Ministry of Power, Energy and Mineral Resources
The People's Republic of Bangladesh

Preparatory Survey on The Natural Gas Efficiency Project in The People's Republic of Bangladesh

FINAL REPORT

APPENDIX (1/2)

March 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD.

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Appendix 1:

PIPELINE NETWORK ANALYSIS

(BGFCL)

Appendix 1. Pipeline Network Analysis

Summary

Natural gas is one of indigenous energy resources in Bangladesh and is significantly contributing the economic growth of the country. However, in recent years, the supply of natural gas has been insufficient for the domestic demand which has rapidly been increasing with the growth of economy.

In this pipeline network analysis, flow simulation is carried out to verify capacity of gas transmission and distribution pipelines in Bangladesh on the basis of pipeline data such as gas supply and demand forecast, operating conditions of pipeline network, currently undergoing and planned projects by using flow simulation software, "PIPESIM". The pipeline capacity is analyzed for future pipeline facility planned in 2015, 2020, 2025 and 2030.

Prior to the simulation, current pipeline network model as of 2013 was developed in accordance with several information collected through site survey and hearing to GTCL. And pipeline network diagrams for 2015, 2020, 2025 and 2030 were prepared every five (5) years in consideration of future pipeline projects that are currently under construction or planned in near future. Refer to Figure 1.1-1 to 1.1-4.

In order to establish simulation model for the pipeline network, current pipeline data was calibrated so as to balance operating conditions such as flow rate, operating pressure and temperature at all the points on the network based on some operating conditions available at this moment. All the input data such as pipeline data, operating conditions mentioned above were described in Chapter 2 and calibration using its current operating data is carried out in Chapter 4.

Using the calibration result, the network analysis was conducted for the above future cases. In this analysis, total gas supply volume forecasted in future was assumed to be equal to total gas demand.

As the results of this study, considerable bottlenecks of the pipeline system are checked and an appropriate improvement plan was proposed for the next engineering stage as an exsample.

Simulation result of the pipeline network analysis in 2015, 2020, 2025 and 2030 is summarized below:

1. Simulation Result

1.1 2015 CASE

As the result of the gas pipeline network simulation for the year 2015, following bottlenecks were revealed. Refer to Figure 1.1-2.

(1) Bottleneck 1

Existing 24" pipeline between Dhanua (N57) and Elenga (N60) does not have enough capacity to transport required amount of demand gas. Therefore, all the delivery points (e.g. N61, 69, 76, 77, 78, 79, 81, 83, 139) located downstream of Elenga cannot supply gas with proper pressure level to end-users.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate of the existing Dhanua–Elenga pipeline is expected to be huge in this year because all the gases from Bibiyana Gas Field (N13) by 36'' pipeline and Monohordi by 24'' & 30'' pipelines are gathered at Dhanua and are transported toward Elenga. Accordingly, it is considered that increment of the flow rate leads to enormous pressure drop in this pipeline section.

2) Countermeasures

Installation of additional Dhanua–Elenga pipeline (duplication of pipeline) or additional booster compressor in Dhanua

As for the above bottleneck, duplication of Dhanua–Elenga pipeline is planned by the year 2017. Accordingly, the additional booster compressor installation scenario for the pipeline section was applied to solve this bottleneck.

According to installation of the compressor, required suction pressure of 650 psig in Elenga compressor station can be achieved, and also existing 24" Dhanua–Elenga pipeline can transport required amount of gas to Elenga without new 30" pipeline mentioned above. In this case, discharge pressure of 1,138 psig is required for the compressor in Dhanua.

(2) Bottleneck 2

Existing 24" N-S Pipeline between N02 and Muchai (N09) does not have enough capacity to transport required amount of demand gas.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in the pipeline section increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2015. It is considered that this phenomenon leads to large pressure drop in this pipeline section.

2) Countermeasures

Maintaining higher production pressure at each well located upstream of Muchai

(3) Bottleneck 3

As for the above "Bottleneck 1", further bottleneck was revealed by installation of the booster compressor in Dhanua.

After installation of the booster booster compressor, suction pressure in Elenga compressor station can fully improve; nevertheless two (2) delivery points (Jessore(N81) and Khulna(N83)) located downstream of Elenga still cannot supply gas with proper pressure level to end-users.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Discharge pressure of 1,000 psig in Elenga compressor station is not enough to deliver the gas to the delivery points (N81, N83).

2) Countermeasures

Installation of booster compressor at upstream of Jessore. Alternatively, discharge pressure (1,138 psig) estimated for the Dhanua booster compressor may be raised so as to cover arrival pressure required at Jessore (N81) and Khulna (N83).

1.2 2020 CASE

As the result of the gas pipeline network simulation for the year 2020, following bottlenecks were revealed. Refer to Figure 1.1-3.

(1) Bottleneck 1

Total capacity of 1,200 MMSCFD in Muchai compressor station is smaller than simulated flow rate of 1,500 MMSCFD.

Moreover, total capacity of 1,500 MMSCFD in Ashuganj compressor station is smaller

than simulated flow rate of 1,716 MMSCFD. Therefore, flow rate required at the each compressor station cannot be covered by the existing compressors.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in all the pipeline located upstream of Muchai and Ashuganj compressor station increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2020. Accordingly, it is considered that increment of the flow rate exceeds rated capacity of the compressor stations.

2) Countermeasures

Installation of additional compressor in both Muchai and Ashuganj compressor station

(2) Bottleneck 2

Arrival pressure of 206.16 psig expected at Ashuganj compressor station is lower than rated suction pressure (600 psig) of the existing compressor. In case of Muchai and Elenga compressor stations, arrival pressure is a little bit smaller than rated pressure of the each existing compressor.

Accordingly, rated discharge pressure cannot be obtained downstream of the three (3) compressor stations.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Similar to “Bottleneck 1”, gas flow rate expected upstream of the three (3) compressor stations increases due to increment of gas production volume of each gas field that is forecasted in 2020. Accordingly, it is considered that this phenomenon leads to large pressure drop in this pipeline section.

2) Countermeasures

Installation of booster compressor at upstream of Muchai

(3) Bottleneck 3

The following pipelines do not have enough capacity to transport required amount of demand gas.

- Pipeline between Dhanua (N57) and RPCL Mymensing (N58)

- Pipeline between N136 and Ashulia (N59)
- Pipeline between N136 and Aminbazar (N122)
- Pipeline between Jessore (N81) and Khulna (N83)
- Pipeline between N135 and TGTCDL Demra (N110)
- Pipeline between N48 and Haripur (N112)

Therefore, all the delivery points located on the above pipeline sections cannot supply gas with proper pressure level to end-users. The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in the above pipelines increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2020. Accordingly, it is considered that increment of the flow rate exceeds capacity of the pipelines.

2) Countermeasures

Due to increment of gas supply volume, bottlenecks occurs in several delivery points on pipeline network. In this case, it is preferable to install booster compressor in order to simultaneously improve transmission capacity of all the pipelines. In case the booster compressor is additionally installed in Ashuganj compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,074 psig.

As for the bottleneck between Jessore (N81) and Khulna (N83), if the booster compressor is additionally installed in Elenga compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,021 psig.

(4) Others

All gas flow lines that transfer gas produced in each gas field must have a capacity enough to send the gas into transmission pipeline. Accordingly, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if the gas production rate increases for future gas demand.

This issue is not a bottleneck at this moment, however proper measures are to be taken so as to overcome the transmission pipeline pressure.

1.3 2025 CASE

As the result of the gas pipeline network simulation for the year 2025, following bottlenecks were revealed. Refer to Figure 1.1-4.

(1) Bottleneck 1

Total capacity of 1,200 MMSCFD in Muchai compressor station is a little bit smaller than simulated flow rate of 1,206 MMSCFD in 2025. Therefore, the flow rate required at the compressor station cannot be covered by the existing compressors.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in all the pipeline located upstream of Muchai compressor station increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2025. Accordingly, it is considered that increment of the flow rate exceeds rated capacity of the compressor stations.

2) Countermeasures

Installation of additional compressor in Muchai compressor station

(2) Bottleneck 2

The following pipelines do not have enough capacity to transport required amount of demand gas.

- Pipeline between Dhanua (N57) and RPCL Mymensing (N58)
- Pipeline between N136 and Ashulia (N59)
- Pipeline between N136 and Aminbazar (N122)
- Pipeline between Jessore (N81) and Khulna (N83)

Therefore, all the delivery points located on the above pipeline sections cannot supply gas with proper pressure level to end-users. The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in the above pipelines increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2025. Accordingly, it is considered that increment of the flow rate exceeds capacity of the pipelines.

2) Countermeasures

Due to increment of gas supply volume, bottlenecks occurs in several delivery points on pipeline network. In this case, it is preferable to install booster compressor in order to simultaneously improve transmission capacity of all the pipelines. In case the booster compressor is additionally installed in Ashuganj compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,098 psig.

As for the bottleneck between Jessore (N81) and Khulna (N83), if the booster compressor is additionally installed in Elenga compressor station, discharge pressure at the station should be increased from 1,000 psig to 1.004 psig.

(3) Bottleneck 3

Existing 24" and 30" pipeline between Dhanua (N57) and Elenga (N60) do not have enough capacity to transport required amount of gas.

The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in the above pipelines increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2025. Accordingly, it is considered that increment of the flow rate exceeds capacity of the pipelines.

2) Countermeasures

Installation of additional booster compressor at upstream of Elenga compressor station

(4) Others

Similar to "Others" described in 2020 CASE, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if the gas production rate increases for future gas demand.

This issue is not a bottleneck at this moment, however proper measures are to be taken so as to overcome the transmission pipeline pressure.

1.4 2030 CASE

As the result of the gas pipeline network simulation for the year 2030, following bottlenecks were revealed. Refer to Figure 1.1-4.

(1) Bottleneck 1

The following pipelines do not have enough capacity to transport required amount of demand gas.

- Pipeline between Dhanua (N57) and RPCL Mymensing (N58)
- Pipeline between N136 and Ashulia (N59)
- Pipeline between N136 and Aminbazar (N122)
- Pipeline between Jhinaidah (N79) and Khulna (N83)

Therefore, all the delivery points located on the above pipeline sections cannot supply gas with proper pressure level to end-users. The reasons and countermeasures against the bottleneck are as follows.

1) Reasons

Gas flow rate in the above pipelines increases due to increment of gas production volume of each gas field that was assumed so as to correspond to gas demand forecasted in 2030. Accordingly, it is considered that increment of the flow rate exceeds capacity of the pipelines.

2) Countermeasures

Due to increment of gas supply volume, some bottlenecks occur in several delivery points on pipeline network. In this case, it is preferable to install booster compressor in order to simultaneously improve transmission capacity of all the pipelines. In case the booster compressor is additionally installed in Ashuganj compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,107 psig.

As for the bottleneck between Jhinaidah (N79) and Khulna (N83), if the booster compressor is additionally installed in Elenga compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,066 psig.

(2) Others

Similar to “Others” described in 2020 CASE, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if the gas production rate increases for future gas demand.

This issue is not a bottleneck at this moment, however proper measures are to be taken so as to overcome the transmission pipeline pressure.

2. Conclusions

This pipeline network analysis was conducted using flow simulation model which was established based on several assumptions. Accordingly, it seems that some differences between simulation result and actual phenomenon might occur by lack of information and the assumptions. Therefore, it is indispensable that all the simulation results are reviewed carefully based on sufficient data and proper assumptions.

Items to be reviewed in the next engineering stage are as follows:

- *Supplement of lack of information*
  - *All pipeline data such as pipe size, wall thickness, and length for the existing and future pipelines*
  - *Pipeline elevation on all pipeline routes*
  - *Data and information for valves and fittings on the gas pipeline network*
- *Review of study assumptions*
  - *Current gas production volume in each gas field*
  - *Current gas delivery volume to each end-user*
  - *Gas supply and demand forecast*
  - *Assumptions of temperature conditions such as soil temperature, gas intake temperature of each gas field*
  - *Assumptions of pipeline friction factor*

And the following issues are recommended for future provision:

(1) For improvement of accuracy on the pipeline network simulation, it is preferable that operating conditions (pressure and flow rate) at several delivery points such as gas terminal, gas manifold station and pipeline blanch point on the pipeline network are reflected faithfully in the simulation model as much as possible. Most effective facility expansion plan is to be developed comprehensively based on the simulation result with sufficient accuracy.

(2) This study was conducted with several assumptions to establish simulation model of pipeline network. All the assumptions shall be reviewed in the next engineering phase.

(3) It is recommended that tight supply situation of gas should be improved before reinforcement of existing gas transmission facility.

(4) Gas supply forecast will fall much below gas demand from around 2021. Therefore, it is recommended that further gas development plans sufficient to the future demand is established and completed by the year.

As the result of this flow simulation, some bottlenecks were found on future pipeline facility in case of applying a delivery pressure of above 350 psig as an evaluation criteria. However, according to GTCL information, some parts of existing pipeline facility has been operated below 350 psig for long periods of time and gas delivery has been done for each end-user successfully without any trouble.

Accordingly, if minimum delivery pressure lower than the 350 psig can be allowed between GTCL and each end-user, several bottlenecks stated in this simulation result may be solved easily. Therefore, critical delivery pressure at each end-user's facility should be confirmed in detail in order to develop optimum facility expansion plan in future.

Therefore, the minimum delivery pressure should be also added to "*Items to be reviewed in the next engineering stage"* above mentioned.

Chapter 1 Introduction

1.1 General

Natural gas is one of indigenous energy resources in Bangladesh and is indispensable for the economic growth of the country.

However, in recent years, supply of the natural gas has been insufficient for the demand which has rapidly been increasing with the growth of economy.

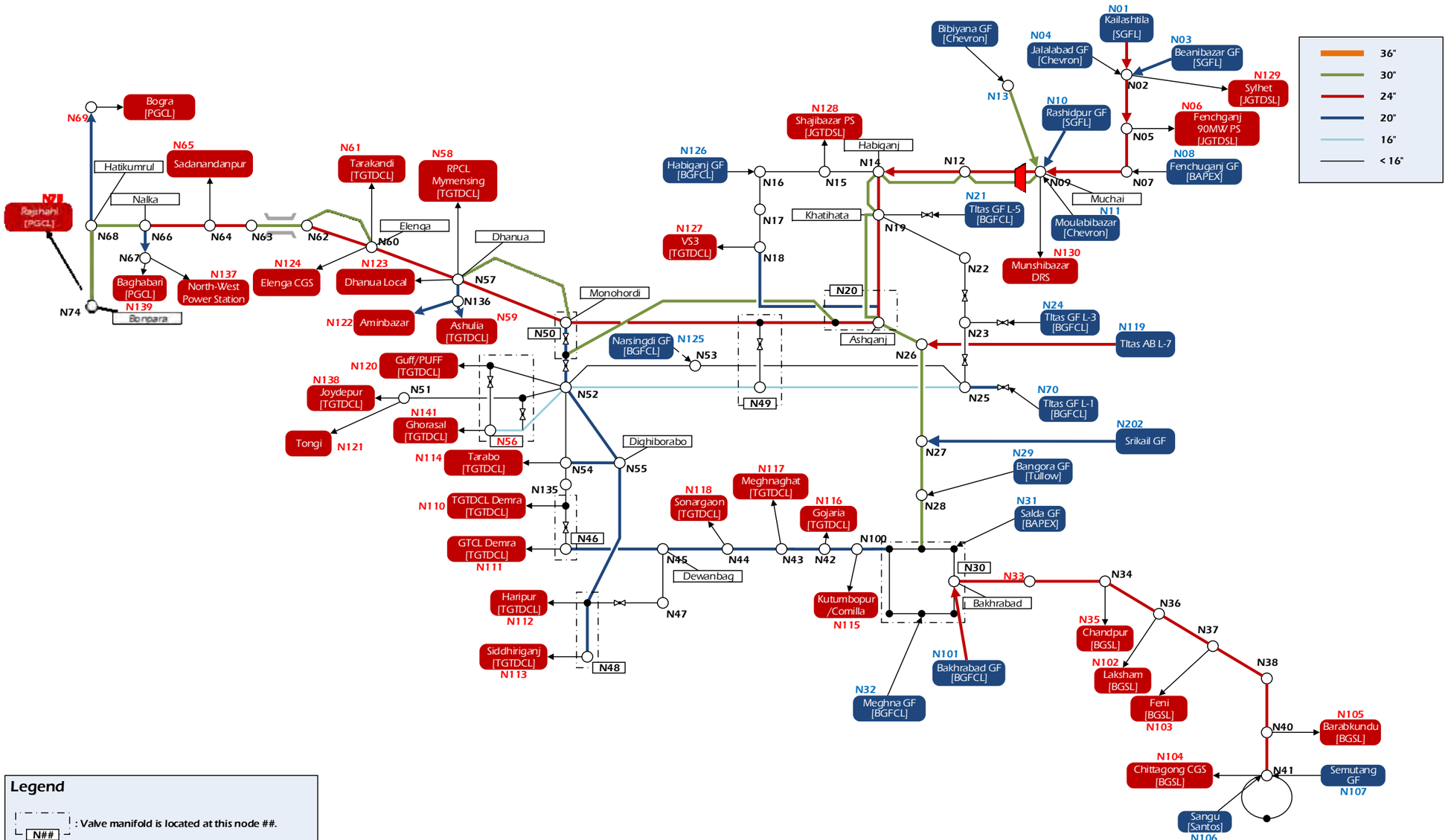
On the basis of the above situation, this pipeline network analysis is carried out to verify pipeline capacity necessary for the demand. As for bottleneck of the pipeline system that is found as results of the analysis, necessary measures are proposed for future provision. Consequently, recommendations and issues to be clarified in the next engineering stage are reported as the conclusion of this pipeline network analysis.

1.2 Pipeline Network in Bangladesh

In order to establish the pipeline network model, current pipeline network diagram (2013) is prepared as a base case based on the latest information collected in site survey. Refer to Figure 1.2-1.

In addition to the base case, pipeline network diagrams for 2015, 2020, 2025 and 2030 are also prepared every five (5) years in consideration of future pipeline projects that are currently under construction and/or planned in near future. Information of the future pipeline projects which are actually planned or relatively practical at this moment were mainly collected from GTCL and reflected on the each pipeline network diagram. Impractical or suspended plans due to governmental policy and other reasons were excluded from the diagrams. The diagrams for the future cases are shown in Figure 1.2-2 to Figure 1.2-4.

On the above four (4) pipeline network diagrams, pipeline nodes dividing the respective pipeline sections are provided with an individual node number on the each figure. As for 2025 and 2030, since any future construction plan is not scheduled at this moment, the future pipeline network diagrams for the said period are unified into one (1) sheet of Figure 1.2-4.



Legend

N## : Valve manifold is located at this node ##.

Pipeline Network Diagram

Present (at 2013)

Figure 1.2-1 Pipeline Network Diagram in 2013

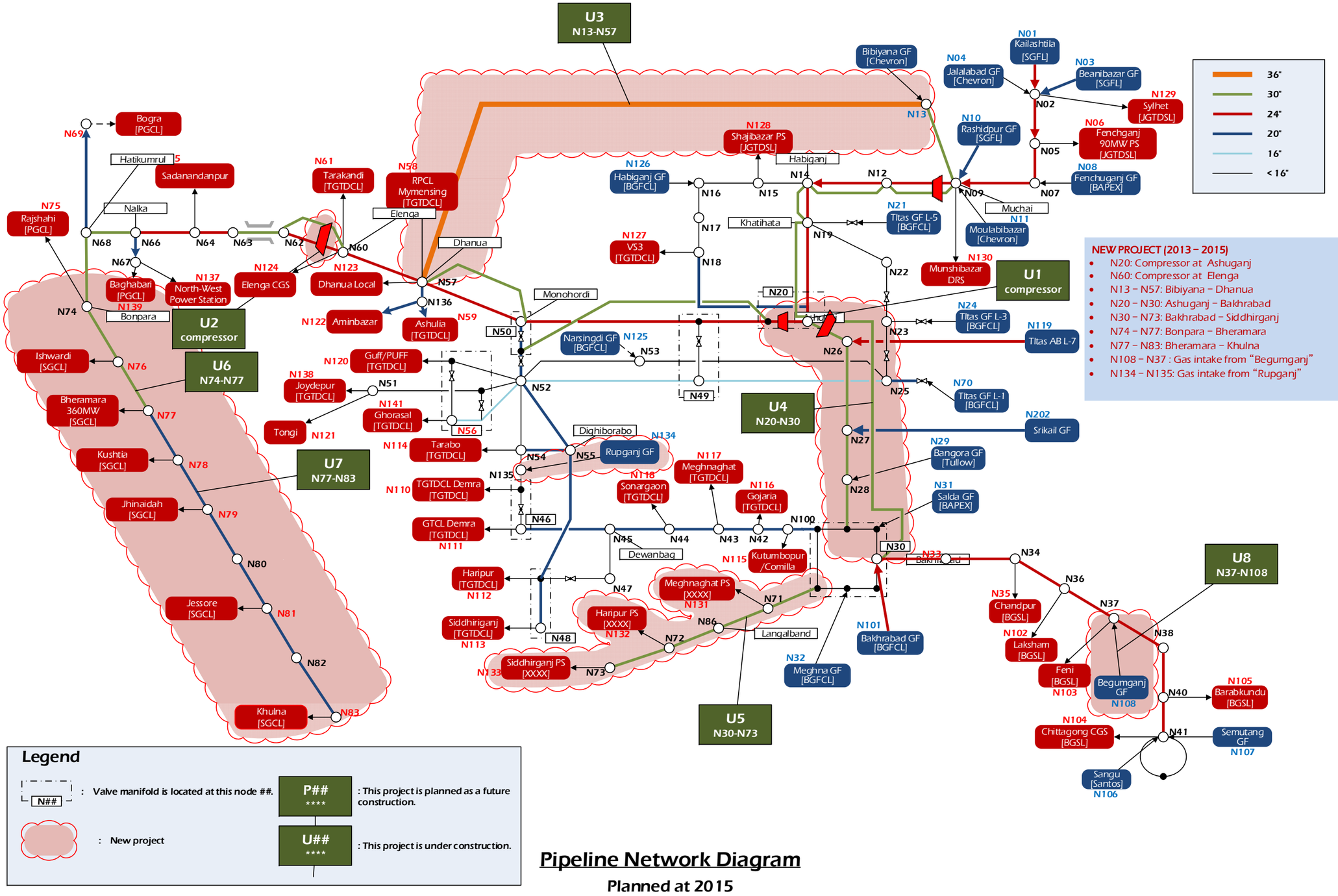
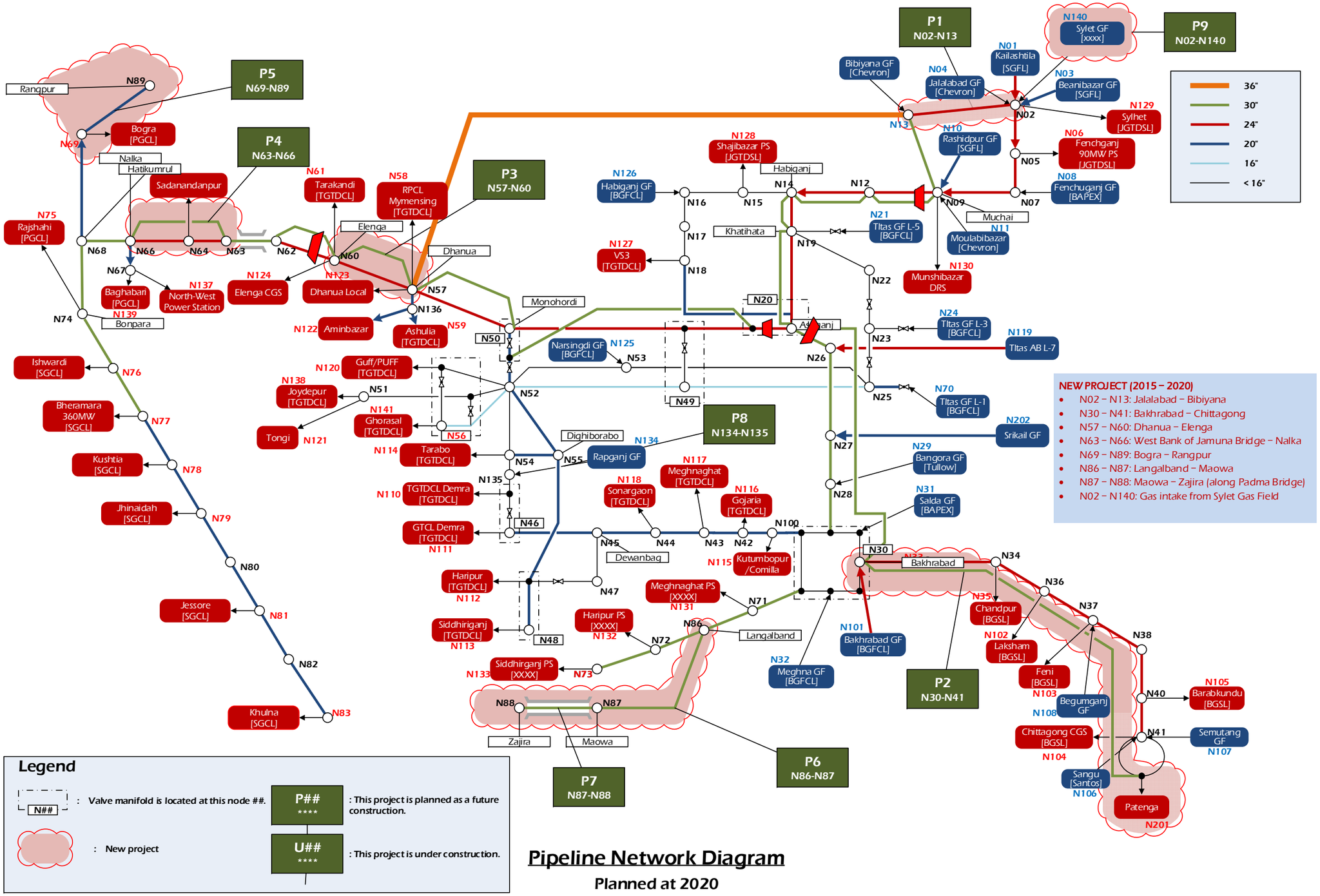


Figure 1.2-2 Pipeline Network Diagram in 2015



Pipeline Network Diagram

Planned at 2020

Figure 1.2-3 Pipeline Network Diagram in 2020

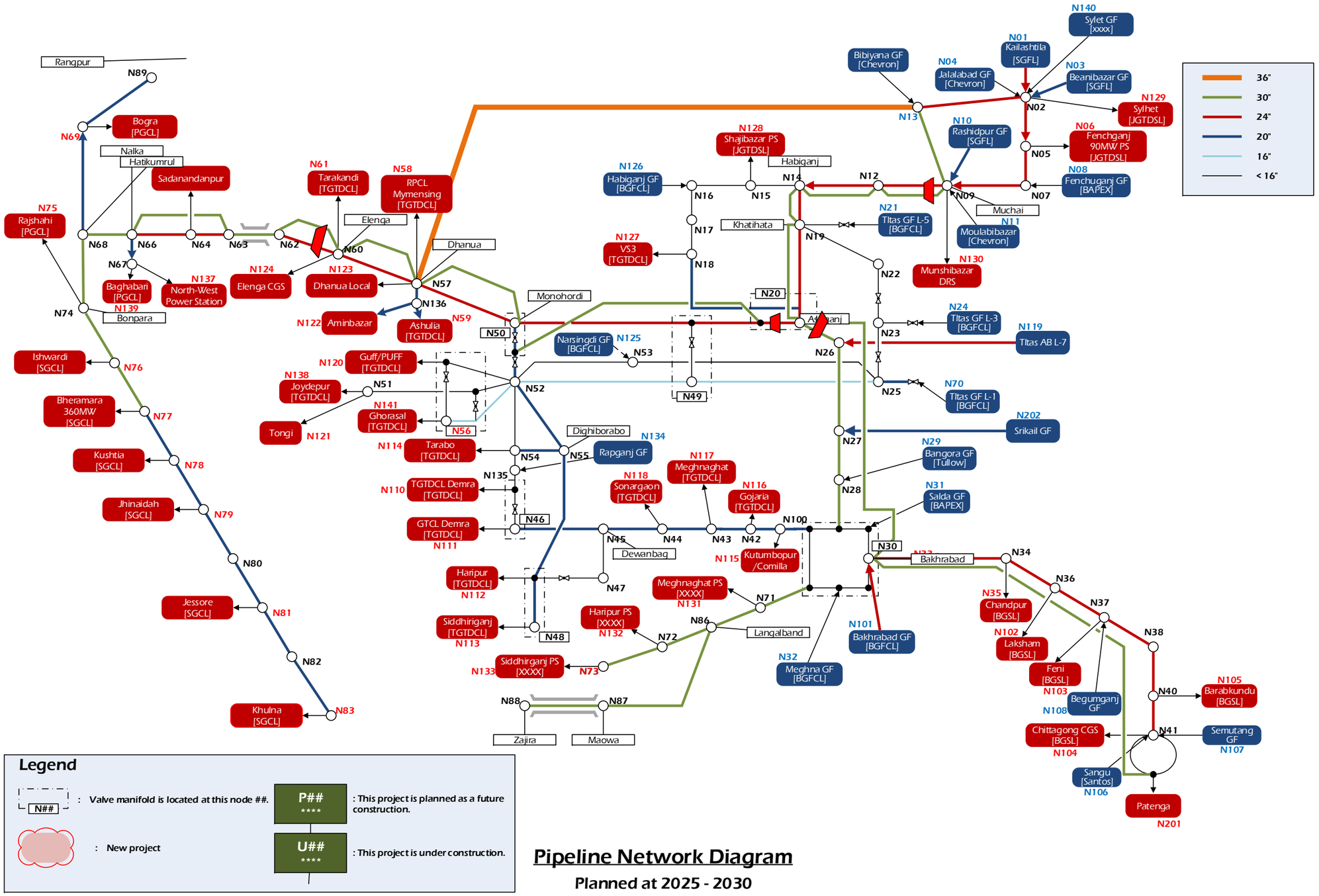


Figure 1.2-4 Pipeline Network Diagram in 2025 - 2030

Chapter 2 Study Basis and Assumption

The following study basis and assumptions are applied to flow simulation of pipeline network in Bangladesh.

2.1 Study Basis

Basically, this flow simulation is carried out for transmission pipeline operated by GTCL excluding distribution pipelines of other gas distribution companies such as TGTDCL, KGDCL, JGTDSL, BGSL, PGCL, SGCL, etc. Based on data and information for the pipeline specification, gas composition, gas production & demand data, pipeline operating condition that was given by executing agencies of Bangladesh, study basis is established as follows:

2.1.1 Temperature Data

Ambient and soil temperature on the existing pipeline route is shown in Table 2.1-1.

Table 2.1-1 Ambient and Soil Temperature Data

	Temperature (°F)	
Ambient temperature	January	65.8
	April	78.6
	July	82.8
	October	79.2
Soil temperature	Year average	78.4

Source: GTCL data

Since most parts of the existing and future pipelines are buried in the ground, soil temperature should be applied to verification of flow assurance including heat loss calculation of the pipeline surface. However, the year average soil temperature of 78.4 deg.F is not the highest value in the year and is lower than monthly average ambient temperature of 82.8 deg.F as shown in Table 2.1-1. In this flow simulation, 82.8 deg.F of the monthly average ambient temperature in July is to be applied to the said calculations as the most severe condition.

On the other hand, temperature of the gas produced in each gas field is to be set to 145 deg.F that is the average temperature of the produced gas.

2.1.2 Gas Composition Data

There are five (5) available composition data of gas transferred by the existing pipeline network. Because of only a little difference among these composition data, typical one (1) composition data is applied to simulation of the pipeline network model. Table 2.1-2 shows the typical composition data.

Table 2.1-2 Gas Composition

Component	Mole%	Mass%
Nitrogen	0.339	0.567
Carbon Dioxide	0.341	0.896
Methane	96.616	92.612
Ethane	1.979	3.556
Propane	0.423	1.115
i-Butane	0.102	0.356
n-Butane	0.061	0.213
i-Pentane	0.026	0.113
n-Pentane	0.022	0.095
Hexane	0.054	0.272
Heptane	0.028	0.163
Octane	0.007	0.043
Nonane	0.000	0.000
Decane+	0.000	0.000
Total	99.998	100.001

Note: Total of each component % is not equal to 100 because of rounding-up calculation.
Source: GTCL Questionnaire Reply (GT-58) Annex-10 "Gas Analysis for GAS TRANSMISSION CO. LTD. (GTCL)"

Since water content is restricted below 7 lb/MMSCF in accordance with the sales gas contract, water content in the gas is assumed in the rate of 7 lb/MMSCF as the most severe condition in gas transmission.

2.1.3 Supply and Demand Data

Data of current production and consumption rate of natural gas were collected with GTCL's cooperation.

Table 2.1-3 and Table 2.1-4 summarizes "Gas Supply Data" corresponding to the gas production rate of each gas field and "Gas Demand Data" corresponding to gas consumption rate at each end-user, respectively.

Table 2.1-3 Gas Supply Data (2013)

Node No.	Field Name	Gas supply [MMSCFD]	Pressure [psig]
N01	Kailashtila GF	55.017	909.5
N03	Beanibazar GF	0	0
N04	Jalalabad GF	185.878	908
N08	Fenchuganj GF	40.107	897
N10	Rashidpur GF	46.678	807.5
N11	Moulabibazar	75.023	847.5
N13	Bibiyana GF	840.811	1100
N21	Titas GF L-5	69.067	960
N24	Titas GF L-3	156.508	935
N29	Bangora GF	76.16	843
N31	Salda GF	15.704	665
N32	Meghna GF	7.877	
N70	Titas GF L-1	222.153	890
N101	Bakhrabad GF	27.923	623.5
N106	Sangu GF	4.121	
N107	Semutang GF	7.105	
N119	Titas AB L-7	16.546	990
N125	Narsingdi GF	30.087	
N126	Habiganj GF	71.458	1000
N202	Srikail GF	25.096	675
Total		1973.319	

Source: "Daily Gas Production and Supply Statistics" prepared by GTCL (Date: 17 July 2013)"

Table 2.1-4 Gas Demand Data (2013)

Node No.	Terminal Name	Gas demand [MMSCFD]	Pressure [psig]
N06	Fenchganj 90MW PS	53.276	877
N35	Chandpur	35	
N58	RPCL Mymensing	27.054	285
N59	Ashulia	110.234	144.5
N61	Tarakandi	34.624	287.5
N65	Sadanandanpur	14.109	
N69	Bogra	13.765	287.5
N75	Rajshahi	1	
N102	Laksham	3	
N103	Feni	20	
N104	Chittagong CGS	166.7	
N105	Barabkundu	25	
N110	TGTDCL Demra	137.214	
N111	GTCL Demra	82.46	
N112	Haripur	70.311	157.25
N113	Siddhiriganj	123.116	

Node No.	Terminal Name	Gas demand [MMSCFD]	Pressure [psig]
N114	Tarabo	30	
N115	Kutumbopur/Comilla	31.28	
N116	Gojaria	25	
N117	Meghnaghat	35.848	
N118	Sonargaon	10	
N120	Guff/PUFF	2.369	
N121	Tongi	26.628	
N122	Aminbazar	77.93	110.25
N123	Dhanua Local	121.187	
N124	Elenga CGS	80.905	
N127	VS3	214.476	
N128	Shajibazar PS	46.54	295
N129	Sylhet	36.826	
N130	Munshibazar	3	862
N137	North-West PS	36.041	
N138	Joydepur	89.585	
N139	Baghabari	46.291	278.5
N141	Ghorasal	205.195	
Total		2035.964	

Source: "Daily Gas Production and Supply Statistics" prepared by GTCL (Date: 17 July 2013)"

As shown in Table 2.1-3 and Table 2.1-4, “Supply” and “Demand” condition does not balance and have a little bit difference because of time lag at the time of data acquisition. In order to conduct the pipeline network simulation, these data is calibrated as described in Section 2.2.3 so as to eliminate the difference.

2.1.4 Pipeline Data

The latest pipeline data including line size, wall thickness, length and installed location was collected from GTCL and is listed in Table 2.1-5 and Table 2.1-6. In these tables, “Pipeline No.” indicating a pipeline section between two (2) node numbers is additionally provided for easy identification of each pipeline section.

As described in the beginning of Section 2.1, although distribution pipelines (e.g. blanch line from GTCL’s transmission pipeline to end-user), which are smaller than 16 inch diameter, are excluded from this study, some of them must be considered as a part of transmission pipeline in order to analyze balance of demand and supply of the gas. **Since lots of these distribution pipeline data is not available in GTCL database, those data are assumed as described in Section 2.2.2.**

And some pipe wall thickness data of old pipelines are not available in GTCL database. Accordingly, the pipe wall thickness was assumed by reference to that of the existing pipelines with same diameter. The assumed pipeline thickness is highlighted in red color in Table 2.1-5 and Table 2.1-6.

Table 2.1-5 Existing Pipeline Data

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length	Pipeline Name
	Start	End	(in)	(in)	(in)	(m)	
1	1	2	24	0.406	23.188	18,000	
2	2	3	20	0.406	19.188	18,000	
3	2	4	14	0.375	13.250	1,500	
4	2	5	24	0.500	23.000	1,500	North - South
5	5	6	12	0.311	11.378	1,500	
6	5	7	24	0.500	23.000	5,000	North - South
7	7	8	12	0.311	11.378	7,500	
8	7	9	24	0.500	23.000	73,000	North - South
9	9	10	20	0.406	19.188	1,700	
10	9	11	14	0.375	13.250	2,200	
11	9	12	24	0.500	23.000	6,000	North - South
12	9	12	30	0.563	28.874	6,000	Rashidpur - Ashuganj
13	9	13	30	0.563	28.874	42,000	
14	12	14	24	0.500	23.000	63,000	North - South
15	12	14	30	0.563	28.874	63,000	Rashidpur - Ashuganj
16	14	15	12	0.311	11.378	500	
17	14	19	24	0.500	23.000	3,000	North - South
18	14	19	30	0.563	28.874	3,000	Rashidpur - Ashuganj
19	15	16	12	0.311	11.378	500	
20	16	17	12	0.311	11.378	40,000	
21	17	18	12	0.311	11.378	13,500	
22	18	20	20	0.406	19.188	2,000	
23	19	20	24	0.500	23.000	10,000	North - South
24	19	20	30	0.563	28.874	10,000	Rashidpur - Ashuganj
25	19	21	12	0.311	11.378	540	
26	19	22	12	0.311	11.378	500	
27	20	26	30	0.626	28.748	40,000	AB Line
28	20	49	24	0.406	23.188	4,000	Ashuganj - Elenga
29	20	50	30	0.563	28.874	37,000	Ashuganj - Monohordi
30	22	23	12	0.311	11.378	5,000	
31	23	24	12	0.311	11.378	500	
32	23	25	12	0.311	11.378	3,000	
33	25	49	16	0.375	15.250	13,920	
34	25	53	14	0.375	13.250	43,770	
35	25	70	20	0.406	19.188	1,000	
36	26	27	30	0.626	28.748	1,500	AB Line

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length	Pipeline Name
	Start	End	(in)	(in)	(in)	(m)	
37	26	119	24	0.406	23.188	8,000	Titas Gas Field - AB Line
38	27	28	30	0.626	28.748	600	AB Line
39	27	202	20	0.406	19.188	1,200	Srikail – AB Line
40	28	29	10	0.307	9.386	1,000	
41	28	30	30	0.626	28.748	17,900	AB Line
42	30	31	10	0.307	9.386	35,000	
43	30	32	8	0.312	7.376	28,000	
44	30	33	24	0.406	23.188	16,000	Bakrabad - Chittagong Line
45	30	100	20	0.406	19.188	12,000	Bakrabad - Demra
46	30	101	24	0.406	23.188	500	
47	33	34	24	0.406	23.188	28,000	B - C Line
48	34	35	8	0.312	7.376	46,000	
49	34	36	24	0.406	23.188	22,000	B - C Line
50	36	37	24	0.406	23.188	24,000	B - C Line
51	37	38	24	0.406	23.188	7,000	B - C Line
52	38	40	24	0.406	23.188	54,000	B - C Line
53	40	41	24	0.406	23.188	26,000	B - C Line
54	42	43	20	0.406	19.188	4,000	Bakrabad - Demra
55	42	100	20	0.406	19.188	37,000	Bakrabad - Demra
56	43	44	20	0.406	19.188	4,000	Bakrabad - Demra
57	44	45	20	0.406	19.188	4,000	Bakrabad - Demra
58	45	46	20	0.406	19.188	3,000	Bakrabad - Demra
59	45	47	14	0.375	13.250	1,580	
60	46	135	14	0.375	13.250	500	
61	47	48	20	0.406	19.188	4,000	
62	47	55	20	0.406	19.188	5,000	
63	49	50	24	0.406	23.188	33,000	Ashuganj - Elenga
64	49	52	16	0.375	15.250	32,390	
65	50	52	20	0.406	19.188	25,000	
66	50	57	24	0.406	23.188	37,000	Ashuganj - Elenga
67	50	57	30	0.563	28.874	37,000	Monohordi - Dhanua
68	51	56	14	0.375	13.250	24,000	
69	52	53	14	0.375	13.250	5,620	
70	52	54	14	0.375	13.250	31,410	
71	52	55	20	0.406	19.188	32,000	
72	52	56	14	0.375	13.250	12,000	
73	52	56	16	0.375	15.250	12,000	
74	54	55	20	0.406	19.188	3,000	
75	54	135	14	0.375	13.250	500	
76	57	58	12	0.311	11.378	40,000	
77	57	60	24	0.406	23.188	52,000	Ashuganj - Elenga
78	57	136	20	0.406	19.188	40,000	
79	59	136	20	0.406	19.188	7,000	
80	60	61	12	0.311	11.378	43,000	

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length	Pipeline Name
	Start	End	(in)	(in)	(in)	(m)	
81	60	62	24	0.406	23.188	14,000	Elenga - Nalka
82	60	62	30	0.563	28.874	14,000	Elenga - East of Jamuna Bridge
83	62	63	30	0.563	28.874	9,000	Jamuna Bridge Portion
84	63	64	24	0.406	23.188	10,000	Elenga - Nalka
85	64	65	8	0.312	7.376	500	
86	64	66	24	0.406	23.188	5,000	Elenga - Nalka
87	66	67	20	0.343	19.314	35,500	Nalka - Baghabari
88	66	68	30	0.500	29.000	6,000	Nalka - Hatikumrul
89	68	69	20	0.343	19.314	54,000	Hatikumrul - Bogra
90	68	74	30	0.563	28.874	36,000	Hatikumrul - Bheramara
91	74	75	12	0.311	11.378	53,000	Bonpara - Rajshahi
92	122	136	20	0.406	19.188	20,000	Dhanua - Aminbazar

Note: The value colored in red at "Wall Thick." indicates assumed value.
Source: GTCL Questionnaire Reply Annex-1 "Projects under implementation of Gas Transmission Company Limited (GTCL)"
GTCL Questionnaire Reply Annex-7 "Pipeline Specification of GTCL Pipeline"
GTCL Questionnaire Reply Annex-12 "Pipeline Data of GTCL Pipeline"

Table 2.1-6 Under Construction / Planned Pipeline Data

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length	Installation	Pipeline Name
	Start	End	(in)	(in)	(in)	(m)	Year	
93	13	57	36	0.625	34.750	137,000	2013	Bibiyana - Dhanua
94	20	30	30	0.563	28.874	61,000	2013	Ashuganj - Bakhrabad
95	74	75	12	0.311	11.378	53,000	2013	Bonpara - Rajshahi
96	30	71	30	0.563	28.874	47,000	2014	Bakhrabad - Siddhiriganj
97	71	86	30	0.563	28.874	5,800	2014	Bakhrabad - Siddhiriganj
98	72	73	30	0.563	28.874	2,000	2014	Bakhrabad - Siddhiriganj
99	72	86	30	0.563	28.874	5,200	2014	Bakhrabad - Siddhiriganj
100	74	76	30	0.563	28.874	36,000	2014	Hatikumrul - Bheramara
101	76	77	30	0.563	28.874	15,000	2014	Hatikumrul - Bheramara
102	77	78	30	0.563	28.874	22,000	2014	Bheramara - Khulna
103	78	79	30	0.563	28.874	43,000	2014	Bheramara - Khulna
104	79	80	30	0.563	28.874	15,000	2014	Bheramara - Khulna
105	80	81	30	0.563	28.874	30,000	2014	Bheramara - Khulna
106	81	82	30	0.563	28.874	28,000	2014	Bheramara - Khulna
107	82	83	30	0.563	28.874	2,700	2014	Bheramara - Khulna
108	26	84	12	0.311	11.378	8,000	2015	Titas G.F. Loc. 7 - A - B Pipeline
109	2	13	24	0.406	23.188	54,000	2017	Jalalabad - Bibiyana (proposed)
110	57	60	30	0.563	28.874	52,000	2017	Dhanua - Elenga (proposed)
111	63	66	30	0.563	28.874	14,000	2017	West of Jamuna Bridge - Nalka (proposed)
112	86	87	30	0.563	28.874	40,000	2017	Langalband - Maowa
113	87	88	30	0.563	28.874	20,000	2017	Maowa - Zajira

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length	Installation	Pipeline Name
	Start	End	(in)	(in)	(in)	(m)	Year	
114	30	41	30	0.563	28.874	201,000	2018	Bakhrabad - Chittagong pipeline
115	69	89	20	0.406	19.188	100,000	2019	Bogra - Rangpur

Note: The value colored in red at "Wall Thick." indicates assumed value.
Source: GTCL Questionnaire Reply Annex-1 "Projects under implementation of Gas Transmission Company Limited (GTCL)"
GTCL Questionnaire Reply Annex-7 "Pipeline Specification of GTCL Pipeline"
GTCL Questionnaire Reply Annex-12 "Pipeline Data of GTCL Pipeline"

2.1.5 Operating Condition at Principal Pipeline Stations

GTCL has operated several pipeline stations on their pipeline network. In most of the pipeline stations, operating condition such as flow rate, pressure and temperature is continuously monitored with field instrument in order to measure sales gas volume. As for other pipeline points on the network, those operating conditions can be obtained by calculation using operating data in related pipeline facilities.

