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No. PFJV/FKNL/017 Date: 16/08/2022

To

The Project Director (JMVP)
Inland Waterways Authority of India,
A-13, Sector – 1,
Noida – 201301, India

Subject: Revised Condition Survey Report of Consultancy Services for Preparation of Detailed Project Report (DPR) for the work of Renovation/Modernization of Existing Navigation Lock at Farakka.

Ref: Contract agreement dated 11.01.2022

Your Letter No. IWAI/NW-1/WB/AG/Study-Exist.Nav.Lock/2020-21 dated 10.08.2022 (By Email)

Sir,

With reference to your letter above we have complied to your comments and incorporated an Annexure to the Condition Survey Report. This Revised Condition Survey Report of Consultancy Services for Preparation of Detailed Project Report (DPR) for the work of Renovation/Modernization of Existing Navigation Lock at Farakka is enclosed herewith the for your kind perusal.

The comments and compliances have also been attached along with the letter.

Submitted against Deliverable 2 of the Contract Agreement please.

Thanking You

.

Yours Sincerely,

16.08.2022
(Er. A K Bajaj)
Team Leader

Encl: As Above

Annexure-8.1

COMMENTS AND COMPLIANCES

Comment

a. The proposal mentioned in the report regarding using of cassion gates of new navigational lock (which is under construction) is not based on the actual construction of the cassion gates of the new navigational lock.

Compliance

Based on the Condition Survey it has been recommended to replace both the cassion gates. It is found that the existing gates are in a very dilapidated state and the complete system of cassion gates and the operating system needs to be replaced.

However, since use of Cassion Gates will be very infrequent in both existing as well as under construction lock for maintenance of mitre gate purposes, the feasibility of utilizing the cassion gates being fabricated for use at the new (under construction) lock structure to be used in the existing lock as well may be explored during the construction phase. It will require some modifications to the existing civil structure of the present lock and some minor modifications to the gate as detailed in para below.

Comment

b. The details with respect to the size (length, width and height) including bottom level of the lock chamber of both the locks shall be compared and clearly mentioned. It shall also be checked whether the grooves provided in the old navigational lock are suitable for placing of cassion gates being constructed for new navigation lock.

Compliance

It has been recommended to replace of both caisson gates with new gates along with the complete system operation. However, the feasibility of utilizing the cassion gates being fabricated for use at the new (under construction) lock structure in the existing lock can be explored. The detailing for this whereby the dimensions and levels are to be checked is being done at the DPR stage. The suitability of the grooves in the wall section and bottom seating arrangement will also be checked in the DPR.

Comment

c. The mechanism for transfer of the cassion gates from the new navigational lock chamber to old navigation lock chamber shall also be mentioned duly examining the mechanism being provided in those cassion gates for their relocation. If any change in design of cassion gate of new navigation lock is required for its transfer, same shall be clearly mentioned. The expenditure and time required for such changes shall also be estimated.

Compliance

Using the gates being provided at the new lock at existing lock structure also, will require provision of a tug boat to tow the gates from the new lock to the old lock and place it in position at the existing lock. It will also require some minor modifications to the gate to make it suitable for towing with the tug boat which will be assessed at the DPR stage.

Ministry of Shipping
Government of India

INLAND WATERWAYS AUTHORITY OF INDIA

CONSULTANCY SERVICES FOR PREPARATION OF DETAILED PROJECT REPORT (DPR) FOR THE WORK OF RENOVATION/MODERNIZATION OF EXISTING NAVIGATION LOCK AT FARAKKA

Condition Survey Report

August 2022

Submitted By:
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DOCUMENT/REPORT CONTROL FORM

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2	16-08-2022	VR, SK, AU, MM, AK, AS, HT, SPR, DKS, BCN	Er. A K Bajaj, Team Leader	

Executive Summary

Inland Waterways Authority of India has assigned M/s PKS-Floodkon JV to carry out Consultancy Services for Preparation of Detailed Project Report (DPR) for the work of renovation/modernization of existing navigation lock at Farakka Project funded by the World Bank under Jal Marg Vikas Project.

2. As per Terms of Reference (ToR) of this Consultancy Project assignment, the Condition Survey Report has been prepared for submission before the project authority for its perusal, offering suggestion, if any, and according approval to this report. This approval will facilitate the Consultant in taking up the activities needed to achieve the third milestone i.e. submission of the Draft DPR as per the TOR.

3. The condition Survey Report covers site investigations and data collection as well analysis of the data including key finding and recommendations. This also creates a roadmap for the preparation of the Draft DPR.

4. A site investigation team for Condition Survey was deployed from 29th March to 12th April 2022 at project site. The team was equipped with underwater investigation capabilities to conduct underwater visual inspections, above water and underwater Ultrasonic Pulse Velocity (UPV) test and underwater Ultrasonic Testing (UT) to determine the health of the navigational lock chamber concrete and the hydromechanical equipment / gates respectively.

5. The expert members of PKS Floodkon JV Team also visited the existing Farakka Lock Gate during this period from 07th to 09th April, 2022 to oversee the survey work being carried out and also visually inspected all the components of the Lock Gate, Control Room, upstream and downstream bank condition of the navigation channel, the construction activities, and the facilities being created in the new Navigation Lock undertaken by L&T.

6. Analyzing the data and findings from the Condition Survey pertaining to deterioration in the structure, the functional condition index of the cassion gates, mitre gates, radial gates, bulkhead gates, and the lock chamber has been estimated.

7. Based on the functional condition index, the following is recommended:

- Complete replacement of the 2 cassion gates along with operating system.

- Replacement of the underwater portion of the skin plate of the mitre gates and repair for the above water gate leaf portion. Complete replacement of the operating system of the mitre gates.
- Replacement of the operating system of the 4 radial gates.
- Complete replacement of the existing bulkhead gates by providing 8 new bulkhead gates with their individual operating systems.
- Major repairs to the concrete of the navigation lock chamber walls and floor as well as filling/emptying system.
- Major repairs in the control room building with all the necessary and modern facilities.
- Replace the mooring equipment.
- Repair and modernize the electrical equipment along with power supply
- Modernization of the control system to state of the art centralized command and control room with remote operations and monitoring of all critical inputs.
- Replacement of the entire wooden and rubber fenders.
- Sensors for monitoring of water level and other lock structure safety parameters shall be installed.
- Lighting system will be modernized along with suitable arrangement for night navigation.

8. The comments/suggestions on the Draft Condition Survey may please be communicated to enable preparation of Detailed Project Report (DPR) for renovation / modernization of existing navigation lock at Farakka.

16.08.2022
(Er. A K Bajaj)
Team Leader

TABLE OF CONTENTS

Executive Summary iii
1.0 Introduction 1
1.1 Project Appreciations 1
1.2 Background of the Project 1
1.3 Objectives of the Assignment (As Per TOR) 2
1.4 Organization of the Report 2
2.0 Condition Survey Scope 4
2.1 Structural Health Assessment 4
2.2 Site Inspection Visit 5
2.3 Condition Survey 6
2.2.1 Visual Inspection 6
2.2.2 Non-Destructive Testing: Ultrasonic Pulse Velocity Method 6
2.2.3 Inspection for Corrosion 8
2.4 Proposed Condition Survey Tests 9
3.0 Task Description 11
4.0 Task Description 14
4.1 Observations from underwater visual inspection 14
4.2 Observations from visual inspection 15
4.2.1 Heatmap of observations at Gate1 East 15
4.2.2 Heatmap of observations at Gate1 West 21
4.2.3 Heatmap of observations at Gate2 East 27
4.2.4 Heatmap of observations at Gate2 West 31
4.2.5 Heatmap of observations at Wall Section 1 West 36
4.2.6 Heatmap of observations at Wall Section 1 East 48
4.2.7 Heatmap of observations at Wall Section 2 East & West 53
4.2.8 Heatmap of observations at Wall Section 3 East & West 60
4.2.9 Heatmap of observations at Wall Section 4 East & West 68
4.2.10 Heatmap of observations at Wall Section 5 East & West 75
4.2.11 Heatmap of observations at Wall Section 6 East 87
4.2.12 Heatmap of observations at Wall Section 6 West 93
4.2.13 Heatmap of observations at Wall Bottom Section 16 - 30 99
4.2.14 Heatmap of observations at Wall Bottom Section 31 - 45 104
4.2.12 Heatmap of observations at Wall Bottom Section 46 - 60 108

4.2.12 Heatmap of observations at Wall Bottom Section 61 - 75 111
4.3 Observations from Above water UPV test 117
4.3.1 Consolidated points detail of East side 117
4.3.2 Consolidated points detail of West side 118
4.3.3 Heatmap of observations at Above water West 1 UPV 119
4.3.4 Heatmap of observations at Above water East 1 UPV 121
4.3.5 Heatmap of observations at Above water 1-2 UPV 123
4.3.6 Heatmap of observations at Above water 3-4 UPV 125
4.3.7 Heatmap of observations at Above water 5-6 UPV 127
4.3.8 Heatmap of observations at Above water 7-8UPV 129
4.3.9 Heatmap of observations at Above water West 9-10 UPV 131
4.3.10 Heatmap of observations at Above water East 9-10 UPV 133
4.4 Observations from Under water UPV test 136
4.4.1 Heatmap of observations at Underwater West 1 UPV 136
4.4.2 Heatmap of observations at Underwater East 1 UPV 139
4.4.3 Heatmap of observations at Underwater East West 2 UPV 142
4.4.4 Heatmap of observations at Underwater East West 3 UPV 147
4.4.5 Heatmap of observations at Underwater East West 4 UPV 152
4.4.6 Heatmap of observations at Underwater East West 5 UPV 157
4.4.7 Heatmap of observations at Underwater East West 6 UPV 162
4.4.8 Heatmap of observations at Underwater East West 7 UPV 167
4.4.9 Heatmap of observations at Underwater East West 8 UPV 172
4.4.10 Heatmap of observations at Underwater East West 9 UPV 177
4.4.11 Heatmap of observations at Underwater East 10 UPV 182
4.4.12 Heatmap of observations at Underwater West 10 UPV 185
4.5 Observations from Underwater UT test 189
4.5.1 Heatmap of observations at UT 1 189
4.5.2 Heatmap of observations at UT 2 193
4.5.3 Heatmap of observations at UT 3 197
4.5.4 Heatmap of observations at UT 4 201
4.6 Observation from site inspection 205
4.6.1 Mitre Gates 205
4.6.2 Cassion Gates 207
4.2.3 Radial Gates 208

