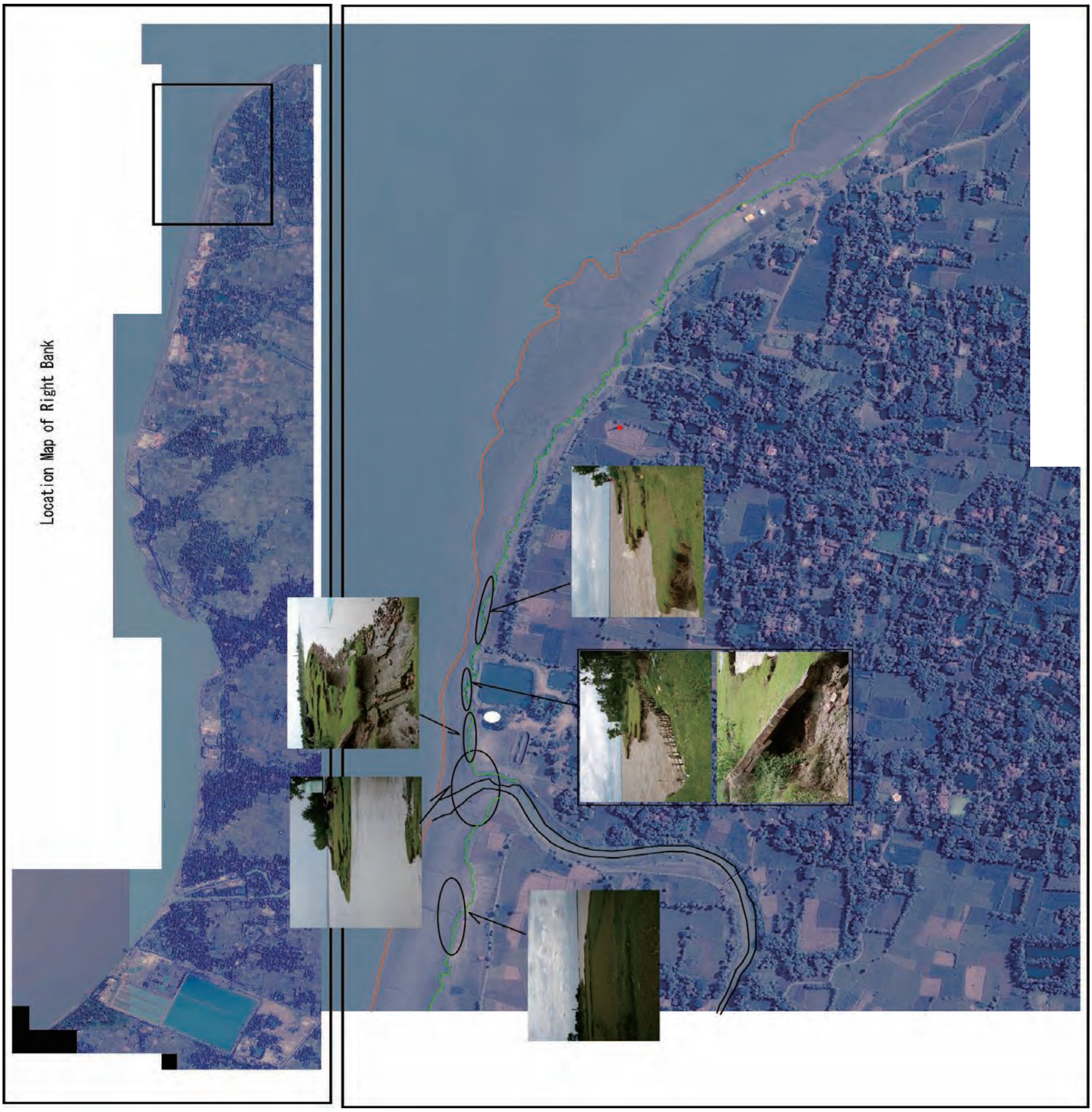


Figure 6.2.5 River Bank Protection Works at Right Bank (5/5)

b) Left bank (Raichak Side) (see Figure 6.2.6 (1)-(6))

The study area of the left bank is divided into five (5) locations, which are:

1) Confluence to about 4km downstream,

2) Up to about 500 m upstream of the ferry port,

3) Up to in front of the Hotel Rasison,

4) Up to the Kalicharanpur River, and

5) Downstream of the Kalicharanpur River.