The measured and calculated dada of current operating condition are available at several points of existing pipeline network and are listed in Table 2.1-7 and Table 2.1-8, respectively.

In order to reproduce actual flow condition as well as possible, those operating conditions are fully utilized for establishment of flow model. In case of making difference between both the measured data and the calculated data, the measured data have the priority to the calculated data.

Table 2.1-7 Operating Condition (Measured Data)

Pipeline No.	Node		Inlet Press.	Station Name
	from	to	(psig)	
22	20	18	786.10	Ashuganj Gas Manifold Station
27	20	26	786.10	
28	20	49	773.05/ 770.15	
29	20	50		
65	50	52	620.00	Monohordi Gas Manifold Station
	104		275.75	Chittagong City Gate Station
	110/111		155	Demra City Gate Station
	115		350	Kutumbopur Town Bordering Station

Note: Operating conditions in the above table are quoted from the Source below and are utilized for calibration at each point.
Source: "Station Operating Condition Data" prepared by GTCL

Table 2.1-8 Operating Condition (Calculated Data)

Pipeline No.	Node		Inlet Press. (psig)	Pipeline Name
	from	to		
44	30	33	650	Bakhrabad - Chittagong Pipeline
45	30	100	640	Bakhrabad - Demra Pipeline
78	57	136	225	Dhanua - Aminbazar Pipeline
81	60	62	390	Elenga - Nalka Pipeline
83	62	63	390	Jamuna Bridge Portion Pipeline
87	66	67	350	Nalka - Baghabari Pipeline
120	18	127	766	Vs-3 Pipeline

Note: Operating conditions in the above table are quoted from the Source below and are utilized for calibration at each point.
Source: Operating Condition of GPCL Pipeline Network" prepared by GTCL

2.1.6 Pipeline Compressor Data

A pipeline compressor station has already been constructed and operated at Muchai which is located in the northeast region of Bangladesh in order to boost up produced gases and transfer it to Ashuganj area. It is far from Muchai pipeline station about 6 to 7 km toward west. Furthermore, two (2) pipeline compressor stations are under construction at Ashuganj and Elenga and the construction period are scheduled by December and November of 2013, respectively. The information of these compressor stations is shown in Table 2.1-9.

Table 2.1-9 Pipeline Compressor Data

Location	Pipeline No.	Node		Suction Press. (psig)	Disch. Press. (psig)	Total Capacity (MMSCFD)	Start-up Year	Remarks
		from	to					
Muchai	11 12	9	12	770	1,135	1,200	Operating	2 Duty and 1 Stand-by Capacity: 600 MMSCFD/Unit
Ashuganj	27	20	26	600	1,000	1,500	Dec. 2013	2 Duty and 1 Stand-by Capacity: 750 MMSCFD/Unit
	28	20	49					
	29	20	50					
Elenga	81 82	60	62	650	1,000	500	Nov. 2013	2 Duty and 1 Stand-by Capacity: 250 MMSCFD/Unit

Note: The compressor stations in the above table has a common valve header for several pipelines. Accordingly, the compressors can boost up the gas flowing into multiple pipelines.
Source: Operating Condition of GTCL Pipeline Network" prepared by GTCL

2.2 Study Assumptions

In order to conduct the pipeline network simulation, some operation data are assumed to establish pipeline flow model. The following sections describe the study assumptions to be applied to the pipeline network simulation.

2.2.1 General

1) **In order to consider the pressure drop by elevation change, pipeline length of each node is increased with 10% length of the pipeline.** Note that pipeline length in Table 2.1-5 and Table 2.1-6 does not include the 10% length margin.

2) **All of the pipeline facilities except for regulating & metering stations, valve stations, etc. are buried in the ground.** Therefore, wind speed which affects heat loss of pipe is not considered. However, the heat loss to the soil is considered automatically by the simulation software to be utilized.

3) It is assumed that **the pipeline intake pressure at each gas field does not decline in future**. **Also, the pressure from each gas field is assumed to be increased so as to meet suction or discharge pressure of the compressor that is installed downstream of the gas field.**

2.2.2 Distribution Pipeline Data

As described in Section 2.1.4, actual diameter and length of some distribution pipelines smaller than 16 inch is not available. Accordingly, **the diameter and the length of all the pipelines are assumed to be 12 inch and 1 km**. All of the assumed data is tabulated in Table 2.2-1 and Table 2.2-2.

Table 2.2-1 Existing Distribution Pipeline Data (Assumed)

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length
	Start	End	(in)	(in)	(in)	(m)
116	2	129	12	0.311	11.378	1,000
117	9	130	12	0.311	11.378	1,000
118	15	128	12	0.311	11.378	1,000
119	16	126	12	0.311	11.378	1,000
120	18	127	12	0.311	11.378	1,000
121	36	102	12	0.311	11.378	1,000
122	37	103	12	0.311	11.378	1,000
123	40	105	12	0.311	11.378	1,000
124	41	104	12	0.311	11.378	1,000

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length
	Start	End	(in)	(in)	(in)	(m)
125	41	106	12	0.311	11.378	1,000
126	41	107	12	0.311	11.378	1,000
127	42	116	12	0.311	11.378	1,000
128	43	117	12	0.311	11.378	1,000
129	44	118	12	0.311	11.378	1,000
130	46	110	12	0.311	11.378	1,000
131	46	111	12	0.311	11.378	1,000
132	48	112	12	0.311	11.378	1,000
133	48	113	12	0.311	11.378	1,000
134	51	121	12	0.311	11.378	1,000
135	51	138	12	0.311	11.378	1,000
136	53	125	12	0.311	11.378	1,000
137	54	114	12	0.311	11.378	1,000
138	56	120	12	0.311	11.378	1,000
139	56	141	12	0.311	11.378	1,000
140	57	123	12	0.311	11.378	1,000
141	60	124	12	0.311	11.378	1,000
142	67	137	12	0.311	11.378	1,000
143	67	139	12	0.311	11.378	1,000
144	71	131	12	0.311	11.378	1,000
145	72	132	12	0.311	11.378	1,000
146	73	133	12	0.311	11.378	1,000
147	100	115	12	0.311	11.378	1,000

Reference: Pipeline Specification of GTCL Pipeline (quoted from Questionnaire Reply)

Table 2.2-2 Under Construction / Planned Gas Intake Pipeline Data (Assumed)

Pipeline No.	Node		Size (OD)	Wall Thick.	Size (ID)	Length	Installation	Pipeline Name (if Available)
	Start	End	(in)	(in)	(in)	(m)	Year	
148	37	108	12	0.311	11.378	1,000	2013	Gas Intake from Begumganj GF
149	134	135	12	0.311	11.378	1,000	2015	Gas Intake from Rupganj GF
150	2	140	12	0.311	11.378	1,000	2016	Gas Intake from Sylet GF

Reference: Pipeline Specification of GTCL Pipeline (quoted from Questionnaire Reply)

2.2.3 Adjustment of Gas Supply Data in 2013

As discussed in Section 2.1.3, current supply and demand data of gas do not balance and have a little bit difference because of time lag at the time of data acquisition. But, in order to carry out pipeline network flow simulation, both the supply and the demand must balance completely. Accordingly, input data for the flow simulation is adjusted so that the total gas supply volume matches with the gas demand. Therefore, the current gas supply volume of each gas field are adjusted proportionally so as to meet the

total current gas demand of 2035.964 MMSCFD (Refer to Table 2.1-4). **Result of the adjustment of current gas supply volume is shown in Table 2.2-3. The adjusted supply volume is applied to the pipeline network flow simulation as the Base Case Model.**

Table 2.2-3 Adjusted Gas Supply Volume (2013)

Node No.	Field Name	Gas supply [MMSCFD]	Gas supply (Adjusted) [MMSCFD]
N01	Kailashtila GF	55.017	56.764
N03	Beanibazar GF	0	0
N04	Jalalabad GF	185.878	191.779
N08	Fenchuganj GF	40.107	41.380
N10	Rashidpur GF	46.678	48.160
N11	Moulabibazar	75.023	77.405
N13	Bibiyana GF	840.811	867.503
N21	Titas GF L-5	69.067	71.260
N24	Titas GF L-3	156.508	161.477
N29	Bangora GF	76.16	78.578
N31	Salda GF	15.704	16.203
N32	Meghna GF	7.877	8.127
N70	Titas GF L-1	222.153	229.205
N101	Bakhrabad GF	27.923	28.809
N106	Sangu GF	4.121	4.252
N107	Semutang GF	7.105	7.331
N119	Titas AB L-7	16.546	17.071
N125	Narsingdi GF	30.087	31.042
N126	Habiganj GF	71.458	73.727
N202	Srikail GF	25.096	25.893
Total		1973.319	2035.964

2.2.4 Gas Supply and Demand Forecast

Demand and supply forecast of gas is available in Final Report “Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development”, December 2012” prepared for Bangladesh Oil, Gas & Mineral Corporation (Petrobangla). Table 2.2-4 shows the forecast of total production rate and total demand volume of the gas in the country. Note that the “Supply” data includes only “Domestic Gas Production Rate”, but does not include any LNG and other energy resources to be imported from overseas market.

Table 2.2-4 Total Supply and Demand Forecast

Year	Supply (a) [MMSCFD]	Demand (b) [MMSCFD]	Gap (a-b) [MMSCFD]
2015	2,850	3,174.1	-324.1
2020	3,224	3,642.3	-418.3
2025	1,805	3,596.8	-1,791.8
2030	1,265	3,871.2	-2,606.2

Source: "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development", December 2012, Bangladesh Oil, Gas & Mineral Corporation (Petrobangla)

In the above described Final Report, production rate in each gas field and gas consumption rate at each end-user is unknown. And also, as shown in Table 2.2-4, the total supply data does not correspond to the total demand data, and also the gap tends to increase every year. Accordingly, tight supply situation of gas is forecasted in subsequent years.

Gas supply in each gas field and gas demand in each end-user that is forecasted in 2015, 2020, 2025 and 2030 is reviewed as follows:

(1) Gas supply forecast

In order to conduct the pipeline network simulation, the supply and the demand data must balance as the input data. Then, the supply data is reviewed so as to match with the demand data which is expected as the total consumption in the country.

According to the above Final Report and "Draft Updated Road Map of Gas Sector", supply forecast in each gas field in every five (5) years is expected as indicated in Table 2.2-5.

Table 2.2-5 Gas Supply Forecast in Each Field

Gas Field Name	Year			
	2015	2020	2025	2030
Titas	600	600	300	200
Habiganj	250	80	50	20
Bakhrabad	50	80	70	20
Meghna	10	0	0	0
Narsingdi	30	20	20	0
Sylet	0	25	20	0
Beanibazar	14	14	10	0
Rashidpur	100	250	250	200
Kailashtila	150	250	250	200
Salda	18	7	0	0

Gas Field Name	Year			
	2015	2020	2025	2030
Fenchuganj	60	40	0	0
Shahbazpur	60	40	30	0
Semutang	25	30	15	10
Begumganj	N/A	N/A	N/A	N/A
Sundalpur	20	8	0	0
Jalalabad	230	0	0	0
Moulabibazar	40	40	40	0
Bibiyana	1,000	1,200	200	50
Sangu	8	0	0	0
Bangora	100	50	10	0
Block 16	0	100	100	100
Offshore	0	200	200	200
Rupganj	N/A	N/A	N/A	N/A
Srikail	N/A	N/A	N/A	N/A
New Discovery	85	190	240	265
Total	2,850	3,224	1,805	1,265

Note:
1. Red color indicates that this gas field will be abandoned or suspended at that time.
2. Information of gas supply forecast marked in black were obtained from Source data 1) below.
3. Information of gas supply forecast marked in blue were obtained from Source data 2) below.

Source:
1) "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development", December 2012, Bangladesh Oil, Gas & Mineral Corporation (Petrobangla)
2) "Draft Updated Road Map of Gas Sector" (Petrobangla)

As for gas supply data in gray column, the supply volume should be excluded from total gas supply volume because of its uncertainty and impracticality of the plans.

The gas supply forecast marked in blue-letter is not listed in the above Source 1), but it is listed in Source 2). However, the future supply volume is not available in Source 2). In this flow simulation, it is assumed that the three (3) gas fields, i.e. Begumganj, Rupganj and Srikail, are considered as one of the future intake sources and the supply volume of the fields is expected as "New Discovery Gas Field" listed in the last cell in Table 2.2-5.

In accordance with the above considerations, the total gas supply forecast and the gap in Table 2.2-5 is reviewed as shown in Table 2.2-6.

Table 2.2-6 Gas Supply Forecast in Each Field (Reviewed)

Gas Field Name		Year			
		2015	2020	2025	2030
A	**Total**	**2,850**	**3,224**	**1,805**	**1,265**
B	**Excluded Gas Field**				
B1.	Shahbazpur	60	40	30	0
B2.	Sundalpur	20	8	0	0
B3.	Block 16	0	100	100	100
B4.	Offshore	0	200	200	200
C	**Grand Total** (= A – B)	**2,770**	**2,876**	**1,475**	**965**
D	**Demand**	**3,174.1**	**3,642.3**	**3,596.8**	**3,871.2**
E	**Gap** (= B – C)	**-404.1**	**-766.3**	**-2,121.8**	**-2,906.2**

As shown in Table 2.2-6, “Grand Total” in Item C is applied to gas supply forecast data. This grand total should correspond to the total demand of the gas in Item D. By the same manner as Section 2.2.3, the gas supply in each field indicated in Table 2.2-5 is adjusted to the total forecasted gas demand shown in Table 2.2-4, proportionally. The result of the adjustment is shown in Table 2.2-7. **The pipeline capacity is verified using this gas supply rate.**

Table 2.2-7 Gas Supply Forecast in Each Field (Adjusted)

Node No.	Field Name	Gas supply [MMSCFD]			
		2015	2020	2025	2030
N01	Kailashtila	171.883	316.612	609.627	802.321
N03	Beanibazar GF	16.042	17.730	24.385	0
N04	Jalalabad GF	263.553	0	0	0
N08	Fenchuganj GF	68.753	50.658	0	0
N10	Rashidpur GF	114.588	316.612	609.627	802.321
N11	Moulabibazar	45.835	50.658	97.540	0
N13	Bibiyana GF	1,145.884	1,519.736	487.702	200.580
N21	Titas GF L-5	102.279	113.041	108.828	119.356
N24	Titas GF L-3	231.768	256.153	246.608	270.465
N29	Bangora GF	114.588	63.322	24.385	0
N31	Salda GF	20.626	8.865	0	0
N32	Meghna GF	11.459	0	0	0
N70	Titas GF L-1	328.980	363.593	350.045	383.907
N101	Bakhrabad GF	57.294	101.316	170.696	80.232
N106	Sangu	9.167	0	0	0
N107	Semutang GF	28.647	37.993	36.578	40.116
N108	Begumganj GF	0	65.625	159.611	289.930
N119	Titas AB L-7	24.503	27.081	26.071	28.593
N125	Narsingdi GF	34.377	25.329	48.770	0

Node No.	Field Name	Gas supply [MMSCFD]			
		2015	2020	2025	2030
N126	Habiganj GF	286.471	101.316	121.925	80.232
N134	Rupganj GF	36.525	65.625	159.611	289.930
N140	Sylet GF		31.661	48.770	0
N202	Srikail GF	60.875	109.375	266.019	483.216
Total Supply		3,174.1	3,642.3	3,596.8	3,871.2
Total Demand		3,174.1	3,642.3	3,596.8	3,871.2
Gap		0	0	0	0

(2) Gas demand forecast

It is assumed that future gas demand at each end-user is set up in proportion to current demand data in Table 2.1-4 so as to match with the total gas demand in Table 2.2-4. As the result of setting it up, gas demand forecast in each field in 2015, 2020, 2025 and 2030 is indicated in Table 2.2-8. **The pipeline capacity is verified using this gas demand rate.**

Table 2.2-8 Gas Demand Forecast in Each Field (Adjusted)

Node No.	Terminal Name	Gas demand [MMSCFD]			
		2015	2020	2025	2030
N06	Fenchganj 90MW PS	70.590	81.002	79.990	86.093
N35	Chandpur	46.374	53.215	52.550	56.559
N58	RPCL Mymensing	35.846	41.134	40.620	43.719
N59	Ashulia	146.058	167.603	165.509	178.135
N61	Tarakandi	45.876	52.643	51.986	55.952
N65	Sadanandanpur	18.694	21.452	21.184	22.800
N69	Bogra	18.238	20.929	20.667	22.244
N75	Rajshahi	1.325	1.520	1.501	1.616
N76	Ishwardi	15	17.213	16.998	18.294
N77	Bheramara 360MW	90	103.276	101.985	109.766
N78	Kushtia	10	11.475	11.332	12.196
N79	Jhinaidah	8	9.180	9.065	9.757
N81	Jessore	20	22.950	22.663	24.392
N83	Khulna	122	139.996	138.247	148.794
N102	Laksham	3.975	4.561	4.504	4.848
N103	Feni	26.500	30.408	30.029	32.320
N104	Chittagong CGS	220.874	253.455	250.289	269.383
N105	Barabkundu	33.125	38.011	37.536	40.399
N110	TGTDCL Demra	181.806	208.624	206.017	221.735
N111	GTCL Demra	109.258	125.374	123.808	133.253
N112	Haripur	93.161	106.903	105.567	113.621
N113	Siddhiriganj	163.126	187.189	184.850	198.952
N114	Tarabo	39.749	45.613	45.043	48.479
N115	Kutumbopur/Comilla	41.445	47.559	46.965	50.548

Node No.	Terminal Name	Gas demand [MMSCFD]			
		2015	2020	2025	2030
N116	Gojaria	33.125	38.011	37.536	40.399
N117	Meghnaghat	47.498	54.504	53.823	57.930
N118	Sonargaon	13.250	15.204	15.014	16.160
N120	Guff/PUFF	3.139	3.602	3.557	3.828
N121	Tongi	35.282	40.486	39.980	43.030
N122	Aminbazar	103.256	118.487	117.007	125.933
N123	Dhanua Local	160.571	184.256	181.954	195.835
N124	Elenga CGS	107.198	123.010	121.473	130.741
N127	VS3	284.177	326.095	322.021	346.588
N128	Shajibazar PS	61.665	70.761	69.877	75.208
N129	Sylhet	48.794	55.991	55.292	59.510
N130	Munshibazar	3.975	4.561	4.504	4.848
N131	Meghnaghat PS	73.485	84.325	83.271	89.624
N132	Haripur PS	55	63.113	62.324	67.079
N133	Siddhiriganj PS	83	95.243	94.053	101.229
N137	North-West PS	47.754	54.798	54.113	58.241
N138	Joydepur	118.698	136.207	134.506	144.767
N139	Baghabari	61.335	70.382	69.503	74.805
N141	Ghorasal	271.880	311.984	308.086	331.590
Total Demand		3,174.1	3,642.3	3,596.8	3,871.2

2.2.5 Evaluation Criteria

Basically, GTCL has a criterion for gas delivery pressure of minimum 450 psig and transfers it to six (6) gas distribution companies at the pressure less than 350 psig. Accordingly, soundness of future pipeline network shall be evaluated based on the pressure of 350 psig or over. Delivery pressure at all the points on the pipeline network are to be verified in accordance with the evaluation criterion.

Chapter 3 Study Procedure

In this chapter, study procedure is established as a preparation work for pipeline network flow simulation. The study is conducted in accordance with the following step:

1) Establishment of Pipeline Network Model
2) Calibration of Current Pipeline Network Model (as of 2013)
3) Verification of Pipeline Capacity for Future Demand (as of 2015, 2020, 2025 and 2030)

At first, pipeline network model in 2013 is established to conduct flow simulation based on current pipeline network diagram shown in Figure 1.2-1. This case is defined as “Base Case” and the flow simulation is carried out using the PIPESIM 2011 which is widely utilized for verification of flow assurance of steady state pipeline in oil and gas industry. Similar to the 2013 Case, pipeline network models for “Future Case” (i.e. 2015, 2020, 2025 and 2030) are also established based on future pipeline network diagrams shown in Figure1.2-2 to Figure1.2-4. Details for establishment of the models are described in Section 3.1.

Subsequently, this PIPESIM model in 2013 Case is calibrated so as to meet the current operation data such as flow rate, arrival pressure and temperature at each gate station. Calibration method is explained in Section 4.1.

After calibrating the PIPESIM model in 2013, flow assurance for the future pipeline network is verified comprehensively. Simulation result for the future cases is described in Section 4.2.

3.1 Establishment of Pipeline Network Model

In order to conduct pipeline network flow simulation, current pipeline network model is established as “Base Case” based on current pipeline network diagram shown in Figure 1.2-1. Moreover, pipeline network model for 2015, 2020, 2025 and 2030 is also developed in consideration of currently undergoing and planned projects which are shown in Figure 1.1-2 to Figure 1.1-4.

A typical pipeline network model established by PIPESIM is shown in Figure 3.1-1.

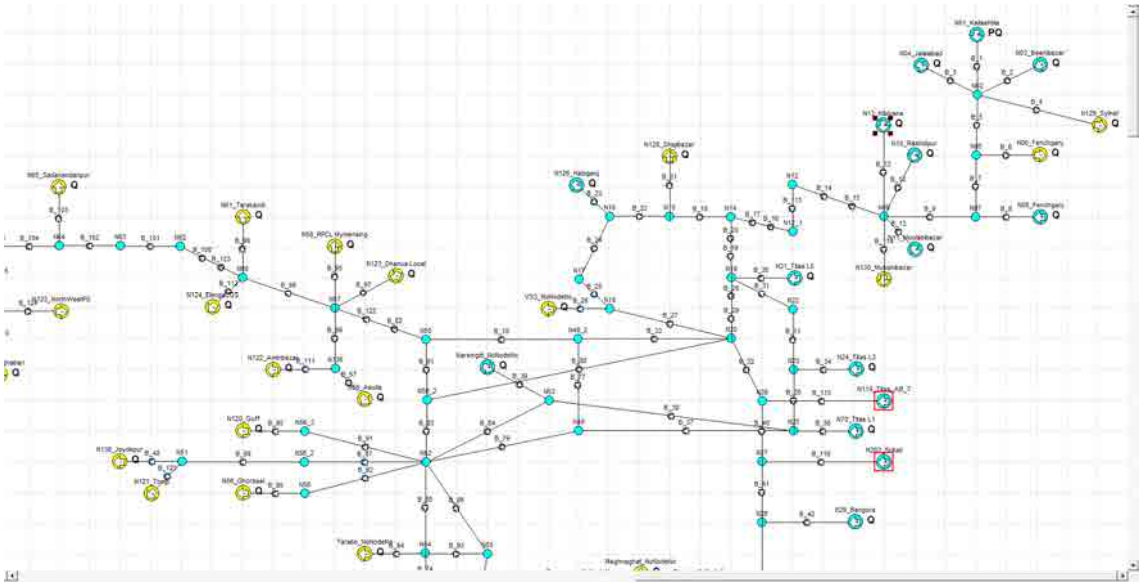


Figure 3.1-1 Typical Pipeline Network Model

3.2 Calibration of Current Pipeline Network Model (as of 2013)

As discussed in 2.2.3, the gas supply data is adjusted so as to meet the gas demand. After this adjustment, Base Case model is calibrated to reproduce the present operating condition on current pipeline network.

Calibration of this Base Case model is achieved by tuning internal pipe roughness to pressure loss expected in any pipeline section. In short, increment of the pipe roughness leads to the increment of the pressure loss on the pipeline section.

3.3 Verification of Pipeline Capacity for Future Demand (as of 2015, 2020, 2025 and 2030)

On the basis of the calibrated simulation model (2013) discussed in Section 3.2, the pipeline capacity for future demand is verified for respective years (2015, 2020, 2025 and 2030) using PIPESIM 2011. In this verification, gas supply and demand volume forecasted in Table 2.2-7 and Table 2.2-8 is applied to input data of the flow simulation.

As for simulation output, the pipeline capacity is verified based on the evaluation criterion described in Section 2.2.5. As a result of the flow simulation, if arrival pressure at a delivery point is calculated at less than 350 psig, pipeline system located upstream of the point is considered as insufficient capacity.

Chapter 4 Simulation Result

4.1 Calibration of Existing Pipeline Network

Based on study basis and assumptions described in Section 2, PIPESIM model in 2013 is established and calibrated so as to meet current operating conditions at principal pipeline stations. The following data is reviewed for the calibration:

- Table 4.1-1 Gas Supply Data (2013)
- Table 4.1-2 Gas Demand Data (2013)
- Table 4.1-3 Operating Condition (Measured Data)
- Table 4.1-4 Operating Condition (Calculated Data)

The calibration result of the existing pipeline network is shown in Table 4.1-1 to Table 4.1-4.

Table 4.1-1 Calibration Result for Gas Supply Data (2013)

Node No.	Field Name	Gas supply [MMSCFD]		Diff. %	Pressure [psig]		Diff. %
		Real	Sim.		Real	Sim.	
N01	Kailashtila GF	56.764	56.764	0.00	909.5	909.5	0.00
N04	Jalalabad GF	191.779	191.78	0.00	908	908.2	0.02
N08	Fenchuganj GF	41.380	41.38	0.00	897	895.04	-0.21
N10	Rashidpur GF	48.160	48.16	0.00	807.5	807.37	-0.02
N11	Moulabibazar	77.405	77.405	0.00	847.5	846.54	-0.11
N13	Bibiyana GF	867.503	867.5	0.00	1100	1101.9	0.17
N21	Titas GF L-5	71.260	71.26	0.00	960	959.77	-0.02
N24	Titas GF L-3	161.477	161.48	0.00	935	933.16	-0.19
N29	Bangora GF	78.578	78.578	0.00	843	844.95	0.23
N31	Salda GF	16.203	16.203	0.00	665	666.37	0.20
N32	Meghna GF	8.127	8.1271	0.00			
N70	Titas GF L-1	229.205	229.21	0.00	890	886.55	-0.38
N101	Bakhrabad GF	28.809	28.809	0.00	623.5	642.72	3.01
N106	Sangu GF	4.252	4.2518	0.00			
N107	Semutang GF	7.331	7.3306	0.00			
N119	Titas GF AB L-7	17.071	17.071	0.00	990	991.1	0.11
N125	Narsingdi GF	31.042	31.042	0.00			
N126	Habiganj GF	73.727	73.727	0.00	1000	999.4	-0.06
N202	Srikail GF	25.893	25.893	0.00	675	675.42	0.06

* Real: Current operating condition, Sim.: Calibrated operating condition

Table 4.1-2 Calibration Result for Gas Demand Data (2013)

Node No.	Terminal Name	Gas Demand [MMSCFD]		Diff. %	Pressure [psig]		Diff. %
		Real	Sim.		Real	Sim.	
N06	Fenchganj 90MW PS	53.276	53.276	0.00	877	881.25	0.48
N35	Chandpur	35	35	0.00			
N58	RPCL Mymensing	27.054	27.054	0.00	285	286.38	0.46
N59	Ashulia	110.234	110.23	0.00	144.5	145.93	0.90
N61	Tarakandi	34.624	34.624	0.00	287.5	288.84	0.44
N65	Sadanandanpur	14.109	14.109	0.00			
N69	Bogra	13.765	13.765	0.00	287.5	287.9	0.13
N75	Rajshahi	1	1	0.00			
N102	Laksham	3	3	0.00			
N103	Feni	20	20	0.00			
N104	Chittagong CGS	166.7	166.7	0.00			
N105	Barabkundu	25	25	0.00			
N110	TGTDCL Demra	137.214	137.21	0.00			
N111	GTCL Demra	82.46	82.46	0.00			
N112	Haripur	70.311	70.311	0.00	157.25	157.18	-0.04
N113	Siddhiriganj	123.116	123.12	0.00			
N114	Tarabo	30	30	0.00			
N115	Kutumbopur/Comilla	31.28	31.28	0.00			
N116	Gojaria	25	25	0.00			
N117	Meghnaghat	35.848	35.848	0.00			
N118	Sonargaon	10	10	0.00			
N120	Guff/PUFF	2.369	2.369	0.00			
N121	Tongi	26.628	26.628	0.00			
N122	Aminbazar	77.93	77.93	0.00	110.25	111.21	0.77
N123	Dhanua Local	121.187	121.19	0.00			
N124	Elenga CGS	80.905	80.905	0.00			
N127	VS3	214.476	214.48	0.00			
N128	Shajibazar PS	46.54	46.54	0.00	295	295.76	0.25
N129	Sylhet	36.826	36.826	0.00			
N130	Munshibazar	3	3	0.00	862	803.94	-6.62
N137	North-West PS	36.041	36.041	0.00			
N138	Joydepur	89.585	89.585	0.00			
N139	Baghabari	46.291	46.291	0.00	278.5	276.32	-0.74
N141	Ghorasal	205.195	205.2	0.00			

* Real: Current operating condition, Sim.: Calibrated operating condition

Table 4.1-3 Calibration Result for Operating Condition (measured data, 2013)

Pipeline No.	Node		Pressure (psig)		Diff. %	Station Name
	from	to	Real	Sim.		
22	20	18	786.10	768.13	0.26	Ashuganj Gas Manifold Station
27	20	26	786.10			
28	20	49	773.05/ 770.15			
29	20	50				
65	50	52	620.00	618.68	-0.21	Monohordi Gas Manifold Station
	104		275.75	277.08	0.46	Chittagong City Gate Station
	110/111		155	156	0.75	Demra City Gate Station
	115		350	353	0.85	Kutumbopur Town Bordering Station

* Real: Current operating condition, Sim.: Calibrated operating condition

Table 4.1-4 Calibration Result for Operating Condition (calculated data, 2013)

Pipeline No.	Node		Inlet Press. (psig)		Diff. %	Station Name
	from	to	Real	Sim.		
44	30	33	650	642.09	0.32	Bakhrabad - Chittagong Pipeline
45	30	100	640			Bakhrabad - Demra Pipeline
78	136	122	225	222.55	-1.02	Dhanua - Aminbazar Pipeline
81	60	62	390	388.57	-0.35	Elenga - Nalka Pipeline
83	62	63	390	387.47	-0.63	Jamuna Bridge Portion Pipeline
87	66	67	350	350.5	0.14	Nalka - Baghabari Pipeline
120	18	127	766	765.67	-0.04	Vs-3 Pipeline

* Real: Current operating condition, Sim.: Calibrated operating condition

Based on the above calibrated data, pipeline capacity is verified for future gas demand.

4.2 Verification of Pipeline Capacity for Future Demand

Verification of future pipeline capacity aims to reveal bottlenecks on pipeline network and is conducted utilizing calibrated PIPESIM model which was established in accordance with the latest information of the future construction projects of pipelines and pipeline compressor stations.

Verification results in 2015 Case, 2020 Case, 2025 Case and 2030 Case are as follows:

4.2.1 Verification Result of Pipeline Capacity in 2015

Verification of pipeline capacity in 2015 is conducted using the PIPESIM model calibrated in Section 4.1. As described in Section 2.2.1, it is assumed that operating pressure of each gas field is appropriately maintained in order to supply the gas to the Muchai compressor station at the rated pressure of 770 psig. In this case, supply

pressure of each gas field and arrival pressure at each terminal are calculated as shown in Table 4.2-1 and Table 4.2-2, respectively.

Table 4.2-1 Calculated Supply Pressure at each Field (in 2015)

Node No.	Field Name	Gas supply [MMSCFD]	Pressure [psig]
		2015	2015
N01	Kailashtila	171.88	1247.5
N03	Beanibazar GF	16.042	1102.4
N04	Jalalabad GF	263.55	1130.5
N08	Fenchuganj GF	68.753	1110.7
N10	Rashidpur GF	114.59	813.58
N11	Moulabibazar	45.835	847.5
N13	Bibiyana GF	1145.9	1100
N21	Titas GF L-5	102.28	1033.2
N24	Titas GF L-3	231.77	1112.7
N29	Bangora GF	114.59	1196.2
N31	Salda GF	20.626	942.29
N32	Meghna GF	11.459	936.83
N70	Titas GF L-1	328.98	1094.1
N101	Bakhrabad GF	57.294	916.15
N106	Sangu	9.167	642.73
N107	Semutang GF	28.647	643.48
N119	Titas AB L-7	24.503	1259.3
N125	Narsingdi GF	34.377	777.88
N126	Habiganj GF	286.47	1941.9
N134	Rapganj GF	36.525	458.25
N202	Srikail GF	60.875	944.39

Note: As for value in gray columns, the pressure data is not available in 2013 and is assumed properly in consideration of pressure balance on pipeline network around the gas field.

Table 4.2-2 Calculated Arrival Pressure at each Terminal (in 2015)

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2015	2015
N06	Fenchganj 90MW PS	70.59	1088.9
N57	**Dhanua**	**1011.1**	**872.87**
N58	RPCL Mymensing	35.846	624.36
N59	Ashulia	146.06	497.83
N60	**Elenga**	**565.41**	**See Note.**
N61	Tarakandi		See Note.
N69	Bogra		See Note.
N76	Ishwardi		See Note.

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2015	2015
N77	Bheramara 360MW		See Note.
N78	Kushtia		See Note.
N79	Jhinaidah		See Note.
N81	Jessore		See Note.
N83	Khulna		See Note.
N110	TGTDCL Demra	181.81	425.57
N112	Haripur	93.161	423.95
N122	Aminbazar	103.26	481.55
N128	Shajibazar PS	61.665	397.09
N130	Munshibazar	3.975	794.01
N131	Meghnaghat PS	73.485	890.27
N132	Haripur PS	55	890.54
N133	Siddhiriganj PS	83	887.67
N139	Baghabari		See Note.

Note: The pressure data cannot be calculated due to insufficient capacity of the pipeline section.

According to Table 4.2-2, the following bottlenecks were revealed in 2015 Case and appropriate measures necessary for the respective bottlenecks are stated with a recommendation:

(1) Bottleneck 1

As indicated in Table 4.2-2, operating pressure forecasted at Elenga and its western section could not be obtained in flow simulation. This means that pipeline model of the section has not sufficient capacity.

Accordingly, the pipeline section between Dhanua (N57) and Elenga (N60) does not have a capacity enough to transport required amount of the gas. Therefore, all the delivery points (e.g. N61, 69, 76, 77, 78, 79, 81, 83, 139) located downstream of Elenga cannot supply gas with proper pressure level to respective end-users.

In 2015, the pipeline section between Dhanua and Elenga is operated by only a 24" single pipeline, and gas from Bibiyana GF (N13) by 36'' pipeline and gas from Monohordi (N50) by bothe 24'' and 30'' pipelines are gathered at Dhanua and flow into the pipeline section. Accordingly, flow rate of the pipeline section extremely increases compared to present flow rate, and the pressure drop at this pipeline section also buildup seriously.

Therefore, duplication of Dhanua – Elenga pipeline or installation of booster compressor in Dhanua is required to solve this phenomenon. However, the Dhanua – Elenga pipeline will be looped by 2017 by construction of new 30" pipeline. In this case, the compressor installation scenario for the pipeline section should be applied to solve this bottleneck.

In case the booster compressor is installed in Dhanua, required suction pressure of 650 psig in Elenga compressor station can be achieved, and also the existing 24" Dhanua – Elenga pipeline can transport required amount of demand gas to Elenga. At this time, discharge pressure of the compressor in Dhanua is estimated at 1,138 psig. Refer to gray curve (Arrival Pressure = 650 psig Case) in Figure 4.2-1.

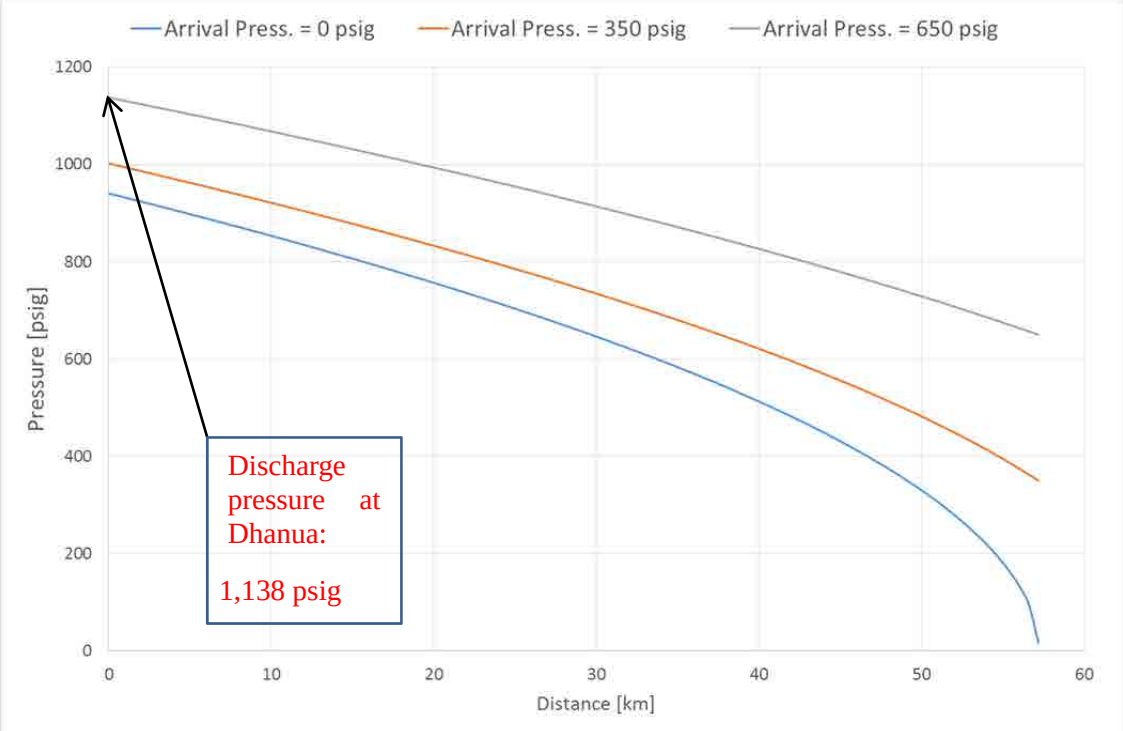


Figure 4.2-1 Existing 24" Dhanua - Elenga (N57 - N 60) Pipeline Pressure Drop

(2) Bottleneck 2

As the result of flow simulation in 2015, flow rate and arrival pressure at each compressor station is calculated as shown in Table 4.2-3.

According to the table, arrival pressure expected at Muchai compressor station is a little bit lower than the rated suction pressure of 770 psig due to increment of gas production volume of each gas field.

Accordingly, existing 24" N-S pipeline between N02 and Muchai (N09) does not have a capacity enough to transport required amount of gas. Therefore, production pressure at each well located upstream of Muchai must be maintained sufficiently to solve this phenomenon.

Table 4.2-3 Required Compressor Specification (in 2015)

Location	Pipeline No.	Node		Suction Press.	Arrival Press. (in 2015)	Diff.	Disch. Press.	Capacity	Flow rate (in 2015)	Margin
		from	to	(psig)	(psig)	(psig)	(psig)	(MMSCFD)	(MMSCFD)	(MMSCFD)
Muchai	11/12	9	12	770	765.44	-4.6	1,135	1,200	1,100	100
Ashuganj	27	20	26	600	740.28	140.3	1,000	1,500	1,333	167
	28	20	49							
	29	20	50							
Elenga	81/82	60	62	650	650	0	1,000	500	412.35	88

(3) Bottleneck 3

As for the above "Bottleneck 1", further bottleneck was revealed by installation of the additional booster compressor in Dhanua.

Arrival pressure at western parts on pipeline network is calculated on the assumption that suction and discharge pressure at Elenga is 650 and 1,000 psig, respectively that is rated operating condition of Elenga compressor station. The calculation result is shown in Table 4.2-4.

Table 4.2-4 Calculated Arrival Pressure at each Terminal (in 2015; Modified)

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2015	2015
N06	Fenchganj 90MW PS	70.59	1088.9
N57	**Dhanua**	**1011.1**	**1138**
N58	RPCL Mymensing	35.846	624.36
N59	Ashulia	146.06	497.83
N60	**Elenga**	**565.41**	**650**
N61	Tarakandi	45.876	552.7
N69	Bogra	18.238	703.6
N77	Bheramara 360MW	90	580.05
N79	Jhinaidah	8	410.77
N81	Jessore	20	265.38
N83	Khulna	122	138.14
N110	TGTDCL Demra	181.81	425.57
N112	Haripur	93.161	423.95
N122	Aminbazar	103.26	481.55

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2015	2015
N128	Shajibazar PS	61.665	397.09
N130	Munshibazar	3.975	794.01
N131	Meghnaghat PS	73.485	890.27
N132	Haripur PS	55	890.54
N133	Siddhiriganj PS	83	887.67
N139	Baghabari	61.335	714.96

As shown in Table 4.2-3, the arrival pressure at Jessore (N81) and Khulna (N83) is expected below 350 psig in case of the discharge pressure of 1,000 psig at Elenga. After installation of the compressor in Dhanua, suction pressure in Elenga compressor station can fully improve; nevertheless the two (2) supply points located downstream of Elenga still cannot supply the gas to end-users. Accordingly, further compression is required upstream of Jessore.

In order to solve this phenomenon, another compressor is required upstream of Jessore (N81) additionally. Alternatively, discharge pressure (1,138 psig) estimated for the Dhanua booster compressor may be raised so as to cover arrival pressure required at Jessore (N81) and Khulna (N83).

(4) Others

As indicated in Table 4.2-1, in order to establish flow simulation model, gas production pressure at each gas field was adjusted so that suction pressure at Muchai and Elenga Compressor Station corresponds to planned suction pressure of the compressor. Accordingly, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if gas production rate increase in the year.

This issue is not a bottleneck at this moment, however proper measures are be to taken for boosting the gas production pressure at each well in future.

As the simulation outputs, the above bottlenecks are summarized in Figure 4.2-2.

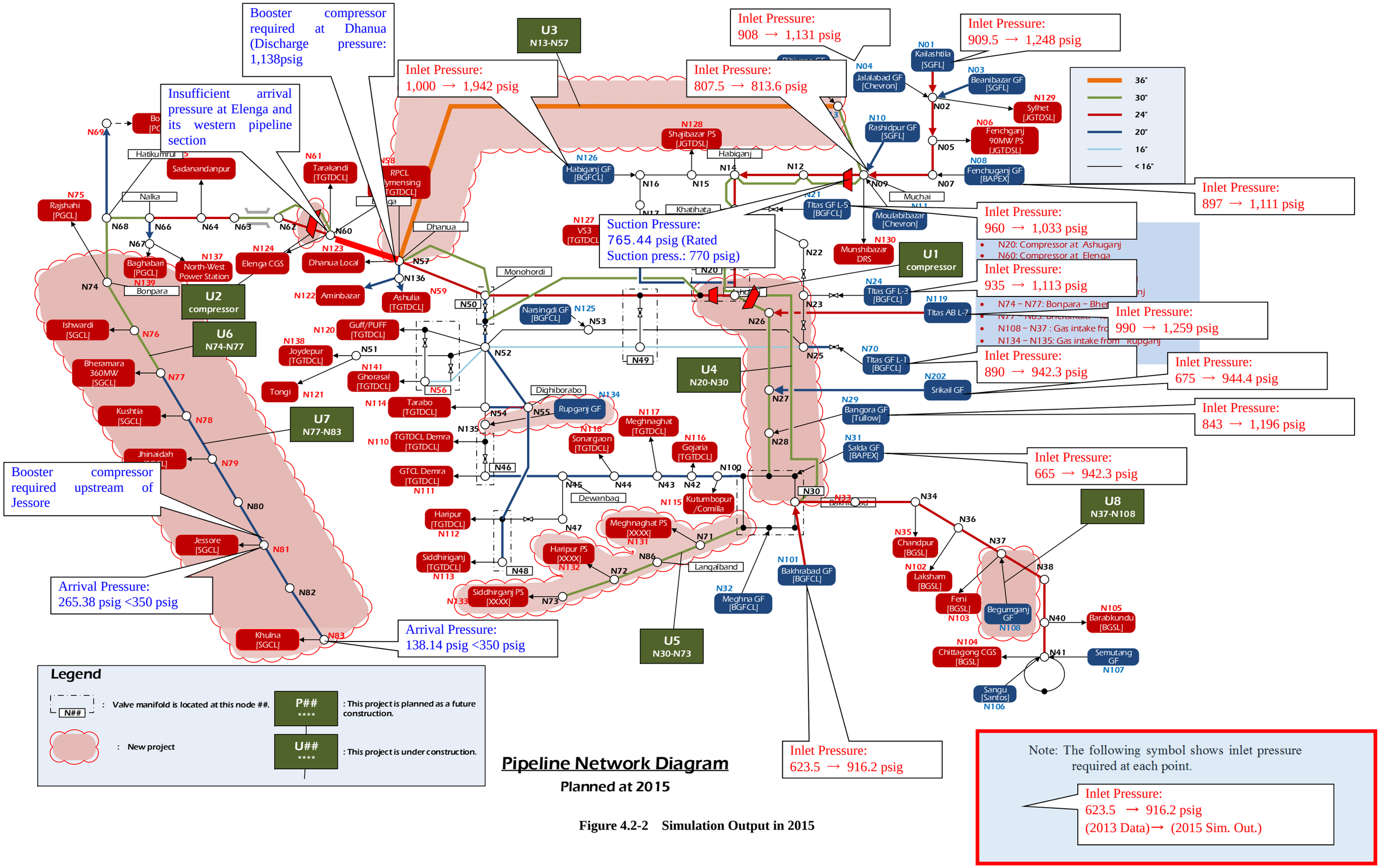


Figure 4.2-2 Simulation Output in 2015

4.2.2 Verification Result of Pipeline Capacity in 2020

Verification of pipeline capacity is conducted based on the PIPESIM model in 2020 Case. As described in Section 2.2.1, it is assumed that operating pressure of each gas field is appropriately maintained in order to supply the gas to the Muchai compressor station at the rated pressure of 770 psig. And also, discharge pressure at three (3) compressor stations (Muchai, Ashuganj and Elenga) is assumed to be set at the rated discharge pressure of the compressors. In this case, supply pressure of each gas field and arrival pressure at each terminal are calculated as shown in Table 4.2-5 and Table 4.2-6, respectively.