4.2.4 Bulkhead Gates 210
4.2.5 Filling / Emptying Systems 212
4.2.6 Mooring Equipment 214
4.2.7 Control Room Building 215
4.2.8 Mechanical and Electrical Equipment 216
4.2.9 Control Systems 219
4.2.10 Instrumentation 220
4.2.11 Power Supplies 221
4.2.12 Communications Systems 223
4.2.13 Lighting and Signaling Equipment 223
4.2.14 Safety Equipment including Fender Arrangement 224
4.2.15 Stocks of Spares 225
4.2.16 Maintenance Equipment 225
4.2.17 Lock Operation Manuals (SOP's) and Existing Technical Records 225
4.2.18 Maintenance Records 225
5.0 Condition Survey Indicators 226
5.1 Performance Indicators 226
5.2 Functional Condition Index 229
6.0 Findings & Recommendations 239
6.1 Introduction 239
6.2 Cassion Gates 239
6.2.1 Possible Performance Improvements 239
6.3 Mitre Gates 239
6.3.1 Possible Performance Improvements 240
6.3.2 Suggested state-of-the-art Technology 240
6.4 Radial Gates 242
6.4.1 Possible Performance Improvements 242
6.4.2 Suggested state-of-the-art Technology 242
6.5 Bulkhead Gates 244
6.5.1 Possible performance improvements 244
6.5.2 Suggested state-of-the-art Technology 244
6.6 Lock Chamber & Approach including Filling/Emptying System 245
6.6.1 Possible performance improvements 246
6.6.2 Suggested state-of-the-art Technology 246

6.7 Mooring Equipment 247
6.7.1 Possible performance improvements 247
6.7.2 Suggested state-of-the-art Technology 247
6.8 Control Room Building 248
6.8.1 Possible performance improvements 248
6.8.2 Suggested state-of-the-art Technology 248
6.9 Mechanical and Electrical Equipment 248
6.9.1 Possible performance improvements 249
6.9.2 Suggested state-of-the-art Technology 249
6.10 Control Systems 249
6.10.1 Possible performance improvements 249
6.10.2 Suggested state-of-the-art Technology 250
6.11 Power Supplies 250
6.11.1 Possible performance improvements 251
6.11.2 Suggested state-of-the-art Technology 251
6.12 Fender Arrangement 251
6.12.1 Possible performance improvements 251
6.12.2 Suggested state-of-the-art Technology 251
6.13 Electrical Ancillaries 252
6.14 Non Electrical Ancillaries 252
6.15 Instrumentation 252
7.0 Hydraulic Balance Imbalance Assessment 258
7.1 Introduction 258
7.2 Hydraulic Balance/Imbalance 258
7.3 Collection of Data 259
7.4 Case Studies 262
7.5 Additional Data Required for Balance Imbalance study 262
7.6 Creation of Model 262

LIST OF FIGURES

Figure 1: Image of the Farakka Navigational Lock 1

Figure 2: Team of Experts with IWAI Officials during Site Inspection Visit 5

Figure 3: Sample image of conducting UPV tests above water 7

Figure 4: Sample image of conducting underwater UPV tests 8

Figure 5: Plan View of the Farakka Navigational Lock 13

Figure 6: Plan View of inspected Unit of Farakka Navigational Lock 14

Figure 7: Heat map and Observations at Gate 1 East 15

Figure 8: Heat map and Observations at Gate1 West 21

Figure 9: Heat map and Observations at Gate2 East 27

Figure 10: Heat map and Observations at Gate2 West 31

Figure 11: Heat map and Observations at Wall Section 1 West 36

Figure 12: Heat map and Observations at Wall Section 1 East 48

Figure 13: Heat map and Observations at Wall Section 2 East & West 53

Figure 14: Heat map and Observations at Wall Section 3 East & West 60

Figure 15: Heat map and Observations at Wall Section 4 East & West 68

Figure 16: Heat map and Observations at Wall Section 5 East & West 75

Figure 17: Heat map and Observations at Wall Section 6 East 87

Figure 18: Heat map and Observations at Wall Section 6 West 93

Figure 19: Heat map and Observations at Wall Bottom Section 16 - 30 99

Figure 20: Heat map and Observations at Wall Bottom Section 31 - 45 104

Figure 21: Heat map and Observations at Wall Bottom Section 46 - 60 108

Figure 22: Heat map and Observations at Wall Bottom Section 61 - 75 111

Figure 23: Heat map and Observations at Above water East 1 UPV 119

Figure 24: Heat map and Observations at Above water East 1 UPV 121

Figure 25: Heat map and Observations at Above water 1-2 UPV 123

Figure 26: Heat map and Observations at Above water 3-4 UPV 125
Figure 27: Heat map and Observations at Above water 5-6 UPV 127
Figure 28: Heat map and Observations at Above water 7-8 UPV 129
Figure 29: Heat map and Observations at Above water West 9-10 UPV 131
Figure 30: Heat map and Observations at Underwater West 10 UPV 133
Figure 31: Heat map and Observations at Underwater West 1 UPV 136
Figure 32: Heat map and Observations at Underwater East 1 UPV 139
Figure 33: Heat map and Observations at Underwater East West 2 UPV 142
Figure 34: Heat map and Observations at Underwater East West 3 UPV 147
Figure 35: Heat map and Observations at Underwater East West 4 UPV 152
Figure 36: Heat map and Observations at Underwater East West 5 UPV 157
Figure 37: Heat map and Observations at Underwater East West 6 UPV 162
Figure 38: Heat map and Observations at Underwater East West 7 UPV 167
Figure 39: Heat map and Observations at Underwater East West 8 UPV 172
Figure 40: Heat map and Observations at Underwater East West 9 UPV 177
Figure 41: Heat map and Observations at Underwater East 10 UPV 182
Figure 42: Heat map and Observations at Underwater West 10 UPV 185
Figure 43: Heat map and Observations at UT 1 189
Figure 44: Heat map and Observations at UT 2 193
Figure 45: Heat map and Observations at UT 3 197
Figure 46: Heat map and Observations at UT 4 201
Figure 47: Mitre Gates of Farakka Lock 205
Figure 48: Condition of Seals of Mitre Gate of Farakka Lock 205
Figure 49: Top Bearing of Mitre Gates of Farakka Lock 206
Figure 50: Operating Mechanism of Mitre Gates of Farakka Lock 207
Figure 51: Cassion Gates for Mitre Gate Maintenance at Farakka Lock 208

Figure 52: Lifting brackets and limb arms of Radial Gates 209
Figure 53: Operating System of Radial Gates 210
Figure 54: Bulkhead Gates for Radial Gate Maintenance 211
Figure 55: Heavy corrosion in Bulkhead Gates 211
Figure 56: Deteriorated equalizing valve of Bulkhead Gates 212
Figure 57: Lifting Assembly of Bulkhead Gates 212
Figure 58: Navigational lock layout with filling/emptying system 213
Figure 59: Details of filling/emptying system 213
Figure 60: Floating Type Bollards 214
Figure 61: Damaged Fixed Type Bollard 214
Figure 62: Control room building 215
Figure 63: Control room building (Close-up view) 215
Figure 64: Present Condition of interiors of Control room building 216
Figure 65: Steel lattice type cable bridges 217
Figure 66: Cable trench for power cables 218
Figure 67: Temporary position indicator used to control gate opening 219
Figure 68: Local control system of u/s Mitre and Radial Gate 220
Figure 69: Fixed water level gauge in ladder recess 220
Figure 70: 11kV to 415V Transformer 221
Figure 71: Electrical sub-station distribution board 221
Figure 72: Electrical Control Room 222
Figure 73: DG Set 222
Figure 74: Lighting system at the lock site 223
Figure 75: Wooden and rubber tyre fender arrangement 224
Figure 76: Functional condition index related to X/Xmax 228
Figure 77: Conceptual drawing of Mitre gate with hydraulic system 241

Figure 78: Conceptual drawing of radial gate with hydraulic system 243
Figure 79: Conceptual drawing of Bulkhead gate 245
Figure 80: Conceptual drawing of Bulkhead gate operating system 245
Figure 81: Dry Mix Shortcrete 246
Figure 82: Plan of Lock System (Not to Scale) 258
Figure 83: Sample Geometry Data of Lock and Gate 263
Figure 84: Photograph of RORV Beluga 265
Figure 85: Dive details at Gate 1 East 270
Figure 86: Dive details at Gate 1 West 270
Figure 87: Dive details at Gate2 East 271
Figure 88: Dive details at Gate2 West 271
Figure 89: Dive details at Wall Section 1 West 272
Figure 90: Dive details at Wall Section 1 East 272
Figure 91: Dive details at Wall Section 2 East & West 273
Figure 92: Dive details at Wall Section 3 East & West 273
Figure 93: Dive details at Wall Section 4 East & West 274
Figure 94: Dive details at Wall Section 5 East & West 274
Figure 95: Dive details at Wall Section 6 East 275
Figure 96: Dive details at Wall Section 6 West 275
Figure 97: Dive details at Radial Gate 276

LIST OF TABLES

Table 1: Condition Survey Tests 10

Table 2: Operational Setup (Visual inspection) 12

Table 6: Observation details at Gate1 East 20

Table 7: Observation details at Gate1 West 26

Table 8: Observation details at Gate2 East 30

Table 9: Observation details at Gate2 West 35

Table 10: Observation details at Wall Section 1 West 47

Table 11: Observation details at Wall Section 1 East 52

Table 12: Observation details at Wall Section 2 East & West 59

Table 13: Observation details at Wall Section 3 East & West 67

Table 14: Observation details at Wall Section 4 East & West 74

Table 15: Observation details at Wall Section 5 East & West 86

Table 16: Observation details at Wall Section 6 East 92

Table 17: Observation details at Wall Section 6 West 98

Table 18: Observation details at Wall Bottom Section 16 - 30 103

Table 19: Observation details at Wall Bottom Section 31 - 45 107

Table 20: Observation details at Wall Bottom Section 46 - 60 110

Table 21: Observation details at Wall Bottom Section 61 - 75 114

Table 22: Observation details at Above water West 1 UPV 120

Table 23: Observation details at Above water East 1 UPV 122

Table 24: Observation details at Above water 1-2 UPV 124

Table 25: Observation details at Above water 3-4 UPV 126

Table 26: Observation details at Above water 5-6 UPV 128

Table 27: Observation details at Above water 7-8 UPV 130

Table 28: Observation details at Above water West 9-10 UPV 132

Table 29: Observation details at Above water East 9-10 UPV 134

Table 30: Observation details at Underwater West 1 UPV 138

Table 31: Observation details at Underwater East 1 UPV 141

Table 32: Observation details at Underwater East West 2 UPV 146

Table 33: Observation details at Underwater East West 3 UPV 151

Table 34: Observation details at Underwater East West 4 UPV 156

Table 35: Observation details at Underwater East West 5 UPV 161

Table 36: Observation details at Underwater East West 6 UPV 166

Table 37: Observation details at Underwater East West 7 UPV 171

Table 38: Observation details at Underwater East West 8 UPV 176

Table 39: Observation details at Underwater East West 9 UPV 181

Table 40: Observation details at Underwater East 10 UPV 184

Table 41: Observation details at Underwater West 10 UPV 187

Table 42: Observation details at UT 1 192

Table 43: Observation details at UT 2 196

Table 44: Observation details at UT 3 200

Table 45: Observation details at UT 4 204

Table 46: Condition index scale and zones 227

Table 47: Functional Condition Index of Cassion Gates of Existing Farakka Navigational Lock 229

Table 48: Functional Condition Index of Upstream Mitre Gate (East Leaf) of Existing Farakka Navigational Lock 230

Table 49: Functional Condition Index of Upstream Mitre Gate (West Leaf) of Existing Farakka Navigational Lock 231

Table 50: Functional Condition Index of Downstream Mitre Gate (East Leaf) of Existing Farakka Navigational Lock 232

Table 51: Functional Condition Index of Downstream Mitre Gate (West Leaf) of Existing Farakka Navigational Lock 233

Table 52: Functional Condition Index of Radial Gates of Existing Farakka Navigational Lock 234

Table 53: Functional Condition Index of Bulkhead Gates of Existing Farakka Navigational Lock 235

Table 54: Functional Condition Index of Lock Chamber of Existing Farakka Navigational Lock 236

Table 55: Functional Condition Index of Mooring Equipment of Existing Farakka Navigational Lock 237

Table 56: Functional Condition Index of Electrical Equipment's of Existing Farakka Navigational Lock 237

Table 57: Operational working life with or without renovation 238

Table 58: Renovate/ Replace/ Modernize strategy with suggested modifications... 254

Table 59: Equipment to be repaired/ replaced/ modernized along with technical specifications and cost implications 257

Table 60: Lock 1 System (From Operation Manual) 259

Table 61: Lock 2 System (From DPR Drawing) 260

Table 62: Proposed Scenarios for Hydraulic Balance Imbalance Study 262

Table 63: Personnel Details 264

Table 64: Weather Details 265

Table 65: Details of Inspection Vehicle 266

Table 66: Observations Guidelines 268

Table 67: Equipment details of UPV test 269

1.0 Introduction

1.1 Project Appreciations

The Inland Waterways Authority of India has awarded PKS FLOODKON JV to carry out the project "Preparation of Detailed Project Report (DPR) for the work of renovation / modernization of existing navigation lock at Farakka" under the Jal Marg Vikas Project (JMVP) with financial assistance of The World Bank. This condition survey report includes project appreciation, scope of condition survey, structural health assessment of the existing navigational lock components and identify components for repair, replace and modernize.