i) Confluence to about 4km downstream

There is riverbank protection by wet brick masonry and gabion mattress provides the foot protection. There is no collapse of the riverbank protection.

ii) Up to about 500 m upstream of ferry port

There are six (6) brick kilns in this area. The riverbank protection is brick masonry. However, in some parts of the protection has collapsed due to erosion. Bamboo fencing and sand bagging is provided near the sluiceway.

iii) Up to in front of the Hotel Rasison

There are two (2) jetties and riverbank protection is provided by wet masonry. Sedimentation has occurred about 200m from Roy Chak ferry port, but there is no sedimentation in other locations. There are some temporary houses on the bank crest.

iv) Up to the Kalicharanpur River

There is an upper-class residential area on the protected land. Access between this area and river is interrupted by a fence. The riverbank protection is constructed in brick masonry.

v) Downstream of the Kalicharanpur River

There is no protection for about 1.2km from the confluence. High river velocity and waves have caused severe erosion in this area. There are many brick kilns in this area with brick masonry bank protection. In some locations there is wave erosion and sedimentation.

vi) Evaluation

The riverbank condition is evaluated based on the above reconnaissance results as follows:

Alternative	Alt-A	Alt-B	Alt-C	Alt-D
Evaluation	B	B	C	C

Note: A: Excellent, B: Good, C: Fair

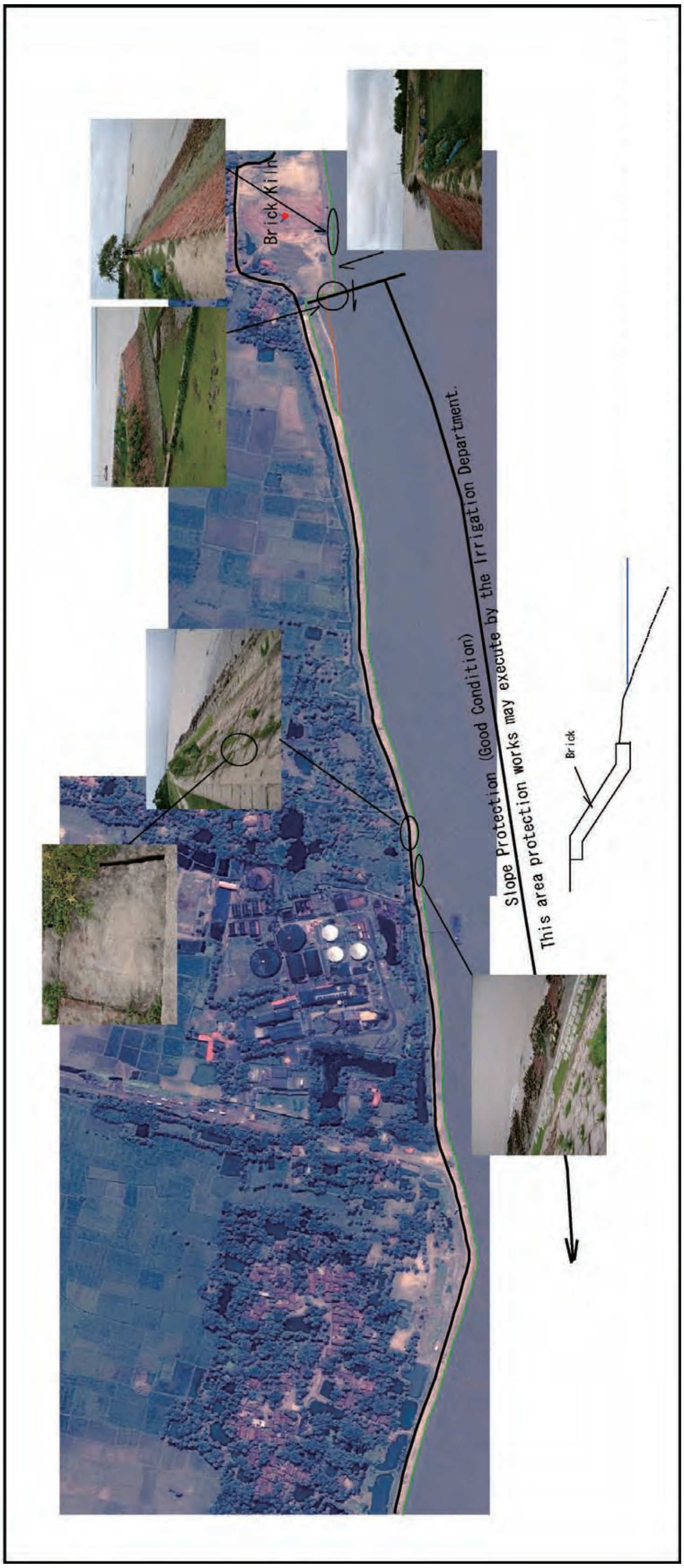


Figure 6.2.6 River Bank Protection Works at Left Bank (1/6)