Table 4.2-5 Calculated Supply Pressure at each Field (in 2020)

Node No.	Field Name	Gas supply [MMSCFD]	Pressure [psig]
		2020	2020
N01	Kailashtila	316.61	1510
N03	Beanibazar GF	17.73	1059.4
N04	Jalalabad GF	0	
N08	Fenchuganj GF	50.658	1060.3
N10	Rashidpur GF	316.61	956.47
N11	Moulabibazar	50.658	847.5
N13	Bibiyana GF	1519.7	1100
N21	Titas GF L-5	113.04	960
N24	Titas GF L-3	256.15	1060.7
N29	Bangora GF	63.322	1024.6
N31	Salda GF	8.865	914.73
N32	Meghna GF	0	
N70	Titas GF L-1	363.59	1040.6
N101	Bakhrabad GF	101.32	909.65
N106	Sangu	0	
N107	Semutang GF	37.993	870.28
N108	Begumganj GF	65.625	890.64
N119	Titas AB L-7	27.081	1256.7
N125	Narsingdi GF	25.329	451.64
N126	Habiganj GF	101.32	1000
N134	Rapganj GF	65.625	126.31
N140	Sylet GF	31.661	1059.8
N202	Srikail GF	109.38	941.39

Note: As for value in gray columns, the pressure data is not available in 2013 and is assumed properly in consideration of pressure balance on pipeline network around the gas field.

Table 4.2-6 Calculated Arrival Pressure at each Terminal (in 2020)

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2020	2020
N06	Fenchganj 90MW PS	81.002	1043.4
N58	RPCL Mymensing	41.134	304.15
N59	Ashulia	167.6	247.26
N61	Tarakandi	52.643	508.08
N69	Bogra	20.929	833.98
N76	Ishwardi	17.213	708.94
N77	Bheramara 360MW	103.28	697.52
N78	Kushtia	11.475	638.29
N79	Jhinaidah	9.18	522.02
N81	Jessore	22.95	381.34
N83	Khulna	140	285.09
N110	TGTDCL Demra	118.96	0.00405
N112	Haripur	71.317	0.00405
N122	Aminbazar	118.49	200.5
N128	Shajibazar PS	70.761	350
N130	Munshibazar	4.561	822.25
N131	Meghnaghat PS	84.325	874.42
N132	Haripur PS	63.113	874.79
N133	Siddhiriganj PS	95.243	870.93
N139	Baghabari	70.382	845.63

According to Table 4.2-6, the following issues can be said:

- Calculated flow rate of 118.96 and 71.317 MMSCFD at TGTDCL Demra (N110) and Haripur (N112) is smaller than the forecasted flow rate of 208.624 and 106.903 MMSCFD (Refer to Table 2.2-8), respectively.
- Calculated arrival pressure below 350 psig is forecasted at RPCL Mymensing, Ashulia, Khulna, TGTDCL Demra, Haripur and Aminbazar.

The above phenomena are attributed to low supply pressure of each gas field and compressor stations. As a simulation result, flow rate and pressure required at each compressor station are shown in Table 4.2-7.

Table 4.2-7 Required Compressor Specification (in 2020)

Location	Pipeline No.	Node		Suction Press.	Arrival Press. (in 2020)	Diff.	Disch. Press.	Capacity	Flow rate (in 2020)	Margin
		from	to	(psig)	(psig)	(psig)	(psig)	(MMSCFD)	(MMSCFD)	(MMSCFD)
Muchai	11/12	9	12	770	768.87	-1.1	1,135	1,200	1,500	-300
Ashuganj	27	20	26	600	206.16	-393.8	1,000	1,500	1,716	-216
	28	20	49							
	29	20	50							
Elenga	81/82	60	62	650	648.82	-1.2	1,000	500	473.17	27

According to the above, the following bottlenecks were revealed in 2020 Case and appropriate measures necessary for the respective bottlenecks are stated with a recommendation:

(1) Bottleneck 1

As shown in Table 4.2-7, total capacity of 1,200 MMSCFD of compressors operated in Muchai compressor station (N09) is smaller than simulated flow rate of 1,500 MMSCFD. Moreover, total capacity of 1,500 MMSCFD of compressors operated in Ashuganj compressor station (N20) is smaller than simulated flow rate of 1,716 MMSCFD.

Accordingly, flow rate required at each compressor station cannot be covered by the compressors, and another compressor with same specification as existing compressor is required at both Muchai and Ashuganj compressor station additionally in order to cover the each flow difference.

(2) Bottleneck 2

As shown in Table 4.2-7, arrival pressure of 206.16 psig expected at Ashuganj compressor station (N20) is lower than rated suction pressure (600 psig) of the compressor. In case of Muchai (N09) and Elenga (N60) compressor stations, arrival pressure is a little bit smaller than rated suction pressure of the each compressor.

Accordingly, it is expected that rated discharge pressure cannot be achieved at outlet of the three (3) compressor stations and additional booster compressor is required at upstream of Muchai.

(3) Bottleneck 3

As shown in Table 4.2-6, delivery pressure at several points such as RPCL Mymensing (N58), Ashulia (N59), TGTCDL Demra (N110), Haripur (N112), Aminbazar (N122) and Khulna (N83) is lower than 350 psig of evaluation criteria. Accordingly, the following pipelines do not have enough capacity to transport required amount of demand gas.

- Pipeline between Dhanua (N57) and RPCL Mymensing (N58)
- Pipeline between N136 and Ashulia (N59)
- Pipeline between N136 and Aminbazar (N122)
- Pipeline between Jessore (N81) and Khulna (N83)
- Pipeline between N135 and TGTCDL Demra (N110)
- Pipeline between N48 and Haripur (N112)

Therefore, all the delivery points cannot supply sufficient amount of gas to end-users.

In 2020 Case, bottlenecks occurs in several points on pipeline network due to increment of gas supply volume. In this case, it is preferable to install booster compressor in order to simultaneously improve transmission capacity of all the pipelines excluding the pipeline between Jessore (N81) and Khulna (N83).

In case the booster compressor is additionally installed in Ashuganj compressor station, discharge pressure of the station should be increased from 1,000 psig to 1,074 psig.

As for the bottleneck between Jessore (N81) and Khulna (N83), if the booster compressor is additionally installed in Elenga compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,021 psig.

(4) Others

All gas flow lines which transfer gas produced in each gas field must have a capacity enough to send the gas into transmission pipeline. Accordingly, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if the gas production rate increases for gas demand.

This issue is not a bottleneck at this moment, however proper measures are to be taken so as to overcome the transmission pipeline pressure.

As the simulation outputs, the above bottlenecks are indicated in Figure 4.2-3.

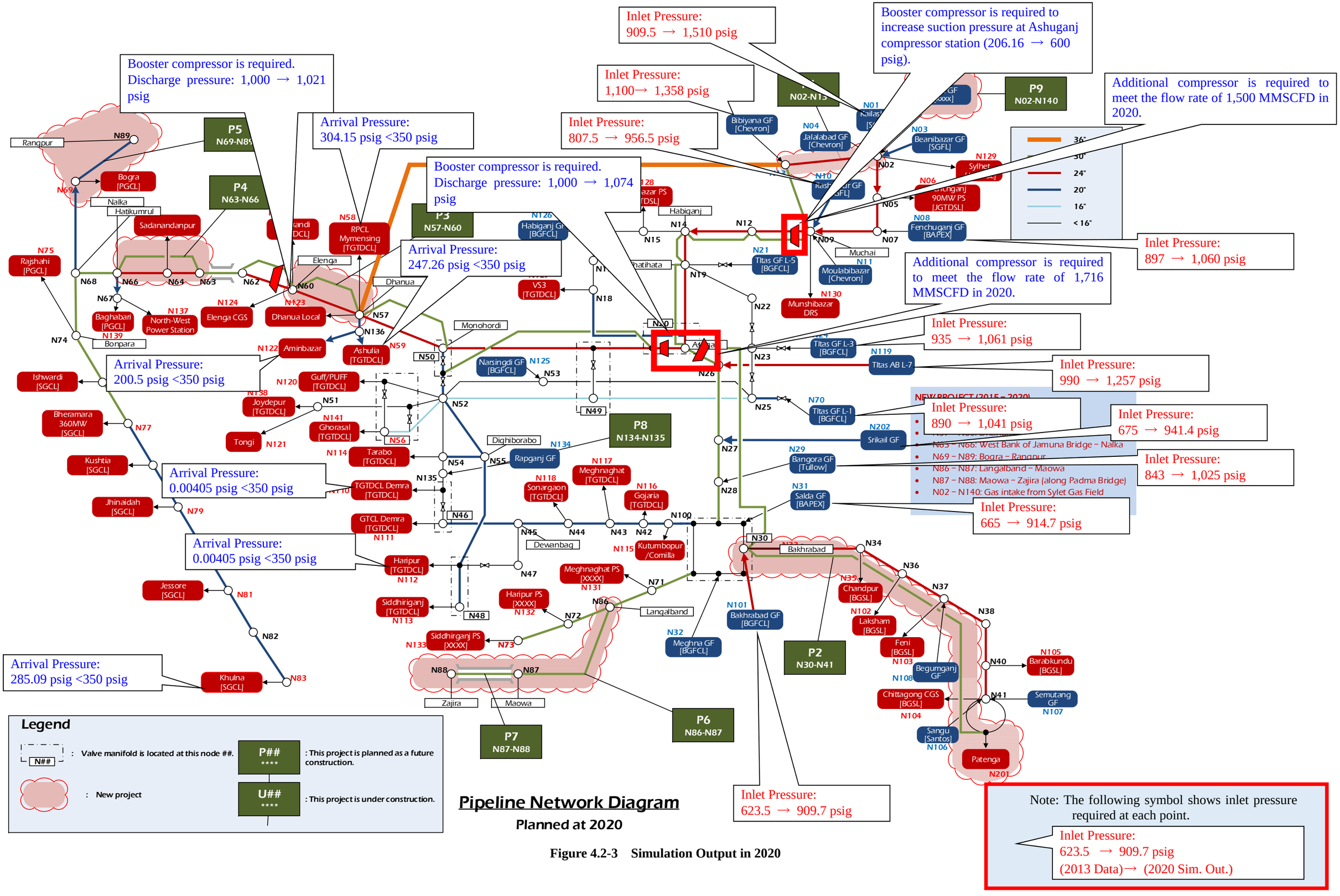


Figure 4.2-3 Simulation Output in 2020

4.2.3 Verification Result of Pipeline Capacity in 2025

Verification of pipeline capacity is conducted based on the PIPESIM model in 2025–2030 Case. As described in Section 2.2.1, it is assumed that operating pressure of each gas field is appropriately maintained in order to supply the gas to the Muchai compressor station at the rated pressure of 770 psig. And also, discharge pressure at three (3) compressor stations (Muchai, Ashuganj and Elenga) is assumed to be set at the rated discharge pressure of the compressors. In this case, supply pressure of each gas field and arrival pressure at each terminal are calculated as shown in Table 4.2-8 and Table 4.2-9, respectively.

Table 4.2-8 Calculated Field Pressure at each Field (in 2025)

Node No.	Field Name	Gas supply [MMSCFD]	Pressure [psig]
		2025	2025
N01	Kailashtila	609.63	2315
N03	Beanibazar GF	24.385	1079.1
N04	Jalalabad GF	0	
N08	Fenchuganj GF	0	
N10	Rashidpur GF	609.63	1327.2
N11	Moulabibazar	97.54	1002.8
N13	Bibiyana GF	487.7	1100
N21	Titas GF L-5	108.83	1032.8
N24	Titas GF L-3	246.61	1117.8
N29	Bangora GF	24.385	1003.4
N31	Salda GF	0	
N32	Meghna GF	0	
N70	Titas GF L-1	350.05	1097.1
N101	Bakhrabad GF	170.7	969.16
N106	Sangu	0	
N107	Semutang GF	36.578	942.08
N108	Begumganj GF	159.61	982.69
N119	Titas AB L-7	26.071	1305.2
N125	Narsingdi GF	48.77	752.04
N126	Habiganj GF	121.93	1157.9
N134	Rapganj GF	159.61	506.47
N140	Sylet GF	48.77	1080
N202	Srikail GF	266.02	995.9

Note: As for value in gray columns, the pressure data is not available in 2013 and is assumed properly in consideration of pressure balance on pipeline network around the gas field.

Table 4.2-9 Calculated Arrival Pressure at each Terminal (in 2025)

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2025	2025
N06	Fenchganj 90MW PS	79.99	1064.3
N58	RPCL Mymensing	40.62	320.82
N59	Ashulia	165.51	259.12
N61	Tarakandi	51.986	516.86
N69	Bogra	20.667	844.54
N76	Ishwardi	16.998	723.92
N77	Bheramara 360MW	101.99	713.11
N78	Kushtia	11.332	658.36
N79	Jhinaidah	9.065	548.49
N81	Jessore	22.663	418.75
N83	Khulna	138.25	333.94
N110	TGTDCL Demra	206.02	415.44
N112	Haripur	105.57	409.79
N122	Aminbazar	117.01	216.04
N128	Shajibazar PS	69.877	350
N130	Munshibazar	4.504	945.35
N131	Meghnaghat PS	83.271	928.39
N132	Haripur PS	62.324	928.73
N133	Siddhiriganj PS	94.053	925.21
N139	Baghabari	69.503	855.05

According to Table 4.2-9, the following issues can be said:

- Calculated arrival pressure below 350 psig is forecasted at RPCL Mymensing, Ashulia, Khulna and Aminbazar.

The above phenomena are attributed to low supply pressure of each gas field and compressor stations. As a simulation result, flow rate and pressure required at each compressor station are shown in Table 4.2-10.

Table 4.2-10 Required Compressor Specification (in 2025)

Location	Pipeline No.	Node		Suction Press.	Arrival Press. (in 2025)	Diff.	Disch. Press.	Capacity	Flow rate (in 2025)	Margin
		from	to	(psig)	(psig)	(psig)	(psig)	(MMSCFD)	(MMSCFD)	(MMSCFD)
Muchai	11/12	9	12	770	916.19	146.2	1,135	1,200	1,206	-6
Ashuganj	27	20	26	600	710.35	110.4	1,000	1,500	1,252	248
	28	20	49							
	29	20	50							
Elenga	81/82	60	62	650	645.66	-4.3	1,000	500	467.26	33

According to the above, the following bottlenecks were revealed in 2025 Case and appropriate measures necessary for the respective bottlenecks are stated with a recommendation:

(1) Bottleneck 1

As shown in Table 4.2-10, total capacity of 1,200 MMSCFD of compressors operated in Muchai compressor station (N09) is a little bit smaller than simulated flow rate of 1,206 MMSCFD.

Accordingly, flow rate required at the compressor station cannot be covered by the compressors, and another compressor with same specification as existing compressor is required at Muchai compressor station additionally in order to cover the flow difference.

(2) Bottleneck 2

As shown in Table 4.2-9, delivery pressure at several points such as RPCL Mymensing (N58), Ashulia (N59), Aminbazar (N122) and Khulna (N83) is lower than 350 psig of evaluation criteria. Accordingly, the following pipelines does not have enough capacity to transport required amount of demand gas.

- Pipeline between Dhanua (N57) and RPCL Mymensing (N58)
- Pipeline between N136 and Ashulia (N59)
- Pipeline between N136 and Aminbazar (N122)
- Pipeline between Jessore (N81) and Khulna (N83)

Therefore, all the delivery points cannot supply sufficient amount of gas to end-users.

In 2025 Case, bottlenecks occurs in several points on pipeline network due to increment of gas supply volume. In this case, it is preferable to install booster compressor in order

to simultaneously improve transmission capacity of all the pipelines excluding the pipeline between Jessore (N81) and Khulna (N83).

In case the booster compressor is additionally installed in Ashuganj compressor station, discharge pressure of the station should be increased from 1,000 psig to 1,098 psig.

As for the bottleneck between Jessore (N81) and Khulna (N83), if the booster compressor is additionally installed in Elenga compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,004 psig.

(3) Bottleneck 3

As shown in Table 4.2-8, arrival pressure of 645.66 psig expected at Elenga compressor station (N60) is a little bit lower than rated suction pressure (650 psig) of the compressor.

Accordingly, it is expected that rated discharge pressure cannot be achieved at outlet of the compressor station and additional booster compressor is required upstream of Elenga.

(4) Others

All gas flow lines which transfer gas produced in each gas field must have a capacity enough to send the gas into transmission pipeline. Accordingly, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if the gas production rate increases for gas demand.

This issue is not a bottleneck at this moment, however proper measures are to be taken so as to overcome the transmission pipeline pressure.

As the simulation outputs, the above bottlenecks are indicated in Figure 4.2-4

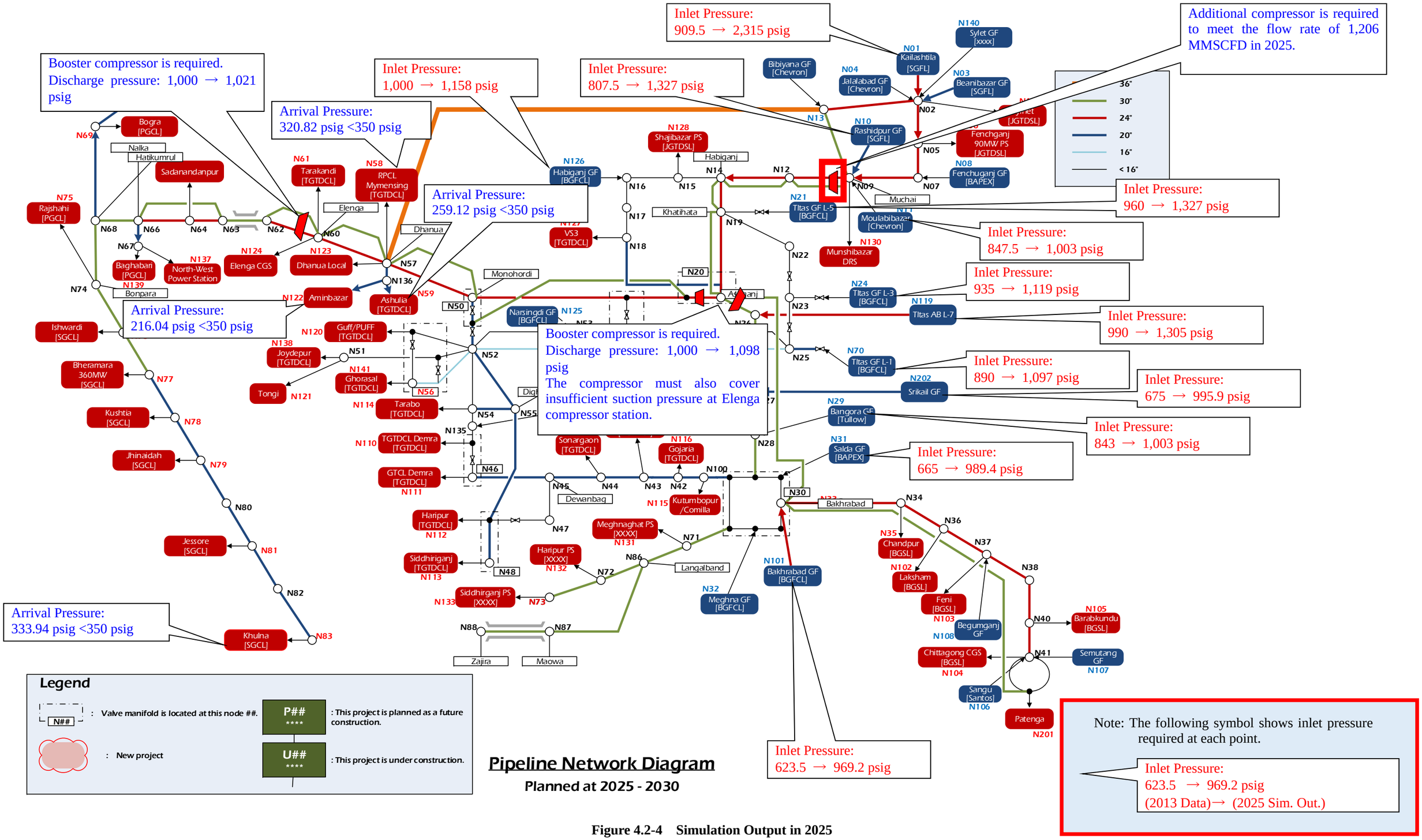


Figure 4.2-4 Simulation Output in 2025

4.2.4 Verification Result of Pipeline Capacity in 2030

Verification of pipeline capacity is conducted based on the PIPESIM model in 2025–2030 Case. As described in Section 2.2.1, it is assumed that operating pressure of each gas field is appropriately maintained in order to supply the gas to the Muchai compressor station at the rated pressure of 770 psig. And also, discharge pressure at three (3) compressor stations (Muchai, Ashuganj and Elenga) is assumed to be set at the rated discharge pressure of the compressors. In this case, supply pressure of each gas field and arrival pressure at each terminal are calculated as shown in Table 4.2-11 and Table 4.2-12, respectively.

Table 4.2-11 Calculated Field Pressure at each Field (in 2030)

Node No.	Field Name	Gas supply [MMSCFD]	Pressure [psig]
		2030	2030
N01	Kailashtila	802.32	2950
N03	Beanibazar GF	0	
N04	Jalalabad GF	0	
N08	Fenchuganj GF	0	
N10	Rashidpur GF	802.32	1612.6
N11	Moulabibazar	0	
N13	Bibiyana GF	200.58	1100
N21	Titas GF L-5	119.36	1106.5
N24	Titas GF L-3	270.46	1169.3
N29	Bangora GF	0	
N31	Salda GF	0	
N32	Meghna GF	0	
N70	Titas GF L-1	383.91	1141.4
N101	Bakhrabad GF	80.232	976.04
N106	Sangu	0	
N107	Semutang GF	40.116	953.27
N108	Begumganj GF	289.93	1040.1
N119	Titas AB L-7	28.593	1314.7
N125	Narsingdi GF	0	
N126	Habiganj GF	80.232	1072.8
N134	Rapganj GF	289.93	633.23
N140	Sylet GF	0	
N202	Srikail GF	483.22	1014.6

Note: As for value in gray columns, the pressure data is not available in 2013 and is assumed properly in consideration of pressure balance on pipeline network around the gas field.

Table 4.2-12 Calculated Arrival Pressure at each Terminal (in 2030)

Node No.	Terminal Name	Gas Demand [MMSCFD]	Pressure [psig]
		2030	2030
N06	Fenchganj 90MW PS	86.093	1195.3
N58	RPCL Mymensing	43.719	244.49
N59	Ashulia	178.13	229.97
N61	Tarakandi	55.952	502.76
N69	Bogra	22.244	831.56
N76	Ishwardi	18.294	680.93
N77	Bheramara 360MW	109.77	667.56
N78	Kushtia	12.196	598.87
N79	Jhinaidah	9.757	452.95
N81	Jessore	24.392	264.23
N83	Khulna	**145.57**	**0.00405**
N110	TGTDCL Demra	221.74	489.69
N112	Haripur	113.62	486.37
N122	Aminbazar	125.93	171.29
N128	Shajibazar PS	75.208	350
N130	Munshibazar	4.848	1058.2
N131	Meghnaghat PS	89.624	939.54
N132	Haripur PS	67.079	939.94
N133	Siddhiriganj PS	101.23	935.9
N139	Baghabari	74.805	840.07

According to Table 4.2-12, the following issues can be said:

- Calculated flow rate of 145.57 MMSCFD at Khulna (N83) is smaller than the forecasted flow rate of 148.794 MMSCFD (Refer to Table 2.2-8).
- Calculated arrival pressure below 350 psig is forecasted at RPCL Mymensing, Ashulia, Aminbazar, Jessore and Khulna.

The above phenomena are attributed to low supply pressure of each gas field and compressor stations. As a simulation result, flow rate and pressure required at each compressor station are shown in Table 4.2-13.

Table 4.2-13 Required Compressor Specification (in 2030)

Location	Pipeline No.	Node		Suction Press.	Arrival Press. (in 2030)	Diff.	Disch. Press.	Capacity	Flow rate (in 2030)	Margin
		from	to	(psig)	(psig)	(psig)	(psig)	(MMSCFD)	(MMSCFD)	(MMSCFD)
Muchai	11/12	9	12	770	1040	270.0	1,135	1,200	1,016	184
Ashuganj	27	20	26	600	858.93	258.9	1,000	1,500	1,058	442
	28	20	49							
	29	20	50							
Elenga	81/82	60	62	650	652.21	2.2	1,000	500	500	0

As shown in Table 4.2-13, flow rate and arrival pressure required at the three (3) compressor stations in 2030 are forecasted within the rated capacity of the compressors. In the pipeline compressor systems, no bottleneck was found in the year.

According to the above, the following bottlenecks were revealed in 2030 Case and appropriate measures necessary for the respective bottlenecks are stated with a recommendation:

(1) Bottleneck 1

As shown in Table 4.2-9, delivery pressure at several points such as RPCL Mymensing (N58), Ashulia (N59), Aminbazar (N122), Jessore (N81) and Khulna (N83) is lower than 350 psig of evaluation criteria. Accordingly, the following pipelines does not have enough capacity to transport required amount of demand gas.

- Pipeline between Dhanua (N57) and RPCL Mymensing (N58)
- Pipeline between N136 and Ashulia (N59)
- Pipeline between N136 and Aminbazar (N122)
- Pipeline between Jhinaidah (N79) and Khulna (N83)

Therefore, all the delivery points cannot supply sufficient amount of gas to end-users.

In 2030 Case, bottlenecks occurs in several points on pipeline network due to increment of gas supply volume. In this case, it is preferable to install booster compressor in order to simultaneously improve transmission capacity of all the pipelines excluding the pipeline between Jhinaidah (N79) and Khulna (N83).

In case the booster compressor is additionally installed in Ashuganj compressor station, discharge pressure of the station should be increased from 1,000 psig to 1,107 psig.

As for the bottleneck between Jhinaidah (N79) and Khulna (N83), if the booster compressor is additionally installed in Elenga compressor station, discharge pressure at the station should be increased from 1,000 psig to 1,066 psig.

(2) Others

All gas flow lines which transfer gas produced in each gas field must have a capacity enough to send the gas into transmission pipeline. Accordingly, it is necessary to increase production pressure at each gas field in order to maintain transmission pipeline pressure, even if the gas production rate increases for gas demand.

This issue is not a bottleneck at this moment, however proper measures are to be taken so as to overcome the transmission pipeline pressure.

As the simulation outputs, the above bottlenecks are indicated in Figure 4.2-5.

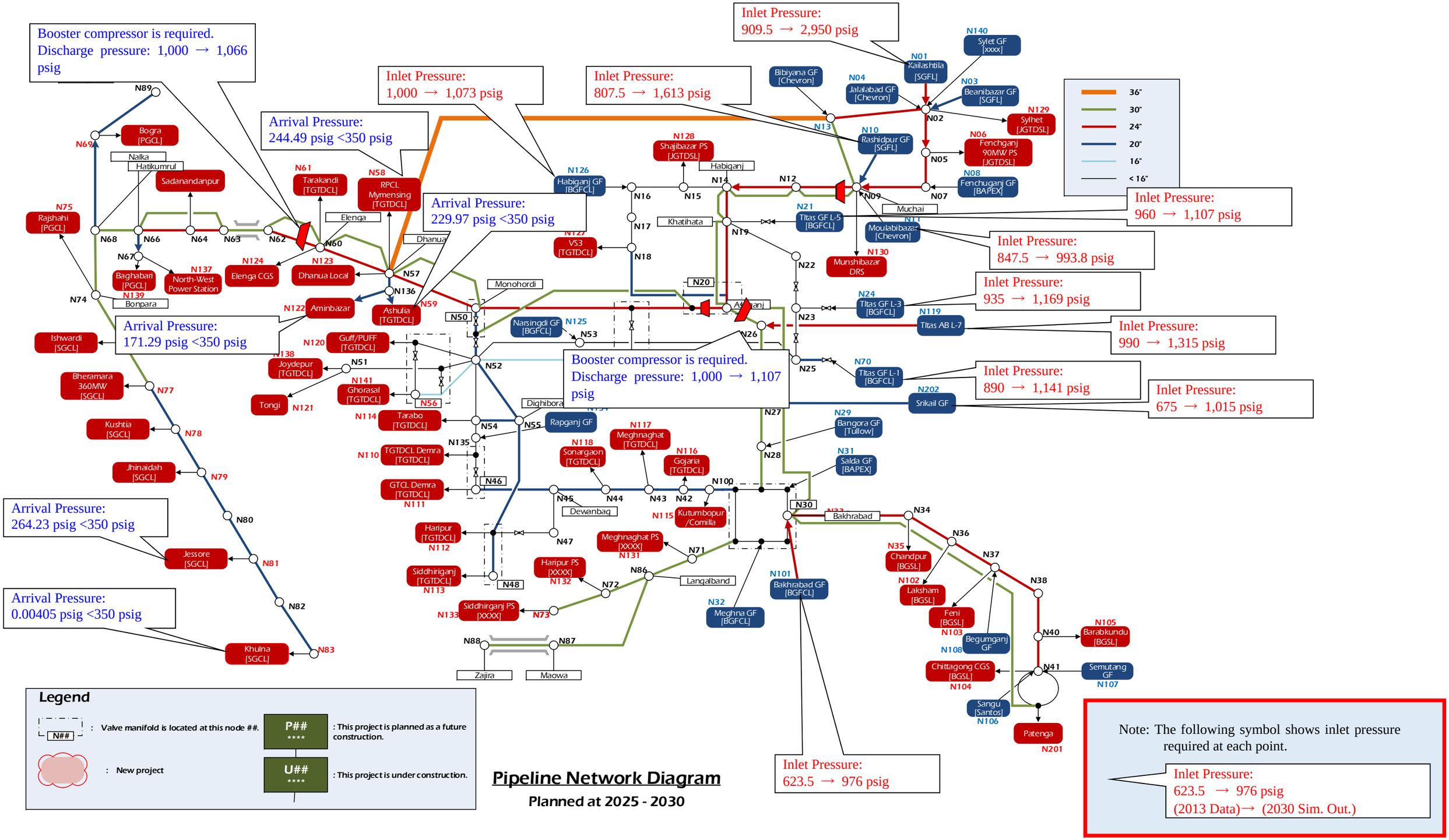


Figure 4.2-5 Simulation Output in 2030

Chapter 5 Conclusion

As the result of flow simulation for pipeline network in the country, the following issues are concluded:

This pipeline network analysis was conducted for 2015, 2020, 2025 and 2030 CASE in order to reveal bottlenecks to be presumed on the future pipeline network. Flow simulation models for the cases were established based on several assumptions and the simulation results were described in Chapter 4.

As a simulation output, no flow condition is occurred especially in Dhanua – Elenga pipeline in 2015 CASE, but this result is somewhat doubtful comparing to the undergoing project such as Elenga compressor station project, etc. It seems that this difference may be occurred by lack of information and assumptions. Accordingly, collection of all the necessary data and review of study assumptions should be carried out in the next stage. Based on these collected data and information, all the results of network analysis are to be reviewed carefully.

Items to be reviewed in the next engineering stage are as follows:

- *Supplement of lack of information*
  - *All pipeline data such as pipe size, wall thickness, and length for the existing and future pipelines*
  - *Pipeline elevation on pipeline route*
  - *Information for valves and fittings on the gas pipeline network*
- *Review of study assumptions*
  - *Current gas production volume in each gas field*
  - *Current gas delivery volume to each end-user*
  - *Gas supply and demand forecast*
  - *Assumptions of temperature conditions such as soil temperature, gas intake temperature*
  - *Assumptions of pipeline friction factor*

The following issues are recommended for future provision:

(1) For improvement of accuracy on the pipeline network simulation, it is preferable that operating conditions (pressure and flow rate) at several points such as gas terminal, gas manifold station and pipeline blanch point on pipeline network are reflected in the simulation model as much as possible. Most

effective facility expansion plan is to be developed comprehensively based on the simulation result with sufficient accuracy.

(2) This study was conducted with several assumptions to establish simulation model of pipeline network. All the assumptions shall be reviewed properly in the next engineering phase.

(3) It is recommended that tight supply situation of gas should be improved before reinforcement of existing gas transmission facility.

(4) Gas supply forecast will fall much below gas demand from around 2021. Therefore, it is recommended that further gas development pla7ns sufficient to the future demand is established and completed by the year.

As the result of this flow simulation, some bottlenecks were found on future pipeline facility in case of applying evaluation criteria of above 350 psig. However, some parts of existing pipeline facility have been operated below 350 psig for quite a while and gas delivery has been done for each end-user successfully without any trouble. (GTCL information)

Accordingly, if minimum delivery pressure to each end-user is further lower than the 350 psig, several bottlenecks stated in this simulation result may be able to solve easily. Therefore, critical delivery pressure at each end-user's facility should be confirmed in detail in order to develop optimum facility expansion plan.

Appendix 2:

TERMS OF REFERENCE (TOR)

OF

ENGINEERING CONSULTANCY SERVICES

FOR

THE PROJECT OF INSTALLATION OF

COMPRESSORS AT NARSINGDI AND TITAS

LOCATION C GAS FIELDS

(BGFCL)

Appendix 2. Terms of Reference (TOR) of Engineering Consultancy Services for the Project of Installation of Compressors at Narsingdi and Titas Location C Gas Fields - BGFCL

(This appendix has been removed because of confidential information.)

Appendix 3:

TERMS OF REFERENCE (TOR)

OF

ENGINEERING CONSULTANCY SERVICES

FOR

THE DHANUA-ELENGA AND WEST BANK OF

JAMUNA BRIDGE-NALKA PIPELINE PROJECT

(GTCL)

Appendix 3. Terms of Reference (TOR) of Engineering Consultancy Services for the DHANUA-ELENGA and WEST BANK of JAMUNA Bridge - NALKA Pipeline Project - GTCL

(This appendix has been removed because of confidential information.)

Appendix 4:

TERMS OF REFERENCE (TOR)

OF

ENGINEERING CONSULTANCY SERVICES

FOR

THE PROJECT OF INSTALLATION OF PRE-PAID GAS METERS IN DHAKA METROPOLITAN AREA

(TGTDCL)

Appendix 4. Terms of Reference (TOR) of Engineering Consultancy Services for the Project of Installation of Pre-paid Gas Meters in Dhaka Metropolitan Area - TGTDCL

(This appendix has been removed because of confidential information.)

Appendix 5:

TERMS OF REFERENCE (TOR)

OF

ENGINEERING CONSULTANCY SERVICES

FOR

THE PROJECT OF INSTALLATION OF PRE-PAID GAS METERS IN CHITTAGONG AREA

(KGDCL)

Appendix 5. Terms of Reference (TOR) of Engineering Consultancy Services for the Project of Installation of Pre-paid Gas Meters in Chittagong Area - KGDCL

(This appendix has been removed because of confidential information.)

Appendix 6:

ENVIRONMENTAL IMPACT

MITIGATION/MANAGEMENT PLAN

FOR

BGFCL COMPRESSOR PROJECTS

(BGFCL)

Appendix 6. Environmental Impact Mitigation/Management Plan for BGFCL Compressor Projects

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1. Construction					
1.1	Accident ✓ Construction workers can have harmful and critical troubles	• Follow Health and Safety Management Plan (HSMP) rules and regulations designated by contractors	Contractor	BGFCL/Supervising Consultant	Included in overall construction cost
1.2	HIV/AIDS ✓ Transmission of disease by inflow of migrant workers	• An HIV-AIDS awareness campaign via approved service provider shall be implemented	Contractor	BGFCL/Supervising Consultant	Included in overall construction cost
1.3	Air Pollution ✓ Dust rising from land clearance unpaved access and others during construction	• Good maintenance and operation of equipment and vehicles • Spraying water to suppress the dust rising • Cover entire load with tarpaulin to prevent the load from being blown. • Good maintenance of material • Monitoring and regular meeting for air quality	Contractor	BGFCL/Supervising Consultant and DOE	Included in overall construction cost
1.4	Soil pollution ✓ leakage of oil at compressor installation sites can contaminate soil	• Disposal at designated dumping site • Disposal of waste oil without leakage • Refueling place having concreted floor • Equipment and vehicles are properly maintained • Batteries containing liquid inside shall be kept on impervious place	Contractor	BGFCL/Supervising Consultant and DOE	Included in overall construction cost
1.5	Waste ✓ Generation of construction sludge and domestic waste	• Segregate waste to minimize waste material • Disposed in designated dumping site • Recycle/reuse of waste materials.	Contractor	BGFCL/Supervising Consultant and DOE	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1.6	Transportation of Material and Equipment	• Minimize interference to regular traffic • Effective measures to be taken to minimize dispersion of dust (in case of dust prone material transport) • Packaging case sizes of equipment and machinery will be fixed-up so that transport safety including no-overloading is ensured	Contractor	BGFCL/Supervising Consultant and DOE	Included in overall construction cost
1.7	Noise and Vibrations ✓ Noise and vibration from construction machines and vehicles	• Periodical maintenance .of construction vehicles • Restriction of high noise/vibration activity to day-time only	Contractor	BGFCL/Supervising Consultant and DOE	Included in overall construction cost
1.8	Construction Safety Measures	• Employees shall be provided with appropriate work related training • Employees shall be provided with appropriate PPE's(safety shoe, safety Helmet, safety goggles, hand gloves, ear plug, etc) • Employees shall be provided with appropriate first aid facility and health surveillance. • Medical tie up shall be established with ambulance facility. • Drinking water with healthy food shall be supplied at site with suitable dining area. • Toilet/mobile toilet shall be arranged. • Suitable lifting equipments and tools & tackles shall be arranged. • Environmental parameters test shall be conducted on frequent interval. • Motivational HSE programs shall be arranged for the promotion of health & safety.	Contractor	BGFCL/Supervising Consultant	Included in overall construction cost
1.9	Emergency Response Plan	• Emergency response team • First aid facilities at sites and camp • 24 Hours Hospital tie - ups with ambulance facility. • Training facility for how to response in any emergency. • Mock drill exercise to response during any real emergency.	Contractor	BGFCL/Supervising Consultant	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1.10	Occupational Health and Safety	• Ensure that where it is possible for a worker to fall through a vertical distance, the worker is protected from the falling by ✓ Guard rail around the work area ✓ Safe net; or ✓ Fall arresting device • Wearing proper clothing • Eye protection • Foot protection • Respiratory protective equipment • Precautions in case of fire • Fencing of machinery	Contractor	BGFCL/Supervising Consultant	Included in overall construction cost
2. Operation					
2.1	Operational Safety	• Updating and implementation of operational safety of the gas fields with compressor operation duly superimposed • Operational safety training and practice of compressor superimposed gas field system.	BGFCL	BGFCL/Petro Bangla	Included in overall operational cost
2.2	Emergency Response System	• Update of emergency response system of gas fields with compressor system superimposed. • Training including mock drills to ensure effectiveness of emergency response system	BGFCL	BGFCL/Petro Bangla	Included in overall operational cost

Appendix 7:

DRAFT ENVIRONMENTAL MONITORING FORM

FOR

GAS COMPRESSOR SYSTEM

(NARSINGDI AND TITAS-LOCATION C GAS FIELDS)

(BGFCL)

Appendix 7. Draft Environmental Monitoring Form for Gas Compressor System (Narsingdi and Titas-Location C Gas Fields) - BGFCL

The monitoring system proposed below will be reviewed and modified as appropriate by the EMP (study to be conducted by BGFCL as the requirement to obtain environmental clearance certificate [ECC] from DoE [Department of Environment]). The proposed environmental monitoring system mainly focuses on the elements of air quality (dust/SPM) and noise/vibration during the construction/installation stage of the project that is considered as adequate.

Ambient Air Quality - *Necessary for the construction/installation stage of the project (compressor) only focused on SPM_{10}/dust monitoring of ambient environment. Dust (represented by SPM_{10} and $SPM_{2.5}$) is the significant air pollutant consequent to site clearance/material transport and other related construction/installation activities (that has to be reviewed and confirmed by EMP Study). Operation of a compressor is not expected to cause significant ambient air pollution consequent to the exhaust emission from the natural gas (a cleaner fuel) fueled engines small-scale electricity generator (to facilitate independent operation of the compressor not dependent on national grid electricity). Proposed monitoring items of ambient air quality for construction/installation stage are given below:*

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
SPM_{10}	µgm/m^3			150 (Statutory Rules 2005)	50 (World Bank Guideline) 150 Interim Value	•One sampling point near the project site, another 1 km away from the project site •One 24-hr. day sampling per month •High volume dust sampler
$SPM_{2.5}$	µgm/m^3			65 (Statutory Rules 2005)	25 (World Bank Guideline) 75 Interim Value	•One sampling point near the project site, another 1 km away from the project site •One 24-hr. day sampling per month •High volume dust sampler

Waste - *Typical for a construction site that would include proper solid waste, sanitary waste, and housekeeping of construction site and worker camp/housing areas during*

construction/installation stage of the project (compressor). Proper solid waste management will continue during operation stage of the compressor as well.