1.2 Background of the Project

Farakka Barrage Project (FBP) was commissioned in the year 1975 with the primary objective of improving the navigation facilities of river Hooghly and maintaining Kolkata Port. As part of FBP, a navigation lock was constructed and commissioned in the year 1987 at Farakka (in Murshidabad district of West Bengal) to facilitate movement of inland vessels on National Waterway-1 (NW-1) through Feeder Canal. The navigation lock along with all ancillary assets was taken over by the Inland Waterways Authority of India from FBP Authority in April 2018.

Figure 1: Image of the Farakka Navigational Lock

The navigation lock has: (a) an internal length of 179.8m & a width of 25.14m and consists of two (2) sets of mitre gates on upstream (u/s) and downstream (d/s) side (two (2) leaves per set, each hinged about a vertical axis); (b) two (2) floating caisson type stop log gates; (c) four (4) sets of radial valve gates with maintenance bulkheads; (d) eight (8) sets of mooring bits; and (e) a control tower for remote control operation.

Since the commissioning of navigation lock in the year 1987, no major repairs of hydraulic and electro-mechanical components have been carried out. As a result, mitre gates, radial valve gates, bulkheads, floating caissons and other mechanical components including electro-mechanical operating system are in dilapidated condition. Hence, it is required to renovate/modernize the existing navigation lock at Farakka.

Since it is an important part of NW-1 and renovation of the navigation lock will helps to achieve overall goals of JMVP and improve the navigability of NW-1 through: (i) fairway development by providing an assured depth of 2.2m to 3.0m throughout the corridor for at least three hundred thirty (330) days in a year to make it navigable for comparatively larger vessels of 1,500-2,000 DWT and (ii) civil structures, logistics and communications interventions required that includes multimodal terminals, jetties, navigational locks, barrages, channel marking systems etc.

1.3 Objectives of the Assignment (As Per TOR)

The major objective of the consultancy is to Preparation of Detailed Project Report (DPR) with the objective to

(a) Renovate and modernize the existing navigation lock at Farakka to the latest technology based on the best practices followed worldwide; and

(b) Synchronization of the operation of existing navigation lock with the new navigation lock being developed to ensure optimum utilization of both the locks, at the same time, for safe navigation & passage of vessels.

1.4 Organization of the Report

Chapter 1 deals with the introduction background of the project. This chapter includes the project appreciations with background of the project and its objectives as per the terms of reference.

Chapter 2 deals with the details of the condition survey and the scope of condition survey location of the study area and project location.

Chapter 3 deals with the description of task and division on the structure in different sections for simplification of task and understanding.

Chapter 4 deals with the observations from visual inspection, above water and underwater UPV and underwater UT of the navigational lock and other appurtenant systems associated with the navigational lock.

Chapter 5 deals with the condition index and functional condition index of the cassion gates, mitre gates, radial gates, bulkhead gates and lock chambers, mooring equipment, electrical equipment, etc.

Chapter 6 deals with the findings and recommendation based on the condition survey assessment and functional condition index pertaining to repair, replace and modernize the navigational lock components including the details of the state of the art technology proposed with conceptual drawings and cost implications.

Chapter 7 deals with the strategy for undertaking the hydraulic balance imbalance study to be given by the consultant.

2.0 Condition Survey Scope

2.1 Structural Health Assessment

Structural Health Assessment (SHA) aims to assess the behaviour of structures, evaluate the performance of materials during the life cycle and give a diagnosis of the "state" of the constituent materials, of the different parts, and the structure as a whole. It refers to the process of implementing a damage detection and characterization strategy for various engineering structures. In an effective Structural management program, strategies for life extension, upgrade, and replacement strategies must be developed.

Any structure after its construction deteriorates due to loading or environmental impacts. Thus, there is a variation in the strength of the structure after it is built in place. If this variation is under a certain threshold limit, the structure is considered as damage-free; otherwise, the structure is considered as damaged, which, eventually may fail. Here, the damage is defined as changes to the material and/or geometric properties of a structural system, which adversely affects the system's performance.

The methods used are based on Visual Inspection and instrument-based Non-Destructive Testing (NDT). The instrument-based NDT includes Ultrasonic Test. Different parts influence the selection of the monitoring method used. Structural phenomena to be studied which include Inclinations, Crack detection and localization, Crack widths, Foundation settlements, Corrosion. The parameters causing these phenomena can be forces, stresses, displacements, rotations, vibrations, and strain or environmental parameters such as temperature, humidity, precipitation, wind etc.

The available SHA procedures for damage detection are classified into four levels as:

Level 1- Determination if the damage is present in a structure,

Level 2- Determination of the geometric location of the damage,

Level 3- Assessment of severity of the damage and

Level 4- Prediction of remaining (residual) life of the structure.

The condition survey and assessment will include the following components:

- Visual Inspection
- Non-Destructive Testing
- Ultrasonic Testing

2.2 Site Inspection Visit

The Consultant Team of Hydromechanical and Structural Experts visited the Farakka Lock during 07th – 09th April while the Condition Survey was in progress and inspected the existing navigation lock and its appurtenant structures. The purpose of the detailed site survey and inspection was to observe and record the present health status of the navigation lock.

Figure 2: Team of Experts with IWAI Officials during Site Inspection Visit

The following components were observed at the site:

A. Lock Gates (Mitre Gates) - Two Pairs forming the primary navigation gates for each end of Lock, each hinged about a vertical axis & operated via twin Wire rope Operating Mechanism.

B. Cassion Stoplogs Gate - Two Nos., intended to be floated into position to isolate mitre gates and lock structure for inspection, repair and maintenance.

C. Radial Gate - 4 no. at each end of F/E culverts to control the equalization of water. Each gate is operated using rope drum mechanism.

D. Bulkhead Gate – 8 nos., to isolate radial gates for Repair & Maintenance. These are slide type.

E. Lock Structure including the base slab and side walls to hold the water and allow for the passage of vessels

2.3 Condition Survey

2.2.1 Visual Inspection

Visual Inspection (VI), or visual testing (VT), is the oldest and most basic method of inspection. In its simplest form, visual inspection is the process of examining a component or piece of equipment using one's naked eye to look for flaws. Visual inspections are generally performed as a precursor to more advanced inspection techniques that are capable of detecting flaws beyond what the human eye can see, such as subsurface cracks. Optical aids such as illuminators, mirrors, borescopes, etc. can be used to enhance one's capability of visually inspecting equipment. Cameras, computer systems, and digital image analyzers can also be used to further the capabilities and benefits of visual inspection.

Remote Visual Inspection (RVI) is an advanced form of visual inspection that uses various types of videoprobes, video borescopes, remotely operated cameras, robotic crawlers, and other specialized tools in order to remotely examine components. In doing so, the risks associated with confined space entry are considerably reduced.

In recent years, Remotely Operated Vehicle, commonly known as ROV, have seen increased adoption and usage for remote visual inspections of underwater structures that are difficult to reach by traditional means. This proposed methodology for underwater inspection has various advantages over manual operations including the ability to inspect in dark and flooded areas, otherwise constricted and risky zones with unlimited endurance, enhanced stability, and reliable data acquisition with repeatability. The results can aid the authorities rapidly make key decisions concerning repair, maintenance, and safety of the structure.

2.2.2 Non-Destructive Testing: Ultrasonic Pulse Velocity Method

Non-destructive testing (NDT) methods are techniques used to obtain information about the properties or internal condition of an object without damaging the object. Non-destructive testing is a descriptive term used for the examination of materials and components in such way that allows materials to be examined without changing or destroying their usefulness.

The principal objectives of the non-destructive testing of concrete in situ are to assess one or more of the properties of structural concrete. The ultrasonic pulse velocity (UPV) method is used for non-destructive testing of plain, reinforced and prestressed concrete whether it is precast or cast in-situ.

An ultrasonic pulse velocity (UPV) test is an in-situ, non-destructive test to check the quality of concrete. It is used to examine the homogeneity, quality, cracks, cavities, and defects in concrete. In this test, the strength and quality of concrete or rock is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure. This test is conducted by passing a pulse of ultrasonic through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids.

Figure 3: Sample image of conducting UPV tests above water

The ultrasonic pulse is generated by an electro acoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed which includes longitudinal (compressional), shear (transverse) and surface (rayleigh) waves. The receiving transducer detects the onset of the longitudinal waves, which is the fastest. Any damage to the concrete will also be measured and recorded. The field measurement data is representative of the current state of the structure.

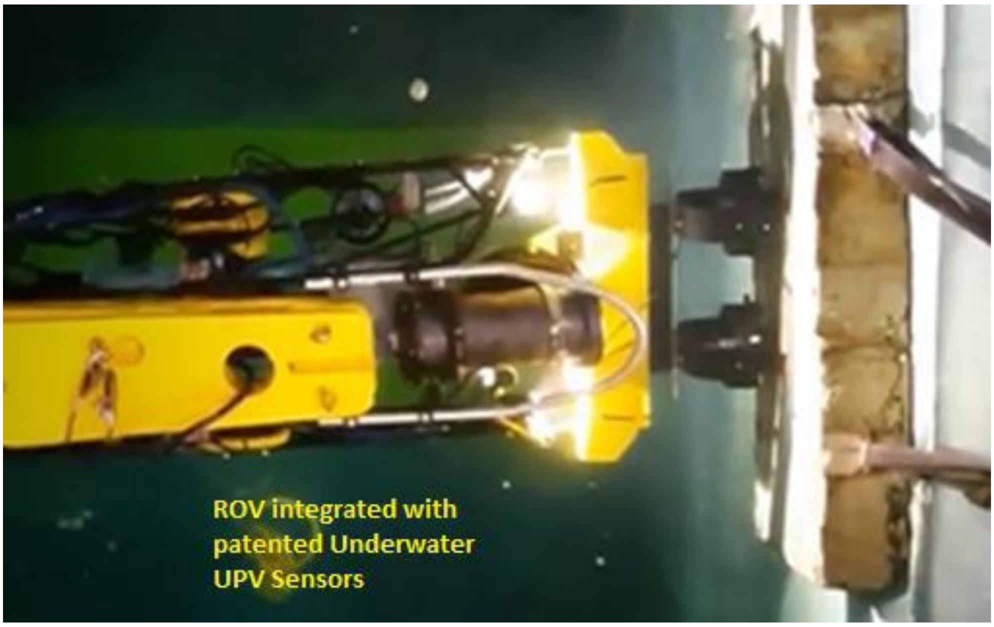


Figure 4: Sample image of conducting underwater UPV tests

Planys has built the World's first underwater UPV testing equipment and has conducted successful field trials for the same. This helps disrupts the underwater NDT world and thus supports authorities in charge of billions of aging submerged assets worldwide take decisions on repair and maintenance.