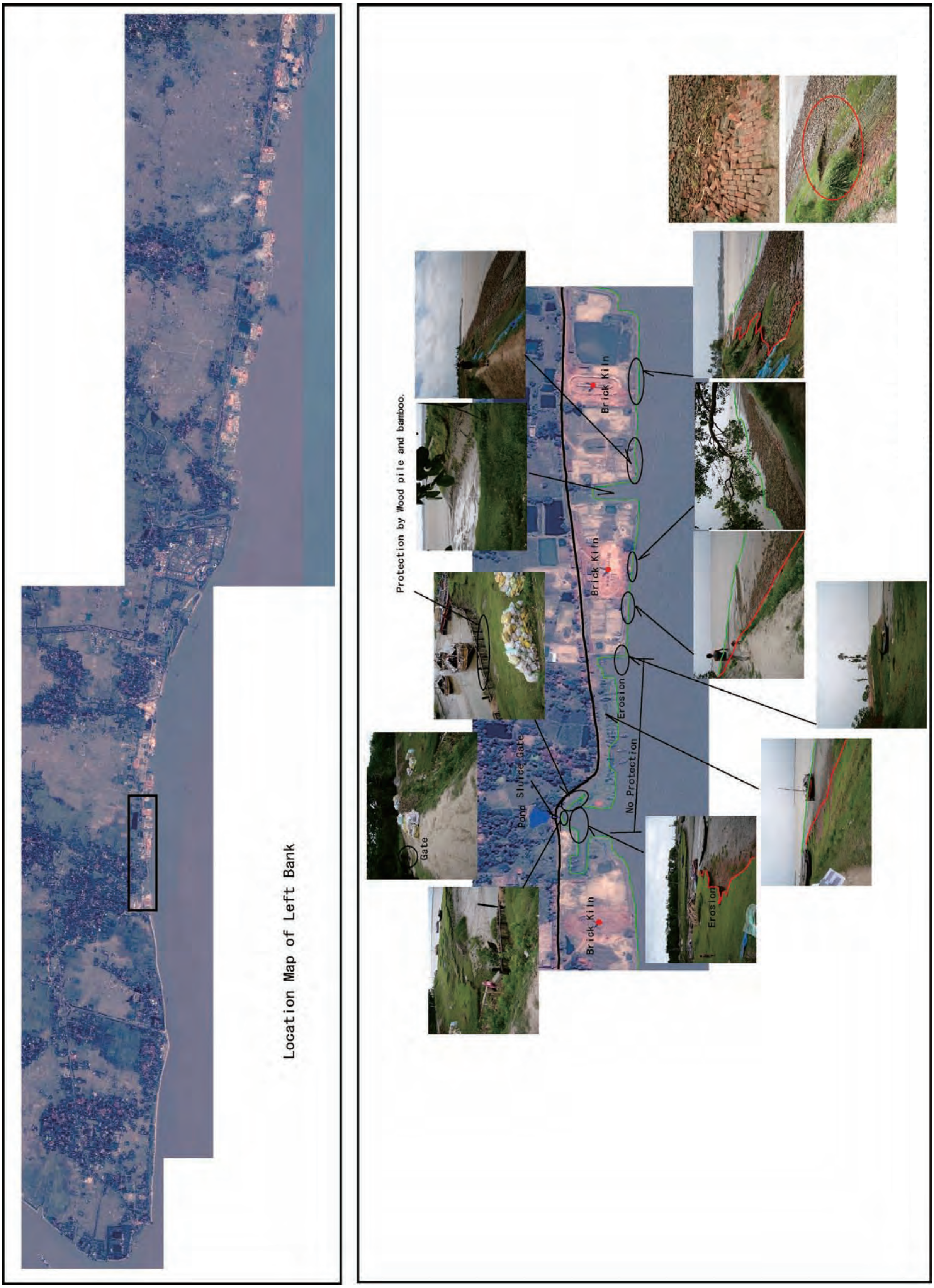


Figure 6.2.6 River Bank Protection Works at Left Bank (2/6)