Monitoring Item	Monitoring Results during Report Period
-Construction/installation stage Solid waste Sanitary waste Housekeeping status *-Operation stage* Solid waste	*(to be filled during construction/installation stage and for solid waste during operation stage)*

Noise / Vibration - *Necessary for construction/installation stage of the project (compressor). Operational stage noise/vibration could be mitigated with sound proofing of generator, if necessary. As such, operational stage noise/vibration monitoring is regarded as not necessary. Proposed monitoring items during construction/installation stage are given below:*

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
Noise level	dB			70 (Night-time) 75 (Daytime) (Industrial Area)	70 (Night-time) 70 (Daytime) (Industrial Area) (World Bank)	• 100 m from the construction site • One 24-hr. day sampling per month • Sound level meter

Appendix 8:

ENVIRONMENTAL CHECKLIST

FOR

GAS COMPRESSOR SYSTEM

(NARSINGDI AND TITAS-LOCATION C GAS FIELDS)

(BGFCL)

Appendix 8. Environmental Checklist for Gas Compressor System (Narsingdi and Titas-Location C Gas Fields) - BGFCL

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
1 Permits and Explanation	(1) EIA and Environmental Permits	1) Have EIA reports been officially completed? 2) Have EIA reports been approved by authorities of the host country's government? 3) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? 4) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	1) Conducting EIA is not necessary. Instead only EMP (Environmental Management Plan) focused on EHS (Environment, Health and Safety) aspects is required since installation of compressor in existing and operational gas field is basically small-scale reinforcement of the natural gas production system. 2) Agreement on conducting only EMP has already been made between DoE and BGFCL. EMP will be formulated and submitted to DoE by BGFCL for review and subsequent approval and issuance of ECC (Environmental Clearance Certificate) by DoE (Department of Environment) 3) Not applicable (only future EMP is necessary) 4) No other permit other than ECC from DoE is necessary
	(2) Explanation to the Public	1) Are contents of the project and the potential impacts adequately explained to the public, based on appropriate procedures, including information disclosure? Is understanding obtained from the public? 2) Are proper responses made to comments from the public and regulatory authorities?	1) Not applicable since EIA is not required and compressor system will be installed within existing gas filled areas (property boundaries) of BGFCL 2) Not applicable

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
2 Mitigation Measures	(1) Air Quality	1) Do air pollutants, such as sulfur oxides (SOx), nitrogen oxides (NOx), soot, and dust emitted from the fired equipment, treatment facilities, and other ancillary facilities comply with the country's emission standards? Is there a possibility that air pollutants emitted from the project will cause areas that do not comply with the country's ambient air quality standards? 2) Is there a possibility that air pollutants emitted from the flare system will adversely affect the surrounding environment? 3) Are adequate measures considered to reduce emissions and leakage of volatile organic compounds (VOCs)?	1) Some air pollutant emission both during installation/construction and later operation of compressor is inevitable. However, their overall effect on ambient environmental quality is regarded as not that significant 2) Not applicable for compressor system (flaring does occur consequent to ongoing gas extraction and its effect is not that significant) 3) Leakage control measures will be integral part of operational management of the compressor
	(2) Water Quality	1) Do pollutants, such as pH, SS, BOD, oil and grease, phenols, organic compounds, sulfide, heavy metals contained in effluents from production facilities, treatment facilities, drilling wastes, and related facilities comply with the country's effluent standards? Is there a possibility that the effluents from the project will cause areas that do not comply with the country's ambient water quality standards? 2) Are drilling muds properly treated in accordance with country's standards? 3) Are adequate measures taken to prevent spills and discharges of crude oil and hazardous materials to the surrounding areas?	1) Not applicable for gas compressor since no significant use of water is involved 2) Not applicable for gas compressor system 3) Not significant since only natural gas will be compressed and no significant use of any liquid is necessary
	(3) Wastes	1) Are drilling wastes, including drilling muds, additives (polymers, oxygen scavengers, biocides, surfactants), lubricants, diesel oil, emulsifying agents, flocculating agents (bentonite), and weighting materials, properly treated and disposed of in accordance with the country's standards? 2) Are wastes and sludges from the treatment facilities properly treated and disposed of in accordance with the country's standards? 3) Are adequate measures taken to prevent contamination of soil and groundwater by leachates from the drilling waste ponds?	1) Gas compressor system will not generate such drilling waste/mud and hence is not applicable for gas compressor system 2) Not applicable for gas compressor system 3) Not applicable for gas compressor system

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
2 Mitigation Measures	(4) Soil Contamination	1) Has the soil of the project site been contaminated in the past, and are adequate measures taken to prevent soil contamination by leaked materials, such as crude oil? (Not applicable to offshore oil and gas development projects)	1) Not applicable for gas compressor system
	(5) Noise and Vibration	1) Do noise and vibrations from the drilling works, production, and treatment facilities comply with the country's standards?	1) Construction/installation and operation of compressor system shall ensure noise and vibration meet the standards of industrial area. Still, sound-proofing of such machinery (like engines) could be considered as mitigation measure during operation of compressor.
	(6) Odor	1) Are there any odor sources, such as hydrogen sulfide and mercaptans originating from crude oil (especially sour oil containing relatively high hydrogen sulfide)? Are adequate odor control measures taken? (Not applicable to offshore oil and gas development projects)	1) Not applicable for gas compressor system
3 Natural Environment	(1) Protected Areas	1) Is the project site located in a protected area designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	1) No (Project sites are designated industrial area of natural gas extraction)
	(2) Ecosystem	1) Does the project site encompass primeval forests, tropical rainforests, or ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? 2) Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? 3) If significant ecological impacts are anticipated, are adequate measures taken to reduce the impacts on the ecosystem? 4) Is there a possibility that the amount of water (e.g., surface water, groundwater) used by the project will adversely affect aquatic environments, such as rivers? Are adequate measures taken to reduce the impacts on aquatic environments and aquatic organisms?	1) No 2) No 3) Not applicable 4) No use of significant amount of water

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
3 Natural Environment	**(3) Hydrology**	**1) In the case of onshore oil and gas development, is there a possibility that groundwater system changes due to alteration of topographic features and surface water system changes due to installation of structures will adversely affect surface water and groundwater flows?** **2) In the case of offshore oil and gas development, is there a possibility that oceanographic condition changes due to installation of structures will adversely affect oceanographic conditions, such as induced currents, waves, and tidal currents? Is the possibility of water quality degradation by the development studied? Are adequate water quality control measures taken, if necessary?**	**1) Not applicable for compressor system** **2) Not applicable**
	(4) Topography and Geology	**1) Is there a possibility that a large-scale alteration of topographic features and geologic structures around the project site will occur as a result of the project? (Not applicable to offshore projects)** **2) Is the stability of the existing topographic conditions adequately considered for alteration of topographic features, such as earth cut and fill operations? (Not applicable to offshore projects)** **3) Is there a possibility that soil runoff will result from earth cut and fill areas? (Not applicable to offshore projects)** **4) Is there a possibility that soil runoff will result from waste soil disposal sites and borrow sites? (Not applicable to offshore projects)** **5) In the case of offshore oil and gas development, is there a possibility that pipeline landings and installation of related facilities at the shoreline will cause a large-scale alteration of shorelines?**	**1) No** **2) Not applicable for compressor system** **3) No** **4) No** **5) Not applicable**

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
4 Social Environment	**(1) Resettlement**	**1) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimise the impacts caused by the resettlement?** **2) Is adequate explanation of relocation and compensation given to affected persons prior to resettlement?** **3) Is the resettlement plan, including proper compensation, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement?** **4) Does the resettlement plan pay particular attention to vulnerable groups or persons, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples?** **5) Are agreements with the affected persons obtained prior to resettlement?** **6) Is the organisational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan?** **7) Is a plan developed to monitor the impacts of resettlement?**	**1) No (No involuntary resettlement since project site is located within the property boundary of gas fields belonging to BGFCL)** **2) Not applicable** **3) Not applicable** **4) Not applicable** **5) Not applicable** **6) Not applicable** **7) Not applicable**

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
4 Social Environment	**(2) Living and Livelihood**	**1) Is there a possibility that the project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary?** **2) In the case of onshore oil and gas development projects, is there a possibility that large vehicle traffic associated with the project will cause impacts on road traffic in the surrounding areas? Are measures considered to reduce the impacts on traffic, if necessary?** **3) In the case of offshore oil and gas development projects, is there a possibility that offshore facilities will affect vessel traffic and the existing water area uses?** **4) In the case of offshore oil and gas development projects, is there a possibility that transportation means, such as vessels and helicopters will cause sea and airspace traffic congestion, and result in an increase in traffic accidents? Are measures taken to reduce the impacts on local traffic, if necessary?** **5) Is there a possibility that diseases (including communicable diseases such as HIV) will be introduced due to immigration of workers associated with the project? Are adequate considerations given to public health, if necessary?**	**1) No inhabitants in the gas field areas of compressor installation** **2) Packaging cases and sizes and weights will be fixed-up in such a manner that they will not hamper road conditions and regular road traffic during transportation of compressor installation-related materials and equipment from port to the project installation sites.** **3) Not applicable** **4) Not applicable** **5) Instilling due awareness on the dangers and mitigation of communicable diseases by the construction contractor is very important.**
	(3) Heritage	**1) Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage sites? Are adequate measures considered to protect these sites in accordance with the country's laws?**	**1) Irrelevant for existing gas fields under operation.**
	(4) Landscape	**1) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?**	**1) No significant effect on landscape of existing gas field areas is anticipated consequent to compressor installation.**

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
5 Others	**(1) Impacts during Construction**	**1) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)?** **2) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts?** **3) If construction activities adversely affect the social environment, are adequate measures considered to reduce impacts?** **4) If necessary, is health and safety education (e.g. traffic safety, public health) provided for project personnel, including workers?**	**1) Mitigation measures for potential dust-induced air pollution during construction include water spraying of dust-prone land and vinyl sheet covering of dust-prone materials. Since construction works involve mostly installation of equipment and machinery, no significant generation of turbid water or wastewater is anticipated. Daytime construction/installation work is regarded as adequate to mitigate adverse effects due to noise and vibration for an already existing industrial area like gas fields.** **2) No significant adverse effect on the natural environment (ecosystem) is anticipated since the areas operational gas fields (industrial areas)** **3) No significant adverse effect on the social environment is anticipated** **4) Health and safety education will be integral components to personnel related to construction/installation works of compressor and to be instituted by the construction contractor.**
	(2) Accident Prevention Measures	**1) Are adequate accident prevention plans and mitigation measures developed to cover both the soft and hard aspects of the project, such as establishment of safety rules, installation of prevention facilities and equipment, and safety education for workers? Are adequate measures for emergency response to accidental events considered?** **2) Are adequate accident prevention measures (e.g., installation of prevention facilities and equipment and establishment of prevention management framework) taken to prevent spills from crude oil and gas storage facilities, loading/unloading operations, transportation, and blow out during drilling?**	**1) EHS as EMP of construction/installation and operation stage will consider accident prevention plans and mitigation measures such as establishment of safety rules, installation of prevention facilities and equipment, safety education for workers, and emergency response to accidental events. In this respect, the construction contractor shall fully commit and adhere to the concept of "Safety First."** **2) Gas leakage control measures shall be integral to proper operational management of the compressor system**

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
5 Others	**(3) Monitoring**	**1) Does the proponent develop and implement a monitoring program for the environmental items that are considered to have potential impacts?** **2) Are the items, methods and frequencies included in the monitoring program judged to be appropriate?** **3) Does the proponent establish an adequate monitoring framework (organisation, personnel, equipment, and adequate budget to sustain the monitoring framework)?** **4) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?**	**1) Development and implementation of a monitoring program during the operation of the compressor is not necessary except for noise and vibration since air pollution emission due to the operation of a gas sourced generator is regarded as not that significant. Even monitoring of noise and vibration could be eliminated if necessary by sound-proofing of engines** **2) No significant monitoring requirement is necessary during operation of the compressor with the provision of sound-proofing of engines, if necessary** **3) No particular long-term monitoring framework is necessary with the provision of sound-proofing of engines as mentioned above.** **4) There is no particular need for any long-term monitoring report system for the operation of the compressor with the provision of sound-proofing mitigation measure for noise nuisance (if sound-proofing is found to be necessary).**
	Reference to Checklist of Other Sectors	**1) Where necessary, pertinent items described in the Oil and Gas Pipelines checklist should also be checked (e.g., projects including construction of oil and gas pipelines).** **2) Where necessary, pertinent items described in the Forestry Projects checklist should also be checked (e.g., projects including large areas of deforestation).** **3) Where necessary, pertinent items described in the Roads and Railways checklist should also be checked (e.g., projects including construction of roads and/or railways for transportation).** **4) In the case of offshore oil and gas development projects, where necessary, pertinent items described in the Ports and Harbours checklist should also be checked (e.g., projects including construction of ports and harbours).**	**1) Checked and found to be not relevant** **2) Checked and found to be not relevant** **3) Checked and found to be not relevant** **4) Not applicable**

Category	Environmental Item	Main Checklist Items	Confirmation of Environmental Considerations
	Note on Using Environmental Checklist	1) If necessary, the impacts to transboundary or global issues should be confirmed (e.g. the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	1) No transboundary or global issues are involved for this compressor installation and operation in gas fields of Bangladesh.

1) Regarding the term "Country's Standards" mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are made, if necessary. In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan's experience).

2) The environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which it is located.

Appendix 9:

PREPARATORY SURVEY

ON

THE NATURAL GAS EFFICIENCY PROJECT

IN

THE PEOPLES REPUBLIC OF BNGLADESH

TERMS OF REFERENCE (TOR)

FOR

EIA AND/OR ARAP UPDATE STUDY ON SELECTED

GAS TRANSMISSION PIPELINE PROJECT

(GTCL)

Appendix 9. Preparatory Survey on the Natural Gas Efficiency Project in the Peoples Republic of Bangladesh Terms of Reference (TOR) for EIA and/or Arap Update Study on Selected Gas Transmission Pipeline Project (GTCL)

1. OBJECTIVE AND TARGET PROJECTS

The objective of the EIA (environmental impact assessment) and/or ARAP (abbreviated resettlement action plan) Study is to formulate relevant updated EIA and/or ARAP reports on a draft basis for the construction of gas transmission pipelines selected for potential JICA financing. GTCL (Gas Transmission Company Limited) will be the executing agency of the project. The draft update EIA/ARAP reports will be formulated as appropriate so as to meet the requirement of environmental clearance of DoE (Department of Environment) of Bangladesh and also to conform to the guidelines for environmental and social considerations of JICA (2010). The term ARAP implies that potential resettlement requirements for the population involved will not be that large in number (small-scale resettlement).

There are 2 target transmission pipeline project components and the relevant update work requirement on EIA/ARAP varies according to the target project component as follows:

(1) Dauna–Elenga sector gas transmission pipeline of 52 kilometres in length and 30 inches in diameter (Component-1)

For this project component, EIA and RAP (as RP) have already been completed once in 2005 and this sector is a sub-component of the originally ADB-planned project of "Monohordi-Dhanua-Elenga-East Bank of Jamuna Bridge Gas Transmission Pipeline Project." As such, the work requirement is to update of both the available EIA and RP reports (2005) for the relevant 52 km sector of Dhanua-Elenga and hence to formulate updated EIA and ARAP reports.

It is further noted that, overall, the route of the pipeline would mostly follow the same route as used in available EIA and RP Reports of 2005. The route assumed for the 2005 EIA and RP studies has been reviewed recently (September, 2013) by GTCL to confirm its suitability under present conditions with a focus on any possible minimisation of resettlement requirements. As the result of the review, realignment of the originally planned ROW (2005) in some places along the initial 32 km sector of the ROW located between Dhanua and Sulgrampur was made so as to

minimise resettlement requirements. This reviewed route survey data will be obtained by the Consultant from GTCL and used for the update studies as appropriate (EIA/ARAP).

(2) West Bank of Jamuna Bridge–Nalka sector gas transmission pipeline of 14 kilometres in length and 30 inches in diameter (Component-2)

For this project component also, similar to Component-1 above, EIA and RAP (as RP) had already been completed once in 2005 and this sector is a sub-component of the originally ADB-planned project of "West bank of Jamuna Bridge-Nalka-Hatikumrul-Ishwardi-Bheramara Gas Transmission Pipeline Project." Still, for this project component the work requirement will be limited to updating the available EIA report (2005) for the relevant 14 km sector of West Bank of Jamuna Bridge–Nalka and hence to formulating updated EIA only since no private sector related land acquisition (land belongs to Jamuna Bridge Authority only) or resettlement is required as the pipeline will be installed along the ROW of existing pipeline route located by the side of the road to Nalka

In summary, the work requirement of each of the 2 project components is as follows:

- Component-1 : Formulation of updated EIA and ARAP Reports (2 study reports)
- Component-2 : Formulation of updated EIA Report only (1 study report)

2. STUDY METHODOLOGY

(1) Introduction

The EIA/ARAP Update Study, as appropriate for the target 2 components of the gas transmission pipeline projects, would initially review the available relevant EIA/RP reports as mentioned under item 1 above. Based on the review, additional data collection works would be conducted so as to update the baseline environmental and social conditions to current status as the most significant work requirement. With the utilisation of the duly updated baseline data, along with updated legal and regulatory requirements, the updated EIA and ARAP Reports will be formulated following format and contents similar to the available EIA and RP reports of 2005.

The consultant of this contract will maintain effective co-ordination with both the JICA Study Team and GTCL since these updated EIA/ARAP studies will be carried out in parallel with the conducting of the technical study by the JICA Study Team as a preparatory survey on the natural gas efficiency project in Bangladesh.

(2) Data Collection

1) Secondary Data

In principle, available secondary data will be utilised to the maximum possible extent to define and update the baseline natural, ecological, soil, water, and ambient environmental conditions (non-social environmental condition) for both the projects targeted for the formulation of updated EIA Reports. The available EIA Reports of 2005 will form the basis for determining the additional data collection work requirement so as to arrive at an updated baseline non-social environmental condition and hence also to account for any recent historical changes since 2005.

2) Primary Data

In principle, primary data collection work will be confined to social aspects associated with public perception and related resettlement and asset compensation aspects for the ARAP and hence most relevant to the updated ARAP studies for Component-1. The social survey would principally focus on direct interview surveys targeting all population identified for resettlement (Component-1) and also public consultation following a similar method used in the available EIA study reports (FGD/focus group discussion method) and required for both of the 2 update EIA studies of project components 1 and 2.

Social Survey

On average 25 households for each of the 2 project components (in total 50 households) are considered as adequate for the social survey. In this respect it is presumed that resettlement households will not exceed 25 for the relevant project Component-1. It is noted that there is no land acquisition or resettlement requirement for project Component-2 targeted for update EIA study only. All households targeted for resettlement (Component-1) will be covered by the social survey. Other households will be selected based on potential for temporary or permanent land acquisition. When these requirements are not sufficient or are invalid (this is the case for project Component-2 since there is no privately owned land acquisition or resettlement requirement) then population living in the vicinity of the pipeline route will be selected as the target for the social survey. Social surveys will be carried out with a direct questionnaire-based interview survey with the head of household (or prime member of household).

The questionnaire for direct interview survey would be composed of 2 parts as follows:

Part-1 of the questionnaire will be focused on public perception of the project by people living in the vicinity of each of the 2 target project components that would also incorporate social indicators of household population composition, housing conditions, including sanitation/public health, utilities like piped water supply, sewage, electricity and gas supply service, occupation and income level, and others. This part will cover the entire population targeted for the social survey.

Part-2 of the questionnaire will be focused on potential resettlement and/or asset compensation aspects consequent to the implementation of the project on update ARAP (Component-1 only) and will be entirely focused on population having potential for resettlement and or asset compensation and hence could be considered as people directly affected by the project. This questionnaire survey will be formulated and conducted so as to determine affected people's preference on type of compensation and related aspects and also to determine the value of housing and related assets so as to determine the amount of compensation and hence to formulate the updated ARAP Report for Component-1.

3. REPORTING OF UPDATED EIA/ARAP

The Consultant (Update EIA/ARAP Team) shall submit the following reports to JICA Study Team at the designated time in both hard copy (one each for each of the 3 Update EIA and ARAP studies) and electronic file form (on CD). The total time frame for the completion of the Update EIA/ARAP Study is 3.5 months.

1) Interim Update EIA Report and ARAP Report (in English, 1 hard copy for each of the 3 update study with total of reports and CD)

The Interim Update EIA Report and ARAP Report will incorporate progress and provisional results of surveys/studies, remaining works and issues (if any), and significant provisional findings of the Update EIA/ARAP Study and will be submitted within 1.5 months after commencement of the Study.

2) Draft Final Update EIA Report and ARAP Report (in English, 1 hard copy for each of the 3 update studies with a total of 3 reports and a CD)

The Draft Final Update EIA Report and ARAP Report for due review and comments by JICA Study Team and related governmental agencies of Bangladesh (GTCL) will be submitted within 3 months after commencement of the study.

3) Final Update EIA Report and ARAP Report (in English, 1 hard copy of each of the 3 update studies with a total of 3 reports and a CD)

The Final Update EIA Report and ARAP Report shall be prepared based on the comments or suggestions, as required by JICA Study Team and related governmental agencies of Bangladesh, such as GTCL. The Final Update Reports shall be submitted within 2 weeks after receipt of comments on the Draft Final Reports. All records, photographs of field surveys, data, and relevant unpublished documents collected during the conducting of the Update EIA/ARAP Study shall be submitted along with this Final Update EIA Report and ARAP Report.

In this regard, typical contents of EIA and ARAP Reports are given in the annexure below.

4. STAFFING REQUIREMENTS FOR THE UPDATE EIA/ARAP STUDY TEAM

The following specialists (experts) provided by the Consultant will be needed as the prime expertise to conduct the Update EIA/ARAP Study. All assigned experts shall conform to the requirements as independent experts with no affiliation to the project proponent (MoPEMR and other natural gas production, transmission, and distribution-related agencies like BGFCL, GTCL, TGTDCL, and KGDCL) and other certification and credentials for conducting EIA/RAP/ARAP Studies as per any relevant governmental (DoE) regulations of Bangladesh.

1) Team Leader / Energy and Environment Expert
2) Biologist
3) Environment / Water Quality Specialist
4) Social Expert (1)
5) Social Expert (2) / ARAP Expert

5. OTHER ISSUES

Any other issues concerning the conducting of the Update EIA/ARAP Study not mentioned above shall be settled amicably with mutual agreement between JICA Study Team and the Consultant.

Annexure

Typical Contents of EIA and ARAP Reports

1 Typical Content of EIA Report

The EIA Report will be organised based on the following typical format as normally followed in Bangladesh with *Executive Summary* followed by *Main Report*, having the following typical contents:

1) Introduction
    a) The objective and scope of the study
    b) The relevant laws, regulations, and guidelines used in EIA study
    c) EIA implementing organisation and experts of the team
2) Policy, legal and administrative framework, guidelines concerning environmental, social, and EIA/RAP aspects of Bangladesh (Legislative, Regulatory, and Policy Considerations), with due focus on the natural gas industrial sector
3) Description of the Project
4) Description of the Baseline Existing Environment
    a) Meteorology (temperature, winds, solar radiation, and rainfall), Topography, and Geology
    b) Aquatic and terrestrial biota (fauna and flora), including protected/peculiar areas in and around the project sites, if any
    c) Environmental conditions of the project sites, principally based on ambient environmental aspects such as terrestrial and aquatic ecology, surface water quality, and ambient air quality
    d) Basic socioeconomic conditions (population, land use, and peculiar features, if any) and cultural/historical/archeological treasures around the project sites
5) Identification and evaluation of potential environmental and social impacts
6) Environmental management and mitigation plans and procedures
    a) Management and mitigating actions at pre-construction stage
    b) Management and mitigating actions at construction stage
    c) Management and mitigating actions at operation (post-construction) stage
7) Environmental monitoring program for performance evaluation

8) Beneficial effects

9) Institutional capacity requirements

10) Public consultation

11) Conclusion and recommendations

12) List of references

13) Appendices

2 Typical Content of the ARAP Report

The ARAP Report will be organised based on a similar format as the EIA report with *Executive Summary* followed by *Main Report*, having the following contents:

1) Introduction (Background, scope, and objective of land acquisition and resettlement)

2) Socio-economic survey and data analysis (Census of project-affected persons, ownership and valuation of assets and others)

3) Policy and legal framework

4) Description of compensation, entitlement (with entitlement policy matrix), and other resettlement assistance to be provided so as to facilitate amicable land acquisition and resettlement

5) Evaluation of the result of consultation with potentially displaced people about acceptable alternatives on means of compensation, areas of resettlement and other aspects

6) Institutional responsibility for implementation of resettlement and the required procedures for grievance redress claims by resettled people (PAPs/project-affected persons) in the form of “Institutional and Implementation Framework”

7) Proposal on arrangement for resettlement monitoring and implementation including required job training assistance and living expense assistance for resettled people

8) Tentative timetable and budget, as deemed appropriate for the implementation of ARAP

9) List of references

10) Appendices

Appendix 10:

ENVIRONMENTAL IMPACT

MITIGATION/MANAGEMENT PLAN

FOR

DHANUA-ELENGA PROJECT

(GTCL)

Appendix 10. Environmental Impact Mitigation/Management Plan for Dhanua-Elenga Project

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
Preconstruction					
1.1	Involuntary Resettlement ✓ Households and people are influenced	• Proper resettlement action Plan (RAP) • Provide adequate compensation in time to PAPs	RAP Implementing Agency	GTCL and External Monitoring Agency	Replacement value of land: 1,149,230,000
1.2	Local Economies such as Employment, livelihood etc. ✓ Shop owners, employees, cultivators, properties and plantation owners are influenced	• All direct income loss must be adequately compensated within the RAP • Income loss can be mitigated by providing alternative job opportunities for PAPs. • Arrangement of skill development training • Micro credit support for SME	RAP Implementing Agency	GTCL and External Monitoring Agency	Training Cost: 5,000,000 Revolving Fund for Microcredit : 10,000,000 One time cash grant for Income Losers: 4,500,000
1.3	Land use and utilization of local resources ✓ Cultivable lands area and three small poultry farms structure, house structures are affected ✓ Loss of Trees (private and Government forest trees)	• Cultivable land area which will be temporarily occupied during construction, will be restored to original state and returned to the land owner after construction • Proper compensation shall be made for the affected structures, trees • Tree plantation cost shall be provided to the private/government organizations to minimize the loss of trees	RAP Implementing Agency	GTCL and External Monitoring Agency	Compensation for affected structure: 10,630,000 Budget for requisition land and Standing Crop: 23,438,126 Compensation for trees: 17,307,000 Compensation for Business Losses: 4,800,000
1.4	Social institutions such as Social infrastructures and decision-making institutions ✓ Social institutions are affected by relocation	• Proper resettlement action Plan (RAP) • Provide adequate compensation in time to Social Institutions	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
1.5	Poor, indigenous people or ethnic minority ✓ Livelihood of poor or female headed households are affected	• Prepare RAP involving the following measures – Define the displaced persons and criteria for determining their eligibility for compensation – Establish external monitoring committee consists of the third party • For poor people, proponent activities improving surface water condition and making groundwater available shall be implemented	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
1.6	Mal-distribution of benefits and damages ✓ Displaced people may be suffered at pipeline route sites	• Prepare RAP involving the following measures – Assessed compensation will base on the market price – Payment will be carried out before resettlement • Establish external monitoring committee consisting of a third party	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall project formation and administration cost
2. Construction					
2.1	Involuntary Resettlement ✓ Households and people are influenced	• Prepare Resettlement Action Plan (RAP) • Provide adequate compensation and assistance in time to PAPs	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
2.2	Local Economies such as Employment, livelihood etc. ✓ Shop owners, employees, cultivators, properties and plantation owners are influenced	• All direct income loss must be adequately compensated within the RAP • Income loss can be mitigated by providing alternative job opportunities for PAPs.	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
2.3	Land use and utilization of local resources ✓ Cultivable lands area and a small poultry farm structure, house structures are affected	• Cultivable land area which will be tentatively occupied during construction, will be restored to original state and returned to the land owner after construction • Proper compensation shall be made for the affected structures	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
2.4	Social institutions such as Social infrastructures and decision-making institutions ✓ Social institutions are affected by relocation and noise	• Proper resettlement action Plan (RAP) • Provide adequate compensation in time to PAPs • Periodical maintenance of construction vehicles • Installation of sound insulation	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
2.5	Existing social infrastructures and Services ✓ Social service utilities are located underground in the affected area	• Proper detailed design is going to be done and the utilities line will be diverted before starting the construction activity.	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
2.6	Poor, indigenous people or ethnic minority ✓ Livelihood of poor or female headed households are affected	• Prepare RAP involving the following measures – Define the displaced persons and criteria for determining their eligibility for compensation – Establish external monitoring committee consists of the third party • For poor people, proponent activities improving surface water condition, making groundwater available and enhancing their job skill shall be implemented	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
2.7	Mal-distribution of benefits and damages ✓ Displaced people may be suffered at pipeline route sites	• Prepare RAP involving the following measures – Assessed compensation will base on the market price – Payment will be carried out before resettlement • Establish external monitoring committee consists of the third party	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost
2.8	Local conflicts of interest ✓ candidates of construction workers may have some conflicts between communities	• Clear information about the needs of labor (number and qualification) should be provided with local people. • The job skills and the priority for the affected people shall be taken into account and the workers can be chosen.	RAP Implementing Agency	GTCL and External Monitoring Agency	Included in overall administration cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
2.9	Accident ✓ Construction workers can have harmful and critical troubles and injuries	• Follow Health and Safety Management Plan (HSMP) rules and regulations designated by contractors	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.10	HIV/AIDS ✓ Transmission of disease by inflow of migrant workers	• An HIV-AIDS awareness campaign via approved service provider shall be implemented	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.11	Gender ✓ Salary gap between genders	• Monitoring of payment to workers by the contractor shall be implemented not to allow payment gaps between male and female.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.12	Children's right ✓ A bunch of children come and work in construction site	• Regular monitoring of sites to guide contactors and their related firms to discourage child labor. • When the child labor will be detected, necessary and decisive actions to the violating firms are implemented. • Some assistance for parents of working child.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.13	Flora and Fauna ✓ Loss of Species diversity, Damage to habitat, Loss of species due to disposal of petroleum oil lubricants and toxic refuse	• Any illegal discharge of waste water, leaked oil shall be prohibited • Construction development area shall be fixed, not to develop or cut trees out of project area • Night lightning in construction should be restricted to the construction site. • Quick recovery of the backfilled trenches in rainy season which will follow the reemergence of vegetation by rain	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
2.14	Air Pollution ✓ Dust rising from unpaved road, emission of Greenhouse gas, heat emission and others during construction	• Good maintenance and operation of equipment and vehicles • Use environmentally-friendly material • Spraying water to suppress the dust rising • Cover the loaded vehicles with tarpaulin to prevent the load materials from being blown. • Good maintenance of material • Monitoring and regular meeting for air quality	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
2.15	Water Pollution ✓ Construction sludge, mud water from earthwork, domestic waster liquid from worker's camp, and oil leaking from construction vessel	• Generated construction sludge is to be treated by silt basin and remaining sludge is disposed at designated dumping site • Drilling fluid used will be managed through bioremediation and applied to irrigable land • Turbid water from construction work area is treated in silt basin for satisfying water quality standard and drain away to the nearest drainage or river • Domestic water is treated by septic tank for satisfying water quality standard and drain away to the nearest drainage or river. • Water quality including contents of arsenic will be checked before using groundwater as potable water for construction workers. • Waste oil shall be stored without leaking before legal disposal process. • Re-fuelling place to equipment/ vehicles shall be concreted floor • Fuel and oil shall be stored at concrete floored tank surrounded with concrete fence • Equipment and vehicles are properly maintained not to cause leaking of fuel onto ground surface. Inspection sheet of maintenance record shall be submitted regularly • Batteries containing liquid inside shall be kept on impervious place to prevent battery liquid that contains hazardous heavy metals leaks and percolate into sub-ground • To be on the safe side, study on groundwater will be implemented by the consultant during detailed design stage in order not to cause adverse impact on surrounding wells. • Preparation of a waste management plan to achieve reuse, reclamation and recycling of materials.	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
2.16	Soil erosion ✓ Practical construction period selection, washed off excavated soil	• Construction work shall be carried out in dry season (practical only in dry season for pipe laying work) only. • Emphasize due construction planning with the intention that the trench portion excavated will be fully completed and backfilled with pipe laid underground within the dry-season so that the topography is fully restored to original condition. • No excess excavated soil mount is left behind to be washed off during rains (erosion soil runoff mitigation).	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.17	Soil pollution ✓ leakage of oil, and borrow can contaminate soil	• Disposal at designated dumping site • Soil quality testing • Disposal of waste oil without leakage • Refueling place having concreted floor • Preserved in the tank surrounded with concrete fence • Equipment and vehicles are properly maintained • Batteries containing liquid inside shall be kept on impervious place	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
2.18	Waste ✓ Generation of construction sludge and domestic waste	• Minimize volume to use silt basin before disposing • Segregate waste to minimize waste material • Disposed in designated dumping site instructed by the section handling waste • Recycled as possible with consideration of soil property.	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
2.19	Transportation of Material, Equipment, Pipes etc.	• Minimize interference to regular traffic • Effective measures to be taken to minimize dispersion of dust (in case of dust prone material excess soil transport)	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
2.20	Noise and Vibrations ✓ Noise and vibration from construction machines and vehicles	• Periodical maintenance of construction vehicles • Installation of sound insulation cover on boundary near residential area	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
2.21	Offensive Odor ✓ Open burning of construction waste, improper treatment of human liquid waste, exhausted smoke from heavy equipment etc.	• Prohibition of open burning • Proper treatment of camp waste • Proper maintenance of heavy equipment.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.22	Bottom sediment ✓ Waste dumped into rivers can contaminate river bed	• Construction contractor will be obliged to no dumping of waste into the river	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.23	Construction Safety Measures	• Employees shall be provided with appropriate training on different topics • Employees shall be provided with appropriate PPE's(safety shoe, safety Helmet, safety goggles, hand gloves, ear plug, etc) • Employees shall be provided with appropriate first aid facility and Health surveillance. • Medical tie up shall be established with ambulance facility. • Drinking water with healthy food shall be supplied at site with suitable dining area. • Toilet/mobile toilet shall be arranged. • Suitable lifting equipments and tools & tackles shall be arranged. • Proper supervision shall be arranged at each location of sites. • Environmental parameters test shall be conducted on frequent interval. • Motivational HSE programs shall be arranged for the promotion of health & safety.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
2.24	Emergency Response Plan	• Emergency response team • First aid facilities at sites and camp • 24 Hours Hospital tie‐ups with ambulance facility. • Training facility for how to response in any emergency. • Mock drill exercise to response during any real emergency.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.25	Occupational Health and Safety	• Ensure that where it is possible for a worker to fall through a vertical distance, the worker is protected from the falling by ✓ A guard rail around the work area ✓ A safe net; or ✓ A fall arresting device • Wearing proper clothing • Eye protection • Foot protection • Respiratory protective equipment • Safety for Building and equipment • Precautions in case of fire • Fencing of machinery • Any dust or fumes or other Impurities likely to be injurious to the workers effective measure shall be taken to prevent its accumulation and its inhalation by workers	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2.26	Hydrostatic test water not treated with biocides, corrosion inhibitor and oxygen scavengers	• The hydro test water will be diluted prior to discharge.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
3. Operation					
3.1	Pigging Waste ✓ Pipe cleaning waste (pigging grit – scale, rust, or other foreign material)	• Pigging waste is assessed as containing mostly silt material by GTCL and currently it is buried underground as government approved disposal method.	GTCL	GTCL/Petro Bangla	Included in overall operational cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost (BDT)
3.2	Operational Safety	• GTCL will continue to follow the gas safety rules and its updates in timely manner	GTCL	GTCL/Petro Bangla	Included in overall operational cost
3.3	Emergency Response System	• It is recommended that GTCL to equip its personnel with due awareness training, appropriate PPE (personnel protective equipment) and safety guidelines to respond emergency situations.	GTCL	GTCL/Petro Bangla	Included in overall operational cost

Appendix 11:

ENVIRONMENTAL IMPACT

MITIGATION/MANAGEMENT PLAN

FOR

WEST BANK OF JAMUNA BRIDGE-NALKA PROJECT

(GTCL)

Appendix 11. Environmental Impact Mitigation/Management Plan (West Bank of Jamuna Bridge-Nalka)

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1. Construction					
1.1	Local Economies such as Employment, livelihood etc. ✓ Cultivators are influenced	• Proper compensation payment for acquired land for CGS at the project area. • Income loss can be mitigated by providing alternative job opportunities for PAPs who has to provide land for CGS construction area.	GTCL/ Contractor	GTCL and External Monirоring Agency	49,400,000 BDT (Total compensation cost of land acquisition for 1 ha (100m*100m) land for CGS at the project area)
1.2	Local conflicts of interest ✓ candidates of construction workers may have some conflicts between communities	• Clear information about the needs of labor (number and qualification) should be provided with local people. • The job skills and the priority for the people of the City Gate Station (CGS) area shall be taken into account and therefore workers can be chosen.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.3	Accident ✓ Construction workers can have harmful and critical troubles	• Follow Health and Safety Management Plan (HSMP) rules and regulations designated by contractors	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.4	HIV/AIDS ✓ Transmission of disease by inflow of migrant workers	• An HIV-AIDS awareness campaign via approved service provider shall be implemented	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.5	Gender ✓ Salary gap between genders	• Monitoring of payment to workers by the contractor shall be implemented not to allow payment gaps between male and female.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.6	Children's right ✓ A bunch of children come and work in construction site	• Regular monitoring of sites to guide contactors and their related firms to discourage child labor. • When the child labor will be detected, necessary and decisive actions to the violating firms are implemented. • Some assistance for parents of working child.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1.7	Flora and Fauna ✓ Loss of Species diversity, Damage to habitat, Loss of species due to disposal of petroleum oil lubricants and toxic refuse	• Any illegal discharge of waste water, leaked oil shall be prohibited • Construction development area shall be fixed, not to develop or cut trees out of project area • Night lightning in construction should be restricted to the construction site. • Quick recovery of the backfilled trenches in rainy season which will follow the reemergence of vegetation by rain	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
1.8	Air Pollution ✓ Dust rising from unpaved road, emission of Greenhouse gas, heat emission and others during construction	• Good maintenance and operation of equipment and vehicles • Use environmentally-friendly material • Spraying water to suppress the dust rising • Cover entire load with tarpaulin to prevent the load from being blown. • Good maintenance of material • Monitoring and regular meeting for air quality	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
1.9	Water Pollution ✓ Construction sludge, mud water from earthwork, domestic waster liquid from worker's camp, and oil leaking from construction vessel	• Generated construction sludge is to be treated by silt basin and remaining sludge is disposed at designated dumping site • Turbid water from construction work area is treated in silt basin for satisfying water quality standard and drain away to the nearest drainage or river • Domestic water is treated by septic tank for satisfying water quality standard and drain away to the nearest drainage or river. • Water quality including contents of arsenic will be checked before using groundwater as potable water for construction workers. • Waste oil shall be stored without leaking before legal disposal process. • Re-fuelling place to equipment/ vehicles shall be concreted floor • Fuel and oil shall be stored at concrete floored tank	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
		surrounded with concrete fence • Equipment and vehicles are properly maintained not to cause leaking of fuel onto ground surface. Inspection sheet of maintenance record shall be submitted regularly • Batteries containing liquid inside shall be kept on impervious place to prevent battery liquid that contains hazardous heavy metals leaks and percolate into sub-ground • To be on the safe side, study on groundwater will be implemented by the consultant during detailed design stage in order not to cause adverse impact on surrounding wells. • Preparation of a waste management plan to achieve reuse, reclamation and recycling of materials.			
1.10	Soil erosion ✓ Practical construction period selection, washed off excavated soil	• Construction work shall be carried out in dry season (practical only in dry season for pipe laying work) only. • Emphasize due construction planning with the intention that the trench portion excavated will be fully completed and backfilled with pipe laid underground within the dry-season so that the topography is fully restored to original condition. • No excess excavated soil mount is left behind to be washed off during rains (erosion soil runoff mitigation).	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.11	Soil pollution ✓ leakage of oil, and borrow can contaminate soil	• Disposal at designated dumping site • Soil quality testing • Disposal of waste oil without leakage • Refueling place having concreted floor • Preserved in the tank surrounded with concrete fence • Equipment and vehicles are properly maintained • Batteries containing liquid inside shall be kept on impervious place	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1.12	Waste ✓ Generation of construction sludge and domestic waste	• Minimize volume to use silt basin before disposing • Segregate waste to minimize waste material • Disposed in designated dumping site instructed by the section handling waste • Recycled as possible with consideration of soil property.	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
1.13	Transportation of Material, Equipment, Pipes etc.	• Minimize interference to regular traffic • Effective measures to be taken to minimize dispersion of dust (in case of dust prone material excess soil transport)	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
1.14	Noise and Vibrations ✓ Noise and vibration from construction machines and vehicles	• Periodical maintenance .of construction vehicles • Installation of sound insulation cover on boundary near residential area	Contractor	GTCL/Supervising Consultant and DOE	Included in overall construction cost
1.15	Offensive Odor ✓ Open burning of construction waste, improper treatment of human liquid waste, exhausted smoke from heavy equipment etc.	• Prohibition of open burning • Proper treatment of camp waste • Proper maintenance of heavy equipment.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.16	Bottom sediment ✓ Waste dumped into nearby ponds can contaminate pond water	• Construction contractor will be obliged to no dumping of waste into the nearby pond	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.17	Construction Safety Measures	• Employees shall be provided with appropriate training on different topics • Employees shall be provided with appropriate PPE's(safety shoe, safety Helmet, safety goggles, hand gloves, ear plug, etc) • Employees shall be provided with appropriate first aid facility and Health surveillance. • Medical tie up shall be established with ambulance facility. • Drinking water with healthy food shall be supplied at site with suitable dining area. • Toilet/mobile toilet shall be arranged.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
		• Suitable lifting equipments and tools & tackles shall be arranged. • Proper supervision shall be arranged at each location of sites. • Environmental parameters test shall be conducted on frequent interval. • Motivational HSE programs shall be arranged for the promotion of health & safety.			
1.18	Emergency Response Plan	• Emergency response team • First aid facilities at sites and camp • 24 Hours Hospital tie - ups with ambulance facility. • Training facility for how to response in any emergency. • Mock drill exercise to response during any real emergency.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
1.19	Occupational Health and Safety	• Ensure that where it is possible for a worker to fall through a vertical distance, the worker is protected from the falling by ✓ A guard rail around the work area ✓ A safe net; or ✓ A fall arresting device • Wearing proper clothing • Eye protection • Foot protection • Respiratory protective equipment • Safety for Building and equipment • Precautions in case of fire • Fencing of machinery • Any dust or fumes or other Impurities likely to be injurious to the workers effective measure shall be taken to prevent its accumulation and its inhalation by workers	Contractor	GTCL/Supervising Consultant	Included in overall construction cost

Sl. No.	Potential Impact	Mitigation/Management Measures	Responsible Agency	Supervising Agency	Cost
1.20	Hydrostatic test water not treated with biocides, corrosion inhibitor and oxygen scavengers	• The hydro test water will be diluted prior to discharge.	Contractor	GTCL/Supervising Consultant	Included in overall construction cost
2. Operation					
2.1	Pigging Waste ✓ Pipe cleaning waste (pigging grit - scale, rust, or other foreign material)	• Pigging waste is assessed as containing mostly silt material by GTCL and currently it is buried underground as government approved disposal method.	GTCL	GTCL/Petro Bangla	Included in overall operational cost
2.2	Operational Safety	• GTCL will continue to follow the gas safety rules and its updates in timely manner	GTCL	GTCL/Petro Bangla	Included in overall operational cost
2.3	Emergency Response System	• It is recommended that GTCL to equip its personnel with due awareness training, appropriate PPE (personnel protective equipment) and safety guidelines to respond emergency situations.	GTCL	GTCL/Petro Bangla	Included in overall operational cost

Appendix 12:

DRAFT ENVIRONMENTAL MONITORING FORM

FOR

GAS TRANSMISSION PIPELINE PROJECT

(DHANUA - ELENGA)

(GTCL)

Appendix 12. Draft Environmental Monitoring Form for Gas Transmission Pipeline Project (Dhanua - Elenga) - GTCL

The monitoring system tentatively proposed by the ongoing EIA/ARAP Study principally focused on the construction stage of the project. Monitoring elements proposed are concerned to surface water quality, wastes, air quality and noise/vibration.

Ambient Air Quality - *Necessary for construction/installation stage of the gas transmission pipeline project. Proposed monitoring items of ambient air quality are given below:*

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
SPM_{10}	µgm/m^3			150(Statutory Rules 2005)	50 (World Bank Guideline) 150 Interim Value	•One sampling point near the project site, another 1 km away from the project site •One 24-hr. day sampling per month •High volume dust sampler
$SPM_{2.5}$	µgm/m^3			65 (Statutory Rules 2005)	25 (World Bank Guideline) 75 Interim Value	•One sampling point near the project site, another 1 km away from the project site •One 24-hr. day sampling per month •High volume dust sampler

Surface Water Quality - ***Necessary for construction/installation stage of the gas transmission pipeline project. Proposed monitoring items of surface water quality are given below:***

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
pH	-			6.5-8.5 (Fishery use)	6.5-9.0 (USEPA)	• Both riverbanks (Bangshai, Slada & Lakha) of the HDD Pipe Crossing • Monthly • pH meter
SS (Suspended Solid)	mg/L			-	-	• Both riverbanks (Bangshai, Slada & Lakha) of the HDD Pipe Crossing • Monthly • Filtration

BOD	mg/L			<6 (BOD) (Fishery use)	-	• Both riverbanks (Bangshai, Slada & Lakha) of the HDD Pipe Crossing • Monthly • Titration
DO	mg/L			>5 (Fishery use)	3-9.5 (USEPA)	• Both riverbanks (Bangshai, Slada & Lakha) of the HDD Pipe Crossing • Monthly • DO meter
Oil and Grease	mg/L			-		• Both riverbanks (Bangshai, Slada & Lakha) of the HDD Pipe Crossing • Monthly • Gravimetric
Temperature	^{o}C			25 (Fishery use)	-	• Both riverbanks (Bangshai, Slada & Lakha) of the HDD Pipe Crossing • Monthly • Thermometer

USEPA: United States Environmental Protection Agency

Waste - ***Necessary for construction/installation and operation stages of the gas transmission pipeline project. Proposed monitoring items are given below:***

Monitoring Item	Monitoring Results during Report Period
• Excess borrow pit soil • Generated solid waste (worksite and camp site) • Sanitary waste (worksite and camp site) • Housekeeping status (worksite and camp site) • Management of pigging waste (operation stage)	

Noise / Vibration - ***Necessary for construction/installation stage of the gas transmission pipeline project. Proposed monitoring items are given below:***

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
Noise level	dB			45 (Night) 55 (Day) (Residential Area)	45 (Night) 55 (Day) (Residential Area) (World Bank)	• 50m from the construction site • Per Month one 24-hr. day sampling • Sound level meter

Appendix 13:

DRAFT ENVIRONMENTAL MONITORING FORM

FOR

GAS TRANSMISSION PIPELINE PROJECT

(WEST BANK OF JAMUNA BRIDGE - NALKA)

(GTCL)

Appendix 13. Draft Environmental Monitoring Form for Transmission Pipeline Project (West Bank of Jamuna Bridge - Nalka) - GTCL

The monitoring system proposed by the ongoing EIA Study is principally focused on the construction stage of the project. Monitoring elements proposed are concerned with air quality, waste, and noise/vibration for the natural environment only, as described below. There is no surface water body located along the entire ROW of the pipeline.