2.2.3 Inspection for Corrosion

Appropriate tools to assist in measuring and defining corrosion damage include a depth micrometer (for pitting), feeler gages (for crevice corrosion), an ultrasonic thickness gage (for thinning), a ball peen or instrumented hammer (for corroded or loose rivets), a camera, a tape measure, and a means to collect water samples. When corrosion is observed, the type, extent, severity, and possible cause should be reported. If the corrosion is severe, the specific locations should be noted and the severity (amount of thinning, etc.) should be quantitatively determined. Common NDT methods that can be applied for inspecting structures for corrosion damage include Visual Testing inspection and Ultrasonic Testing inspection.

The extent of paint system failure and regions of localized discoloration of structural components should be recorded. In areas where paint failure has occurred, the surface should be visually examined for pitting. When pitting is present, it should be quantified using a probe type depth gauge following guidance specified in ASTM G46.

Ultrasonic inspection is useful when corrosion appears to have caused significant thickness loss in critical components and can be used to obtain a baseline reference for thickness. The thickness of a steel plate or part can be determined to an accuracy of ±0.01 cm (0.005 in.). The technique can be performed through a paint film or through surface corrosion with only a slight loss in accuracy. Ultrasonic transducers are available in a number of sizes. Ultrasonic inspection is useful in determining both general and localized thickness loss due to corrosion, even on curved skin plates. Ultrasonic inspection can be used when only one side of a component is accessible. The open surface can be scanned with the transducer to identify thickness variation over the surface and to determine where corrosion has occurred. Ultrasonic inspection to determine thickness is generally not reliable when pitting corrosion is prevalent, because the size and depth of the pitting impair the output signal of the transducer.

Underwater Ultrasonic Thickness Gauging (UTG) technology can be used to determine the thickness of the steel material submerged under water. UTG sensor is attached in the front side of the ROV and integrated with the ROV systems. The ROV will be lowered at the Gate locations where UT measurements are to be performed and accordingly the ROV would will take readings across the all the submerged portions of the gate structures.

2.4 Proposed Condition Survey Tests

Based on the site reconnaissance and inputs from the condition survey team the following tests have been undertaken in order to assess the overall health of the navigational lock:

1. Underwater visual inspection (VI) of the lock chambers including the side walls and base slab, lock gates (mitre and radial gates) using Remotely Operated Vehicle.

2. To carry out above water and Underwater non-destructive tests of the concrete walls of Lock using Ultrasonic Pulse velocity (UPV) technology.

3. To carry out Underwater non-destructive tests of the steel gates walls (mitre gates) of lock using Ultrasonic Thickness Gauging (UTG) technology.

Area of Inspection	1. East & West side wall
	2. Base Slab
	3. Mitre Gate East side Gate 1 and 2
	4. Mitre Gate West side Gate 1 and 2
	5. Radial Gates
	6. Cassion Gate
	7. Bulkhead Gate

Table 1: Condition Survey Tests

3.0 Task description & Methodology

3.1 Operational Setup (Visual Inspection)

1	Area / Location	Gate 1- [East, West], Gate 2 - [East, West], Wall Section Area 1-48- [East, West], Radial Gate 1- (East, West), Radial Gate 2- (East, West).
	Control Station	Top of the walkway
	Position of Umbilical	Top of the walkway
	Method of Deployment	Manually from the Walkway
	Number of Dives	179
	Section Detail	1.Gate 1 East 2.Gate 1 West 3.Gate 2 East 4.Gate 2 West 5. Wall Section 1 to 6 6. Radial Gate
	Dive Locations	Gate-1 [East, West] - 30 Gate-2 [East, West] -30 Wall [East, West] -109 Radial Gate 1- (East, West) - 3 Radial Gate 2- (East, West) - 7
	Dive Details	Gate 1 East - (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O) Gate 1 West - (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O) Gate 2 East - (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O) Gate 2 West - (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O) Wall (1 to 84) Radial Gate 1- (East, West) Radial Gate 2- (East, West)
	Operation Duration (Days)	11 days (30-03-2022 to 09-04-2022)

	Number of crew Members	6
	Source of Power	Generator

Table 2: Operational Setup (Visual inspection)

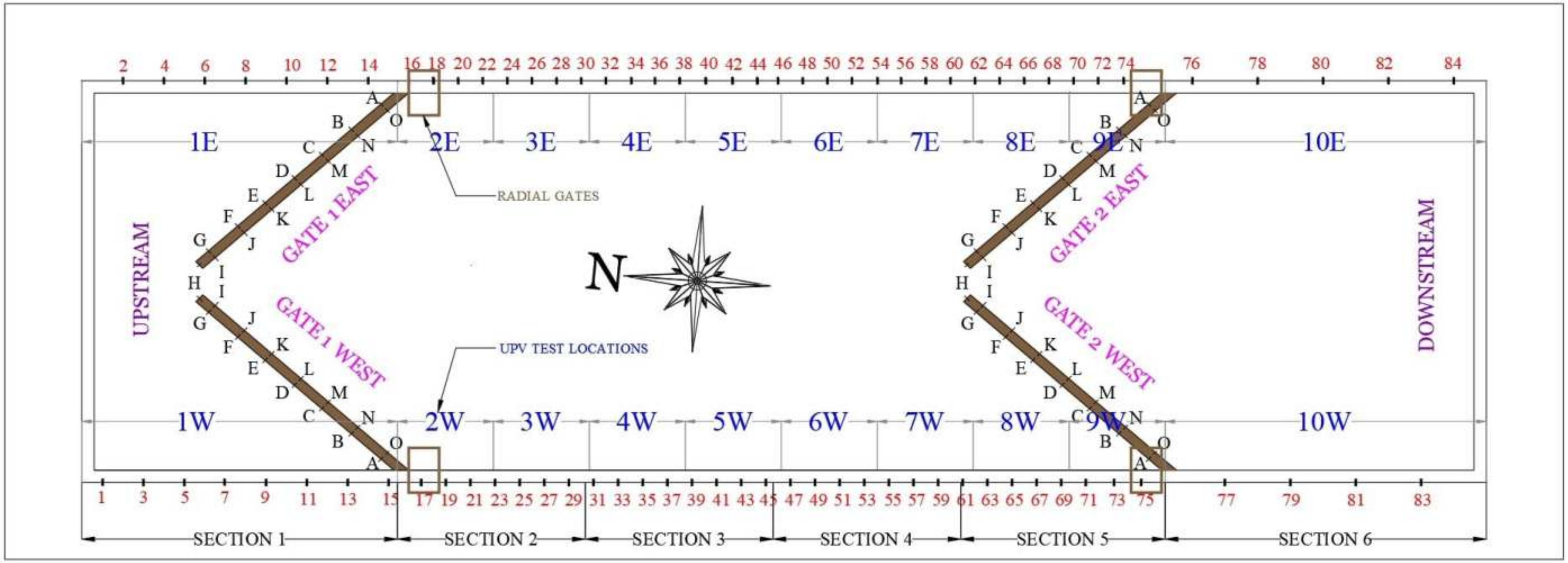


Figure 5: Plan View of the Farakka Navigational Lock

The lock structure and the mitre gates have been divided into sections and sub-sections for better representation and analysis of the data. The section and sub-section details are given in Figure 5.

4.0 Observations

4.1 Observations from underwater visual inspection

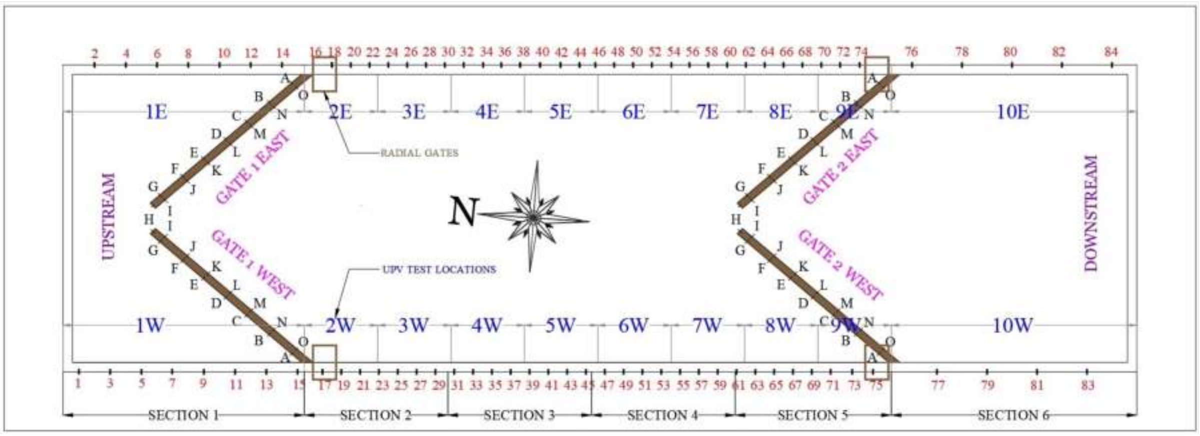


Figure 6: Plan View of inspected Unit of Farakka Navigational Lock

For the purpose of this report below Visual inspection's observations were classified into 3 categories based on its severity

1. Observations marked in Red ( ) markers termed as Major Observation
2. Observations marked in Orange ( ) markers termed as Moderate Observation
3. Observations marked in Yellow ( ) markers termed as Minor Observation