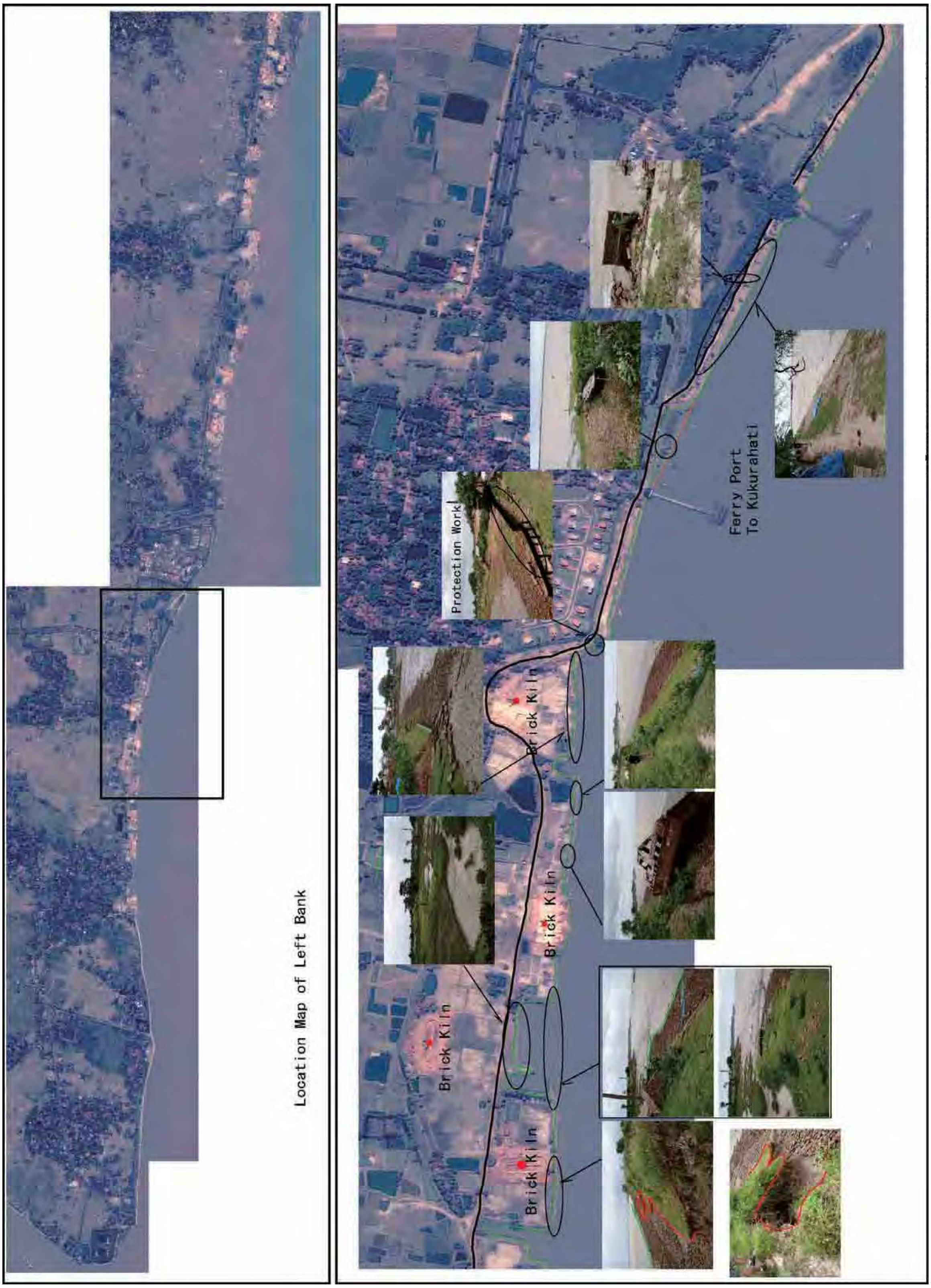


Figure 6.2.6 River Bank Protection Works at Left Bank (3/6)