Ambient Air Quality - ***Necessary for construction/installation stage of the gas transmission pipeline project. Proposed monitoring items of ambient air quality are given below:***

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
SPM_{10}	µgm/m^3			150 (Statutory Rules 2005)	50 (World Bank Guideline) 150 Interim Value	•One sampling point near the project site, another 1 km away from the project site •One 24-hr. day sampling per month •High volume dust sampler
$SPM_{2.5}$	µgm/m^3			65 (Statutory Rules 2005)	25 (World Bank Guideline) 75 Interim Value	•One sampling point near the project site, another 1 km away from the project site •One 24-hr. day sampling per month •High volume dust sampler

- Waste - ***Necessary for construction/installation and operation stages of the gas transmission pipeline project. Proposed Monitoring items are given below:***

Monitoring Item	Monitoring Results during Report Period
• Excess borrow pit soil • Generated solid waste (worksite and camp site) • Sanitary waste (worksite and camp site) • Housekeeping status (worksite and camp site) • Management of pigging waste (operation stage)	

Noise / Vibration - ***Necessary for construction/installation stage of the gas transmission pipeline project. Proposed monitoring items are given below:***

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Bangladesh Standards	Referred International Standards	Remarks (Measurement Point, Frequency, Method)
Noise level	dB			45 (Night-time) 55 (Daytime) (Residential Area)	45 (Night-time) 55 (Daytime) (Residential Area) (World Bank)	• 50 m from the construction site • One 24-hr. day sampling per month • Sound level meter

Appendix 14:

ENVIRONMENTAL CHECKLIST

FOR

GAS TRANSMISSION PIPELINE PROJECT

(DHANUA - ELENGA)

(GTCL)

Appendix 14. Environmental Checklist for Gas Transmission Pipeline Project (Dhanua - Elenga) - GTCL

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
1 Permits and Explanation	(1) EIA and Environmental Permits	① Have EIA reports been officially completed? ② Have EIA reports been approved by authorities of the host country's government? ③ Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? ④ In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	① Once completed long ago in 2005 and Environmental Clearance Certificate (ECC) for the Project was issued but it is no longer valid for this project. So, the EIA study (including ARAP Study) was completed in the middle of February 2014 since conducting of EIA is mandatory in Bangladesh for any gas pipeline project irrespective of the project scale. GTCL will submit this EIA report with necessary modification along with local authority clearance (NOC/No Objection Certificate) for obtaining the ECC from DoE. ② No. EIA report approval obtained in 2005 is no longer valid now. GTCL will submit this EIA report with necessary modification, if any and obtaining local authority clearance (NOC) for approval of the Government authority (DoE). ③ No. EIA report approved in 2005 is no longer valid now. GTCL will submit this EIA report with necessary modification and local authority clearance (NOC) for approval of the Government authority (DoE). ④ No. GTCL will collect NOC from concerned local authorities of the ROW of the pipeline for this project.
	(2) Explanation to the Public	① Are contents of the project and the potential impacts adequately explained to the public based on appropriate procedures, including information disclosure? Is understanding obtained from the public? ② Are proper responses made to comments from the public and regulatory authorities?	① EIA study included public consultation using FGD (focus group discussion method) & KII (Key Informant Interview) including interview survey which is an appropriate procedure used in Bangladesh where information disclosure was also made. Yes, the understanding of the public about the project was made and explained in brief in Section-10.2.1 & 10.3 of Chapter-10 of the EIA report and in details in Chapter-8 of the ARAP report. ② Proper response and comments of public are delineated in brief in Section-10.4 of Chapter-10 of the EIA report and in detail in Section 8.5 of Chapter-8 of the ARAP report. The Regulatory Authorities feedback shall come after the EIA report placement to the DoE.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
2 Mitigation Measures	(1) Water Quality	① Are adequate measures taken to prevent spills and discharges of crude oil and hazardous materials to the surrounding water areas?	① Not significant for this gas pipeline project.
	(2) Wastes	① Are sludge's containing pollutants, such as oils, greases and heavy metals generated by pipeline cleaning (pigging operations) properly treated and disposed of in accordance with the country's standards?	① No obnoxious ingredients observed in pigging hole during construction. Existing gas pipeline operation (operational experience is more than 20 years) indicates waste generated by pipeline cleaning (pigging operations) is properly treated and disposed of in accordance with the standard requirement (buried underground).
	(3) Soil Contamination	① Has the soil at the project site been contaminated in the past, and are adequate measures taken to prevent soil contamination by leaked materials, such as crude oil?	① Not significant for this gas pipeline project.
	(4) Noise and Vibration	① Do noise and vibrations from facility operations, such as pumping operations comply with the country's standards? ② Is there a possibility that noise from facility operations, such as pumping operations will affect humans and animals (wildlife and livestock)?	① No significant noise and vibrations from gas transmission pipeline operation is anticipated as also evident from existing operational pipelines of more than 1000 km in length of GTCL. ② As of above no significant noise/vibration is anticipated.
3 Natural Environment	(1) Protected Areas	① Is the project site located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	① No. The project site is located in human (anthropogenic) influenced areas of residential, agricultural and vacant land areas only and there are no protected areas in its vicinity.Section-4.5.3 of Chapter-4 of EIA report described the ecologically sensitive areas (ESA) of Bangladesh. The project area is out of any national protected areas.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
3 Natural Environment	(2) Ecosystem	① Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? ② Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? ③ If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? ④ Are adequate measures taken to prevent impacts on wildlife and livestock, such as disruption of migration routes, and habitat fragmentation of wildlife and livestock? ⑤ Is there a possibility that installation of pipelines will cause impacts, such as destruction of forest, poaching, desertification, reduction in wetland areas, disturbance of ecosystems due to introduction of exotic species (non-native inhabitants in the region) and pests? Are adequate measures for preventing such impacts considered?	① No ② No ③ Not applicable as no significant ecological impacts are anticipated ④ Not significant for an underground pipeline laid through areas of human/anthropogenic influence (There exists more than 1000 km of operational pipelines with no apparent adverse effects on ecosystem). ⑤ No such effects are anticipated consequent to this pipeline installation similar to the already installed and in operation pipelines as noted above. Except temporary clearing & grading of right of way in the pipeline route and which are duly reinstated after laying of pipeline. Section-4.5 of Chapter-4 of EIA described the biological environment of the project area that has high anthropogenic influence (predominantly farm lands).
	(3) Hydrology	① In the case of offshore pipeline projects, is there a possibility that oceanographic condition changes due to installation of structures will adversely affect oceanographic conditions, such as induced currents, waves, and tidal currents? Is the possibility of water quality degradation by the installation of structures studied? Are adequate water quality control measures taken, if necessary?	① Not applicable
	(4) Topography and Geology	① In the case of onshore pipeline installation, is there a possibility that the installation of structures will cause a large-scale alteration of topographic features and geologic structures around the project site? In the case of coastal pipeline installation, is there a possibility that the installation of structures will result in elimination of beaches?	① This project is an onshore pipeline installation project and no adverse effects on either topographic features or geologic structures around the project site are anticipated consequent to the pipeline installation. Section 4.3.1 & 4.3.2 of Chapter-4 of the EIA report described the topography and geology of the project area.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
4 Social Environment	(1) Resettlement	① Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? ② Is adequate explanation on relocation and compensation given to affected persons prior to resettlement? ③ Is the resettlement plan, including proper compensation, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? ④ Does the resettlement plan pay particular attention to vulnerable groups or persons, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? ⑤ Are agreements with the affected persons obtained prior to resettlement? ⑥ Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? ⑦ Is a plan developed to monitor the impacts of resettlement?	① Yes. There will be small-scale involuntary resettlement caused by project implementation. The ROW is selected so as to minimize resettlement requirement to the maximum possible extent and the resettlement requirement is estimated at 25 households (total population is about 121 persons). The detail description of households' resettlement has been given in Chapter-4 of the ARAP report. ② No. This will be done as part of the official ARAP (abbreviated resettlement action plan) later by GTCL during project implementation and not done by this EIA/ARAP Studies. ARAP implies the resettlement requirement would be of small-scale only since ROW is selected so as to minimize resettlement requirement (25 HHs i.e. 121 persons only). Chapter-5 of the ARAP report described the policy framework of resettlement. ③ Yes. The ARAP Study conducted in depth socioeconomic studies targeting population identified for involuntary resettlement and hence to formulate the ARAP Report conforming the relevant WB (World Bank) OPs (in particular OP 4.12 on involuntary resettlement) and JICA guideline. Chapter-4 of the ARAP report described the socioeconomic analysis. ④ Yes. Due attention to such aspects has been given during the ARAP Study even though there is no presence of ethnic minorities and indigenous people in the project area. ⑤ No. GTCL will do the necessary agreement with the PAPs and the ARAP study paid due attention to obtain consent from people resettled in an amicable manner. ⑥ Yes. Figure6.1.2.1 of Chapter-6 of the ARAP report described the organizational framework for properly implement the resettlement including the required capacity and Chapter-10 of the same report describes the budget for the ARAP implementation. ⑦ Yes. Format for resettlement monitoring is given in Chapter-9 of the ARAP report (given in Appendix 19).

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
4 Social Environment	(2) Living and Livelihood	① Is there a possibility that existence of pipeline will cause impacts on traffic in the surrounding areas, and impede the movement of inhabitants?	① Since pipeline is laid underground no such long-term impacts are anticipated as also could be visualized from the already operational pipelines of more than 1000 km in length. (Except for temporary dislocation during construction).
	(3) Heritage	① Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage sites? Are adequate measures considered to protect these sites in accordance with the country's laws?	① There are no archeological, historical, cultural, and religious heritage sites in and around the vicinity of the ROW of the pipeline.
	(4) Landscape	① Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	① No adverse effect on the local landscape is anticipated since the pipeline is laid underground as also could be visualized from the already operational pipelines of more than 1000 km in length.
	(5) Ethnic Minorities and Indigenous Peoples	① Does the project comply with the country's laws for rights of ethnic minorities and indigenous peoples? ② Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples?	① The pipeline will not interfere with any rights of ethnic minorities or indigenous peoples since there are no such people living in the project vicinity (confirmed by the ARAP Study). ② Not applicable, since there is no such ethnic minority or indigenous people living in the project vicinity.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
5 Others	(1) Impacts during Construction	① Are adequate measures considered to reduce impacts during construction (e.g. noise, vibrations, turbid water, dust, exhaust gases, and wastes)? ② If construction activities adversely affect the land use and livelihood of inhabitants, is adequate compensation provided to local inhabitants for losses of land and livelihoods? ③ If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? ④ If construction activities cause impacts on traffic in surrounding areas, and impede the movement of inhabitants, are adequate measures considered to reduce impacts? ⑤ If construction activities adversely affect the social environment (including communicable diseases, such as HIV), are adequate measures considered to reduce impacts? ⑥ If necessary, is health and safety education (e.g., traffic safety, public health) provided for project personnel, including workers?	① Table-6.2-1 of Chapter-6 of the EIA report (given in Appendix 10) deals with these aspects as EHS for construction stage of the project. Mitigation measures for potential dust induced air pollution during construction include water spraying of dust prone land cleared site and vinyl sheet covering of dust prone materials. Since construction works will be conducted only in dry season no significant generation of turbid and wastewater is anticipated. ② Yes. The required compensation due to construction activities on the land use and livelihood of inhabitants is duly determined in the EIA/ARAP Studies. Chapter-10 of the ARAP report describes the tentative budget. ③ No significant adverse effect by construction activities on the natural environment (ecosystem) is anticipated since there are no ecologically important areas located in and around the vicinity of the project site. Table 5.2-1 of Chapter-5 and Table-6.2-1 of Chapter-6 (Appendix 10) of the EIA report describes the environmental scoping and mitigation/management plan of the project area. ④ Table-6.2-1 of Chapter-6 of the EIA report (Appendix 10) deals with these aspects as EHS for construction stage of the project. Mitigation measures to minimize interference with regular traffic include transportation of construction related materials during off-peak hours and holidays and others. ⑤ Table-6.2-1 of Chapter-6 of the EIA report (Appendix 10) deals with these aspects as EHS for construction stage of the project. In this respect instilling due awareness on the dangers and mitigation of communicable diseases by the construction contractor will be emphasized by the project management. ⑥ Table-6.2-1 of Chapter-6 of the EIA report (Appendix 10) deals with these aspects as EHS of construction stages of the project. Construction contractor shall fully commit and abide to the concept of “Safety First”.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
5 Others	(2) Accident Prevention Measures	① Are adequate accident prevention plans and mitigation measures developed to cover both the soft and hard aspects of the project, such as establishment of safety rules, installation of prevention facilities and equipment, and safety education for workers? Are adequate measures for emergency response to accidental events considered? ② Are adequate accident prevention measures (e.g., installation of prevention facilities and equipment and establishment of prevention management framework) taken to prevent spills from crude oil and gas storage facilities, loading/unloading operations, transportation, and blow out during drilling?	① Table 6.2-1 and Section-6.5 of Chapter-6 of the EIA study (Appendix 10) dealt with these aspects as EHS duly separated between construction and operational stages of the project. Yes, adequate provision of implementing the emergency response plan would be committed and abided by the executing contractor. ② There are no such significant activities in this gas transmission pipeline to take accident prevention measures except taking care of occupational health and safety measures. Table 6.2-1 and Section-6.5 of Chapter-6 of the EIA study (Appendix 10) dealt with accident prevention measures.
	(3) Monitoring	① Does the proponent develops and implement monitoring program for the environmental items that are considered to have potential impacts? ② Are the items, methods and frequencies included in the monitoring program judged to be appropriate? ③ Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? ④ Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	① Table-7.2-1 of Chapter-7 of the EIA study developed the required monitoring program for implementation for the environmental items that are considered to have potential impacts. Monitoring program focused on air pollution (dust), noise, waste and water pollution control is regarded as necessary for the construction stage of the project only.(Monitoring form is given in Appendix 12). ② Yes, the items, methods and frequencies included in the monitoring program is well judged and appropriate. Periodical testing of the environmental parameters & results thereof subscribed to the adequacy of the EMP. ③ Figure-7.3-1 of Chapter-7 of the EIA study established an adequate monitoring framework of the project. ④ Yes. Section-7.2 of Chapter-7 of the EIA report described about the requirement and format and frequency of monitoring reports from the proponent to the regulatory authorities as per provisions of the existing regulatory framework. (Monitoring form is given in Appendix 12).
6 Note	Reference to Checklist of Other Sectors	① Where necessary, pertinent items described in the Forestry Projects checklist should also be checked (e.g., projects including large areas of deforestation).	① Checked and regarded as not that relevant since there is no forestry along the planned ROW of the pipeline installation.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
6 Note	Note on Using Environmental Checklist	① If necessary, the impacts to trans-boundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as trans-boundary waste treatment, acid rain, destruction of ozone layer, global warming).	① There is no significant trans-boundary or global issues to be impacted or involved by this project.

1) Regarding the term “Country’s Standards” mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are made, if necessary. In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan' experience).

2) Environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which it is located.

Appendix 15:

ENVIRONMENTAL CHECKLIST

FOR

GAS TRANSMISSION PIPE LINE PROJECT

(WEST BANK OF JAMUNA BRIDGE - NALKA)

(GTCL)

Appendix 15. Environmental Checklist for Gas Transmission Pipeline Project (West Bank of Jamuna Bridge - Nalka) - GTCL

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
1 Permits and Explanation	(1) EIA and Environmental Permits	① Have EIA reports been officially completed? ② Have EIA reports been approved by authorities of the host country's government? ③ Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? ④ In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	① Once completed long ago in 2005and Environmental Clearance Certificate (ECC) for the Project was issued but it is no longer valid for this project. So, the EIA study was completed in the middle of February 2014 since conducting of EIA is mandatory in Bangladesh for any gas pipeline project irrespective of the project scale. GTCL will submit this EIA report with necessary modification along with local authority clearance (NOC/No Objection Certificate) for obtaining the ECC from DoE. ② No. EIA report approval obtained in 2005 is no longer valid now. GTCL will submit this EIA report with necessary modification, if any and obtaining local authority clearance (NOC) for approval of the Government authority (DoE). ③ No. EIA report approved in 2005 is no longer valid now. GTCL will submit this EIA report with necessary modification and local authority clearance (NOC) for approval of the Government authority (DoE). ④ No. GTCL will collect NOC from Jamuna Bridge Authority (for 14 km of ROW of pipeline) and concerned local authorities (for vacant land acquired for CGS/City Gate Station at Nalka) for this project.
	(2) Explanation to the Public	① Are contents of the project and the potential impacts adequately explained to the public based on appropriate procedures, including information disclosure? Is understanding obtained from the public? ② Are proper responses made to comments from the public and regulatory authorities?	① EIA study included public consultation using FGD (focus group discussion method) including interview survey which is an appropriate procedure used in Bangladesh where information disclosure was also made. Yes, the understanding of the public about the project was made and explained in brief in Section-10.3 of Chapter-10 of the EIA report. ② Proper response and comments of public are delineated in brief in Section-10.4 of Chapter-10 of the EIA report. The Regulatory Authorities feedback shall come after the EIA report placement to the DoE.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
2 Mitigation Measures	(1) Water Quality	① Are adequate measures taken prevent spills and discharges of crude oil and hazardous materials to the surrounding water areas?	① Not significant for this gas pipeline project.
	(2) Wastes	① Are sludges containing pollutants, such as oils, greases and heavy metals generated by pipeline cleaning (pigging operations) properly treated and disposed of in accordance with the country's standards?	① No obnoxious ingredients observed in pigging hole during construction. Existing gas pipeline operation (operational experience is more than 20 years) indicates waste generated by pipeline cleaning (pigging operations) is properly treated and disposed of in accordance with the standard requirement (buried underground).
	(3) Soil Contamination	① Has the soil at the project site been contaminated in the past, and are adequate measures taken to prevent soil contamination by leaked materials, such as crude oil?	① Not significant for this gas pipeline project.
	(4) Noise and Vibration	① Do noise and vibrations from facility operations, such as pumping operations comply with the country's standards? ② Is there a possibility that noise from facility operations, such as pumping operations will affect humans and animals (wildlife and livestock)?	① No significant noise and vibrations from gas transmission pipeline operations is anticipated that is also evident from existing operational pipelines of more than 1000 km in length of GTCL. ② As of above no significant noise/vibration is anticipated.
3 Natural Environment	(1) Protected Areas	① Is the project site located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	① No. The project site is located in human (anthropogenic) influenced agricultural and vacant land areas only and there are no protected areas in its vicinity. Section-4.5.3 of Chapter-4 of EIA report described the ecologically sensitive areas (ESA) of Bangladesh. The project area is out of any national protected areas.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
3 Natural Environment	(2) Ecosystem	① Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? ② Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? ③ If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? ④ Are adequate measures taken to prevent impacts on wildlife and livestock, such as disruption of migration routes, and habitat fragmentation of wildlife and livestock? ⑤ Is there a possibility that installation of pipelines will cause impacts, such as destruction of forest, poaching, desertification, reduction in wetland areas, disturbance of ecosystems due to introduction of exotic species (non-native inhabitants in the region) and pests? Are adequate measures for preventing such impacts considered?	① No ② No ③ Not applicable as no significant ecological impacts are anticipated ④ Not applicable for an underground pipeline laid by the side of road ⑤ No such effects are anticipated consequent to this pipeline installation. Except temporary clearing & grading of right of way in the pipeline route which are duly reinstated after laying of pipeline. Section-4.5 of Chapter-4 described the Biological environment of the project area that has high anthropogenic influence (vacant land by the side of road).
	(3) Hydrology	① In the case of offshore pipeline projects, is there a possibility that oceanographic condition changes due to installation of structures will adversely affect oceanographic conditions, such as induced currents, waves, and tidal currents? Is the possibility of water quality degradation by the installation of structures studied? Are adequate water quality control measures taken, if necessary?	① Not applicable
	(4) Topography and Geology	① In the case of onshore pipeline installation, is there a possibility that the installation of structures will cause a large-scale alteration of topographic features and geologic structures around the project site? In the case of coastal pipeline installation, is there a possibility that the installation of structures will result in elimination of beaches?	① This project is an onshore pipeline installation project and no adverse effects on either topographic features or geologic structures around the project site are anticipated consequent to the pipeline installation. Section4.3.1 & 4.3.2 of Chapter-4 of the EIA report described the topography and geology of the project area.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
4 Social Environment	(1) Resettlement	① Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? ② Is adequate explanation on relocation and compensation given to affected persons prior to resettlement? ③ Is the resettlement plan, including proper compensation, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? ④ Does the resettlement plan pay particular attention to vulnerable groups or persons, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? ⑤ Are agreements with the affected persons obtained prior to resettlement? ⑥ Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? ⑦ Is a plan developed to monitor the impacts of resettlement?	① There is no involuntary resettlement caused by project implementation. ② Not applicable since there is no involuntary resettlement. ③ Not applicable since there is no involuntary resettlement. ④ Not applicable since there is no involuntary resettlement. ⑤ Not applicable since there is no involuntary resettlement. ⑥ Not applicable since there is no involuntary resettlement. ⑦ Not applicable since there is no involuntary resettlement.
	(2) Living and Livelihood	① Is there a possibility that existence of pipeline will cause impacts on traffic in the surrounding areas, and impede the movement of inhabitants?	① Since pipeline is laid underground no such long-term impacts are anticipated as also could be visualized from the already operational pipelines of more than 1000 km in length. (Except for temporary dislocation during construction).
	(3) Heritage	① Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage sites? Are adequate measures considered to protect these sites in accordance with the country's laws?	① There are no archeological, historical, cultural, and religious heritage sites in and around the vicinity of the ROW of the pipeline.
	(4) Landscape	① Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	① No adverse effect on the local landscape is anticipated since the pipeline is laid underground as also could be visualized from the already operational pipelines of more than 1000 km in length.
	(5) Ethnic Minorities and Indigenous Peoples	① Does the project comply with the country's laws for rights of ethnic minorities and indigenous peoples? ② Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples?	① The pipeline will not interfere with any rights of ethnic minorities or indigenous peoples since there are no such people living in the project vicinity. ② Not applicable since there are no such ethnic minorities or indigenous people living in the project vicinity.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
5 Others	(1) Impacts during Construction	① Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? ② If construction activities adversely affect the land use and livelihood of inhabitants, is adequate compensation provided to local inhabitants for losses of land and livelihoods? ③ If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? ④ If construction activities cause impacts on traffic in surrounding areas, and impede the movement of inhabitants, are adequate measures considered to reduce impacts? ⑤ If construction activities adversely affect the social environment (including communicable diseases, such as HIV), are adequate measures considered to reduce impacts? ⑥ If necessary, is health and safety education (e.g., traffic safety, public health) provided for project personnel, including workers?	① Table-6.2-1 of Chapter-6 of the EIA report (given in Appendix 11) deals with these aspects as EHS for construction stage of the project. Mitigation measures for potential dust induced air pollution during construction include water spraying of dust prone land cleared site and vinyl sheet covering of dust prone materials. Since construction works will be conducted only in dry season no significant generation of turbid and wastewater is anticipated. ② Yes. The required compensation due to construction activities on the land (1 ha area) for City Gate Station (CGS) which will be in a vacant land will be duly provided and the cost is tentatively estimated and given in Table 6.2-1: Environmental Impact Mitigation/Management Plan (WBJB-Nalka) of Chapter-6 of the EIA report (Appendix 11). ③ No significant adverse effect by construction activities on the natural environment (ecosystem) is anticipated since there are no ecologically important areas located in and around the vicinity of the project site. Table 5.2-1 of Chapter-5 and Table-6.2-1 of Chapter-6 of the EIA report (Appendix 11) describes the environmental scoping and mitigation/management plan of the project area. ④ Table-6.2-1 of Chapter-6 of the EIA report (Appendix 11) deals with these aspects as EHS for construction stage of the project. Mitigation measures to minimize interference with regular traffic include transportation of construction related materials during off-peak hours and holidays and others. ⑤ Table-6.2-1 of Chapter-6 of the EIA report (Appendix 11) deals with these aspects as EHS for construction stage of the project. In this respect instilling due awareness on the dangers and mitigation of communicable diseases by the construction contractor will be emphasized by the project management. ⑥ Table-6.2-1 of Chapter-6 of the EIA report (Appendix 11) deals with these aspects as EHS of construction stages of the project. Construction contractor shall fully commit and abide to the concept of “Safety First”.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
5 Others	(2) Accident Prevention Measures	① Are adequate accident prevention plans and mitigation measures developed to cover both the soft and hard aspects of the project, such as establishment of safety rules, installation of prevention facilities and equipment, and safety education for workers? Are adequate measures for emergency response to accidental events considered? ② Are adequate accident prevention measures (e.g., installation of prevention facilities and equipment and establishment of prevention management framework) taken to prevent spills from crude oil and gas storage facilities, loading/unloading operations, transportation, and blow out during drilling?	① Table 6.2-1 and Section-6.5 of Chapter-6 of the EIA study (Appendix 11) dealt with these aspects as EHS duly separated between construction and operational stages of the project. Yes, adequate provision of implementing the emergency response plan would be committed and abided by the executing contractor. ② There are no such significant activities in this gas transmission pipeline to take accident prevention measures except taking care of occupational health and safety measures. Table 6.2-1 and Section-6.5 of Chapter-6 of the EIA study (Appendix 11) dealt with accident prevention measures.
	(3) Monitoring	① Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts? ② Are the items, methods and frequencies included in the monitoring program judged to be appropriate? ③ Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? ④ Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	① Table-7.2-1 of Chapter-7 of the EIA study developed the required monitoring program for implementation for the environmental items that are considered to have potential impacts. Monitoring program focused on air pollution (dust), noise and waste pollution control is regarded as necessary for the construction stage of the project only. (Monitoring form is given in Appendix 13). ② Yes, the items, methods and frequencies included in the monitoring program is well judged and appropriate. Periodical testing of the environmental parameters & results thereof subscribed to the adequacy of the EMP. ③ Figure-7.3-1 of Chapter-7 of the EIA study established an adequate monitoring framework of the project. ④ Yes. Section-7.2 of Chapter-7 of the EIA report described about the requirement and format and frequency of monitoring reports from the proponent to the regulatory authorities as per provisions of the existing regulatory framework. (Monitoring form is given in Appendix 13)
6 Note	Reference to Checklist of Other Sectors	① Where necessary, pertinent items described in the Forestry Projects checklist should also be checked (e.g. projects including large areas of deforestation).	① Checked and regarded as not that relevant since there is no forestry along the planned ROW of the pipeline installation.

Category	Environmental Item	Main Check Items	Confirmation of Environmental Considerations
6 Note	Note on Using Environmental Checklist	① If necessary, the impacts to trans-boundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as trans-boundary waste treatment, acid rain, destruction of ozone layer, global warming).	① There is no significant trans-boundary or global issues to be impacted or involved by this project.

1) Regarding the term “Country’s Standards” mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are made, if necessary. In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan' experience).
2) Environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which it is located.

Appendix 16:

GAP BETWEEN JICA GUIDELINES AND LAWS OF BANGLADESH ON INVOLUNTARY RESETTLEMENT

(GTCL)

Appendix 16. Gaps between JICA Guidelines and Laws of Bangladesh on Involuntary Resettlement

Sl. No.	JICA Guidelines	Laws of Bangladesh	Gap between JICA Guidelines and Laws of Bangladesh	Adopted Measure in ARAP
1.	Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives. (JICA GL)	No formal laws, act or ordinance but common practice at the time of project formulation	There is practice but not legally bound	Income restoration grant and Income Generating Activities(IGA) training
2.	When population displacement is unavoidable, effective measures to minimize impact and to compensate for losses should be taken. (JICA GL)	No formal laws, act or ordinance but common practice at the time of project formulation; compensation by DC as Cash compensation under law(CCL);50% premium on calculated amount	It is insufficient in terms of actual market price as replacement value	Additional amount on DC's payment which is calculated on Land market survey(LMS) decided by property valuation advisory committee(PVAC)
3.	People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels. (JICA GL)	No legal provision	Insufficient compensation, support and practice to restore pre project living standard and production level	1. Additional grant on DC's payment as LMS 2. Stamp duty refund by body GTCL 3. IGA training etc
4.	Compensation must be based on the full replacement cost as much as possible. (JICA GL)	No legal provision	Compensation is below the replacement cost	Additional grant on DC's payment as LMS decided by PVAC
5.	Compensation and other kinds of assistance must be provided prior to displacement. (JICA GL)	No legal provision	Normally displaced before getting compensation and support	1. Provision at least 50% PAPs are paid 2. Tansfer grant(TG), and construction grant(CG) are paid prior to displacement
6.	For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public. (JICA GL)	Not such legal bindings in the law	Though no legal provision but practice in donor funded project	Abbreviated Resettlement Action Plan(ARAP) has provision to disclosure key provisions of resettlement issues to disclose among public

Sl. No.	JICA Guidelines	Laws of Bangladesh	Gap between JICA Guidelines and Laws of Bangladesh	Adopted Measure in ARAP
7.	In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance. (JICA GL)	No such arrangement in the law, even no scope of RAP	Preparation of RAP is a social reality	ARAP has been prepared on the basis of prior consultations of affected people and their communities
8.	When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people. (JICA GL)	No provision of consultations in the law but there is a practice of consultations in donor project	In fact when consultations held, it is clearly understandable to the affected in their local language	Provision of consultations in their local language in ARAP, before the project formulation, implementation period and post project period, at least 2 years after project completion. Project authority will distribute a brochure highlighting key issues of the project and ARAP to the affected.
9.	Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of resettlement action plans. (JICA GL)	No provision and guideline in law	Stakeholders normally remain in dark regarding project formulation, implementation and monitoring issues	PAPs are consulted about the ARAP issues during Socio Economic survey(SES) and ARAP has clearly outlined PAP's participation through GRC and PVAC
10.	Appropriate and accessible grievance mechanisms must be established for the affected people and their communities. (JICA GL)	There is a scope of arbitration regarding payment related issues for titled owner in case of under Acquisition and Requisition of Immovable Property Ordinance(ARIPO)-1982	But this is not easy for common people and doesn't ensure compensation at the rate of full replacement cost, but for non titled owners do not get any compensation and not get income restoration support	Through PVAC and GRC both titled and non titled owner can able grievances except any issue in the court
11.	Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advance of such benefits. (WB OP4.12 Para.6)	No provisions of early identification of affected persons, there is act in case of Jamuna Bridge Project (land acquisition)(Compensation Refusal Laws)-1994(Act No-14); for refusal of compensation of fake structure.	Cut of date off date is treated Section-3 notice and SES which is later as a practice	Provision of Joint Inventory Verification Team(JIVT) and video filming for structure and tree loss and Socio economic survey for overall loss assets, structure and identification of PAPs

Sl. No.	JICA Guidelines	Laws of Bangladesh	Gap between JICA Guidelines and Laws of Bangladesh	Adopted Measure in ARAP
12.	Eligibility of benefits includes, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupying. (WB OP4.12 Para.15)	No compensation for non titled owner and squatter in the law	Vulnerable and squatter are deprived	Non titled owner and squatter have right to get compensation TG, CG, structure value and IGA support from NGO/implementing agency
13.	Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based. (WB OP4.12 Para.11)	No support in the law	Lack of legal support, but in donor supported project there is example of Resettlement Site(RS) specially for vulnerable homestead loser	Support of land purchase if PAPs purchase land e.g. Stamp duty, money refund up to replacement value
14.	Provide support for the transition period (between displacement and livelihood restoration). (WB OP4.12 Para.6)	No support in the law	Lack Livelihood restoration support	Three months Grant of livelihood support
15.	Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities etc. (WB OP4.12 Para.8)	No guideline in the line	No distinction or priority in Bangladesh's law regarding vulnerability	Special priority in ARAP, income generating activities(IGA), microcredit etc; No indigenous people in the project area
16.	For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan is to be prepared. (WB OP4.12 Para.25)	No such guideline in the law	Bangladesh law is not clear	No. of households resettled is 25 with resettled population of 121 persons (less than 200). Accordingly this ARAP study was conducted.

Appendix 17:

LOST AND AFFECTED PROPERTY INVENTORY

FOR

DHANUA-ELENGA PIPELINE PROJECT

17-1 List of Affected Structure Loser PAPs

17-2 Permanently Affected Types of Land

17-3 Lost Trees

(GTCL)

Appendix 17. Lost and Affected Property Inventory for Dhanua-Elenga Gas Pipeline Project-GTCL

(This appendix has been removed because of confidential information.)

Appendix 18:

ENTITLEMENT POLICY MATRIX

ON

LAND ACQUISITION AND RESETTLEMENT

FOR

GAS TRANSMISSION PIPELINE PROJECT

(DHANUA-ELENGA)

(GTCL)

Appendix 18. Entitlement Policy Matrix on Land Acquisition and Resettlement for Gas Transmission Pipeline Project (Dhanua-Elenga) of GTCL

(This appendix has been removed because of confidential information.)

Appendix 19:

RESETTLEMENT MONITORING

AND

EVALUATION FORMS

FOR

DHANUA-ELENGA GAS PIPELINE PROJECT

(GTCL)

Appendix 19. Resettlement Monitoring and Evaluation Forms for Dhanua-Elenga Gas Pipeline Project of GTCL

Monitoring Format-1: Monthly Progress Report Format for Resettlement Monitoring

Reporting Month: ……							
Sl. No.	**Component**	**Unit Total**	**Completed %**	**Cumulative Achievement**	**Completed**	**Progress During Reporting Month**	**Status & Remarks**
1.Resettlement Preparation:							
1.1	Identification of PAPs	No.					
1.2	Group Meeting with PAPs,	No.					
1.3	Distribution of Compensation for Structures	Tk.					
1.4	Compensation for crop/tree	Tk.					
2.Payment of Compensation							
2.1	Land: (agriculture/homestead)	Tk.					
2.2	Compensation for Structures	Tk.					
2.3	Compensation for Crop/tree	Tk.					
3.Relocation and Income Restoration Activities							
3.1	Relocation of Households	No.					
3.2	Payment of Transfer Grant	Tk.					
3.3	Income Restoration Grant	Tk.					

Public consultation is a very important aspect for monitoring purpose and it is a continuous process. Resettlement Unit (RU) of GTCL will use this format for reporting public consultation in their monthly and quarterly progress report. NGO or implementing agency will submit it to the GTCL RU unit and to the JICA.

Monitoring Format-2: Monitoring Format for Public Consultation

Serial	**Date**	**Place**	**No. of Participants**	**Contents of the consultation, main comments and answers**
1				
2				

Following format is intended for exclusive use of RU of GTCL. After recruiting NGO, relevant part will be used by the NGO for monitoring and the report will be submitted to RU of GTCL and JICA.

Monitoring Format-3: Acquisition and Resettlement Activities Monitoring Form

Resettlement Activities	Planned Total	Unit	Progress in Quantity			Progress in %		Expected Date of Completion	Responsible Organization
			During the quarter	Till the last quarter	Up to the quarter	Till the last quarter	Up to the quarter		
Preparation of ARAP									
Employment of Consultants		Man month							
Implementation of Census Survey(Including Socio Economic Survey)									
Approval of ARAP			Date of Approval						
Finalization of PAPs List		No of PAPs							
Progress of Compensation payment		No of HHs							
Lot 1		No of HHs							
Lot 2		No of HHs							
Lot 3		No of HHs							
Lot 4		No of HHs							
Progress of Land Acquisition (All Lots)		m^2							
Lot 1		m^2							
Lot 2		m^2							
Lot 3		m^2							
Lot 4		m^2							
Progress of Asset Replacement (All lots)		No of HHs							
Lot 1		No of HHs							
Lot 2		No of HHs							

Resettlement Activities	Planned Total	Unit	Progress in Quantity			Progress in %		Expected Date of Completion	Responsible Organization
			During the quarter	Till the last quarter	Up to the quarter	Till the last quarter	Up to the quarter		
Lot 3		No of HHs							
Lot 4		No of HHs							
Progress of Relocation of People (All Lots)		No of HHs							
Lot 1		No of HHs							
Lot 2		No of HHs							
Lot 3		No of HHs							
Lot 4		No of HHs							

Monitoring of certain indicators are very important for due implementation of involuntary resettlement issues and thus ensuring congenial social environment. As per JICA guidelines it should be at least for a minimum of 2 years period after the last date of completion of all resettlement activities. It is expected that minimum 2 years period of monitoring is adequate considering the small scale nature of resettlement is involved. Proposed monitoring items are given below on a tentative basis for livelihood and resettlement monitoring. In addition to above, the monitoring indicators will be reported on monthly, quarterly and annual basis. The reporting will be on the following monitoring indicators.

Monitoring Format-4: Indicator-wise Monitoring Results during Report Period

Serial	Monitoring Item/Indicator	Report Period			
		Month-1	Month-2	Month-3	----------
1	Amicable Negotiation (Total 100%) Cumulative progress				
2	Successful grievance resolution(No.) Cumulative progress				
3	Timely delivery of Compensation(in Taka) Cumulative progress				
4	Satisfied with agreed resettlement (No. of PAPs) Cumulative progress				
5	Restoration of income (No. of PAPs) Cumulative progress				

Serial	Monitoring Item/Indicator	Report Period			
		Month-1	Month-2	Month-3	----------
6	Restoration of economic/agricultural activities (No. of PAPs) Cumulative progress				
7	No of occupational disruption and major damages (No. of PAPs) Cumulative Figure				
8	Home/homestead rehabilitated (No. of PAPs) Cumulative progress				
9	Uninterrupted access to community facilities and services (No. of PAPs) Cumulative progress				
10	Wells, drains, canals, road reinstated (No./length in meter) Cumulative progress				
11	Enhanced social relations and networks (No. of PAPs) Cumulative progress				
12	Enhanced livelihood through effective use of compensation (No. of PAPs) Cumulative progress				
13	Training Provided(Nos. of PAPs) -Trade 1 -Trade 2 -Trade 3				
14	Microcredit Provided -In Tk. -No. PAPs				
15	-Transfer Grants(TG) -Construction Grants (CG)				

Note: Initial Assumptions:

- No. of Total PAPs:
- Total amount of Compensation in Tk.
- Total No. of PAPs having access to community facilities
- Total no. of wells, drains to be reinstated
- Total length of canals to be reinstated in Km.
- Total length of roads to be reinstated in Km.

Appendix 20:

SUBSIDIARY LOAN AGREEMENT

BETWEEN

THE GOVENMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

AND

BANGLADESH GAS FIELDS COMPANY LIMITED

FOR

THE NATURAL GAS EFFICIENCY PROJECT

(COMPONENT 1: WELLHEAD GAS COMPRESSORS OF BANGLADESH GAS FIELDS COMPANY LIMITED)

FINANCED BY THE JAPAN INTERNATIONAL COOPERATION AGENCY

Appendix 20. Draft Subsidiary Loan Agreement Between GOB and BGFCL for Component 1: Wellhead Gas Compressors

(This appendix has been removed because of confidential information.)

Appendix 21:

SUBSIDIARY LOAN AGREEMENT

BETWEEN

THE GOVENMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

AND

GAS TRANSMISSION COMPANY LIMITED

FOR

THE NATURAL GAS EFFICIENCY PROJECT

(COMPONENT 2: GAS TRANSMISSION PIPELINES OF GAS TRANSMISSION COMPANY LIMITED)

FINANCED BY THE JAPAN INTERNATIONAL COOPERATION AGENCY

Appendix 21. Draft Subsidiary Loan Agreement between GOB and GTCL for Component 2: Gas Transmission Pipelines

(This appendix has been removed because of confidential information.)

Appendix 22:

SUBSIDIARY LOAN AGREEMENT

BETWEEN

THE GOVENMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

AND

TITAS GAS TRANSMISSION AND DISTRIBUTION COMPANY LIMITED

FOR

THE NATURAL GAS EFFICIENCY PROJECT

(COMPONENT 3: PRE-PAID GAS METERS OF TITAS GAS TRANSMISSION AND DISTRIBUTION COMPANY LIMITED)

FINANCED BY THE JAPAN INTERNATIONAL COOPERATION AGENCY

Appendix 22. Draft Subsidiary Loan Agreement Between GOB and TGTDCL for Component 3: Pre-paid Gas Meters

(This appendix has been removed because of confidential information.)

Appendix 23:

SUBSIDIARY LOAN AGREEMENT

BETWEEN

THE GOVENMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

AND

KARNAPHULI GAS DISTRIBUTION COMPAMY LIMITED

FOR

THE NATURAL GAS EFFICIENCY PROJECT

(COMPONENT 4: PRE-PAID GAS METERS OF KARNAPHULI GAS DISTRIBUTION COMPAMY LIMITED)

FINANCED BY THE JAPAN INTERNATIONAL COOPERATION AGENCY

Appendix 23. Draft Subsidiary Loan Agreement Between GOB and KGDCL for Component 4: Pre-paid Gas Meters

(This appendix has been removed because of confidential information.)

Appendix 24:

POSSIBILITY OF FUTURE ASSISTANCE:

DETAILS OF POSSIBILE LARGE-SCALE PROJECTS

FOR

THE DEVELOPMENT OF NATURAL GAS IN FUTURE

AND

TECHNICAL CAPACITY BUILDING

Appendix 24. Possibility of Future Assistance: Details of Possible Large-scale Projects for the Development of Natural Gas Sector in Future and Technical Capacity Building

1. Current Status of Hydrocarbon Exploration and Development Activities in Bangladesh

It is important to understand the current status of hydrocarbon exploration and development activities in Bangladesh so that possible large-scale projects for the development of natural gas sector in future can be proposed. On the 4th August, 2013, a meeting was held in Petrobangla with Deputy General Manager, Strategic Planning Division of Petrobangla and JICA Survey Team members of the Gas Sector area. The Survey Team sought answers to the questions like 1) future plan of BAPEX in exploring difficult areas like big rivers, swampy and coastal areas, 2) information regarding exploration of unconventional resources (coal bed methane (CBM), shale gas, etc.), 3) exploration and development of oil/gas targeting in deep structures in Bangladesh and 4) information regarding gas exploration drilling machine, seismic equipment, processing software and so on, from Petrobangla. Earlier, BAPEX was requested to provide answers to the same questions, but there were no response from BAPEX, instead, BAPEX insisted that the Survey Team visits BAPEX Website for the answers (unfortunately, BAPEX website is not updated regularly) or to obtain answers directly from Petrobangla. However, Deputy General Manager, Strategic Planning Division of Petrobangla tried to answer these questions and also provided few documents related to future work plan of BAPEX, Petrobangla and EMRD.

Based on that discussion of the meeting, documents made available and along with published articles, books, magazines, maps, etc., collected from different organizations related to the energy sector of Bangladesh and information available on the Web, an analysis and data synthesis has been made to find out the immediate requirement of the energy sector of Bangladesh and to identify areas, where there is “Possibility of Future Assistance” on the Gas Sector Infrastructure Development. The analysis is presented below.

1.1 Exploration and Development Programme of Bapex until 2030

Following a directive of the EMRD, Bapex prepared a 20 years roadmap to explore oil and gas in 74 exploratory and development wells in 23 structures on onshore block in the country and submitted to Petrobangla October, 2011. According to the roadmap, Bapex would drill 13

exploratory wels and 22 development wells in 2011-2015, nine exploratory wells and three development wells during 2015-2020, seven exploratory wells and five development wells between 2020-2025 and 10 exploratory wells and five development wells between 2025 and 2030.

Bapex has plan to conduct 2D seismic surveys at Savar, Hararganj, patharia, Feni, Bhola, Kuchma, Bogra, Sherpur, Sitapahar, Kasalang, patia and Jaldi in 2011-2015 and Batchia and Nandail in 2015-2020.

Besides these Bapex will also conduct 3D seismic surveys at Fenchuganj, Shahbazpur, Salda, Semutang, kamta, begumganj, Sundalpur, and Sunetra in 2011-2015, while it would conduct similar surveys at Khaliajuri, kapasia, Srikail, Chhatak, Bajitpur, Madan, Mobarakpur, Savar and Hararganj in 2015-2020 and Patharia, Feni and Bhola in 2025. (Source: The Daily Sun, October 16, 2011; http://www.bangladesh-economy.org.)

Approximate locations of the above mentioned Bapex's drilling and seismic programme is shown in Figure A24.1-1. It is evident from the figure that there will still remain plenty of potential under-explored and unexplored areas for additional comprehensive exploration/development programme to be undertaken.

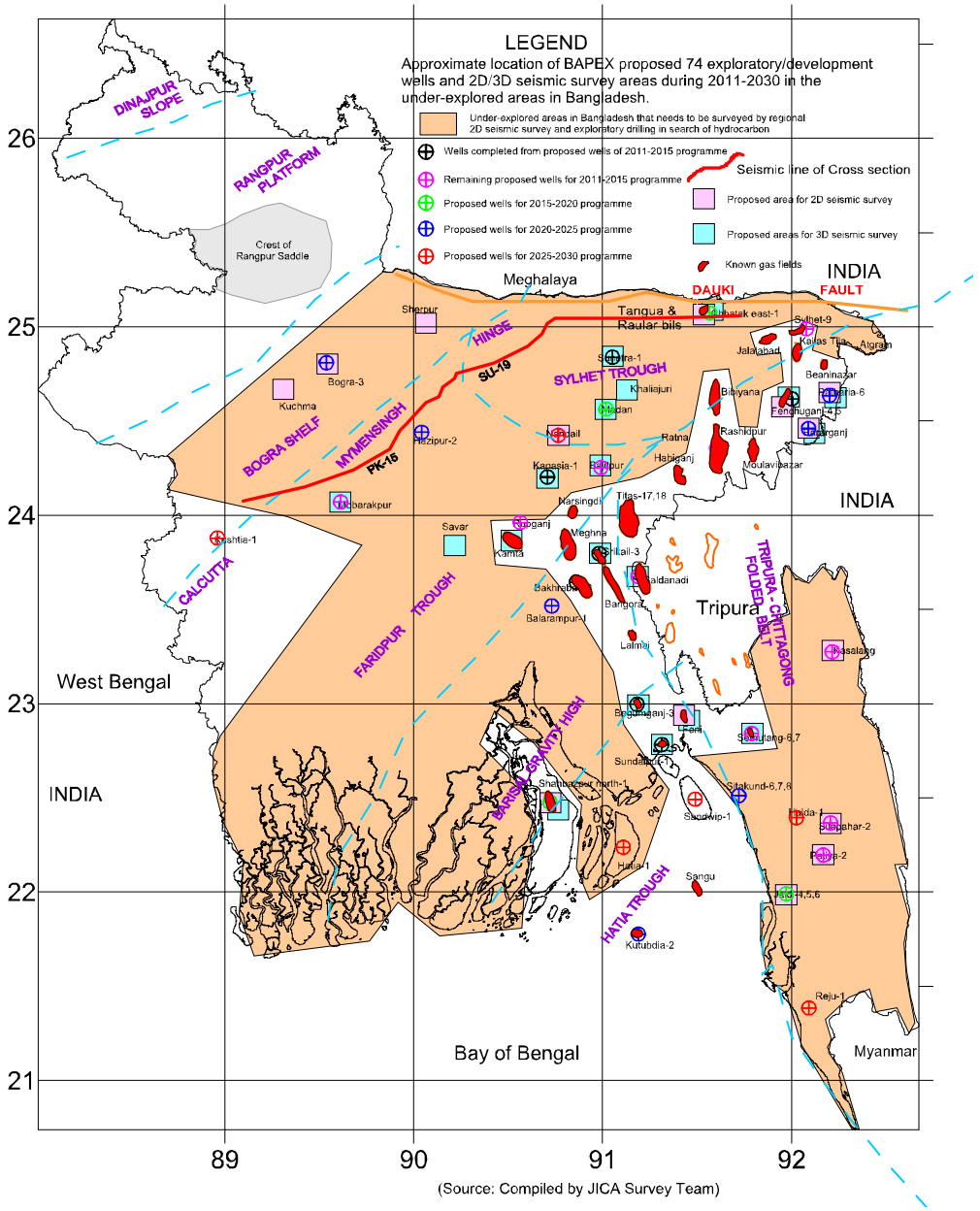
1.2 Draft Updated Road Map of Gas Sector

In March 2013, a "Draft Updated Road Map of Gas Sector" was prepared by the Executive Agencies and EMRD/Petrobangla for submission to Asian Development Bank (ADB)'s Consultation Mission for the "Proposed Natural Gas Production and Transmission Development Investment Programme".

"Expected Increase in Gas Production" presented in the "Road Map" are modified by adding the information on updated actural progress, and are shown in Table A24.1-1 to Table A24.1-5.