4.2 Observations from the Visual Inspection

4.2.1 Heatmap of observations at Gate1 East

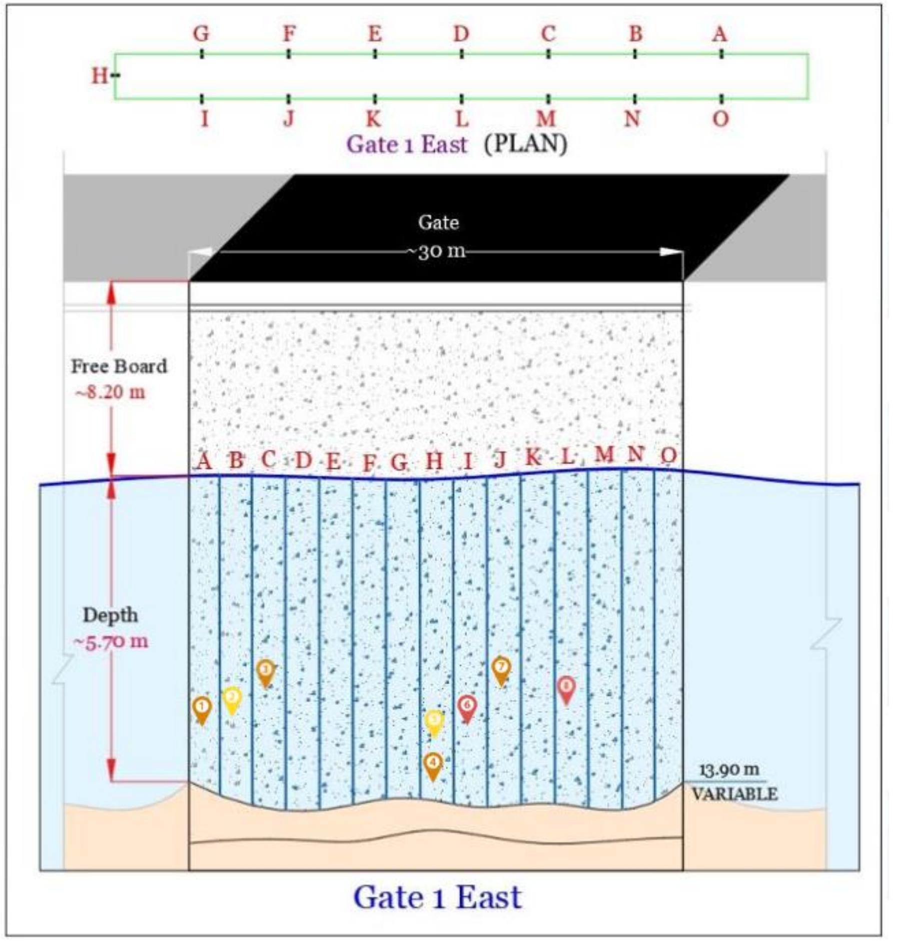


Figure 7: Heat map and Observations at Gate1 East

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O1	Cavity/Moderate	Gate 1 East B & 9.76	87.80 X 76.38	

O2	Cavity/Minor	Gate 1 East B & 9.06	54.64 X 46.97	
O3	Cavity/Moderate	Gate 1 East C & 8.33	120.00 X 97.13	

04	Cavity/Moderate	Gate 1 East H & 12.38	110.60 X 30.64	
05	Cavity/Minor	Gate 1 East H & 10.12	43.96 X 43.04	

06	Corrosion/Major	Gate 1 East I & 8.95	234.57 X 110.44	
07	Corrosion/Moderate	Gate 1 East J & 8.73	149.23 X 65.81	

08	Corrosion/Major	Gate 1 East L & 8.92	159.81 X 85.84	

Table 6: Observation details at Gate1 East

4.2.2 Heatmap of observations at Gate1 West

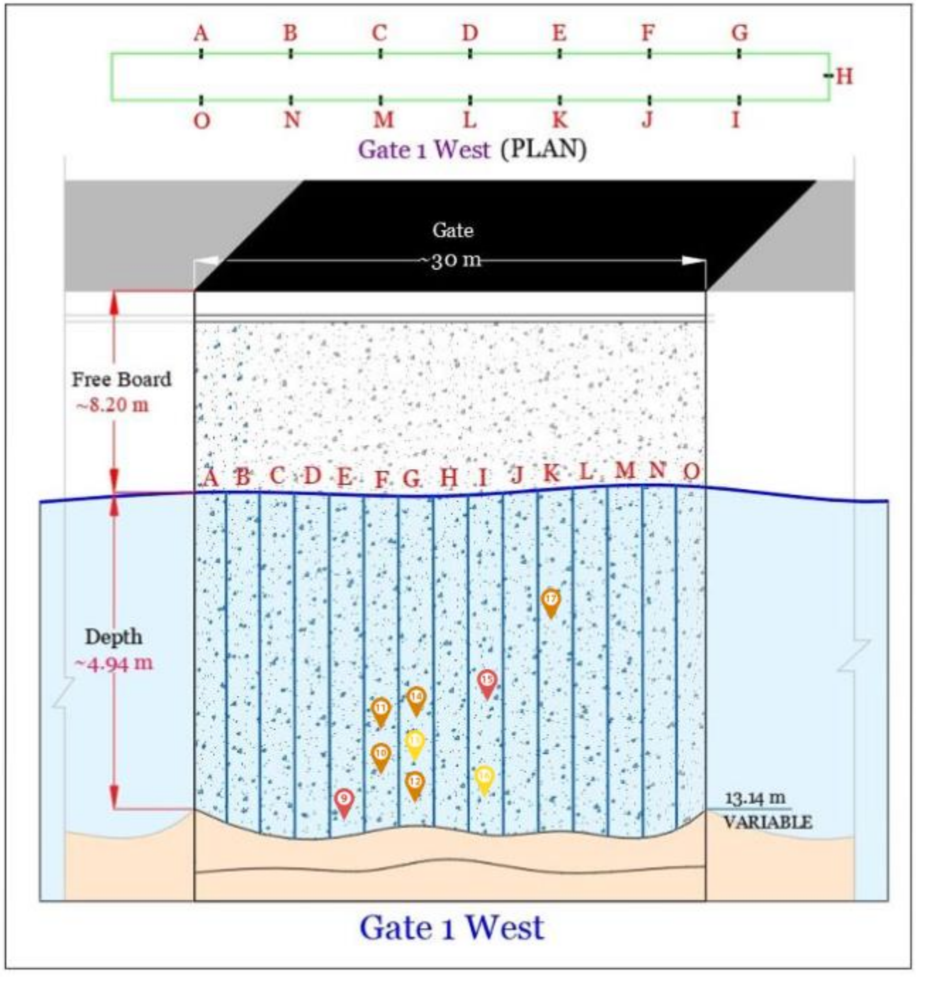


Figure 8: Heat map and Observations at Gate1 West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O9	Corrosion/Major	Gate 1 West E & 12.46	196.43 X 92.03	

O10	Cavity/Moderate	Gate 1 West F & 9.98	98.72 X 49.99	
O11	Cavity/Moderate	Gate 1 West F & 8.54	118.98 X 38.57	

O12	Cavity/Moderate	Gate 1 West H & 11.69	95.27 X 52.03	
O13	Cavity/Minor	Gate 1 West H & 9.78	44.40 X 27.23	

O14	Cavity/Moderate	Gate 1 West H & 9.25	132.39 X 15.39	
O15	Corrosion/Major	Gate 1 West I & 8.64	277.65 X 129.33	

O16	Corrosion/Minor	Gate 1 West I & 11.50	55.91 X 39.77	
O17	Corrosion/Moderate	Gate 1 West K & 7.21	149.87 X 70.47	

Table 7: Observation details at Gate1 West

4.2.3 Heatmap of observations at Gate2 East

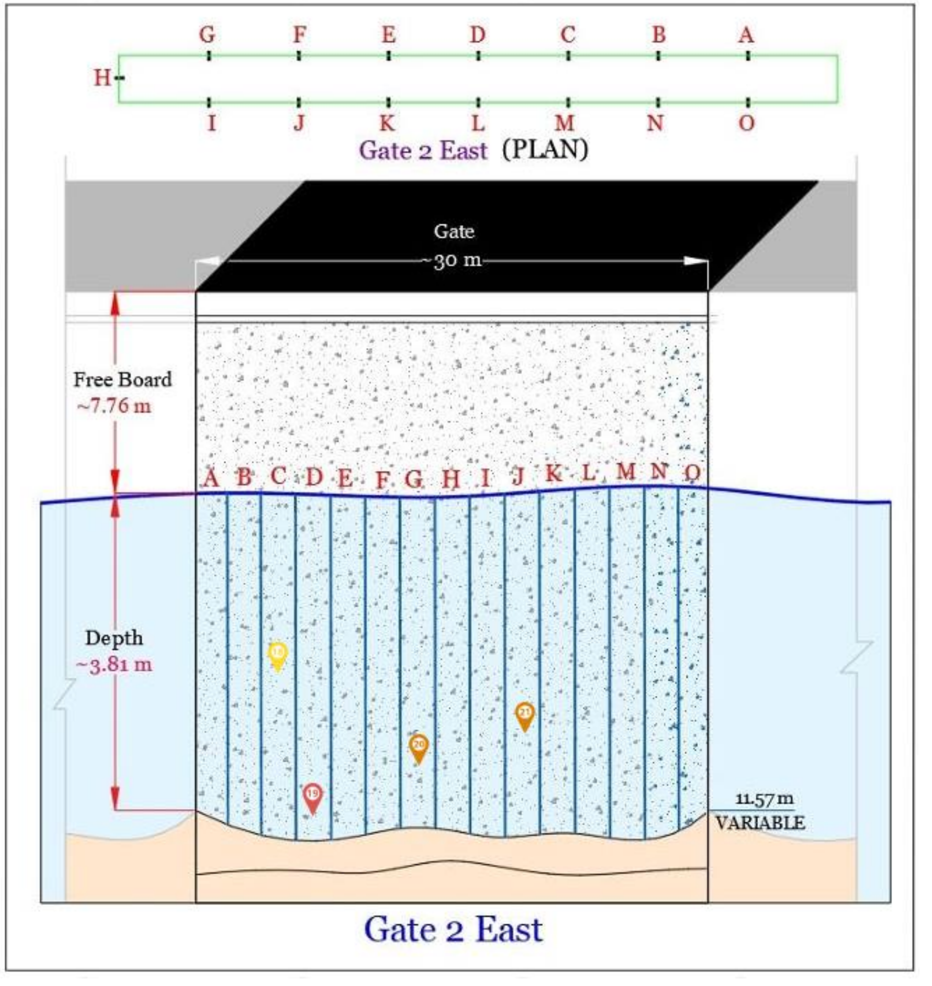


Figure 9: Heat map and Observations at Gate2 East

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O18	Cavity/Minor	Gate 2 East C & 9.13	69.73 X 67.07	

O19	Corrosion/Major	Gate 2 East D & 11.03	162.15 X 75.77	
O20	Surface Deformation/Moderate	Gate 2 East G & 10.23	187.42 X 53.73	