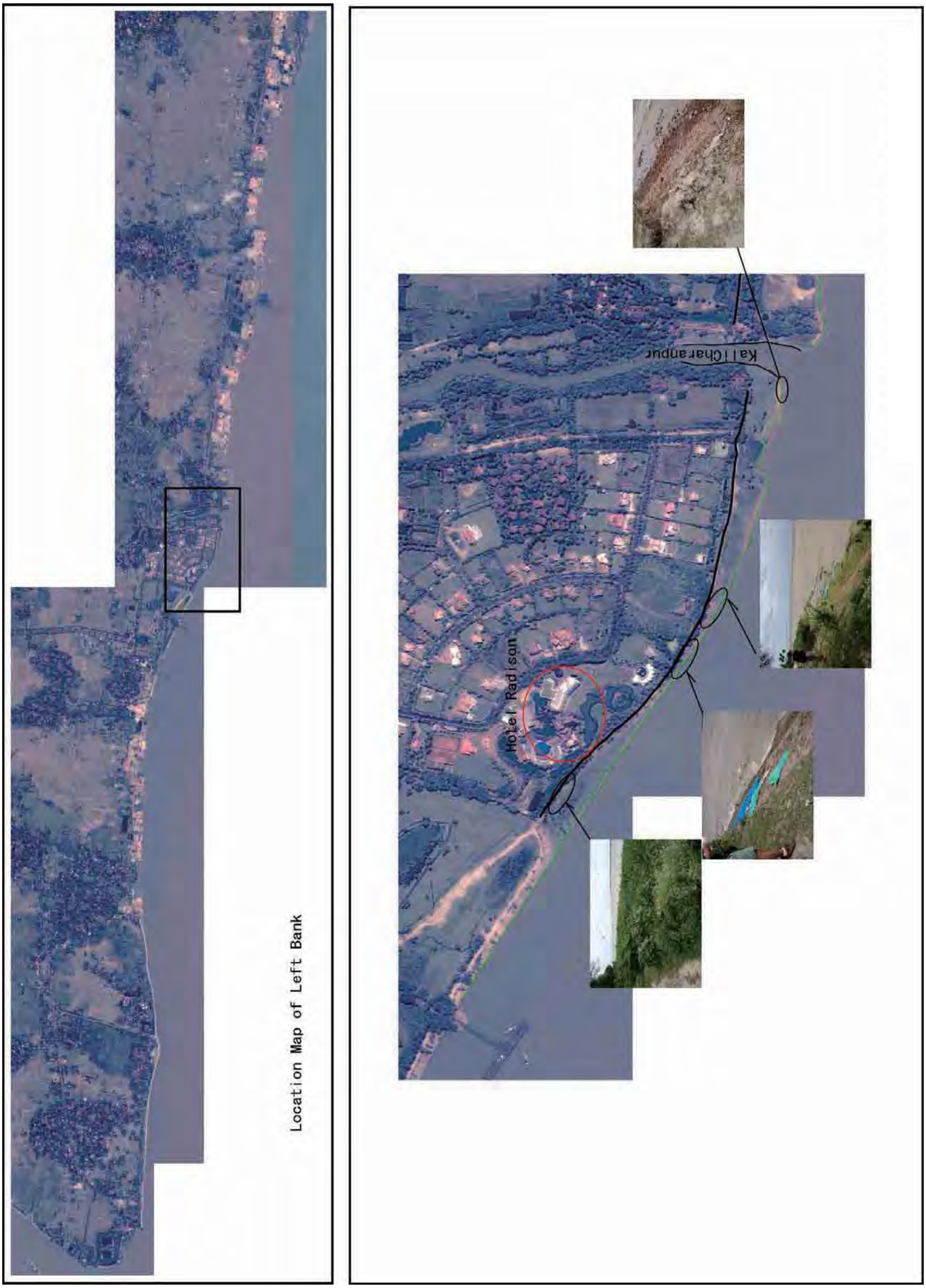


Figure 6.2.6 River Bank Protection Works at Left Bank (4/6)