It is observed that completion time has been delayed for the March-June, 2013 part of the project and actual production is less than expected.

For the July-December, 2013 part, although delayed, some progress has been made, but some projects have not started yet. Although delayed, BAPEX completed their part of the projects and in case of Bakhrabad # 9, gas production is higher than expected but for Titas 18, production is much less than what was expected. On the other hand, progress of drilling by Gazprom have been severely delayed and will not be able to meet their target in time. Titas 20 completed by Gazprom in October, 2013 is producing less than 10mmcfd, where 30mmcfd was expected. Gazprom completed Titas 21 in December, 2013 ans is producing only around 16 mmcfd, where 30mmcfd was expected.



(Source: Compiled by JICA Survey Team)

Figure A24.1-1 Map of Bangladesh showing low or no seismic and drilling coverage areas, even after including Bapex's 2011-2030 drilling and 2D/3D seismic programme.

It is therefore evident that, the projected progress and eventually expected increase in gas production will not be possible to achieve by the efforts of BAPEX and Gazprom together, these two companies are currently engaged in the exploration and development of gas sector of Bangladesh. Therefore, engagement of additional drilling companies, necessarily from foreign drilling companies, will be required to meet the drilling target in the expected time period and to adequately address the gas demand and to meet the energy challanges in near furure.

In the “Road Map”, a summary of plans for 2D and 3D seismic survey by BAPEX from 2012 to 2016 also are shown. Table A24.1-6 shows the 2D seismic survey plan in the “Road Map”.

Table A24.1-1 Expected Increase in gas Production (March-June 2013)

Programme	Activity	Increase in Gas production (mmcfd)	Completion Time	Actual Progress	
				Actual Completion Time	Actual Production
Titas # 17	Development	20	March 2013	Completed in March 2013	20 mmcfd
Srikail # 2	Workover	24	March 2013	Completed in March 2013	22 mmcfd
Bangora # 2	Workover	15	May 2013	?	
Salda # 1	Workover	02	April 2013	?	
Titas # 20	Development	30	May 2013	Completed, October 2013	9.6 mmcfd
Srikail # 3	Development	25	May 2013	Completed in August 2013	22 mmcfd
Total		116			

Source: Draft Updated Road Map of Gas Sector

Table A24.1-2 Expected Increase in gas Production (July-December 2013)

Programme	Activity	Increase in Gas production (mmcfd)	Completion Time	Actual Progress	
				Actual Completion Time	Actual daily Production
Fenchuganj # 2	Workover	15	July	?	
Titas # 18	Development	30	July 2013	Completed in July.	21 mmcfd
Bakhrabad # 9	Development	12	July 2013	Completed in August 2013.	14.5mmcfd
Titas # 21	Development	30	August 2013	Completed in December	16mmcfd
Salda # 2	Workover	10	July	?	
Begumganj # 3	Development	15	September	Completed in November 2013.	Tested to produce @10mmcfd
Titas # 19	Development	30	November	Not started yet	
Titas # 27	Development	25	December	Drilling started in November, 2013	
Total		167			

Source: Draft Updated Road Map of Gas Sector

Table A24.1-3 Expected Increase in gas Production (January-June 2014)

Programme	Activity	Increase in Gas production (mmcfd)	Completion Time	Actual Progress	
				Actual Completion Time	Actual Production
Semutang # 6	Development	15			
Fenchuganj # 5	Development	30	Drilling ongoing		
Titas # 22	Development	30			
Fenchuganj # 4	Workover	30			
Shahbazpur # 3	Development	25			
Shahbazpur # 4	Development	25			
Rashidpur # 8	Development	30			
Salda # 4	Development	25			
Rupganj # 1	Exploration	15	Preparation ongoing		
Total		195			

Source: Draft Updated Road Map of Gas Sector

Table A24.1-4 Expected Increase in gas Production (July 2014-June 2015)

Programme	Activity	Increase in Gas production (mmcfd)	Completion Time	Actual Progress	
				Actual Completion Time	Actual Production
Bibiyana gas Field (6 wells)	Development	300	Project Ongoing		
Titas # 23, 24	Development	60			
Rashidpur # 9, 10	Development	50			
Begumganj# 1/a	Development	15			
Sundalpur # 2	Development	15			
Semutang # 1/a	Development	15			
Total		455			

Source: Draft Updated Road Map of Gas Sector

Table A24.1-5 Expected Increase in gas Production (July 2015-June 2016)

Programme	Activity	Increase in Gas production (mmcfd)	Completion Time	Actual Progress	
				Actual Completion Time	Actual Production
Rashidpur # 11	Development	25			
Sylhet # 9	Development	10			
KailashTila # 8	development	20			
Titas # 25, 26	Development	60			
Total		115			

Source: Draft Updated Road Map of Gas Sector

Table A24.1-6 Seimic survey plan by BAPEX from 2012 to 2016.

Year	Location	Length (Line Kilometer)	Remarks
2012-2013	Gopajganj, Khulna, Madaripur, Shariatpur, Bhola, Madan (6 Nos.)	400	Ongoing
2013-2014	Savar, Singair, Munshiganj (3 Nos.)	500	
2014-2015	Islampur, Sreebardi, Madarganj, Melandaha, Sherpur, Nalitabari, Modhupur, Gopalpur, Bhaluka, Nakla (10 Nos.)	500	
2015-2016	Batchia (Fenchuganj South), Hararganj, Patharia, Habiganj (South), Sylhet (5 Nos.)	400	

Source: Plan for 2D Seismic Survey, Draft Updated Road Map of Gas Sector

Since the proved gas reserve will not last for a long time, a “Demand-Supply Balance”, analysis made by Petrobangla, indicated that, to keep the GDP growth around 6.8%, and even if probable reserve are firmed up and converted to proved reserve, then Bangladesh can meet supply up to 2015. Even if the possible reserves and yet-to-find resources are proven, Bangladesh would fail to meet demand after 2023[1]. Therefore, an additional 20-25 tcf gas needs to be proved up within very short period based on a reasonable 5 year discovery to production schedule. Additionally, confirmation of new large reserves by exploration drilling must be needed prior to starting large-scale projects for natural gas development in the future. However, such new large reserves have not confirmed yet by recent exploration drilling in Bangladesh. Possibility of large-scale projects for natural gas development is also closely related to exploration activities to be expected in under-explored areas shown in Section 2.

1.3 Mid Term Plan

The information on the Mid Term Plan was obtained from Petrobangla and the plan is summarised as follows.

Mid Term Plan (Translated from the original in Bangla)

pp-663.

Grant No- 38

42-Energy and Mineral Resources Division

Mid Term Expenditure

[1] MPEMR, with the assistance of Wood Mackenzie, "Bangladesh Gas Sector Master plan and Strategy" January 2006

Table A24.1-7 Priority Spending Areas/Programme

Priority Spending Areas/Programme	Priority
1. Gas exploration and production	1
2. Development of Coal sector	2

Table A24.1-8 Ministry/Divisions Key performance indicators

Indicator	Priority	Unit	2011-2012		2012-2013		Mid Term Aim				
			Corrected target	Actual	Target	Corrected target	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Discovery of new fields											
A: Gas	**1**	No.	**4**	**1**	**4**	**3**	**0**	**4**	**3**	**0**	**3**
B: Coal			**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
2. Gas Exploration/Development/Drilling Production well	**1**	No.	**8**	**1**	**12**	**4**	**9**	**28**	**0**	**11**	**0**
Increase Gas production	1, 2	**%**	**-**	**-**	**-**	**-**	**15**	**16.25**	**17.5**	**18.75**	**20**
		BCF	**730**	**730**	**912**	**800***	**-**	**-**	**-**	**-**	**-**
Increase Coal production	**1**	**%**	**-**	**-**	**-**	**-**	**15.38**	**69.23**	**69.23**	**69.23**	**23.08**
		M.Mt.	**0.86**	**0.67**	**1.00**	**0.65***	**-**	**-**	**-**	**-**	**-**

Source: Key Performance Indicator table prepared by executing agencies and EMRD/Petrobangla, Mid Term Plan of EMRD, pp-667

Table A24.1-9 Comparison of Target and actual achievement

Period	Exploration well target	Corrected Exploration well target	Achievement	Development well target	Corrected Development well target	Achievement
2011-2012	-	4	1	-	8	1
2012-2013	4	3	1	12	4	3
2013-2014	0	0		9	9	
2014-2015	4	4		28	28	
2015-2016	3	3		0	0	
2016-2017	0	0		11	11	
2017-2018	3	3		0	0	
Total		17		60	60	

In the Key Performance Indicator table prepared by executing agencies and EMRD and Petrobangla, for the “Mid Term Planning”, there are provision of 13 exploration wells during 2013-2016 period. But, in the proposed Road Map, there is provision for only one exploration well in Rupganj until June, 2016. A comparison of the Key Performance Indicator table with the Draft Road Map of Gas Sector reveals that, there is practically no scope for finding new or big reserves in the absence of any appropriate exploration programme. Also Key Performance Indicator table shows plan for drilling 52 gas exploration/development/production wells during 2013-2017 period. But the Draft Road Map of Gas Sector has plan for 41 wells until

June, 2016, most of which are already being delayed for completion. In view of the performance, work progress, it is evident that without engagement, assistance and cooperation from foreign drilling/survey companies, it will not be possible to meet the drilling target in expected time period and discover new gas fields needed to adequately address the gas demand of the country within the current “Mid Term Plan” of the Government, since BAPEX and Gazprom will remain busy with the implementation of their ongoing gas field development projects.

2. Hydrocarbon Exploration in Under-explored Areas

There are very little to no hydrocarbon exploration activities in the large northwestern part of Bangladesh. This part of the country is highly under-explored. There is a vast area in the south-western part of the country that is also under-explored. Figure A24.2-1 shows the areas having thin seismic coverage and a few or no drill holes. The Chittagong and Chittagong hill tracts areas are also thinly covered by seismic survey.

So far only 4 wells drilled in the northwestern part of the country and three of them showed the presence of both of oil and gas. There are also possibility of finding fault controlled and stratigraphic traps. There are instances of direct hydrocarbon indicator (DHI) in the seismic sections of the Madarganj and Sariakandi areas. Further exploration using seismic survey and several exploratory wells in the area including in the Madarganj-Sariakandi area is necessary to adequately assess the hydrocarbon potential of the area.

Figure A24.2-1 indicates that a large part of the country is still under-explored for hydrocarbon potential.

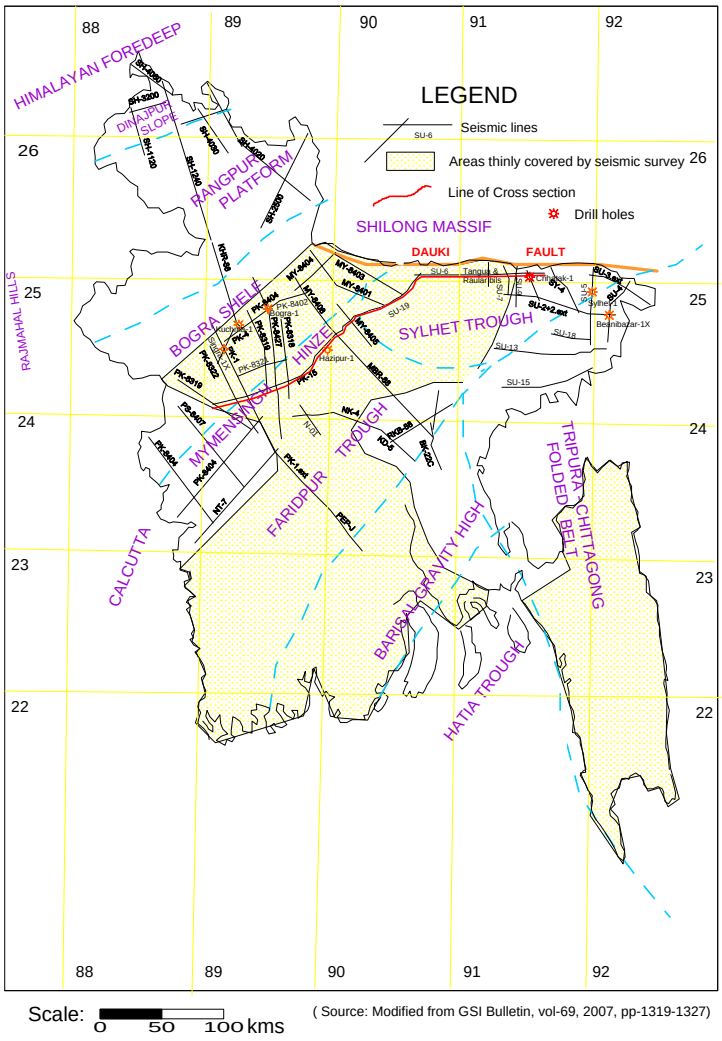


Figure A24.2-1 Map of Bangladesh showing tectonic divisions, location of regional seismic lines and the areas having thin seismic coverage.

2.1 Bogra-Lalmai low amplitude broad regional stuctures

Figure A24.2-2 and Figure A24.2-3 show the vertical and spatial distribution respectively of Pleistocene to Recent sediments in the northern part of Bangladesh including the Surma basin and Bogra Shelf areas. Figure A24.2-4 shows the two-way time contour maps (Alam, 2004, 2007) of the J horizon (Plio-Pleistocene Dupi Tila Formation). It appears that Dupitila reflects the structural pattern of the deeper formations both in the Surma basin and the Bogra Shelf and part of the basin area. It is evident from the two figures that there exists low amplitude broad

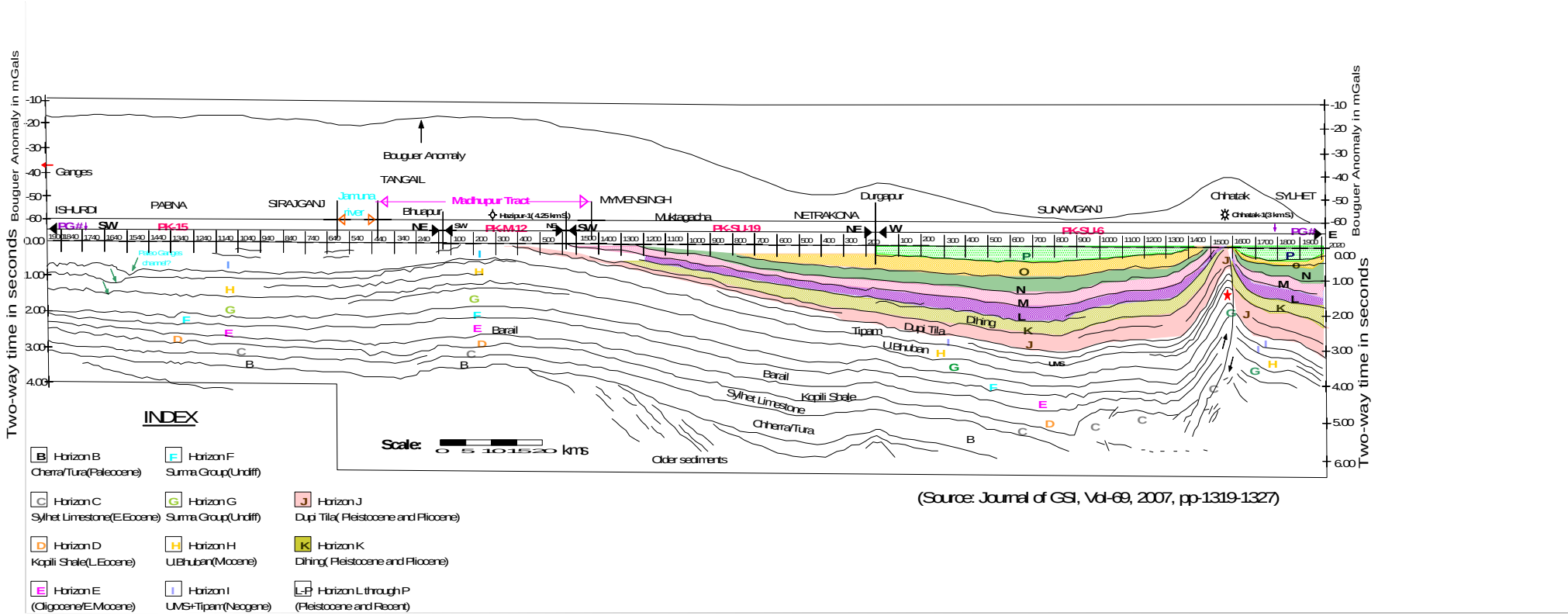


Figure A24.2-2 The composite section comparing PK-15, PK-15 (west), PK-M-12, PK-U19 and PK-SU-6 over the Bogra Shelf (outer), Hinge Zone and the Surma basin area.

anticlinal structure stretching from Sariakandi in Bogra in the north west, through Tangail to Lalmai area in th south east. It may be noticed that there also exists a number of small low amplitude structures on both the flanks of this regional structure. Of these smaller structures are Kamta, Narsingdi field and the proposed Rupganj structures lie on top of this structure. DHI like bright spot and flat spot are also present in the Madarganj and Sariakandi areas, that lies in the north-west end of this structure. A careful look also reveals indication of many other anticlinal features on both sides until Sariakandi in its nortwestern end and Srikail, Bangora, Lalmai field lie on its south-eastern end. Therefore this broad structure needs to studied carefully with regional 2D seismic lines and deep drilling to reveal its hydrocarbon potential.

Although it is generally assumed that the western part of the country is devoid of any structures. A close look at the Figure A24.2-4 reveals the presence of several low amplitude anticlinal trends on the DupiTila surface, both over the shelf and Surma basin area. Two of these structures correlate well with the already discovered gas fields like Kamta and Narsingdi (Figure A24.2-4). Since Figure A24.2-4 was mainly based on very few sparse 2D seismic data, a detailed and well planned 2D seismic survey is necessary to explore these under-explored areas for better definition of these and other possible structures over the region.

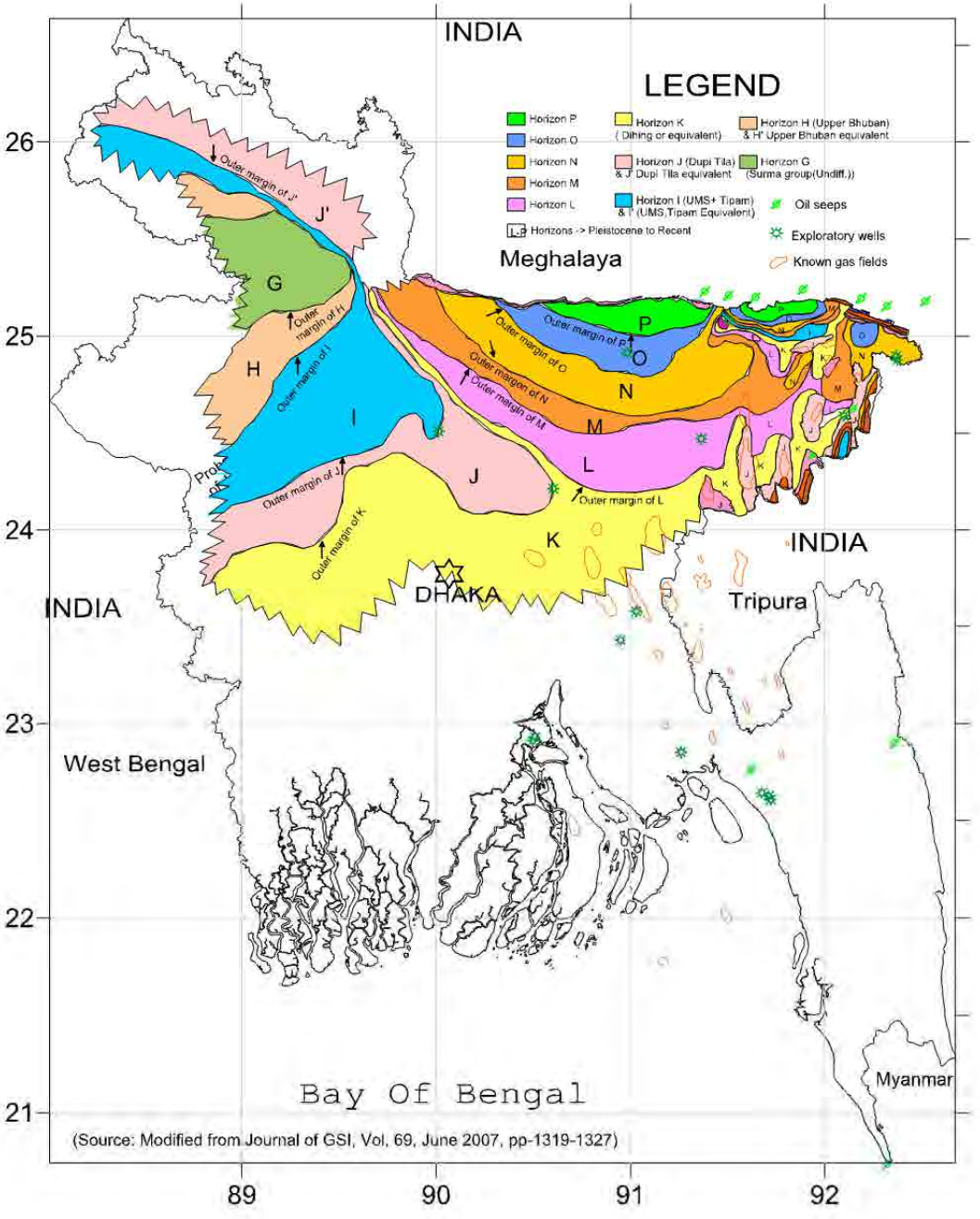


Figure A24.2-3 Map of Bangladesh showing the arrangement and spatial distribution of different near surface seismo-stratigraphifc horizons (G through P) as identified in the two-way time sections.

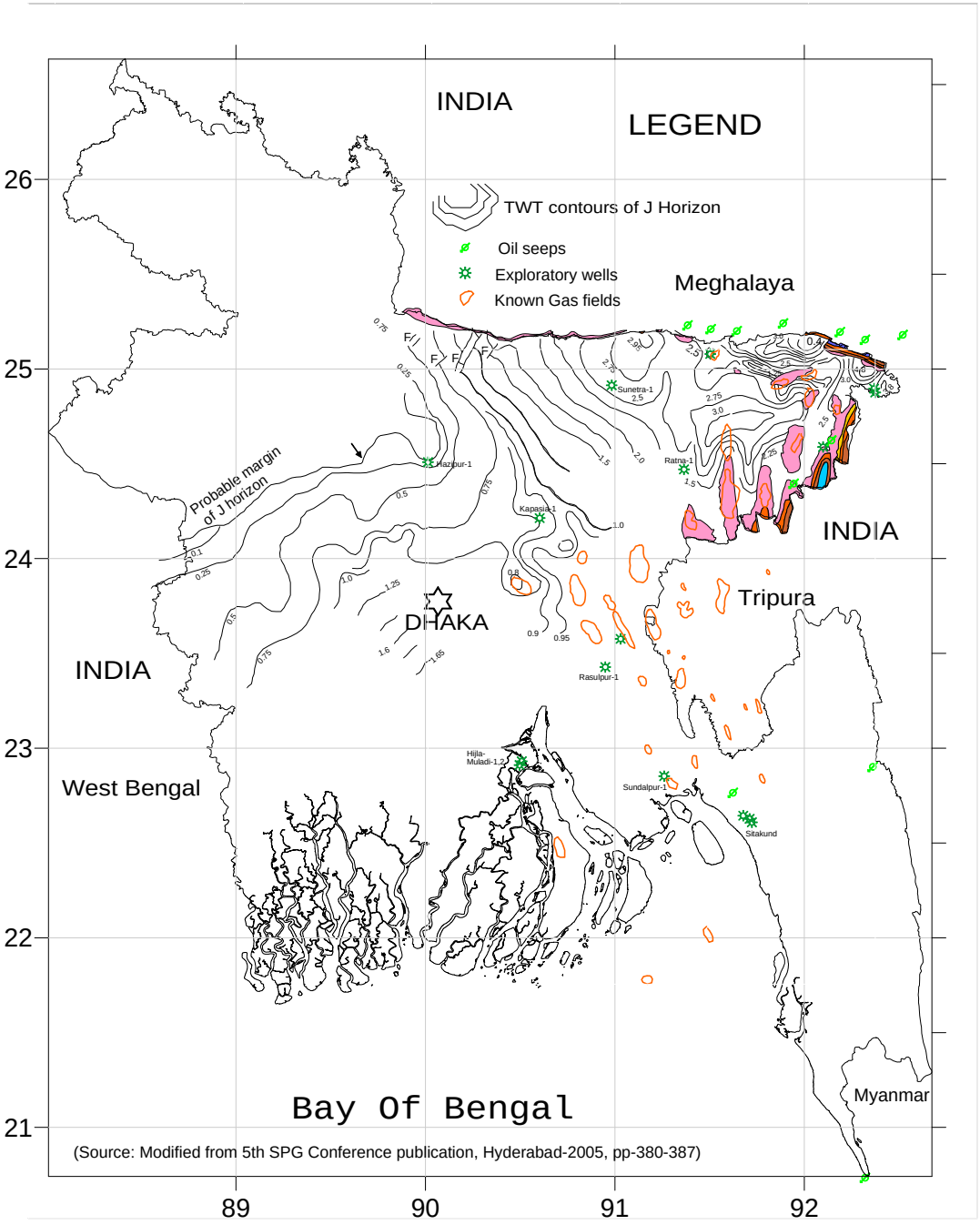


Figure A24.2-4 Map of Bangladesh showing location and distribution of J horizon (Dupi Tila) in the Surma basin area.

2.2 DHI in the Madarganj-Sariakandi Area

Seismic data interpretation, as shown in Figure A24.2-6 and Figure A24.2-7, revealed fault controlled low amplitude structures in the Madarganj and Sariakandi areas located over the crestal part of the regionally broad low amplitude Bogra-Lalmai structure. Presence of seismic

amplitude anomalies (bright spot) in the Oligocene-Miocene level of the section having direct detection features like polarity reversal and minor diffractions at the edges are indicative of the presence of hydrocarbon in those structures. Presence of time-sag beneath these amplitude anomalies and flat spots further indicate considerable thickness of the feature. Having Bangabandhu Bridge, power generation and fertilizer production facilities in close proximity, any hydrocarbon discovery in this area would certainly boost industrialization of Bogra, Sirajganj, Tangail and Jamalpur areas and in the northwestern part of Bangladesh at large. Few more seismic lines (as shown in Figure A24.2-5) over these two structures followed by two test drill holes, one at Madarganj and the other at Saraiakandi are necessary to confirm the presence of hydrocarbon and to study their commercial viability (Alam, 2004, 2007).

Bogra Shelf bears potential for hydrocarbon. It is therefore necessary to carry out high resolution seismic survey over the enetire Inner Bogra Shelf area to locate low amplitude structural and stratigraphic traps etc.

A project may be undertaken as follows with few more seismic lines over these two structures followed by two test drill holes, one at Madarganj and the other at Saraiakandi are necessary to confirm the presence of hydrocarbon and to study their commercial viability.

Project Title: 2D seismic survey and drilling programme in the Madarganj and Sariakandi areas around Jamuna river to confirm the presence of hydrocarbon.

Scope of the project:

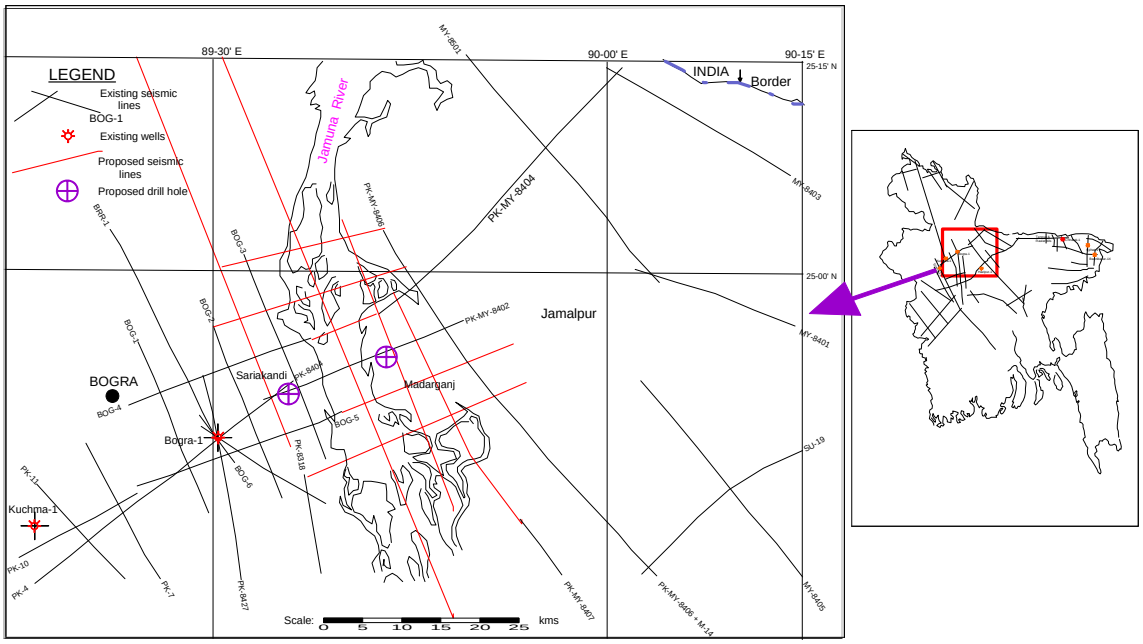
1) 400 LKM 2D seismic data acquisition in the Madarganj and Sariakandi areas around Jamuna river
2) Two exploratory drill holes for the confirmation of hydrocarbon.
3) Training and manpower development for large river crossing technology
4) Estimated cost: US$ 30-35 million (seismic + 2 exploratory drilling, excluding cost for the development wells and construction of gas processing and transmission facilities)
5) Duration of the project: 2-3 years
6) Drilling of development wells and construction of gas processing and transmission facilities, if hydrocarbon is discovered

Importance:

1) Result of the project can be obtained within a shord period of time and at a low cost and therefore given priority over other projects
2) Presence of DHI in the area
3) Located in less developed area
4) Nearby a urea fertilizer plant that uses natural gas

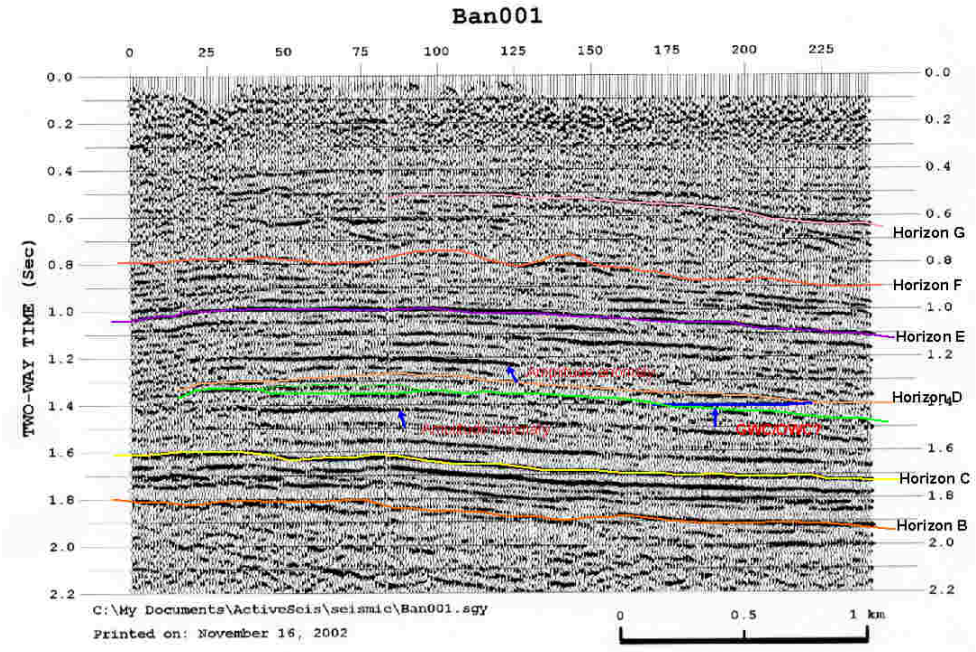
5) Near Jamuna Bridge, for easy transmission across the river

6) Will help to set up power plants and other industries in the northwestern Bangladesh for faster economic development



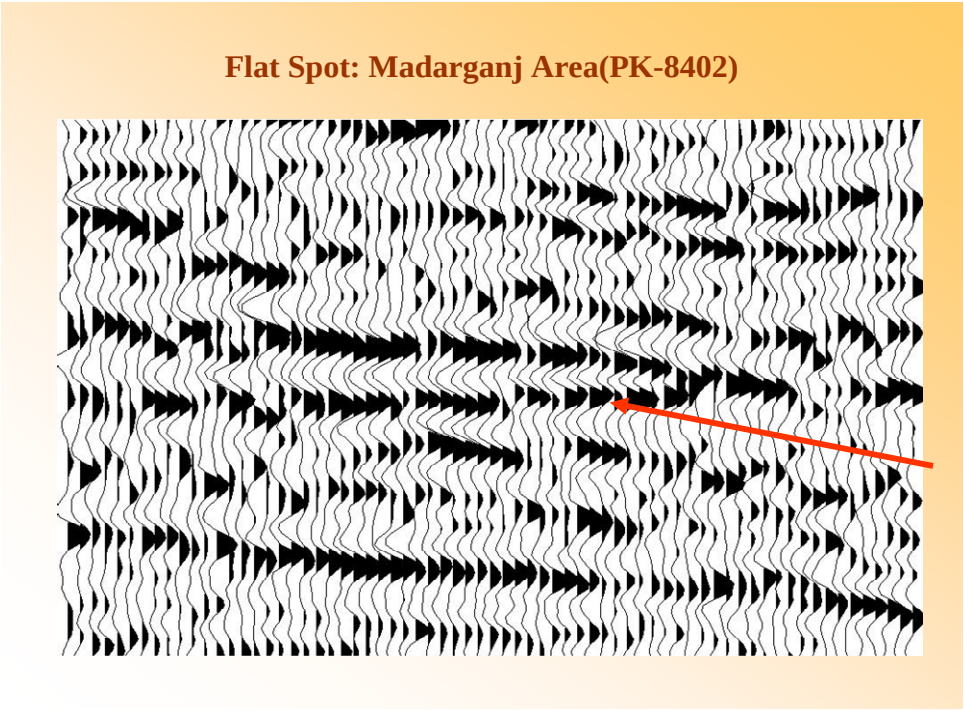
(Source: 5th SPG Conference Publication, Hyderabad-2004, India, pp-380-387)

Figure A24.2-5 Proposed lines and drill hole locations for detailed study to confirm the Madarganj and Sariakandi structures and their hydrocarbon potential.



Source: 5th SPG Conference publication, Hyderabad-2004, India, pp. 380-387

Figure A24.2-6 Bright spot and flat spot in the Madarganj area on PK-8402 line.



Source: Modified from 5th Conference publication, Hyderabad-2004, India, pp. 380-387

Figure A24.2-7 Flat spot on the seismic line PK-84

2.3 Possibility of Stratigraphic Traps along the Hinge Zone of the Bengal Basin

There are large scale clinoforms all along the Shelf edge and basinward of the Calcutta (Kolkata)-Mymensingh Hinge Zone of the Bengal basin (Figure A20.2-8).

1D basin modeling and petroleum stsyem analysis of the Bogra Shelf area revealed that the strata penetrated in the Bogra-1 well generally contain about 0.5 to 0.8 percent total organic carbon (TOC). Earlier Basin modeling and petroleum system analysis indicate that potential source rocks of the rift system include the Gondwana coal, and the shelf system are shales and carbonaceous shales of Paleocene-Miocene age. Kerogen type was mainly mixed with varying proportion of type I, II and III but mostly type II and III. Potential source rocks include the shales and carbonaceous shales of from Miocene to Paleocene and Permo-Carboniferous age. So Bogra Shelf has three petroleum systems (Alam et al., 2006). They are the Oligocene-Miocene-Pliocene, Paleocene-Eocene and the Gondwana petroleum systems.

2D basin modeling done by ONGC, in the West Bengal area of Bengal Shelf shows similar results.

Figure A24.2-8 is also showing the areas along the slope and Hinge Zone of the Bengal basin having large clinoforms. These clinoforms can be good reservoirs for hydrocarbon.

Similar to Bangladesh area, there are four tectonic zones: basin margin, stable shelf, hinge zone and deep basin in the West Bengal part of the basin. More than fifty years of exploration for hydrocarbons in the West Bengal part of the Bengal Basin has not yet led to a commercial success. Oil and gas indications in a number of drilled wells and seepages have confirmed hydrocarbon generation in the basin. A 2D basin modeling across the shelf ans basin area of West Bengal is presented here since similar sedimentation and environment of deposition prevailed all over the Shelf area (Figure A24.2-9).

In the A-A’ section (Figure A24.2-9), main oil window extends from the Gondawana sequence at western margin of Bengal shelf to bottom part of the Matla sequence (Miocene) at the eastern shelf edge and Hinge Zone (Figure A24.2-8). The Cretaceous-Tertiary source rocks at eastern shelf edge, slope and Hinge Zone are within the main oil to dry gas window at the present-day (vitrinite reflectance (Ro) = 0.7–4.0%). Further basinward, these source rocks may have already generated its full potential and could be over mature at present. Gondwana and Cretaceous prospects may contain some hydrocarbon generated during 136 to 30 Ma from terrestrial Gondwana source rocks. Whereas, Cretaceous and Tertiary prospects may hold hydrocarbon charge generated during 30 Ma to recent. Petroleum saturation in the

Cretaceous-Tertiary source rocks are only 10% at eastern shelf edge and gone up to about 30% at deeper sediments in the Hinge Zone (Figure A24.2-9). The study also concluded that:

1) Excellent source rocks are present in the Gondwana sequence.
1) Cretaceous and Tertiary sections possess fair to good source rock characteristics.
2) Bengal sediments from various formations are mostly type III kerogen except some Oligocene to Middle Miocene sediments. Deeper parts of the succession are less rich in organic carbon and seem to contain a greater proportion of terrigeneous type III kerogen.

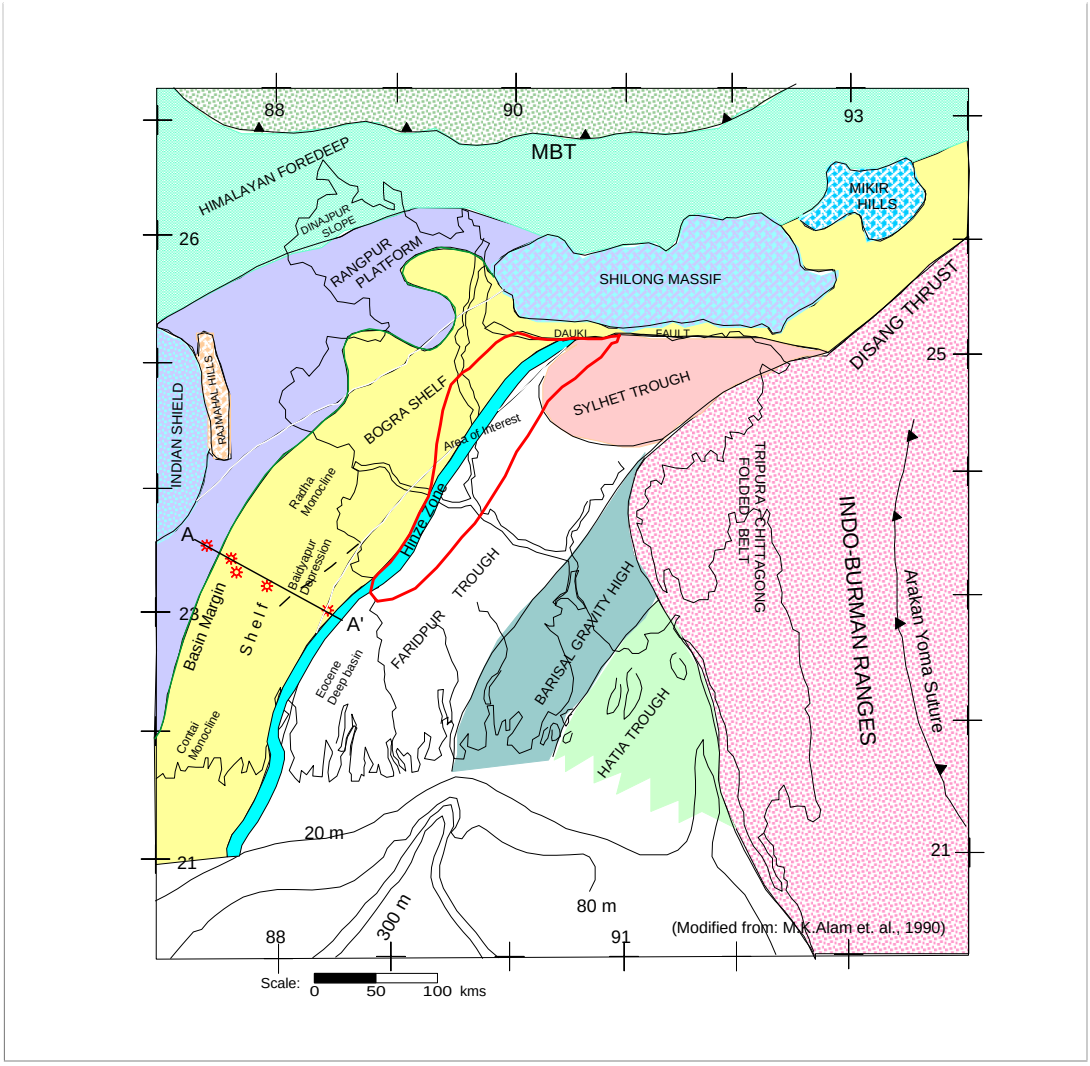
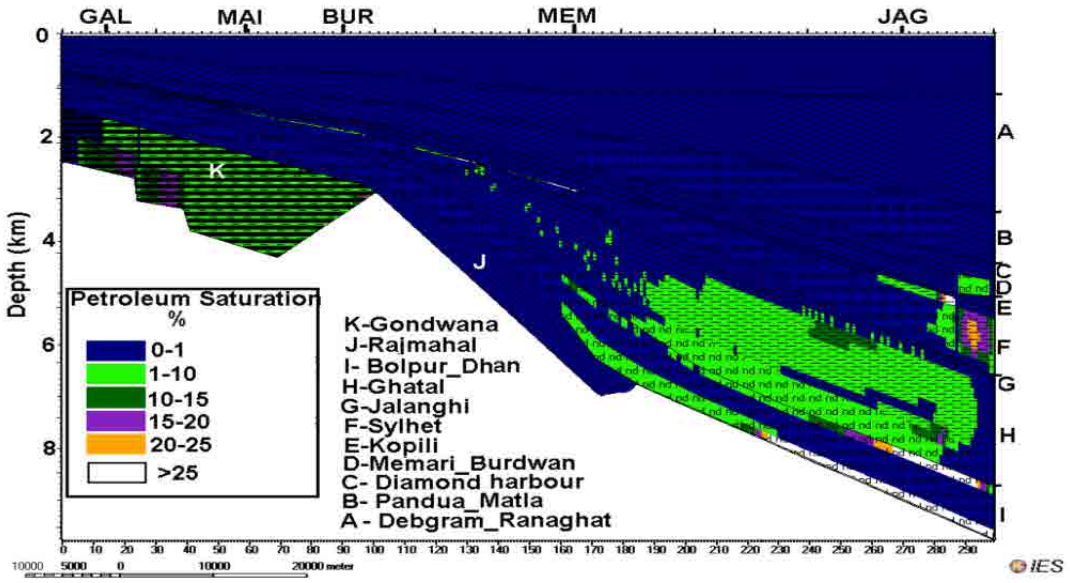


Figure A24.2-8 Generalized tectonic map of Bangladesh and adjoining areas showing location of cross section AA', used for 2D petroleum saturation modeling and the zone of interest for stratigraphic traps around the Hinge Zone.

However, better source characteristics of Paleogene sediments towards basinal side could not be ruled out.

It is therefore very important to carryout regional 2D seismic survey across and along the Hinge zone (as shown in Figure A24.2-8) to detect and assess the hydrocarbon potential in the possible stratigraphic traps of this region.



Source: S. Pahar et al., SPG, Hyderabad, 2010

Figure A24.2-9 Petroleum saturation along cross section AA' (Figure A20.2-8).

Figure A24.2-10 shows the identified anticlinal features as reflected over the DupiTila subcrop. Location of Kamta and Narsingdi gas fields correlates well with the Bogra-Lalmai broad regional anticline and it can be postulated that more gas fields will be discovered north-westward over this large anticline in future upto Sariakandi area in Bogra, if properly designed 2D regional seismic data is acquired followed by few deep drilling. Since it is an anticlinal structure, deeper formations like Barail should be present at a relatively shallower depth and be targeted in drill holes over this feature. It may be recalled that, Barail is already penetrated in Hazipur-1 well drilled in the northeast flank of this structure at a depth of 3,130 m and oil shows was reported at the contact of Bhuban (Miocene) and Barail (Oligocene) formations.