O21	Cavity/Moderate	Gate 2 East J & 9.44	87.42 X 42.24	

Table 8: Observation details at Gate2 East

4.2.4 Heatmap of observations at Gate2 West

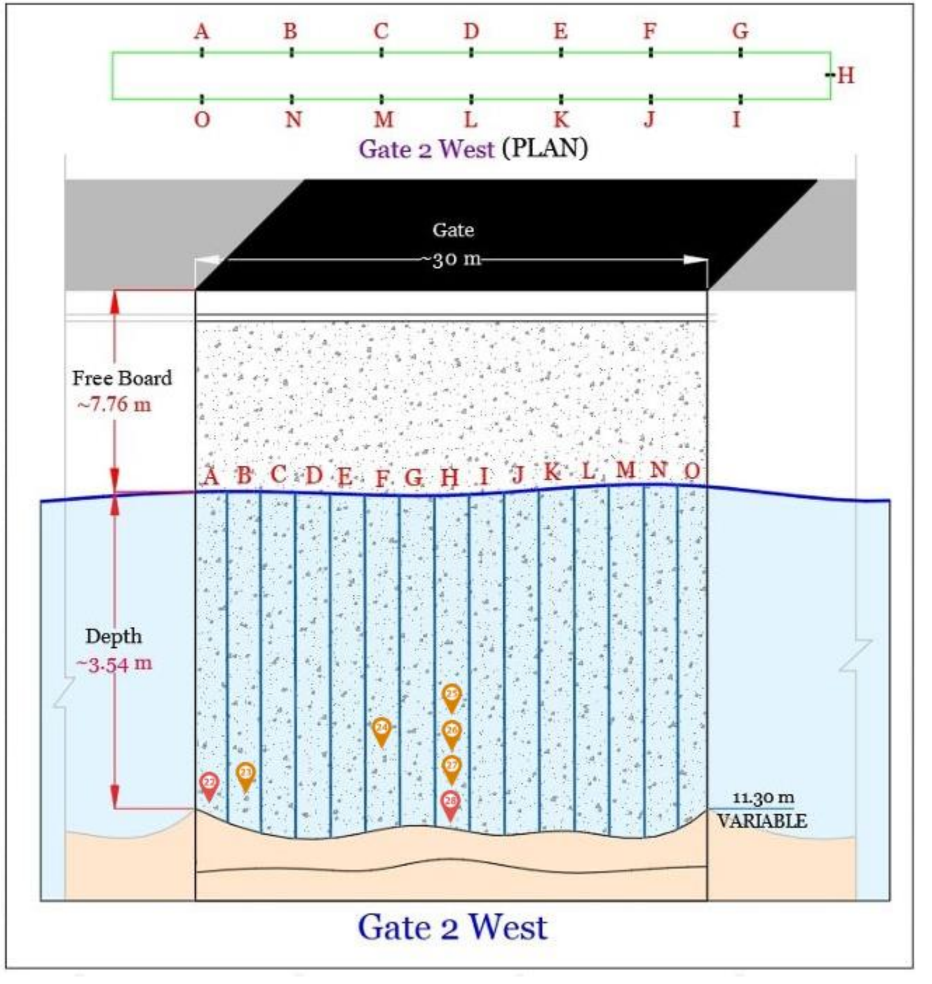


Figure 10: Heat map and Observations at Gate2 West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O22	Corrosion/Major	Gate 2 West A & 9.81	171.85 X 89.64	

O23	Cavity/Moderate	Gate 2 West B & 9.64	76.31 X 32.51	
O24	Corrosion/Moderate	Gate 2 West F & 8.62	70.26 X 61.27	

O25	Cavity/Moderate	Gate 2 West H & 7.75	138.13 X 65.34	
O26	Cavity/Moderate	Gate 2 West H & 8.62	102.24 X 84.16	

O27	Cavity/Moderate	Gate 2 West H & 9.00	75.12 X 63.83	
O28	Cavity/Major	Gate 2 West H & 9.65	99.19 X 26.32	

Table 9: Observation details at Gate2 West

4.2.5 Heatmap of observations at Wall Section 1 West

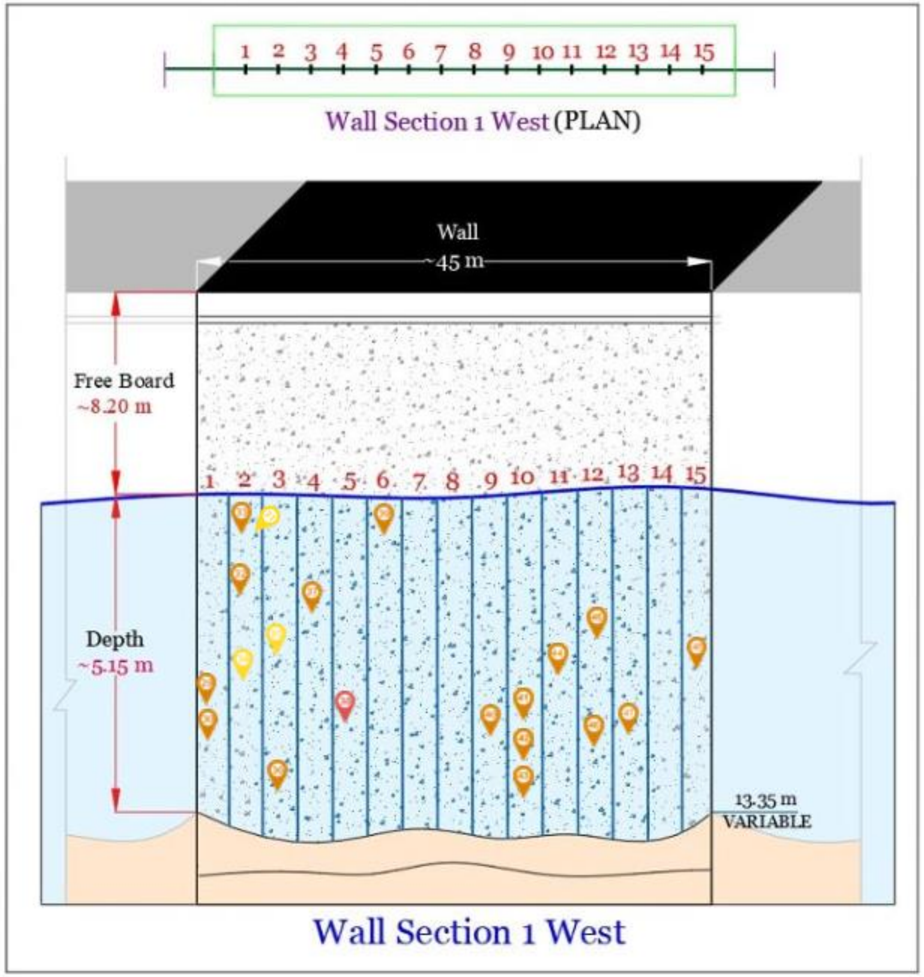


Figure 11: Heat map and Observations at Wall Section 1 West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O29	Crack/Moderate	Wall West 1 & 11.33	80.62 X 9.30	

O30	Surface Deformation/Moderate	Wall West 1 & 11.90	113.25 X 38.39	
O31	Cavity/Minor	Wall West 2 & 8.21	37.54 X 34.90	

O32	Cavity/Moderate	Wall West 2 & 8.85	83.77 X 67.78	
O33	Cavity/Moderate	Wall West 2 & 8.21	87.23 X 84.20	

O34	Surface Deformation/Minor	Wall West 2 & 10.70	71.85 X 14.04

O35	Pin Holes/Minor	Wall West 3 & 10.59	174.79 X 108.87

O36	Crack/Moderate	Wall West 3 & 12.04	118.71 X 11.91	
O37	Crack/Moderate	Wall West 4 & 10.67	118.59 X 82.63	

O38	Crack/Major	Wall West 5 & 11.04	188.83 X 57.08
O39	Honeycomb Formation/Moderate	Wall West 6 & 8.37	142.45 X 87.23

O40	Cavity/Moderate	Wall West 9 & 11.47	70.49 X 40.68	
O41	Crack/Moderate	Wall West 10 & 11.45	136.89 X 114.22	

O42	Cavity/Moderate	Wall West 10 & 12.22	100.33 X 68.68	
O43	Honeycomb Formation/Moderate	Wall West 10 & 12.73	139.45 X 65.59	

044	Crack/Moderate	Wall West 11 & 11.11	94.38 X 10.76	
045	Crack/Moderate	Wall West 12 & 10.20	129.40 X 80.19	

046	Crack/Moderate	Wall West 12 & 11.37	140.77 X 19.18	
047	Honeycomb Formation/Moderate	Wall West 13 & 11.25	131.74 X 61.66	

O48	Surface Deformation/Moderate	Wall West 15 & 10.44	172.51 X 150.60	

Table 10: Observation details at Wall Section 1 West

4.2.6 Heatmap of observations at Wall Section 1 East

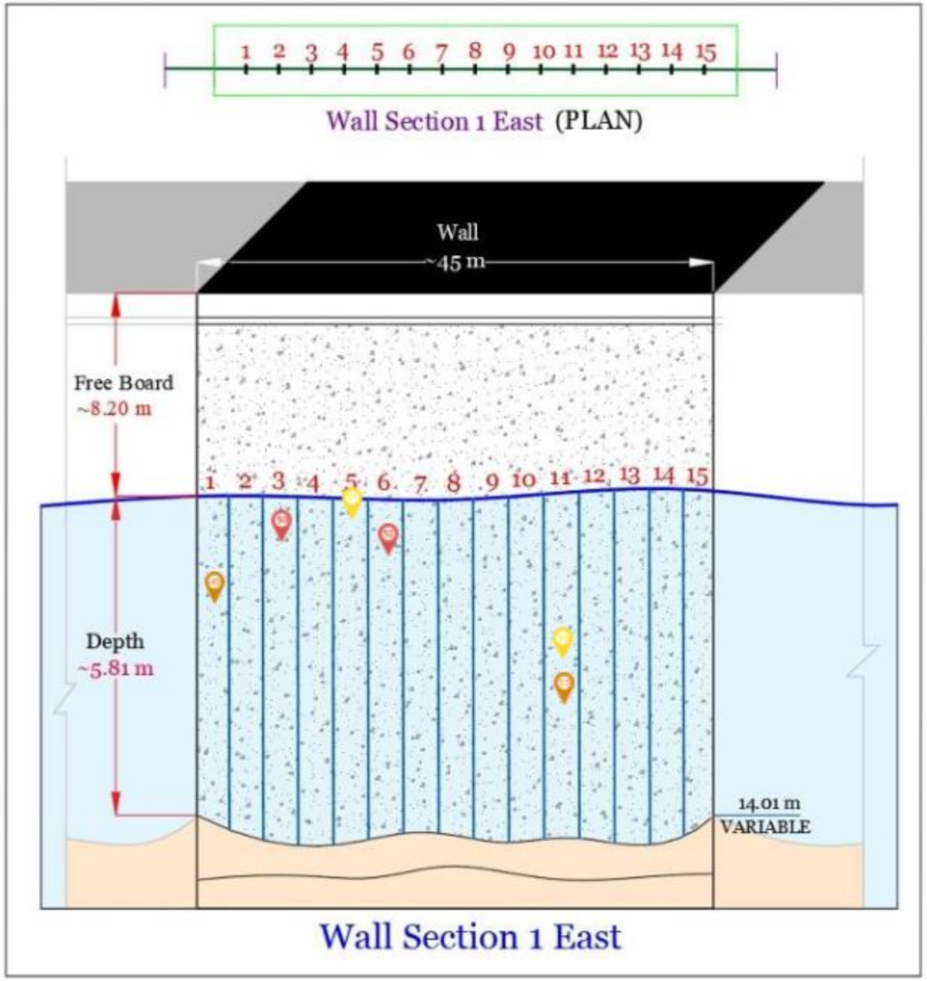


Figure 12: Heat map and Observations at Wall Section 1 East

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O49	Surface Deformation/Moderate	Wall East 1 & 10.55	216.56 X 101.27	