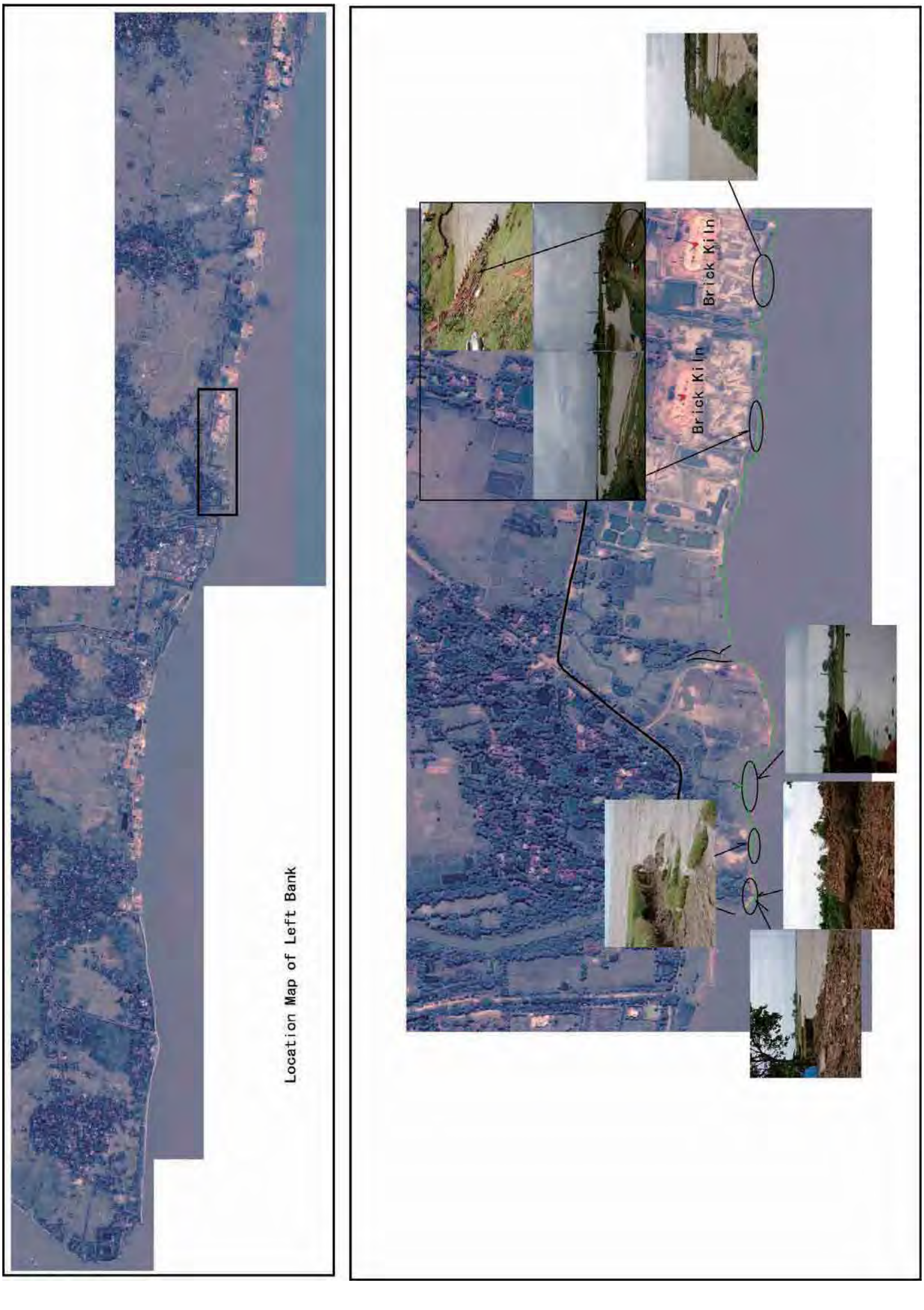


Figure 6.2.6 River Bank Protection Works at Left Bank (5/6)

Figure 6.2.6 River Bank Protection Works at Left Bank (6/6)

(5) Evaluation

A comprehensive evaluation has been carried out from a river engineering viewpoint.

Alternative	Alt-A	Alt-B	Alt-C	Alt-D
River Movement	B	B	C	C
Flow Direction	C	D	B	B
Bank Protection	B	B	C	C

Note: A: Excellent, B: Good, C: Fair, D: No good

Alternative B is not recommended from the flow direction. The bank protection at alternatives C and D are estimated as C. If wet brick masonry is provided to the bridge locations in this project, erosion problems will not be occurred.

6.2.2 Geotechnical Engineering

The existing boring data of three (3) projects has been obtained. One is at Haldia 20 km away in southeast from the project site. The second is for NH41 15 km away in the south. Another is for Rupnarayan River Crossing 15km away in east-northeast.

The boring logs for NH41 and Rupnarayan Crossing show a stable bearing strata below the depth of 30 m from the ground surface. On the contrary, the boring logs in Haldia show so big a deviation that the stable bearing stratum is not verified and beneath the relatively dense sandy soil, a soft to medium clay is confirmed.