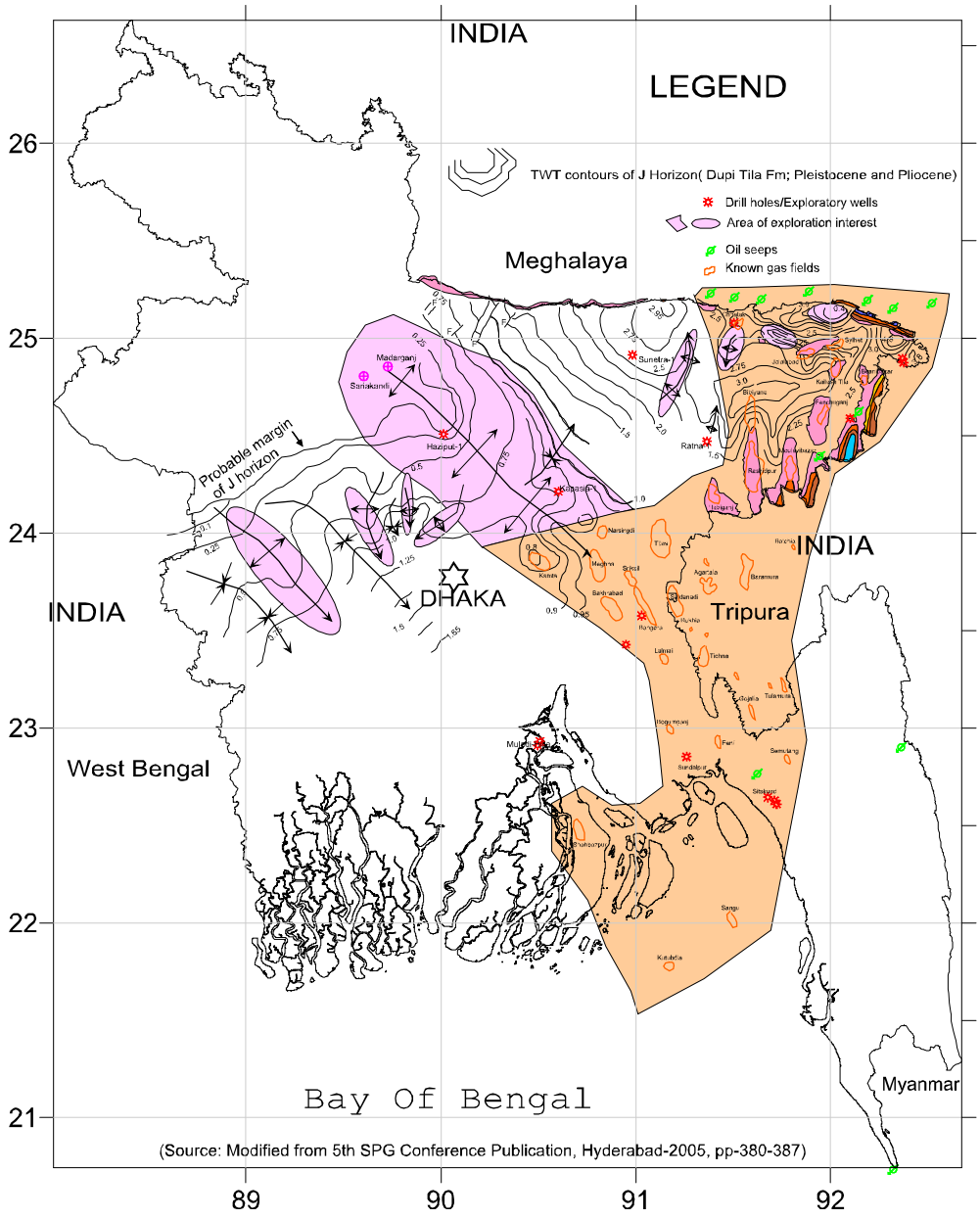


Figure A24.2-10 Map of Bangladesh showing trend of distribution of existing gas fields and distribution of concealed structures having prospect for hydrocarbon trapping in the Surma basin, shelf, slope and basin areas.

Some new concealed anticlinal structural trends in the Surma basin are also indicated in Figure A24.2-10 and are coloured in pink. These structural trends needs to studied very carefully with 2D regional seismic for better definition, since such concealed structures, being within the kitchen area, bears great potential for trapping hydrocarbon. For example, Bibiyana gas field is a similar concealed structure within the kitchen area.

2.4 Hydrocarbon Exploration in Shallow Structures

From long hydrocarbon exploration activities in Bangladesh, it is a common experience to hit shallow gas zones (at depths of around 800 to 1,000 m) in the Surma basin and Chittagong areas. Several blowouts, which indicated reserves of several bcf of gas have been burnt out. Any technology to tap such shallow gas may become a viable energy sources for local consumers, who often demand gasfrom thegas fields grid pipelines.

The first gas blowout in Bangladesh territory took place in Sylhet Gas field in 1955. The explorer, Pakistan Petroleum Ltd, had then failed to manage the post-blowout situation and left the well without even plug the well. Still today there is continuous gas seepage is going on.

The second gas blowout took place on June 14, 1997, at Magurcharra, in the northeast Moulavibazar district. The blowout occurred when drilling reached a depth around 800m. It is estimated that the blowout destroyed around 245 million cubic feet of gas, worth around 39 billion takas and caused considerable damage to forestry, the railways, highways and tea gardens.

At Tangra Tila two blowout occurred in the Chhatak Gas field. In January 2005, the first one took place when drilling reached at a depth of 550 m. According to the estimates of the explorers, the gas reserves below the first layer at 550 m are no less than 115 bcf and the gas loss has been initially forecast at Tk 1,150 crore ($185m). The second explosion of Tangratila took place in June 2005 at a depth of 435 m. It is estimated that, the blowout might have burnt 260 bcf gross reserve.

It can be assumed that there are sand layers charged with gas in the figure of multi billion cubic feet at depths ranging from 500 to 800 m in the Surma basin area. Any safe method/technology to identify and to tap them could be beneficial to this country facing energy shortages. It is observed in the Chhatak structure that, once what was a stratigraphic base lap now appears as onlap due to uplifting and folding. Therefore, gas, if any, charged these clinoforms, may now be reversely migrated to the base lap area along the formation boundaries and possibly being tapped there. Therefore, while drilling in the Chhatak structure, synclinal horizons should be very good exploration targets and gas must be expected from the most unlikely part of the structure. Being very close to the kitchen area and suitable structural setup, its hydrocarbon potential is still very high.

3. Hydrocarbon Exploration in Difficult Areas

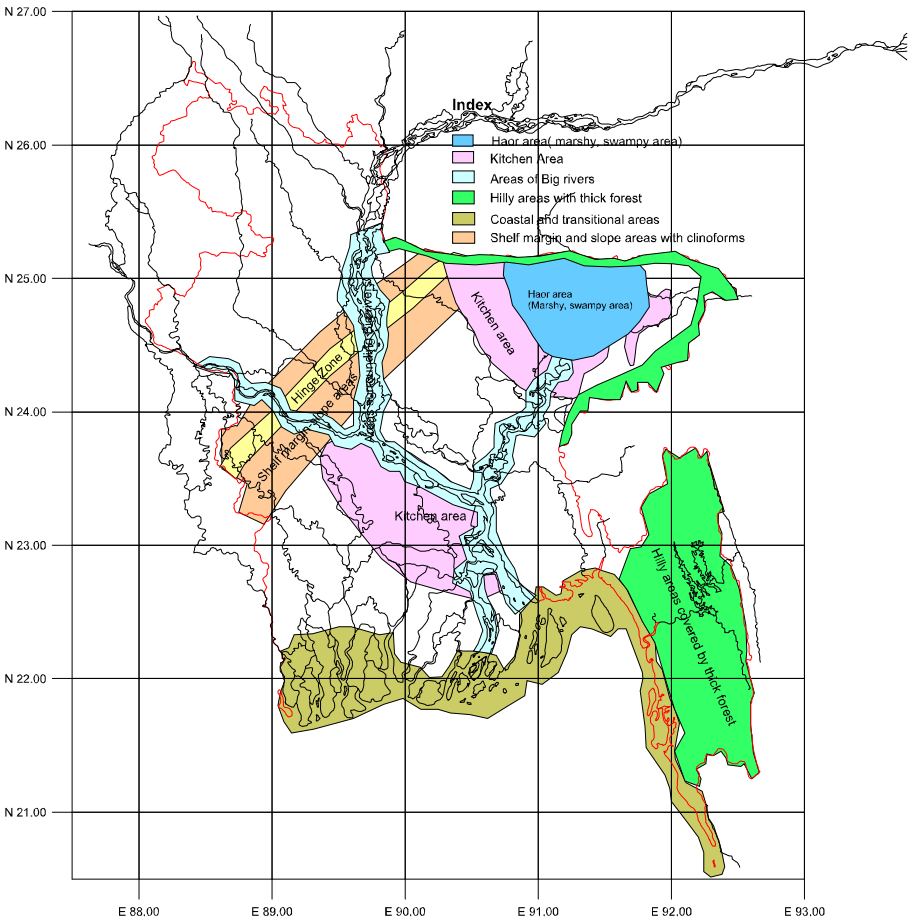
"Difficult areas" falls in and around big rivers, swampy-marshy lands, hilly forest areas and deep forest areas, coastal and transitional areas where seismic survey and drilling are difficult to conduct.

3.1 Areas Covered by Big Rivers and Swampy-Marshy Areas

"Difficult areas" are included in under-explored areas are mentioned above. Onshore hydrocarbon exploration activities are often constrained by difficult areas like big rivers such as Jamuna, Padma and Meghna. Local experts and resources for exploration in large river crossing, large lakes/water bodies and coastal or transitional areas, and for offshore marine survey/exploration have not been developed yet. gnForei cooperation, assistance in training and developing local manpower and acquiring necessary equipments will be very helpful for this.

Areas covered by big rivers, lakes and hilly areas are shown in Figure A24.3-1. A significantly large surface area above the kitchen areas falls under big and wide rivers, marshy-swampy areas (Haor areas), where seismic coverage is poor to none. It is therefore important to obtain data from the areas under these difficult areas falls under big rivers, swampy, hilly areas and coastal and transitional areas. Figure A24.3-1 shows the big rivers of Bangladesh and the distribution of other difficult areas, for example, big water bodies like lakes, marshes, swamps etc., that makes geological and geophysical surveys like seismic survey very difficult. There are also some hilly and forest areas in Sylhet and Chittagong areas that makes access difficult for the surveyors. There are areas under big rivers and anticlines with thick forests that are very prospective for hydrocarbon and needs to be surveyed. Assistance of experienced foreign experts may be sought to acquire quality data from these areas.

A joint venture project may be undertaken with experienced foreign organizations/companies to explore, develop and the transfer of knowledge and to develop local expertise to carry out surveys in difficult areas.



Source: Compiled by JICA Survey Team from various published materials

Figure A24.3-1 Map showing difficult areas for seismic survey due to big rivers, hilly areas with forest, coastal and transitional areas.

3.2 Coastal, Transitional and Offshore Areas

Bangladesh has significant reserves of gas and condensate from its onshore fields, but only a few modest offshore gas fields, such as Sangu and Kutibidia. Of which Sangu is depleted and already shutdown. The pace of new discoveries both on and offshore has also been disappointing with only 1 major gas field (Tullow's onshore 2004 Bangora gas field).

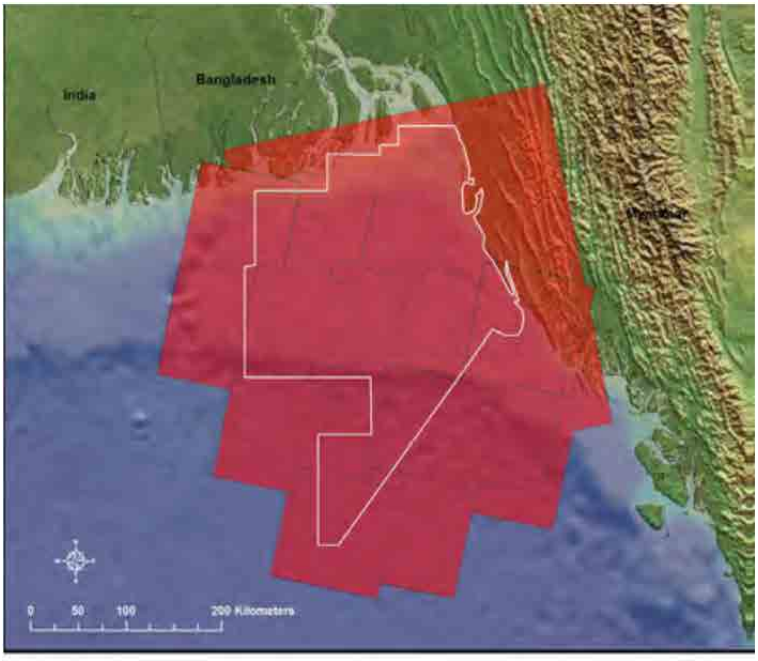
Comprehensive mapping and categorisation of offshore oil seeps is essential for efficient offshore oil and gas exploration. Enhanced and interpreted SAR satellite imagery is capable of identifying key regions of seepage, thus focusing exploration efforts and reducing costs.

A Bangladesh Seepage Study carried out by CGG Veritus in 2013. The 2013 Bangladesh licensing round is offering approximately 60,000 km^2 of offshore acreage, comprised of shallow and deepwater blocks. These blocks have already been covered by NPA's satellite seepage detection project (Figure A24.3-2). Seepage detection by SAR (Synthetic Aperture

Radar) is a proven technique for mapping surface oil seeps which could provide the first indication of a petroleum system in these blocks (Source: CGG Veritus study, 2013).

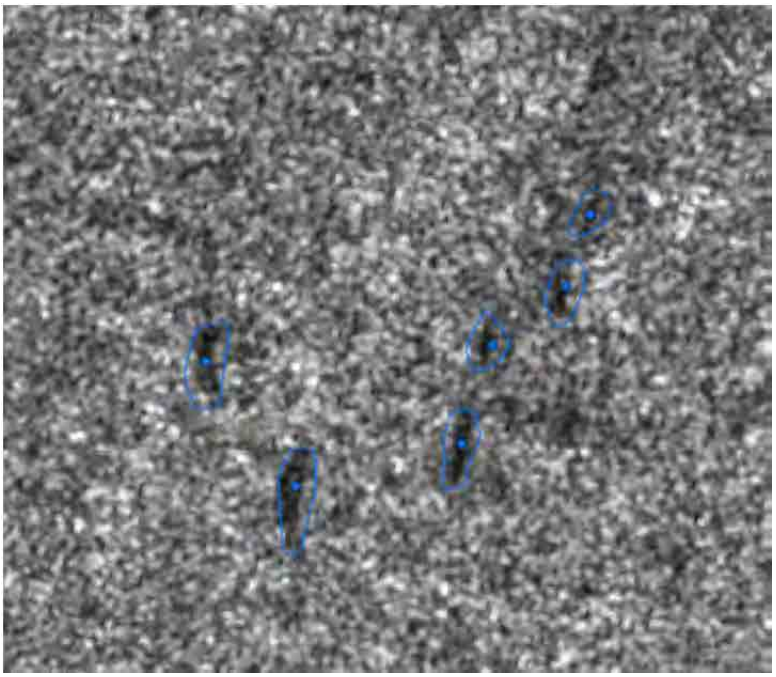
CGG Veritus and NPA Satellite Mapping (NPA) detect, interpret, classify and monitor natural seepage and pollution slicks occurring in offshore environments. CGG Veritus had done Offshore Seeps Study offshore Bangladesh in 2013. NPA seep study could provide the first positive indication that the offshore Bay of Bengal in Bangladesh has oil potential. Evidence of active seepage would allow a major reduction in source risk in these unexplored basins (Figure A24.3-3 and Figure A24.3-4).

Although offshore explorations so far did not doscover large hydrocarbon reserves, it is evident from the very recent investigation with cutting edge technology that there are presence of several oil seepages in the Bay of Bengal offshore Bangladesh, indicating presence of hydrocarbon in the area. Figure A24.3-4 shown above indicates the oil seepage in the Bay of Bengal taken by satellite surveys done in recent time.



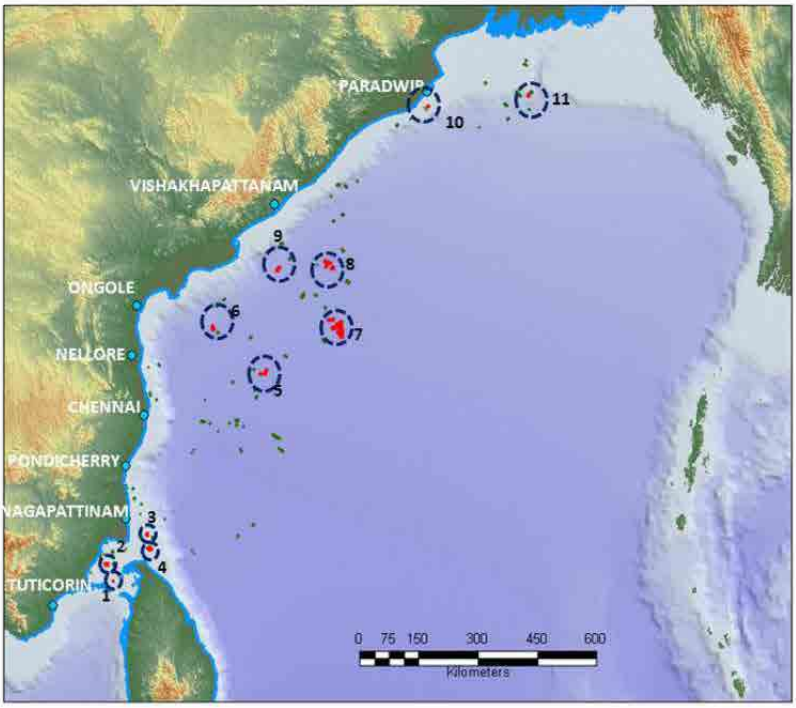
Source: © NPA 2013, CGG; cgg.com

Figure A24.3-2 Archive coverage over the Bangladesh 2013 offshore blocks.



Source: © NPA 2013, CGG; cgg.com

Figure A24.3-3 Possible seepage slicks identified offshore Bangladesh.



Source: H.D Dave et al., SPG 9th, 2012, Hyderabad, P-037

Figure A24.3-4 Natural hydrocarbon seepages in the eastern offshore of India with the areas of seepages marked in green whereas the areas of seepage repetitions are marked in red

4. Hydrocarbon Exploration in Deep Structures

There are possibilities for large-scale hydrocarbon reserves in deep structures in the Bengal Basin. Drilling deep wells are often very difficult due to existence of abnormally high pressure zones, and generally not attempted by local experts. Assistance and cooperation of foreign experts experienced in deep drilling may be very useful to go for deep structure exploration programme for oil and gas.

According to Petrobangla, an appraisal cum development well for oil in the KailashTila Gas Field in the Sylhet district is expected to be drilled by June 2014 with a target depth of 3,500+50 m.

Deep structures at depths deeper than 4,000 m are to be targeted in future exploration to reach Oligocene Barail formation. Such deep wells must cross the high pressure zone occurs around 3,500-4,000 m. But further 2D seismic survey and G&G study will be needed before selecting suitable well locations.

So far 25 gas/gas-condensate fields have been discovered in Bangladesh, thereby establishing it as one of potential hydrocarbon province (Figure A24.4-1). There are also gas shows, oil seepages are reported from a number of places. There are seven gas-condensate fields discovered in Bangladesh. About 2,312 mmcfd gas and 7,088 bbl of condensate is being produced every day. Reservoirs are mainly in fluvial and deltaic sandstone of Miocene and Pliocene age (Upper Bhuban, Bokabil and Tipam Formations/Group), occurring commonly in multiple stacked layers. The producing depth ranges in between 1,100 m to 3,000 m with individual reservoir thickness up to 250 m and porosity of 20-22% (Brown et al., 2001).

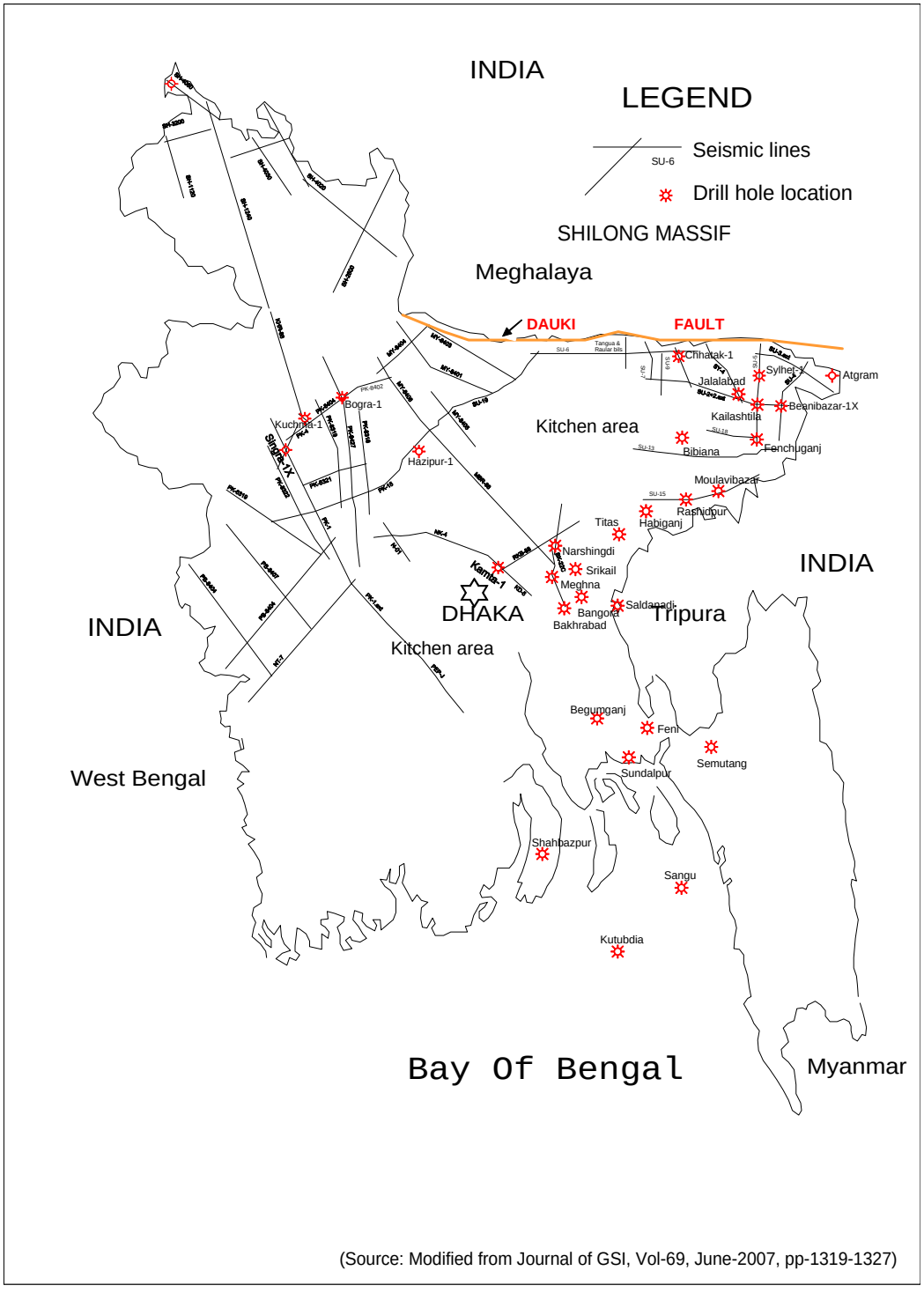
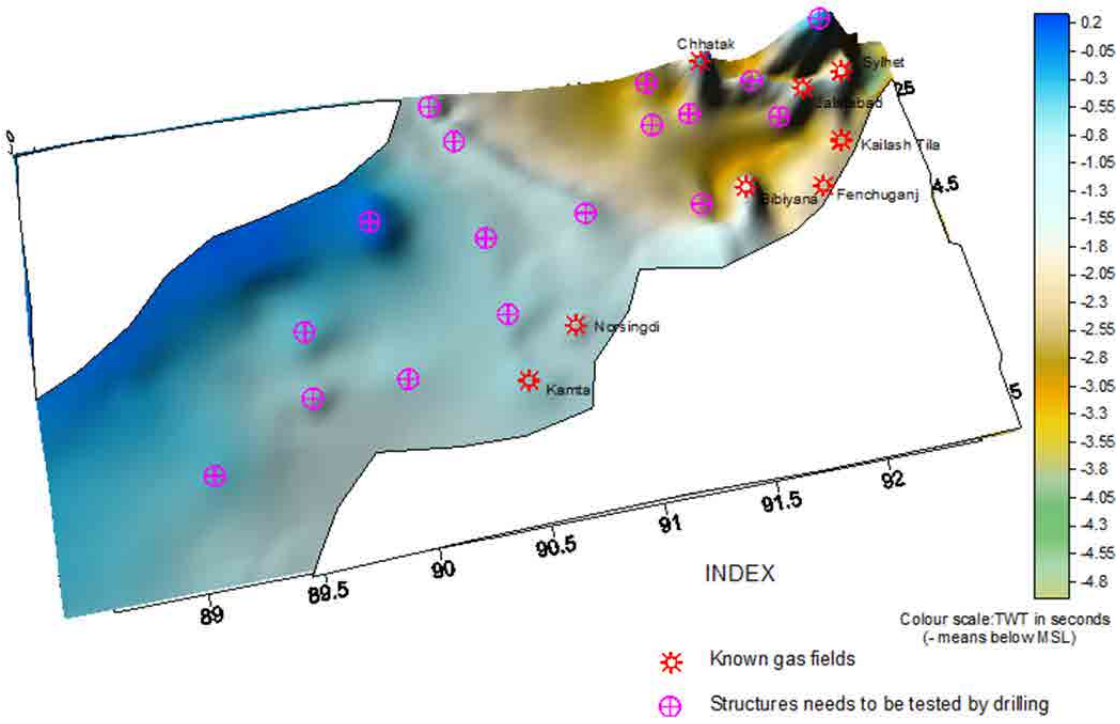


Figure A24.4-1 Map of Bangladesh showing location of gas fields, seismic lines, drill holes and the area of detailed study

Figure A24.4-2 reveals that formations occurring at relatively shallow depths over the Bogra Shelf, slope and basin areas in the west and south western part of Bangladesh subsided much deeper in the Surma basin. Therefore deep wells are needed to reach the potential horizons which occur at deeper depths, where these formations may be heavily charged with hydrocarbon.



Basic data source: 5th SPG Conference publication, Hyderabad-2004, pp. 380-387

Figure A24.4-2 J horizon (Dupi Tila) subcrop topography in the Bogra Shelf, slope and Surma basin areas reflecting structural patterns of deeper horizons.

Table A24.4-1 Gas fields, exploratory wells, depths, reserves and daily production, etc.

Sl. No.	Gas field well name, Owner	TD of Deepest well	GIIP in BCF	Daily Gas production	Daily condensate	
1	Titas Gas field, BGFCL	3758m, Titas-1	8148.9	476mmcfd	355bbl	Condensate
2	Habiganj Gas field, BGFCL	3508m, Habiganj-1	3684	225mmcfd	11.6bbl	
3	Bakhrabad Gas field BGFCL	2838m, Bakhrabad-1	1701	43mmcfd	11bbl	
4	Narshingdi Gas field BGFCL	3450m, Narsingdi-1(BK-10)	369	28mmcfd	59.2bbl	Condensate
5	Meghna Gas field, BGFCL	3069m, Meghna-1, (BK-9)	122.1	10.7mmcfd	19bbl	
6	Rashidpur Gas field, SGFL	3861m, Rashidpur-1	3650	46.8mmcfd	61bbl	Condensate
7	Sylhet gas field (Haripur,not in production, SGFL)	2819m, Sylhet-2	370	8.9mmcfd	66.5bbl	Condensate
8	Kailash Tila gas field, SGFL	4139m, Kailash Tila-1	3610	28.5mmcfd +59.3mmcfd	256.4bbl+ 480bbl	Condensate
9	Beanibazar gas field, SGFL	4109m, Beanibazar-1	230	10.5mmcfd	161.9bbl	Condensate
10	Fenchuganj Gas field, SGFL	4977m, Fenchuganj-2	553	39.3mmcfd	26bbl	
11	Begumganj Gas field, SGFL	3655m, Begumganj-1	39			
12	Chattak-1 (suspended), SGFL	2135m, Chhatak-1	1039			
13	Salda Nadi gas field, BAPEX	2511m, Salda Nadi-1	379.9	14.8mmcfd	4.3bbl	
14	Sundalpur gas field, BAPEX	3327m, Sundalpur-1	62.2	10.4mmcfd	0.2bbl	
15	Srikail gas field, BAPEX	3583m, Srikail-1		45.1mmcfd	45bbl	Condensate
16	Semutang gas field, BAPEX	4088m, Semutang-1	653.8	6.8mmcfd	2.5bbl	
17	Kamta gas field (suspended), BAPEX	3614m, Kamta-1	71.8	0	0	
18	Shahbazpur gas field, BAPEX	3342m, Shahbazpur-1	677	45.1mmcfd	45bbl	Condensate
19	Jalalabad gas field, Chevron	2626m, Jalalabad-1	1491	249.1mmcfd	1912bbl	Condensate
20	Bibiyana gas field, Chevron	4014m, Bibiyana-1	7437	812mmcfd	3270bbl	Condensate
21	Moulavibzar gas field, Chevron	3510m, Moulavibazar-2	1053	85.4mmcfd	11.1bbl	
22	Bangora gas field, Tullow	3635m, Bangora-1	1198	111.3mmcfd	335bbl	Condensate
23	Feni gas field (suspended), Niko	3200m, Feni-1	185.2	0	0	
24	Sangu gas field, Santos	3500m, Sangu-1	899.6	0	0	
25	Kutubdia gas field (not in production yet)	3508m, Kutubdia-1	65	0	0	
	TOTAL			2312mmcfd	7088bbl	

Source: Petrobangla website

The most likely source rock of the gas-condensate is the early Miocene to late Oligocene shale (Jenam Formation) in the basin centre and in the synclinal troughs between the fold trends. The source of oil has been presumed as the Late Oligocene shales. In both cases, the source rocks are terrestrial in origin (Shamsuddin and Abdullah, 1997). The generated hydrocarbons must have migrated relatively long distance into the traps, as the shales interbedded with or adjacent to the reservoirs are both lean and immature for hydrocarbon generation (Murphy et al., 1988). Hydrocarbon traps are mainly folded anticlinal plays.

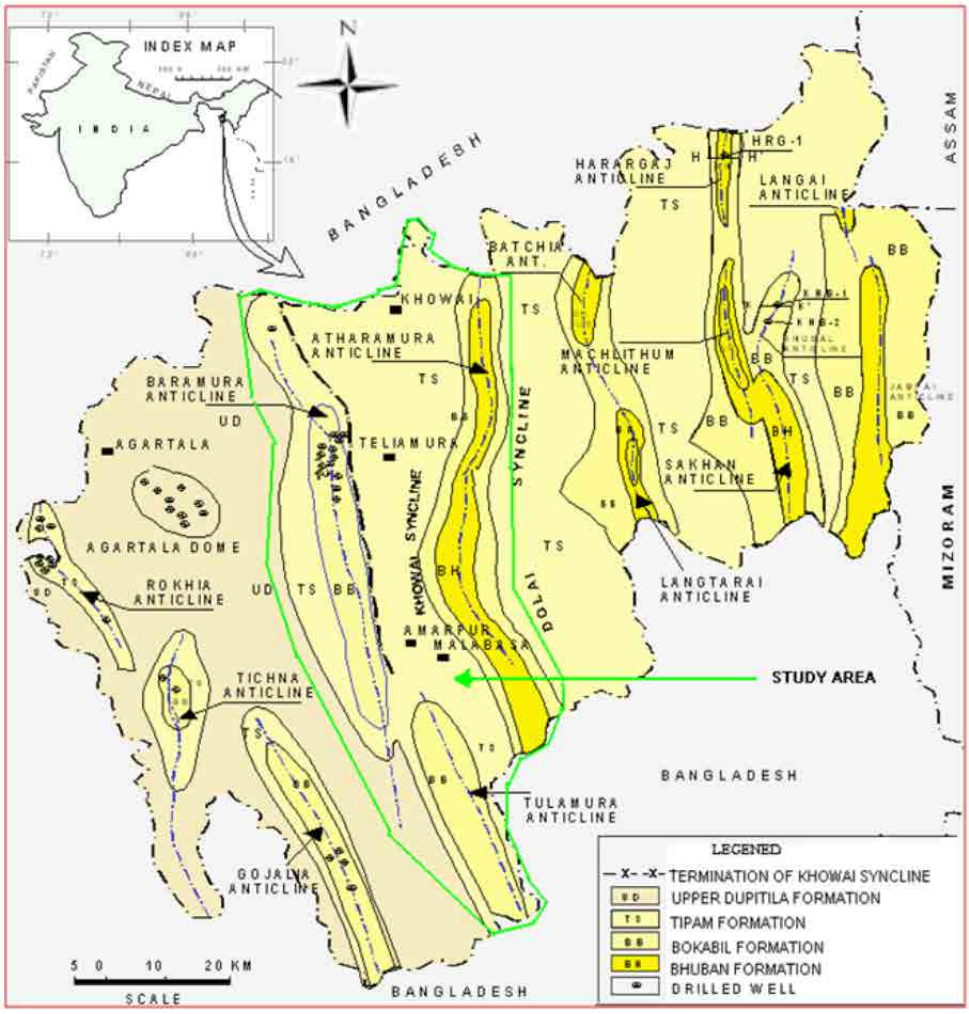
It is evident that very few wells in the known gas fields have penetrated depths below 4,000 m. 4 wells, viz., KailashTila, Beanibazar, Fenchuganj and Bibiyana in the Surma Basin

crossed 4,000 m. All four fields are rich in Gas Condensate. It may be noticed that gas fields nearest and surrounding the Surma basin kitchen area (Figure A24.4-1 and Figure A24.4-2) in the south of Sunamganj area, viz., Bibiyana, Jalalabad, KailashTila, Rashidpur, Habiganj, Titas fields, have reserves of the order of multiple tcf. Also gas fileds surrounding the kitchen area of the Faridpur-Barisal area, viz., Titas, Bakhrabad and Bangora also have gas reserve in tcf figure. So, deeper horizons in those areas and also new structural trends shown in Figure A24.2-10 and Figure A24.4-1 also be investigated by deep wells, because these deep concealed structures bear potential similar to Bibiyana gas field.

Almost all the gas reservoirs are in the Miocene Bokabil and Bhuban formations. In addition, Oligocene Barail formatio, which is the prime target for oil in neighbouring Assam area, occurs at greater depths in most part of Bangladesh. Moreover, the Barail formation was encountered in the Slope area in Hazipur-1 well with oil shows at the Lower Bhuban and Barail contact at a depth of 3,130 m.

It is of great importance to note from the hydrocarbon exploration point of view, that all the elongated fold structures of the Surma basin and Chittagong fold belt area, are directly belong/related geologically and tectonically to the Tripura fold belt of the Assam-Arakan folded belt structures of India. Any conceptual discovery on either side may bring success to the other side as well. Therefore a careful analysis of the Tripura gas field success story will be very informative and useful for successful exploration in Bangladesh. Following is an analysis of the Tripura gas fields neighbouring Bangladesh gas fields.

Figure A24.4-3 shows the anticlinal and synclinal trends in Tripura. It is apparent from Figure A24.4-3 that, the cores of the anticlines in Tripura usually expose the Bokabil or Bhuban formations flanked by Bokabil and Tipam/Post Tipam formations exposures. The pre-Surma sediments have not been penetrated in the subsurface and are present beyond this depth. Most of the gas bearing concealed structures of Bangladesh suround the Tripura fold belt area in north, south and west directions. A careful re-look at the contemporary exploration / exploitation strategy in the Surma basin and Chittagong fold belt is therefore necessary.



Source: Jena et al., ONGC, 2012 Hyderabad, SPG

Figure A24.4-3 Anticlines and synclines in and round Atharamura, Baramur and Tulamura anticlines (Ganguly, 1993).

Tripura Gas Fields

Few unconventional approaches had led to the discovery of gas in Mio-Pliocene sands in Rokhia, Agartala Dome, Gojalia, Tichna, Baramura, Kunjaban, Sundalbari and of late Tulamura and Khubal structures of the fold belt part of Tripura. These success may also guide us to think a bit of unconventional way and adopt different strategies to understand the hydrocarbon plays in the structures of the Chittagong and Surma basin, like it was done in the Tripura fold belt.

The following are some of the unconventional approaches for success in Tripura were:

1) Synclinal exploration,
2) Exploration in plunge parts of the structures,

3) Determination of axial region of the structures,
4) Identifying the stress directions and pressure regimes,
5) Challenges in petrophysical evaluation and
6) Overcoming drilling problems.

To cite a few examples: The broad flat synclines between anticlines have become target for stratigraphic traps and concealed structures. Success in tapping gas from sands belonging to a relict feature of Upper Bhuban formation in synclinal area of Sundalbari structure, discovery of gas in a lower Bhuban sand in Khubal structure in synclinal area indicates the possibility to find out similar ones in other synclinal areas between the structures in Bangladesh also.

The gas discovery in the Kunjaban structure which is the northern plunge part of the Agartala dome has proved the potential of the plunge parts of different structures particularly the northern plunge parts. For example, crest and plunge along the axis of anticlines of the Tripura Cachar Fold Belt have already been proved as highly prospective by the various gas discoveries. The Tulamura anticline is enechelon to the gas bearing Baramura anticline. Towards the immediate east of Tulamura is the Gojalia anticline, which is having a similar structural set up like Tulamura. This Gojalia anticline is enechelon to Rokhia and Tichna anticline respectively in the west and northwest. The plunge of this Gojalia anticline has proved hydrocarbon entrapment. Similarly, at the plunge of the Atharamura anticline, Moulavi Bazar gas field is located (in Bangladesh). Bibiyana gas field in the northern plunge of Rashidpur structure is a good example for us.

A number of crosscutting faults have divided the Atharamura anticline into a number of compartments. Identification of fault cuts in the Baramura structure provided a better understanding of the structure compartmentalization. It is also observed that particularly in the Baramura structure, finding out the axial region is a challenge and slightly away from the axial region, the wells fall to water bearing sands. It is also an observation that the flank part of the anticlines are less affected.

The possible entrapments like small culminations, relict features, updip pinchouts in synclinal areas, fault closures in plunge parts, unconformity related entrapments should also be considered.

Poor seismic response below the Middle Bhuban are the prime constraints for a fruitful resource assessment for the deeper prospects. The role of overpressure sequence below the middle part of the Middle Bhuban has a great significance in hydrocarbon migration. This overpressure seal might have formed a partial barrier to the upward movement of hydrocarbon and thus, favored accumulation within the reservoir facies of overpressure sequence and underlying Oligocene reservoirs of the Barail Formation (Momin and Choudhury, 1999).

There are also some risks involved such as: The super charged aquifers present in the structures pose serious problem while drilling with water blow outs like what happened in the Gojalia structure. The high pressure sands in lower part of Upper Bhuban and in Middle Bhuban formation pose problem so far as drilling is concerned. The recent water blow out situation at a depth of 2004 m dictates a careful planning of the drilling fluid balance with pore pressure has to be made. With a careful planning another well has been successfully drilled and is a producer in the same anticline.

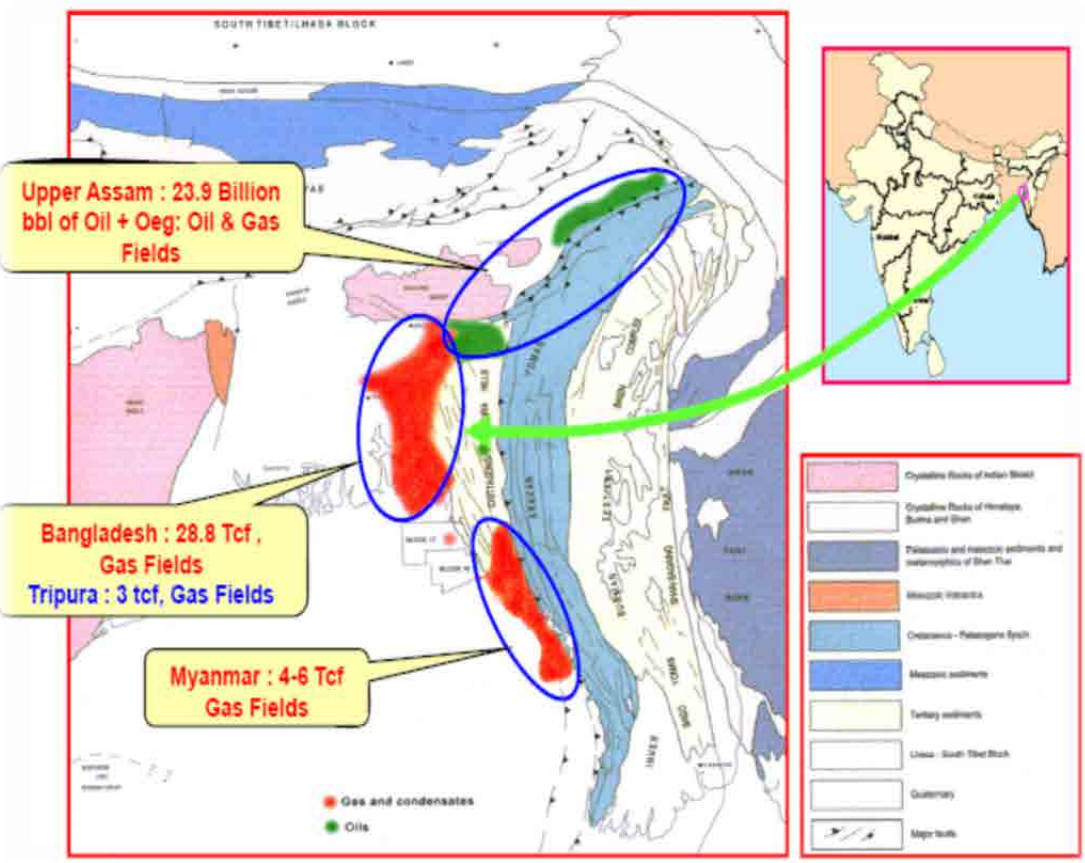
Another technological challenge is that it was not possible to complete the deep wells meant for the lower Bhuban formation because of super charged aquifers/reservoirs. The examples are in the Rokhia and Agartala dome wells. Because of heavy mud weight, the cementation was poor and testing of potential reservoirs remain inconclusive. It is also another observation that wells drilled in synclinal parts could be completed with lesser mud weight than the counterparts in the anticlinal highs.

Hydrocarbon potential of deeper reservoirs within super pressure regime is not adequately established due to drilling complicacy related to overpressure. However, there are hydrocarbon indications reported in the super pressure sequence during drilling and testing with encouraging log response (Babu and Sircar, 2011).

Interpretation of hydrocarbon bearing sands where resistivity contrast is poor with high resistivity shales is also a problem in exploration.

Some answers to these problems with a contemporary approach but a change in thinking patterns to come up with solutions for way ahead in exploration. Therefore,

- Determination of axial region of the structures is very important for the structures like the Baramura structure to avoid wells falling to water bearing parts of the reservoirs.
- It is the time to overcome the technological challenges to drill successfully the wells meant for the Lower Bhuban sands in the western part of the Surma basin to tap its hydrocarbon potential.



Source: Jwngsar Brahma et al. 2013, JGG, Vol. 5, No.3, pp-116

Figure A24.4-4 Oil and gas provinces in Assam-Arakan basin.

Figure A24.4-4 shows the regional trend of oil and gas occurrence of the Assam-Arakan basin in general. It is important to note that unlike the Assam-Arakan basin, the northeastern corner of the Surma basin is the common ground for both oil and gas prone regions of the Assam-Arakan basin. Therefore, finding oil in the Surma basin is not a speculation any more. The Haripur oil field in Sylhet is the proof. The possibility of finding commercial volume of oil at KailashTila is not unlikely.

The Assam basin is located in the alluvial covered foreland shelf zone (known as Upper Assam Valley) and contains several oil and gas fields. A few oil and gas fields discovered here are located in the Naga thrust sheets of the Assam-Arakan fold belt. Both these units constitute a part of the Assam-Arakan Basin. Parts of the Assam-Arakan basin fall in the northeastern part of India, the eastern part of Bangladesh, and the western part of Myanmar. The northeastern part of India has been drawing attention of geologists since 1825 due to a large number of oil and gas seepage in the area. The well-known oil fields of this region are Digboi (oldest field, 1866), Naharkatiya, Moran, Rudrasagar, Lakwa, Lakhmani, Galeki, Borholla-Changpan, Hugrijan, etc. The major oil accumulations in the Upper Assam are

known in Barail and Tipam Groups of Oligocene and Miocene age respectively. The source rock is carbonaceous shale. The principal reservoirs in this oil basin are sandstone in the Barail and Tipam groups. The Girujan clay is the main cap rock for accumulation. In the Tirap district of Arunachal Pradesh, there is Nigru oil field. In the nearby Nagaland, oil fields are at Borholla, close to Nagaland-Assam border.

In view of the above analysis, the following structures in Bangladesh also need to be re-studied carefully for their possible hydrocarbon potential. Figure A24.4-4 indicates the strong possiblity of deep oil occurrence in the structures of eastern and northern Surma basin.

The promising structures are: **Hazipur structure** located at Madhupur in the greater Mymensingh

Patharia structure corresponding to the easternmost anticline in the Sylhet trough

Jaintiapur structure lying between two contrasting structural setups, the uplifting Shillong massif in the north and the subsiding Surma Basin in the south

Hararganj structure situated in the eastern part of the Maulavi Bazar district

Since some earlier attempts did not bring success, unconventional approaches, like that were applied in Tripura may be applied.

In the Chittagong area also the following structures needs to be studied with greater care and using unconventional approaches. The structures are:

Dakhin Nhila structure lying under Teknaf upazila of the Cox’s Bazaar district

Inani structure lying in Cox’s Bazar sadar upazila

Maheshkhali structure situated in the Cox's Bazar district

Sitakunda structure corresponding to one of the westernmost structures of Chittagong and Chittagong Hill Tracts

Sitapahar structure lying east of the Patiya

Jinjira structure including the geological structure of Jinjira, or St. Martin Island

Based on the above discussions, a comprehensive large project may be undertaken in collaboration with experienced foreign seismic/drilling companies to drill upto deeper horizons in those areas including 2D/3D seismic survey, G&G study followed by 20-30 deep wells (4,000 m+ deep) at suitable locations in search of deeper oil and gas below the existing gas fields and in potential virgin areas.