O50	Cavity/Major	Wall East 3 & 8.98	194.85 X 23.67	
O51	Debonding Between Two Layers/Minor	Wall East 5 & 8.19	67.88 X 22.05	

O52	Cavity/Major	Wall East 6 & 8.98	186.88 X 101.82	
O53	Crack/Moderate	Wall East 11 & 10.75	110.26 X 14.48	

O54	Cavity/Minor	Wall East 11 & 10.87	43.41 X 21.76	

Table 11: Observation details at Wall Section 1 East

4.2.7 Heatmap of observations at Wall Section 2 East & West

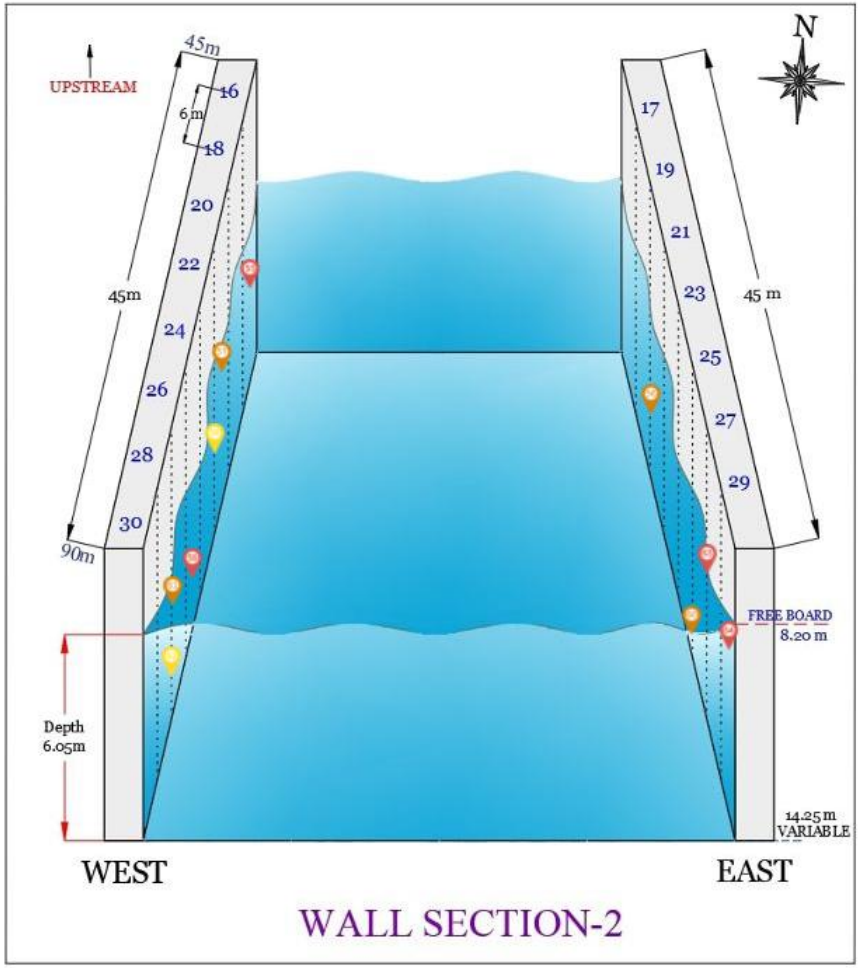
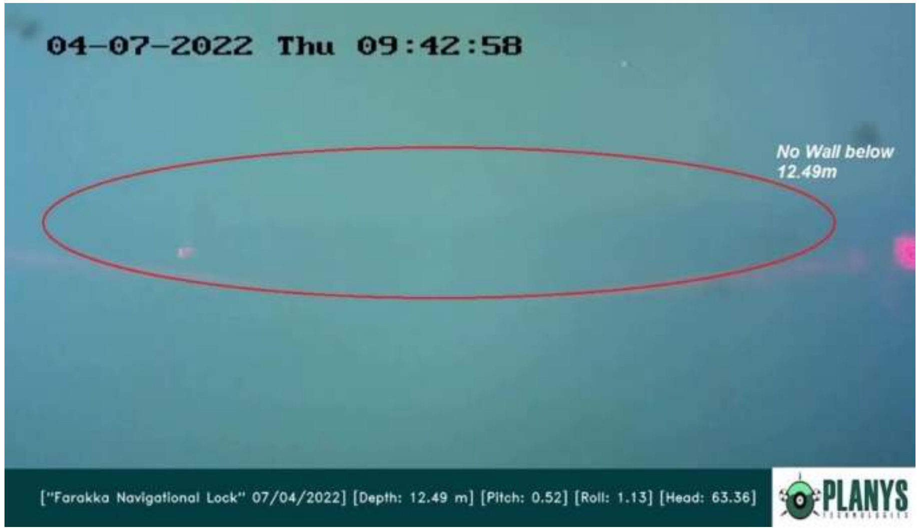


Figure 13: Heat map and Observations at Wall Section 2 East & West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O55	Honeycomb Formation/Major	Wall West 16East 16 & 9.75	207.65	

O56	Cavity and Honeycomb Formation/Moderate	Wall East19 West 19 & 9.71	142.46 X 66.60	
O57	Honeycomb Formation/Moderate	Wall West 20 East 20 & 8.51	133.40 X 71.64	

O58	Cavity/Minor	Wall West 20 East 20 & 10.13	28.49 X 26.28	
O59	No Wall/Major	Wall West 23 East 23 & 12.49	NA X NA	

O60	Surface Deformation/Moderate	Wall West 25 East 25 & 13.94	124.59 X 58.77	
O61	Cavity/Moderate	Wall West 27 East 27 & 8.98	78.62 X 45.07	

O62	Cavity/Minor	Wall West 27 East 27 & 10.24	68.06 X 18.46	
O63	Cavity and Honeycomb Formation/Major	Wall West 27 East 27 & 8.20	292.21 X 141.25	

064	Cavity/Major	Wall East 30 West 30 & 8.67	263.99 X 63.81	

Table 12: Observation details at Wall Section 2 East & West

4.2.8 Heatmap of observations at Wall Section 3 East & West

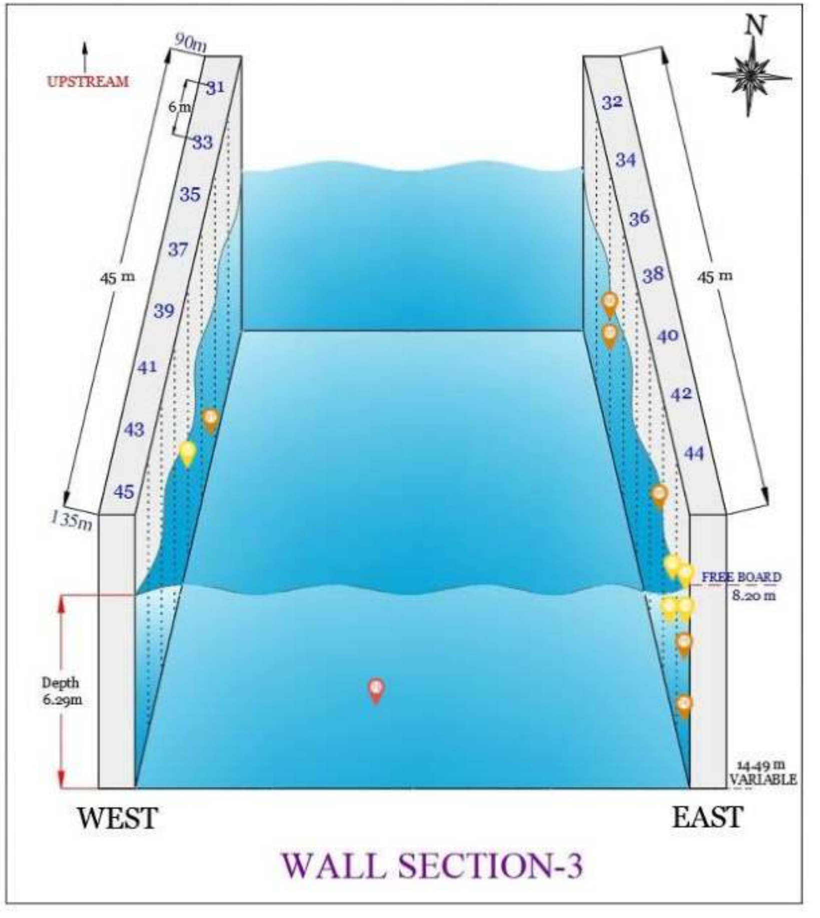


Figure 14: Heat map and Observations at Wall Section 3 East & West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O65	Cavity/Moderate	Wall West 34 East 34 & 9.93	146.89 X 57.70	

O66	Surface Deformation/Moderate	Wall West 34 East 34 & 8.42	171.34 X 54.94	
O67	Surface Deformation/Moderate	Wall East 35 West 35 & 13.54	109.03 X 66.33	

O68	Cavity/Minor	Wall West 38 East 38 & 8.53	64.74 X 35.66	
O69	Surface Deformation/Moderate	Wall East 41 West 41 & 9.06	150.63 X 55.24	

O70	Cavity/Minor	Wall East 43 West 43 & 8.53	46.81 X 36.97	
O71	Debris/Minor	Wall West 44 East 44 & 13.51	NA X NA	

O72	Cavity/Minor	Wall West 44 East 44 & 8.42	44.89 X 28.91	
O73	Surface Deformation/Minor	Wall West 44 East 44 & 8.96	74.05 X 28.13	

074	Cavity/Minor	Wall East 45 West 45 & 9.62	63.29 X 43.15
075	Cavity/Moderate	Wall East 45 West 45 & 10.18	118.00 X 73.12

O76	Debonding Between Two Layers/Moderate	Wall East 45 West 45 & 13.85	77.32 X 43.99	