Therefore, at the project site it needs to be verified that a stable bearing strata exists andthat the compressive clay beneath the bearing strata will not consolidate.

6.2.3 Topography

The project area is completely flat. Therefore features, other than topographical ones, such as housing, monuments, places of worship, cremation or burial grounds, utility lines, existing road and railway lines, streams, rivers, canal crossings and drainage are more critical for the planning of the access roads.

6.2.4 Highway Engineering

(1) Features of Alternatives

The requirements for connecting to the existing road network have been evaluated for the crossing location alternatives:

Table 6.2.1 Evaluation from a Road Network Context

Alternatives	Evaluation
Alt-A	This alternative is distant from the existing major road NH 117 and Haldia Industrial Complex, which generates much traffic. This forces vehicles to travel longer route. In addition, this crosses the widest part of the river.
Alt-B	This alternative crosses the middle of the straight channel while skewed to the river. The skew brings about inefficiency in the construction cost.
Alt-C	This alternative has a shorter access to existing major road NH 117. Some villages along the river need to be relocated on the Raichak side. Bridge length is the shortest to cross the river indicating efficiency in the construction cost.
Alt-D	This has almost the same characteristics as alternative C showing the shortest access to NH 117. Some villages along the river need to be relocated on the Kukrahati side.

(2) Future Road Development Context

a) Future Road Network Consideration

The bridge will be connected to NH117 near Sarisha on the Raichak side and to NH41 on the Kukrahati side. A high volume of traffic is expected to use the bridge crossing the river due to the short distance between Haldia and Kolkata though there has not been a forecast of traffic demand so far. In other words, widening of NH117 is required to cater to the future traffic after the completion of the bridge. On the other hand, there are several large villages along the NH117 between Sarisha and Kolkata such as Sarisha, Sirakol, Fatepur, Amtala and Joka (see **Table 6.2.2**). In addition, many houses and shops are also located facing the road even on the stretches outside these large villages. It is very difficult to widen the NH117 between Sarisha and Joka according to the current circumstances.

Table 6.2.2 Village Population along the Route

Unit Persons

Side	Village/Town	Population
Raichak Side	Raichak	1,091
	Sarisha	3,690
	Fatepur	7,330
	Sirakol	8,661
	Amtala	7,603
	Daulatpur	5,136
	Joka	7,670
	Kholkhali	2,015
	S. Total	43,196
Kukrahati Side	Chaitanyapur	2,459

Source: Population census in 2001

Several road development projects are observed in the study area. The Eastern and Southern Expressway is one of the focal road development projects together with the Barasat Bypass with a view to relieving the current and future traffic congestion around Kolkata City. In addition, the plan for a NH 117 bypass has been examined in the past under a north-south corridor development scheme. Taking the existing narrow width of NH117 and built-up areas into consideration, a NH117 bypass development is one of prerequisites to develop the bridge between Raichak and Kukrahati.

All these facts indicate that a higher score will be given to the route passing on the east side of Sarisha. This will enable the approach road of the bridge to easily connect to a future NH117 bypass. This will minimize additional resettlement, which may accrue from a new extension development to connect between the approach road of the bridge and a NH 117 bypass on the Raichak side.

b) Interchange Development

The approach road of the bridge needs to be connected to NH117 near Sarisha on the Raichak side and NH 41 on the Kukrahati side. As NH117 and NH41 are two of the major roads in West Bengal, an interchange needs to be developed at both connecting points. It will, however, be discussed in the next stage because it does not affect the consideration of the crossing-location alternatives at this moment.

(3) Geometric Design Criteria for Forthcoming Examination

a) Comparison between Standards

Design criteria and the standards for roads are described in codebooks issued by the Indian Road Congress (IRC) in India. Geometric design criteria are also mentioned in Geometric Design Standards for Rural Highways, IRC 73-1980 (see **Table 6.2.3**).

Table 6.2.4 shows a comparison between the Indian criteria and those of other major countries. The only apparent substantial difference between the criteria is in the longitudinal gradient. The Indian code independently describes the longitudinal gradient apart from design speed, i.e. 3.3 % for national and state highways under the condition of plain terrain while the standards in other countries usually describe the longitudinal gradient in relation with the design speed. Considering traffic conditions in India and that many overage buses and trucks can be observed, it seems reasonable to take a longitudinal gradient of 3.3 % for the bridge and approach road.