Similar deep exploration projects may be undertaken for the Sylhet, Kailas Tila, Beanibazar, Fenchuganj, Rashidpur, Habiganj, Titas gas fields and in new areas where prospect for deeper hydrocarbons are bright.

5. Unconventional Hydrocarbon Resources

From the discussions with several organizations relating to management, production and research in energy sector of Bangladesh, like Petrobangla, Hydrocarbon Unit, BGFCL, Geological Survey of Bangladesh, Geology Department, Dhaka University, it has been realized that no specific research on the prospect of CBM and shale gas has been done in Bangladesh. Hydrocarbon Unit has engaged a contractor to assess the prospect of shale gas in Bangladesh on the basis of available data. This assessment is funded by ADB. It is reported recently in the media that some result has already reached at HCU.

5.1 Shale Gas

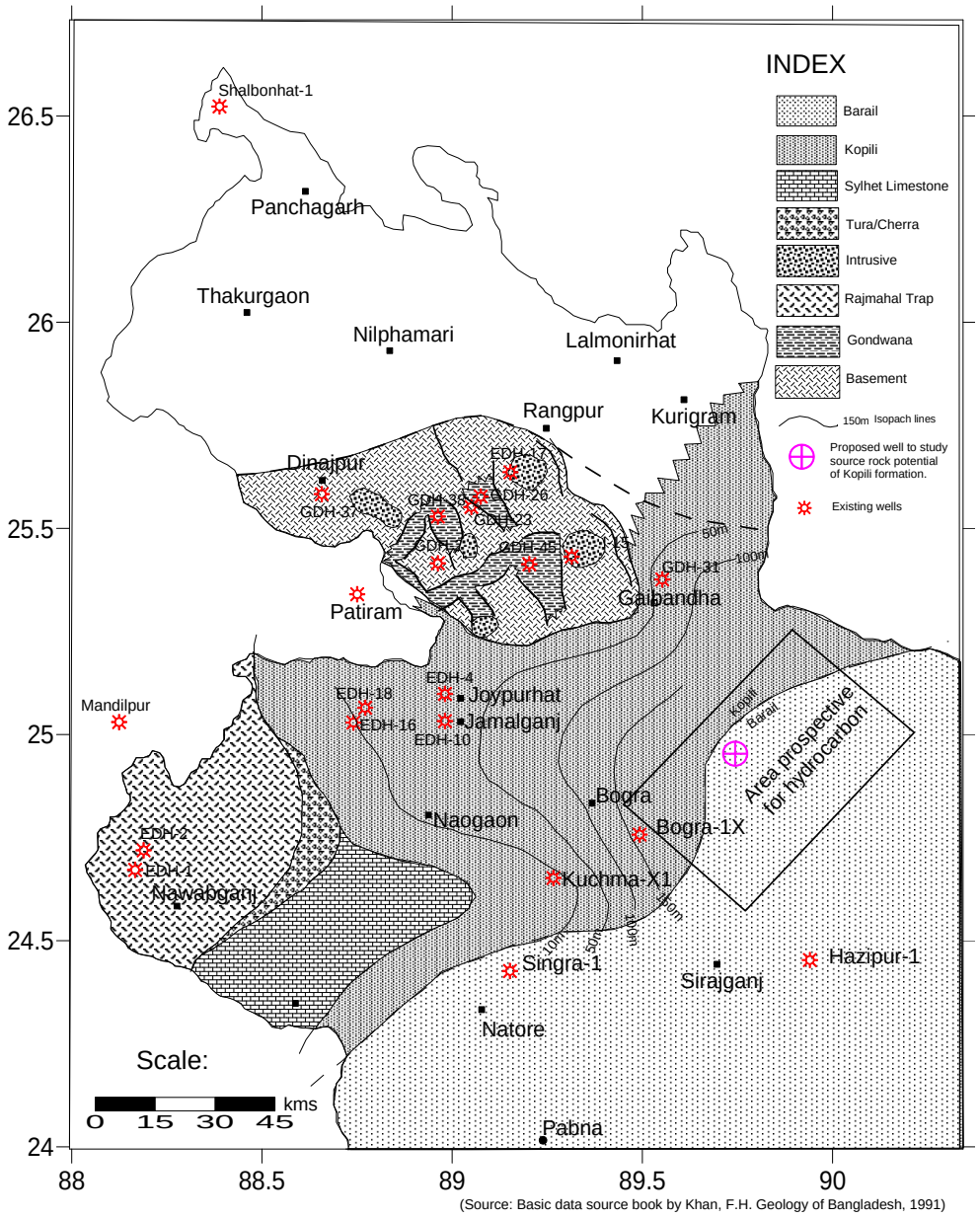
From the exploration history, geological information obtained so far, basin and petroleum system studies carried out in the Bengal basin, it is understandable that the source rocks, responsible for the generation of natural gas being produced in Bangladesh, has not been established yet. It is imperative to know the source rock of hydrocarbon generation for the exploration of shale gas. Under the situation, it is essential to analyse the available information of the source rocks of the surrounding areas, viz., Assam and Tripura in India and Arakan of Myanmar.

Source Rocks of Assam in India

The potential source rocks in the Assam–Arakan basin are mainly the late Eocene to early Oligocene Barail coal–shale and middle to late Eocene Kopili shale sequence. The Kopili rocks have similar source specific parameters to those of the Sylhet oils, whereas genetically the Barail rocks are correlatable with the Bokabil oils. The oil from the Sylhet formation is different as compared to those in the Bokabil formation (early to middle Miocene) across the Khoraghat and Nambar field. There are two petroleum systems in the Khoraghat–Nambar area namely, the Barail–Bokabil and the Kopili–Sylhet (Goswami et al., 2005). The overlying Surma group sediments have relatively low organic contents with TOC values varying from 0.2% to 0.6% as compared to the Barail group (Khan et al., 1988). In general the Surma group has TOC below the threshold value (0.5%) for a source bed (Tissot and Welte, 1978; Waples, 1985) in Bangladesh side. The Surma group is not mature having average vitrinite reflectance

(Ro) values ranges from 0.55% to 0.63% (Shamsuddin and Khan, 1991). The Eocene Kopili shales are potential sources of hydrocarbons in the Surma group (Leitz and Kabir, 1982).

The sediments within Tura and Sylhet possess fair to good mature source rock characteristics. The Kopili sediments also possess fair to good source rock characteristics and are marginally mature. The Barail sediments are found to be highly organic rich among all the sequences but immature, as indicated by conventional maturity parameters like vitrinite reflectance (Ro), Rock Eval Tmax, biomarker ratios and production index (PI) values in the shelf area. The southern parts of the upper Assam Shelf do not have high organic richness as compared to the northern part in all sequences (Pahari et al., 2008).



(Source: Basic data source book by Khan, F.H. Geology of Bangladesh, 1991)

Figure A24.5-1 Possible subsurface distribution of Kopili and Barail formations in the northwestern Bangladesh.

The Eocene Kopili shale occurs at great depths in the Surma basin and therefore cannot be tested for their source potential in Bangladesh territory. However in the Bogra Shelf and in the Platform area, the occurrence of the Kopili shale is widespread as shown in Figure A24.5-1. The Kopili shale is being penetrated in Kuchma-X1, Bogra-1X, Singra-1X, many wells in the Jamalganj, Joypurhat area. In seismic sections of the Rangpur Platform area, the Kopili shale can be traced upto Kurigram in the north through the east side of the crest of the Rangpur Saddle shown in Figure A24.5-1. A drill hole for both exploration and academic point of view

may be made in the outer shelf area to study its source potential in Bangladesh area as shown in Figure A24.5-1. Large-scale and long-term research is necessary for such studies including 1 or 2 exploration drill holes. Foreign organization, with their relevant research facilities, experience, deep drilling capabilities and experience in overcoming high pressure issues may provide future assistance in this respect.

5.2 CBM

In the northwestern part of Bangladesh, there is abundance of thick Gondowana bituminous coal ranging in depths from 200 to 3,000 m spreading over a very large area. So far, practically, no activities have been observed relating to CBM exploration. Petrobangla has taken up a small pilot project on the CBM. Petrobangla has formulated a project titled “Feasibility Study of Coal Bed Methane at Jamalganj Coal Field”. A project proposal was submitted to EMRD for approval. The approved project will be a feasibility study in Jamalganj coal field, including two drill holes and analysis of coal samples for their CBM potential. The budget will be around 3 million US$ equivalent. Depending on the results, a pilot project may be undertaken later.

But so far, no practical progress has been made. It is understandable that CBM has a huge potential in the northwestern part of Bangladesh. A very large-scale and long-term exploration/research is necessary to avail such important resources. In support of this potential, few maps have been presented on the basis of published data sources. Large-scale and long-term exploration/research are necessary for evaluating such potential resources including 20 to 50 exploration drill holes (ranging from 500 to 3,000 m) and a project is proposed below. Foreign organizations, with their long experience and expertise, may provide future assistance in this respect.

Some Analysis of CBM Potential Done by a Number of Authors:

The most important parameters for CBM prospecting are the presence of a large volume of coal with high methane content and sufficient permeability within the seam to allow gas production. Global CBM appraisal in recent years has indicated that the gas content in coal is generally not a problem. Until the present date there has been little study on the feasibility of CBM development in any of the 5 known coal fields, viz., Jamalganj, Barapukuria, Khalaspir, Phulbari and Dighipara in the northwestern part of Bangladesh can be one of the prime targets in this respect. The coal occurs in Gondwana succession within the depth range of 640 to 1,158 m the Jamalganj coal field. In Jamalganj coal field there are a total of seven major coal seams where at least one very thick and widespread coal seam. Jamalganj coal is high-volatile to medium-volatile bituminous coal. No direct measurement of the methane gas content of

Jamalganj coal has ever been made. Fried Krupp Rohstaff reported evolution of gas in several drill holes when drilling penetrated coal, supporting the view that the coal will give off large quantities of gas.

In assessing the prospectivity of CBM development, the following are among the important factors to be considered: methane content of coal; coal rank; coal permeability; thickness of coal seams; and depth of burial of coal. Generally, high rank coal with thickness in excess of 30 m, burial depth of more than 600 m, gas content of 6 to 7 m^3/ton, permeability greater than 1.5 md, and an in-situ reserve of more than 1 billion tons of coal is considered reasonably viable for developing CBM prospect in a Gondwana coal basin. With the background information on the geologic occurrence of Jamalganj coal described in the previous section, this may now be assessed as to its CBM prospectivity (Imam et al., 2002).

Large deposit of Gondwana bituminous coal was also discovered at shallower depth of 116 m below the ground surface at Barapukuria basin in Dinajpur district in 1985. Depth of Gondwana in Kuchma-X1 well 2,363 to 2,858 m+, Singra-1X well 900 to 4,100 m, Barapukuria GDH-38 133 to 514 m., Khalaspir, Phulbari and Dighipara areas.

Islam and Hayashi (2008) have estimated the CBM concentration for the high-volatile bituminous coals at Barapukuria, and found gas concentrations in the range 6.51-12.68 m^3/t. Observations of similar quality coals elsewhere in the world suggest it is unlikely that the gas concentrations in Bangladesh will be higher than the upper limit, nor significantly lower than the lower limit. By extrapolating the Barapukuria gas concentration estimates to all other basins in northwestern Bangladesh where the in-situ coal resource is known (Table A24.5-1), an estimate of the total in-situ CBM resource (for all seams in all basins) can be determined, as shown in detail in Table A24.5-2, and summarised below:

- Upper-limit estimate: 60.15 Gm^3
- Average estimate: 45.52 Gm^3
- Lower-limit estimate: 30.88 Gm^3

While the CBM resources for the Barapukuria, Phulbari, and Dighipara basins are most likely to fall close to the average-value estimates in Table A24.5-2, there is good reason to expect, or at least hope, that the resources at both Khalaspir and Jamalganj might fall closer to the upper-limit estimates. The coal at Khalaspir is known to have a 25% higher calorific value when compared to the other basins, suggesting higher quality coal. At Jamalganj the greater depth of burial of the seams would favour higher resident gas concentrations.

Table A24.5-1 Summary of the known coal resources in northwestern Bangladesh.

Coal field	Discovery date	Areal extent of basin (km2)	Number of coal seams	Depth range of coal seams (m below surface)	In-situ coal resource (Mt)	Average aggregate thickness of coal-seams (m)	Comments
Coal fields with known or estimated coal resources							
Jamalganj	1962	11.7	7	650 – 1158	2,513	64.0 (a)	
Barapukuria	1985	5.2	6	118 – 518	377	51.0	
Phulbari	1997	51.9	2	150 – 250	426	38.4	
Khalaspir	1987	12.3	8	257 – 483	828	42.3	
Dighipara	1995	Unproven	1	328 – 422	600	42.0 (b)	
Coal fields with reported coal but unproven resources							
Nawabgonj							
Dangapara							
Coal field with known coal, but too deep for current exploitation							
Kuchma (Bogra)	1959	Unproven	5	2380 - 2876	Unproven	51.8 (c)	
Gondwana basins with no coal reported to date							
Badargonj							
Osmanpur							
Burirdoba							
Shimnagar							
TOTALS					**4,744**		

Source: Muller (2009)

The estimated CBM gas concentration, in-situ resource and seam thickness in the Bangladeshi deposits is comparable with that at other active CBM projects elsewhere in the world. Recovery factors (the percentage of gas recovered relative to the total gas contained in the target seams) in these comparative projects are between 20-66%. Jamalganj, in particular, looks to be the single basin with the most potential as a stand-alone project. If the two seams hosting 80% of the in-situ resource were to be targeted at Jamalganj (seams III and VII), the recoverable CBM would be about 10 Gm^3, assuming a 50% recovery factor. In comparison with the 0.9 Mt per year coal-feed to the 250 MW power plant at Barapukuria, 10 Gm^3 of gas at Jamalganj could power the same 250 MW plant for over 15 years (Muller, 2009).

Table A24.5-2 Estimated in-situ coal bed methane (CBM) resources in Bangladesh.

Coal field	Number of coal seams	Depth range of coal-seams (meters below surface)	In-situ coal resource (Mt)	High estimate in-situ CBM resource 12.68 m^3/ton (Gm^3)	Average estimate in-situ CBM resource 9.56 m^3/ton (Gm^3)	Low estimate in-situ CBM resource 6.51 m^3/ton (Gm^3)
Jamalganj	7	650 – 1158	2,513	31.86	24.11	16.36
Barapukuria	6	118 – 518	377	4.78	3.62	2.45
Phulbari	2	150 – 250	426	5.40	4.09	2.77
Khalaspir	8	257 – 483	828	10.50	7.94	5.39
Dighipara	1	328 - 422	600	7.61	5.76	3.91
TOTALS			**4,744**	**60.15**	**45.52**	**30.88**

Source: Muller (2009)

CBM potential in Bangladesh, estimated by different entities are primarily based on the published information of the 5 discovered coal fields area, reserve, seam thickness, permeability, etc. It is an important fact to recall and admit that coal fields, viz., Barapukuria, Phulbari, Khalaspir and Dighipara are primarily identified and mapped on the basis of Bouguer gravity data modeling done at Geological Survey of Bangladesh during mid eighties to early nineties of the last century (1984-1993), some of which are later on drilled and confirmed the presence of coal without fail. In the early nineties several other Gondwana basins were also identified and mapped in the northwestern part of Bangladesh, but they are yet to be drilled and confirmed. The following analysis of Bouguer gravity data of Bangladesh reveals that there are several other large basins that remains to be tested by drilling for their coal potential. The results of the interpretation of such basins are presented below to give an idea of coal potential northwestern part of Bangladesh may possess.

The Bouguer gravity anomaly map of the northwestern Bangladesh is shown in Figure A24.5-2. Locations of the gravity profiles which are illustrated in Figure A24.5-3 to Fugure A24.5-7 are also shown in the figure. Gravity models were constructed along profiles 1 to 5, respectively, and the distributions of the interpreted Gondwana sediments which contain coal are shown on the profiles (Figure A24.5-3 to Figure A24.5-7).

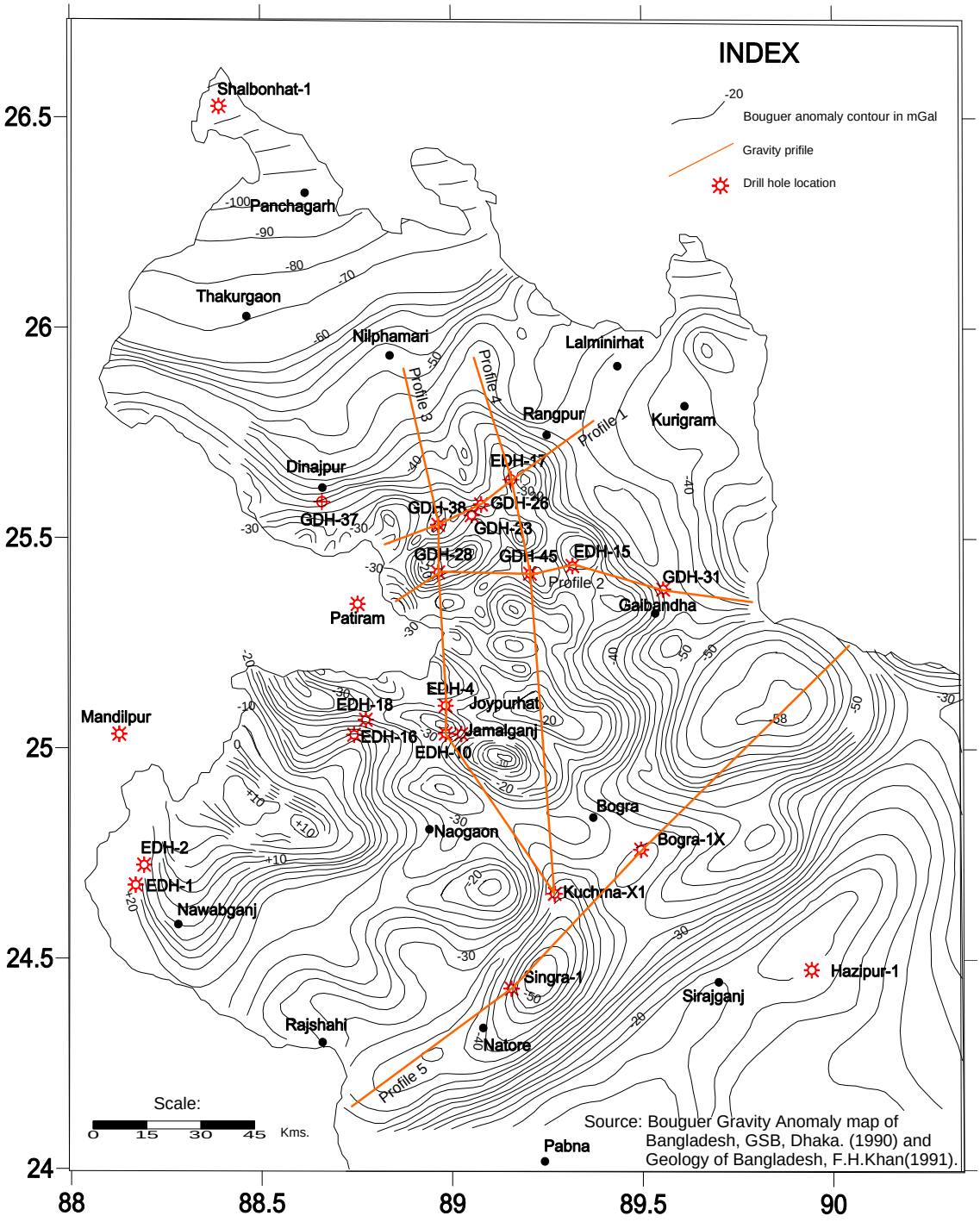
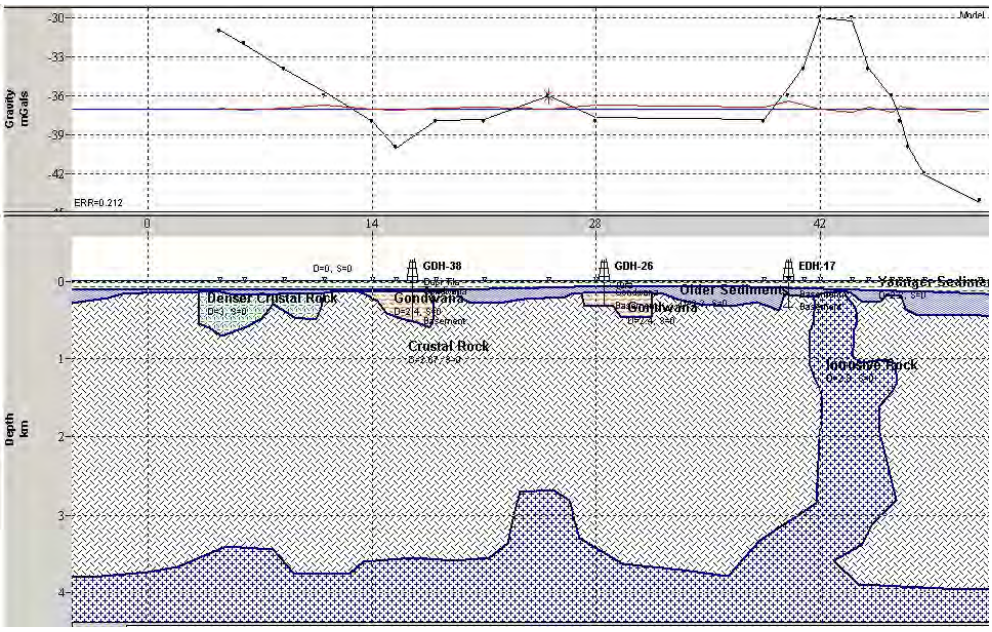
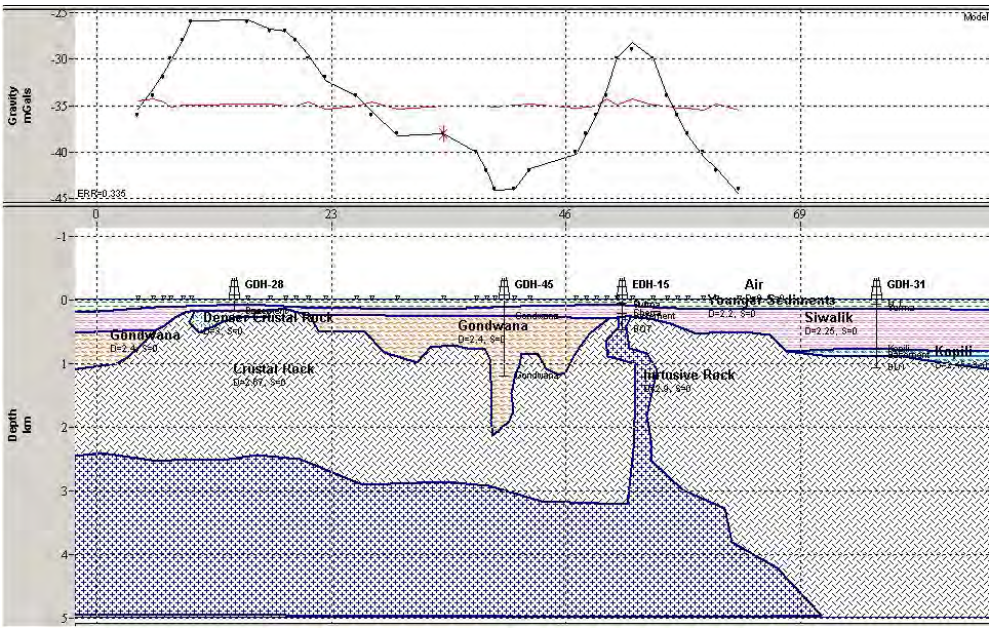


Figure A24.5-2 Bouguer gravity anomaly map of northwestern Bangladesh (contour interval 2 mGals) showing location of gravity profiles.



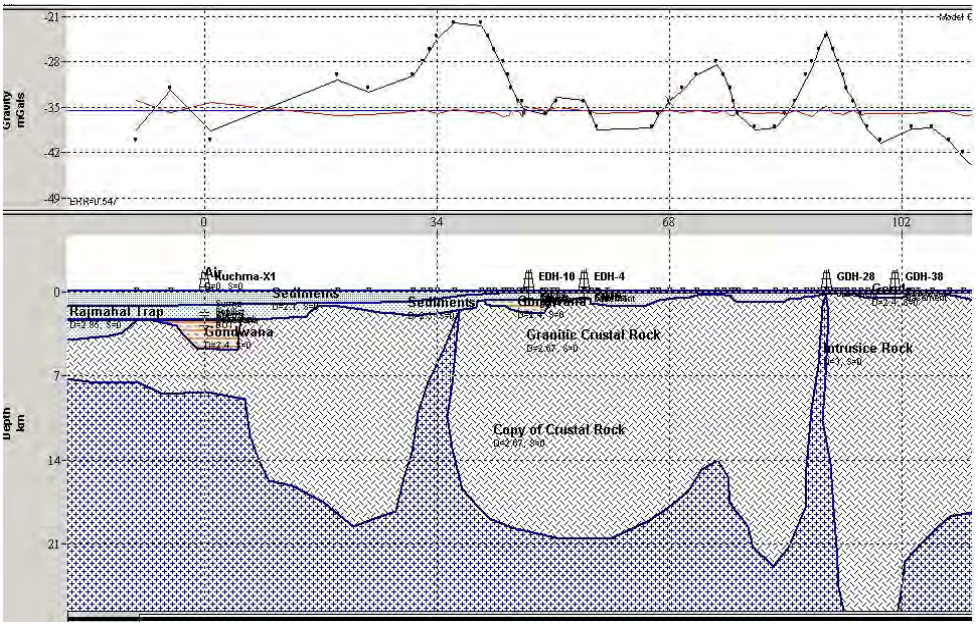
Source: JICA Survey Team using basic data from Bouguer Anomaly Map of Bangladesh, GSB (1990) and Khan, F.H. (1991)

Figure A24.5-3 Gravity model along profile 1 passing through GDH-38, GDH-26 and EDH-17 wells.



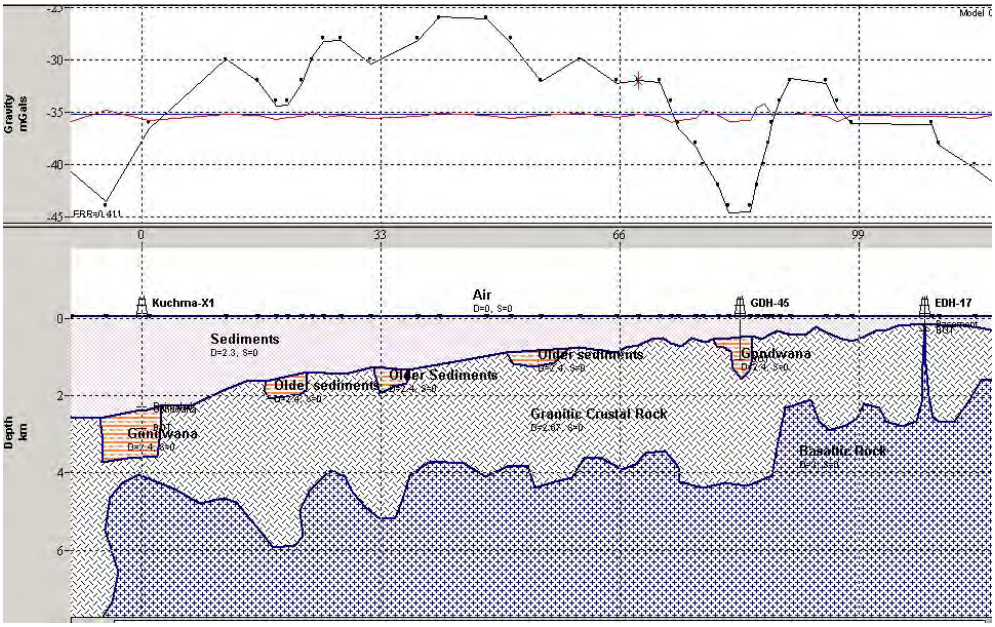
Source: JICA Survey Team using basic data from Bouguer Anomaly Map of Bangladesh, GSB (1990) and Khan, F.H. (1991)

Figure A24.5-4 Gravity model along profile 2 passing through GDH-28, GDH-45, EDH-15 and GDH-31 wells.



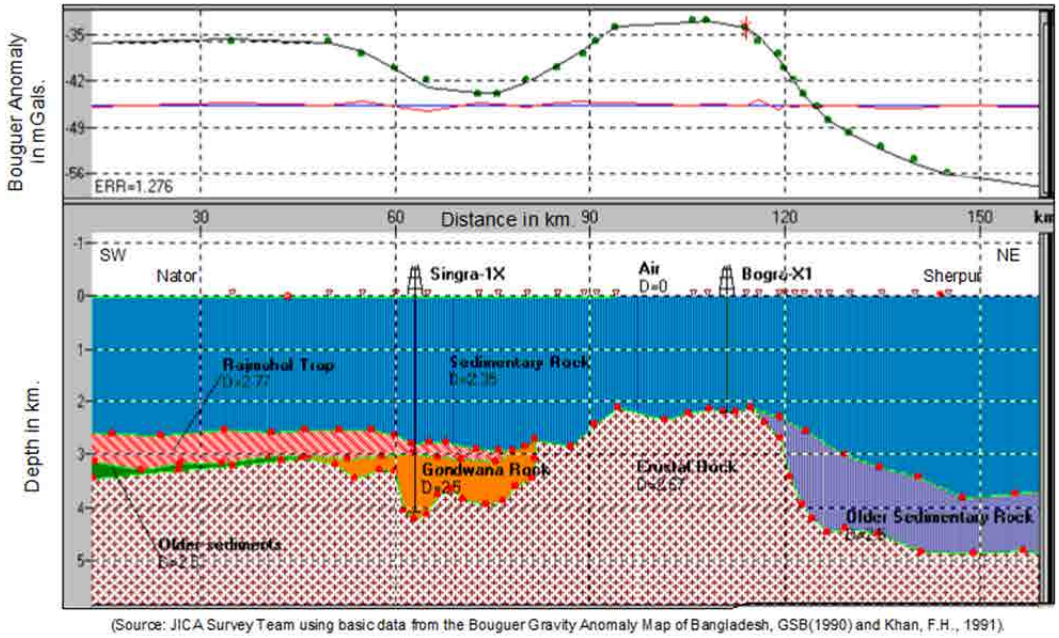
Source: JICA Survey Team using basic data from Bouguer Anomaly Map of Bangladesh, GSB (1990) and Khan, F.H. (1991)

Figure A24.5-5 Gravity model along profile 3 passing through Kuchma-X1, EDH-10, EDH-4, GDH-28 and GDH-38 wells.



Source: JICA Survey Team using basic data from Bouguer Anomaly Map of Bangladesh, GSB (1990) and Khan, F.H. (1991)

Figure A24.5-6 Gravity model along profile 4 passing through Kuchma-X1, GDH-45 and EDH-17 wells.



(Source: JICA Survey Team using basic data from the Bouguer Gravity Anomaly Map of Bangladesh, GSB(1990) and Khan, F.H., 1991).

Figure A24.5-7 A 2D gravity model along a NE-SW profiled passing through Singra-1X wells over the Bogra shelf area.

The discovery of the formations of the Lower Gondwana Group in the Madhyapara, Barapukuria, Khalaspir, Jamalaganj, and Kuchma area suggests that the Gondwana sediments fill all the graben/half-graben like structures within the Pre-Cambrian basement rocks. All those grabens/basins are directly correlatable to the gravity lows and therefore, it has been postulated in an earlier report (Alam, 1990, 1995) that “Every gravity low in the Rangpur Saddle is a Gondwana basin”. Over the Crest of the Saddle, these basins are of elongated graben/half-graben type, whereas in the south and southeastern quadrant of the investigated area they are of wider as shown in Figure A24.5-8. Figure A24.5-9 shows the proposed locations of the exploration well for CBM.

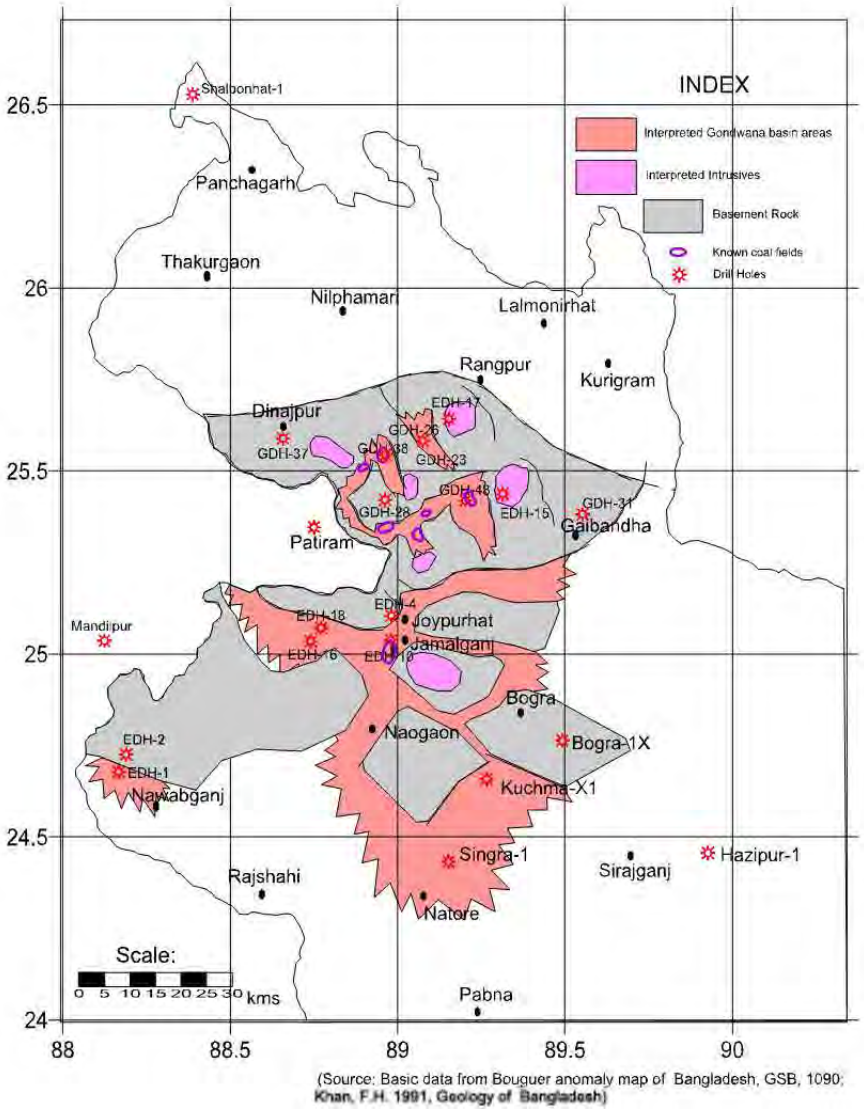


Figure A24.5-8 Map showing location of known coal fields in Bangladesh and possible subsurface distribution of Gondwana rocks in the northwestern Bangladesh as interpreted from gravity modeling.

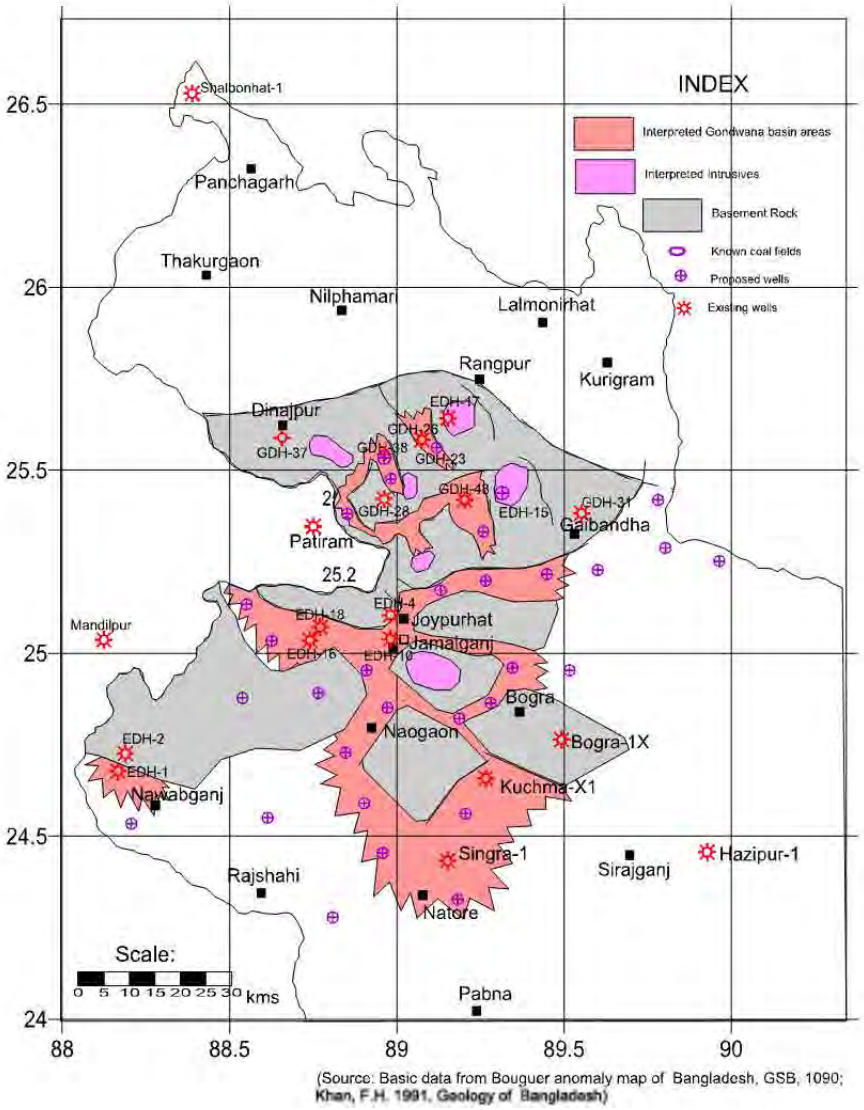


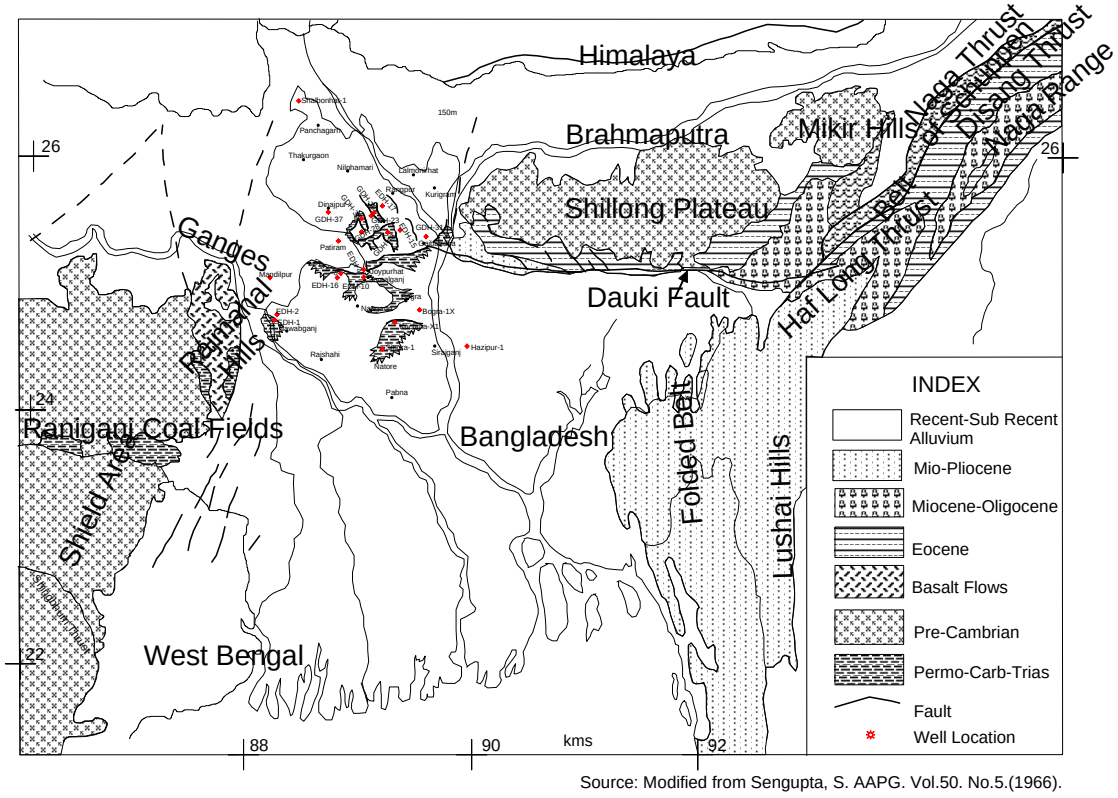
Figure A24.5-9 Map showing location of known coal fields in Bangladesh along with the proposed locations of exploratory wells to confirm the presence of Gondwana coal in the northwestern Bangladesh.

An attempt has also been made to correlate the geology of the northwestern Bangladesh with the geology of the surrounding areas in Bangladesh and India, particularly, the Paleozoic and Mesozoic geological units.

The Lower Gondwana sediments probably continue in the northwesterly direction from the Jamalganj area to the Purnea Gondwana basins in India (Rao, 1973). A regional picture of probable distribution of the Rajmahal trap and the Lower Gondwana formations have been shown in Figure A24.5-10. Form the figure, it may be assumed that the Lower Gondwana sediments are common in all the grabens and half-grabens in that region.

Earlier studies (Alam, 2007) have shown that the western margin of the Surma basin in fact starts from Gaibandha, i.e., from the southeast corner of the Rangpur Saddle area (Figures A24.2-3 and A24.5-1). In case the Dauki Fault turns out to be a Gondwana basin marginal fault, then it is possible that the Surma basin might have been originated from Gondwana basin and we should expect Gondwana sediments at a great depth there. The coal within the Gondwana sediments at such a great depth, under high pressure and temperature, might have generated significant amount of hydrocarbons that had migrated upwards and entrapped into the younger formations. Recent basin modeling and petroleum system analysis of the Bengal basin (Alam et al., 2006) indicated that the Gondwana sediments of the Bogra Shelf area have produced significant amount of hydrocarbon (both oil and gas) and are still producing and expelling hydrocarbons. Therefore the Bogra Shelf and the Slope areas within the greater Mymensingh possess a brighter prospect for hydrocarbon exploration in future.

Northeastern end of the fault bounding the northern limit of the Jamalganj Gondwana basin (Buzruk Fault) may be connected to the western end of the Dauki Fault.



Source: Modified from Sengupta, S. AAPG. Vol.50. No.5.(1966).

Figure A24.5-10 Surface and subsurface distribution of the Gondwana formations in the shelf area against Pre-Cambrian basement rocks in the Bengal basin and adjacent areas.

Conclusions:

Gondwana basins are much wider over the Bogra Shelf in the south than those over the crest of the Rangpur Saddle and the Gondwana sediments seems to be wide spread in that region. The Lower Gondwana sediments are present over the Bogra Shelf area filling the grabens/basins. Over the crest of the saddle, they are confined to the grabens/half-grabens only, whereas in the south of Jamalganj, they are much broader. It is therefore can be safely assumed that the CBM potential in the northwestern part of Bangladesh is much more greater than it is currently assumed, and deserves greater national attention to take necessary measures for their exploration and exploitation and useful utilization.

5.3 Gas Hydrates

Potential of gas hydrates in the Bay of Bengal have not been studied yet. It a very important area from future energy sources point of view. Some countries have experience and leading expertise in the area of gas hydrates. Engagement, assistance, cooperation from the experienced countries may be sought for the assessment and future development of gas hydrates.

6. Technical Capacity Building

In order to achieve, maintain and manage the energy sector effectively and efficiently a requisite number of local expertise needs to be developed by arranging local and foreign training and higher education in the related areas of expertise. Bangladesh do not have such academic institutions capable of providing such state-of-the-art and cutting-edge technologies and lab facilities to address such limitations. Bangladesh also do not have capabilities, equipment or facilities for shallow or deep marine survey and exploration activities also. Assistance and cooperation from technically advanced countries having such experience and technology may be sought under a long term training project to meet such requirements and develop such expertise here.

- To develop expertise in exploration geoscience (G&G) and reservoir management areas.
- To develop expertise in basin studies and geochemical analysis
- To develop expertise in drilling in abnormally high-pressure zones
- To develop expertise in production and O&M
- To develop expertise in shallow and deep marine survey including difficult areas
- To develop expertise in horizontal well drilling and completion

Some comments on the expertise shown above are made as follows.

Exploration geoscience (geology and geophysics) is basically important in both exploration and development.

Reservoir management should include conducting reservoir simulation studies for the existing gas fields using a geological model.

Results derived from basin studies or basin modeling studies are important to identify potential risks in new exploration targets in the early stage of exploration. In Bangladesh this approach is required for exploration in under-explored areas.

Geochemical analysis may be focused on the analysis of formation fluids (hydrocarbon and water) rather than hydrocarbon source rocks. The expertise in geochemical analysis should include practical analysis techniques using the latest equipment which is recommended to purchase.

Drilling practices in abnormally high-pressure zones which are estimated to be at depths of around 3,500-4,000 m (see Section 4.) are required for drilling wells for deeper targets.

Production technology and O&M practices are important for optimizing and maximizing gas production for a specific field and extending the field life. The installation of wellhead gas compressor in the existing gas field is one of the measures for maximizing gas production from a well with a declining flow rate and will also result in extending the field life.

Seismic surveys in shallow and deep marine areas and difficult areas such as swampy-marshy areas require site specific techniques for field data acquisition and also need to purchase the latest equipments.

Horizontal well drilling and completion technology is required for the development of shale gas and CBM. Horizontal well drilling and completion technology can also be applied to increasing gas production from conventional sand reservoirs in the existing gas fields.

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