Table 6.2.3 Major Design Components in Indian Code

Component	No.	Terrain Classification	Unit	
Basic Information	1	Plain	%	0-10
	2	Rolling	%	10-25
	3	Mountainous	%	25-60
	4	Steep	%	More than 60

Item		Case	Ruling Design Speed	Minimum		
Design Speed (NH & SH)		km/h	100	80		
Cross Section	Land Width (NH & SH)	Case	Plain			
			Open area		Built-up area	
			Normal	Range	Normal	Range
		m	45	30-60	30	30-60
	Building and Control Lines for NH & SH	Case	Plain and Rolling Terrain			
			Open Area		Built-up Area	
			Building line	Control line	Building line	
		m	80	150	3-6	
	Road Width for NH & SH	m	12	Carriageway+hard & soft Shoulder		
	Width of Carriageway for 2 Lanes	Case	Without raised curb	Raised curb		
		m	7	7.5		
	Shoulder Width	Case	For one direction			
		m	2.5	(12-7)/2		
	Median Width	Case	Minimum desirable	Reduced to	Not less than	
		m	5	3	1.2	
Sight Distance	Stopping Sight Distance	Case	DS 100km/H	DS 80km/h		
		m	180	120		
Horizontal Curve	Radius (plain/D Speed 80km/h)	Case	Ruling Min.(100km/h)	Absolute Min.(80km/h)		
		m	360	230		
Gradients	Longitudinal (plain)	Case	Ruling gradients	Limiting gradient	Slow moving traffic	
		%	3.3	5	2	
Vertical Curve	L > Stopping Distance*1	Case	DS (100km/h)	DS 80km/h		
		m	486	216		

Note: *1) $L=NS^2/4.4$. N:Deviation angle. S:Safe stopping distnace (120m for the design speed of 80km/h) L:216m under 3.3% grade

Table 6.2.4 Comparison between Major Geometric Design Standards

No.	Component	Unit	India	AASHTO	Asian Hwy	Japan
1	Terrain		Plain	Level	Class II/level	Flat
2	Access Control		-	-	-	
3	Design Speed	km/h	80	100-110	80	80
4	Width of Lane	m	3.5	3.6	3.5	3.5
5	Width of Shoulder	m	2.5	2.4	3.0	1.25
6	Min. Horizontal Curve	m	230	330	215	280
7	Max. Longitudinal Grade	%	3.3	3	4	4

Source: IRC, AASHTO for rural highways, Asian Highway Standard and Japanese ordinance.

Through the above comparison, the longitudinal gradient of 3.3% is adopted for the bridge and approach road due to local conditions in India.

The design speed of 80 km/h was proposed for the bridge and approach road due to the following reasons:

- The bridge and approach road will be located in road network isolated from the arterial national highway grid such as NH2 and 6;
- Minimization of the construction cost of the bridge and approach road is required;
- Many large vehicles such as truck traffic are expected to use the bridge; and
- Minimization of resettlement and affected persons by the project is required.

The route of the approach road needs to pass through built-up areas, especially on the Raichak side. Adoption of small radius bends will result in both less construction cost and minimum resettlement. In other words, if a design speed of 100 km/h was adopted the cost would increase and there would be more resettlement and people affected by the project.

b) Proposed Geometric Design Criteria

After the examination mentioned above, the following geometric design criteria were proposed for the route alignment of the project (see **Table 6.2.5**). The design standard for the bridge itself will be discussed later.

Table 6.2.5 Proposed Geometric Design Criteria

Components	Criteria	Remarks
Terrain condition	Plain	
Design speed	80 km	
Longitudinal gradient	3.3%	
Land width	45 m	
Minimum horizontal radius	230 m	
Building control line	80 m (Open area)	3-6m (built-up area)
Vertical curve	216 m	
Road width		Carriageway + hard & soft Shoulder
Width of carriageway	7 m	Without raised curb
Shoulder width	2.5 m	Based on L=NS2/4.4
Median width	5 m (approach road)	
Stopping sight distance	120 m	

6.3 Environmental and Social Impact Evaluation of each Alternative

As discussed in Chapter 5, the number of houses that will be affected by the approach roads of each crossing alternative are roughly estimated at the following:

Alternative A: About 10 on Raichak side and 20 on Kukrahati side

Alternative B: About 25 on Raichaku side and 15 on Kukrahati side

Alternative C: 10 or less on Raichak side and 5 or less on Kukrahati side

Alternative D: About 10 on Raichak side and 10 or less on Kukrahati side