Table 13: Observation details at Wall Section 3 East & West

4.2.9 Heatmap of observations at Wall Section 4 East & West

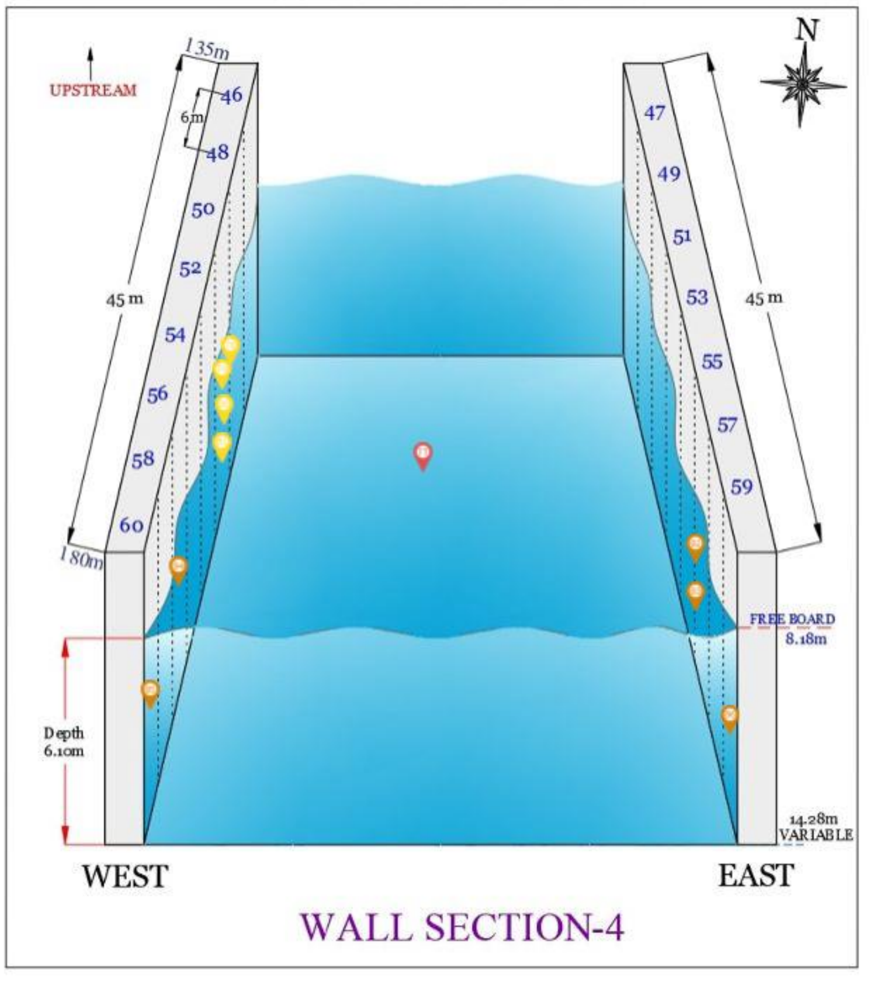


Figure 15: Heat map and Observations at Wall Section 4 East & West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O77	Rebar Protruding/Minor	Wall East49 West49 & 13.34	NA X NA	

078	Pin Holes/Minor	Wall East49 West49 & 9.91	65.57 X 47.31	
079	Cavity/Minor	Wall West50 East50 & 8.76	44.25 X 21.98	

080	Cavity/Minor	Wall West50 East50 & 9.66	32.21 X 20.08
081	Cavity/Minor	Wall West52 East52 & 8.20	64.67 X 42.00

082	Crack/Moderate	Wall East55 West55 & 8.79	128.52 X 17.49	
083	Crack/Moderate	Wall East55 West55 & 10.50	113.85 X 13.00	

084	Honeycomb Formation/Moderate	Wall East55 West55 & 9.99	125.86 X 60.27	
085	Cavity and Honeycomb Formation/Moderate	Wall West60 East60 & 9.68	135.78 X 65.8	

086	Cavity/Moderate	Wall West60 East60 & 10.97	89.41 X 79.46	

Table 14: Observation details at Wall Section 4 East & West

4.2.10 Heatmap of observations at Wall Section 5 East & West

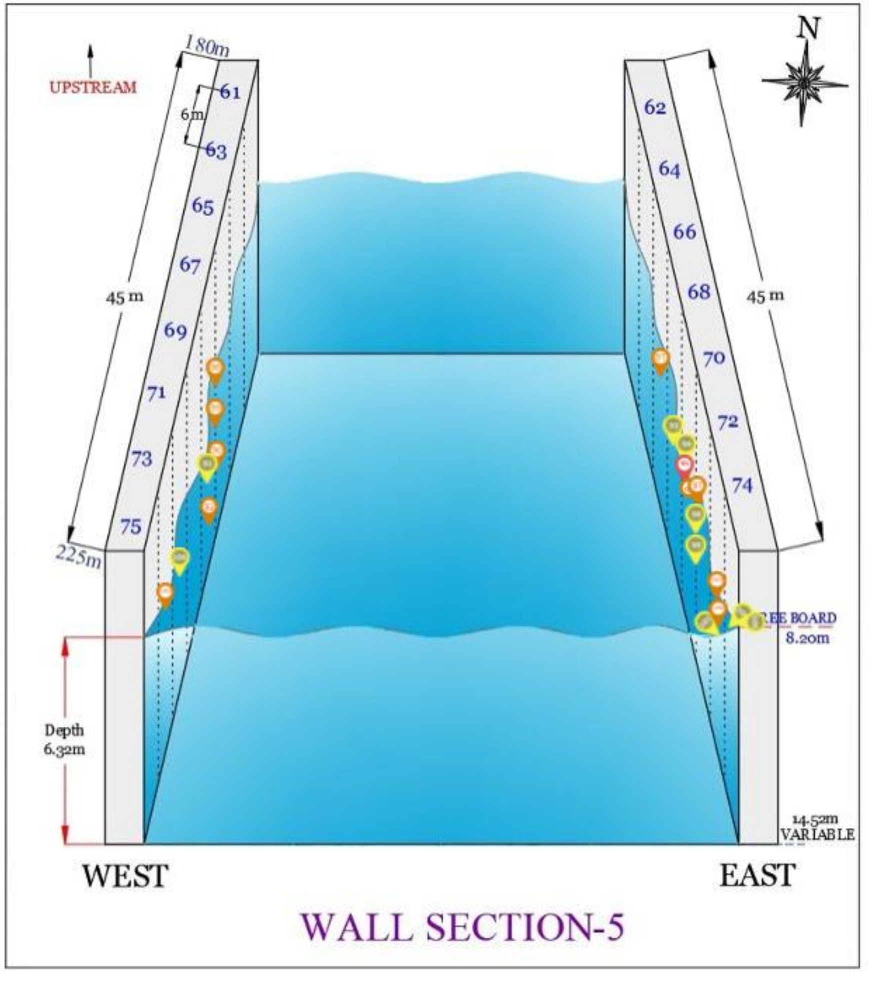


Figure 16: Heat map and Observations at Wall Section 5 East & West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O87	Cavity and Honeycomb Formation/Moderate	Wall East65 & 9.62	119.06 X 64.69	

088	Cavity/Moderate	Wall East66 West66 & 9.08	88.9 X 28.74	
089	Surface Deformation/Moderate	Wall East66 West66 & 12.57	116.97 X 103.46	

O90	Debonding Between Two Layers/Moderate	Wall East66 West66 & 12.02	81.34 X 18.35	
O91	Cavity/Minor	Wall West67 East67 & 8.57	56.53 X 26.27	

O92	Surface Deformation/Moderate	Wall West67 East67 & 11.98	114.08 X 97.8	
O93	Crack/Minor	Wall West67 East67 & 10.24	67.23 X 15.98	

094	Cavity/Minor	Wall East68 West68 & 9.08	21.03 X 20.26	
095	Cavity/Major	Wall East68 West68 & 9.17	194.39 X 46.38	

O96	Crack/Moderate	Wall East70 West70 & 8.21	80.39 X 17.87	
O97	Cavity/Moderate	Wall East70 West70 & 8.22	71.99 X 22.89	

O98	Surface Deformation/Minor	Wall East70 West70 & 9.97	95.13 X 76.31	
O99	Cavity/Minor	Wall East70 West70 & 10.13	26.85 X 25.55	

O100	Cavity/Minor	Wall East71 West71 & 8.65	36.01 X 35.33	
O101	Cavity/Minor	Wall East72 West72 & 10.01	30.72 X 19.09	

O102	Cavity/Moderate	Wall East72 West72 & 8.72	149.88 X 44.85	
O103	Cavity/Moderate	Wall East73 West73 & 8.73	143.90 X 20.70	

O104	Cavity/Minor	Wall East73 West73 & 8.81	50.17 X 38.71
O105	Cavity/Minor	Wall East73 West73 & 8.81	38.10 X 19.15

O106	Cavity/Moderate	Wall East73 West73 & 8.81	143.19 X 46.48	

Table 15: Observation details at Wall Section 5 East & West

4.2.11 Heatmap of observations at Wall Section 6 East

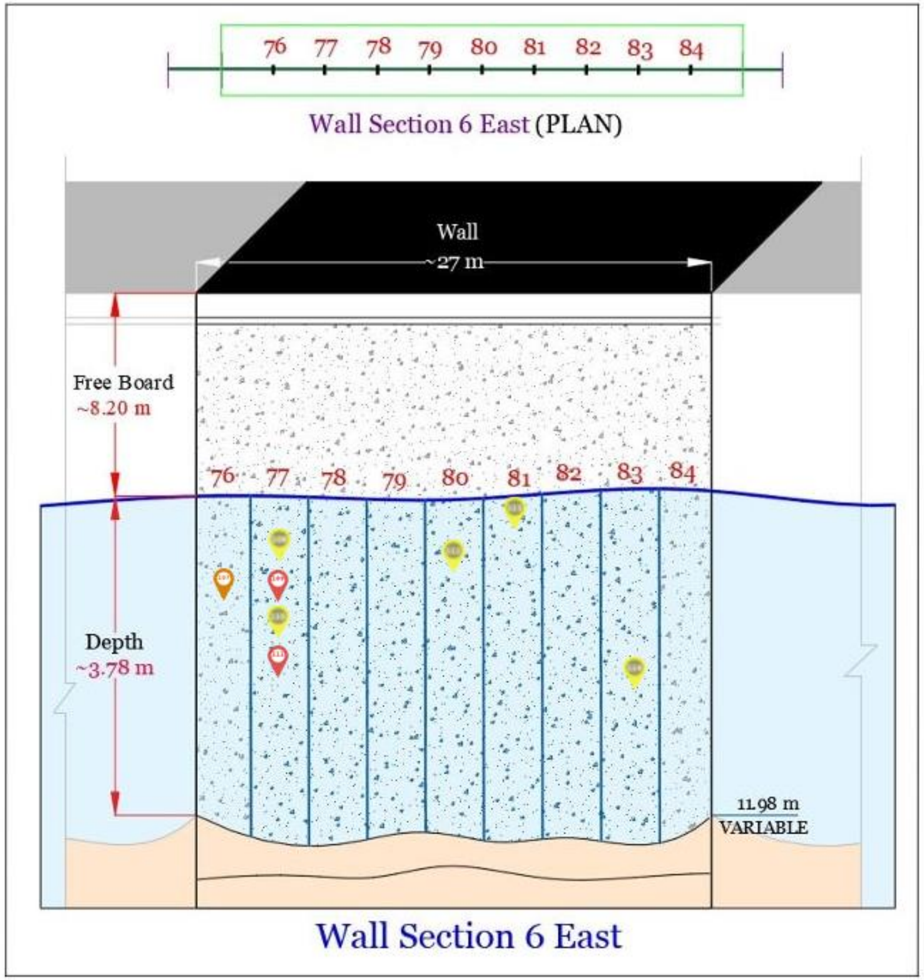


Figure 17: Heat map and Observations at Wall Section 6 East

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O107	Crack/Moderate	Wall East76 & 9.16	146.42 X 31.76	

O108	Debris/Minor	Wall East77 & 8.67	NA X NA	
O109	Cavity/Major	Wall East77 & 9.05	307.88 X 91.34	

O110	Cavity/Minor	Wall East77 & 9.41	32.78 X 30.13	
O111	Cavity/Major	Wall East77 & 10.24	152.28 X 62.16	

O112	Pin Holes/Minor	Wall East80 & 9.81	29.71 X 13.73	
O113	Pin Holes/Minor	Wall East81 & 8.64	24.55 X 20.61	

O114	Pin Holes/Minor	Wall East83 & 9.61	35.80 X 16.81	

Table 16: Observation details at Wall Section 6 East

4.2.12 Heatmap of observations at Wall Section 6 West

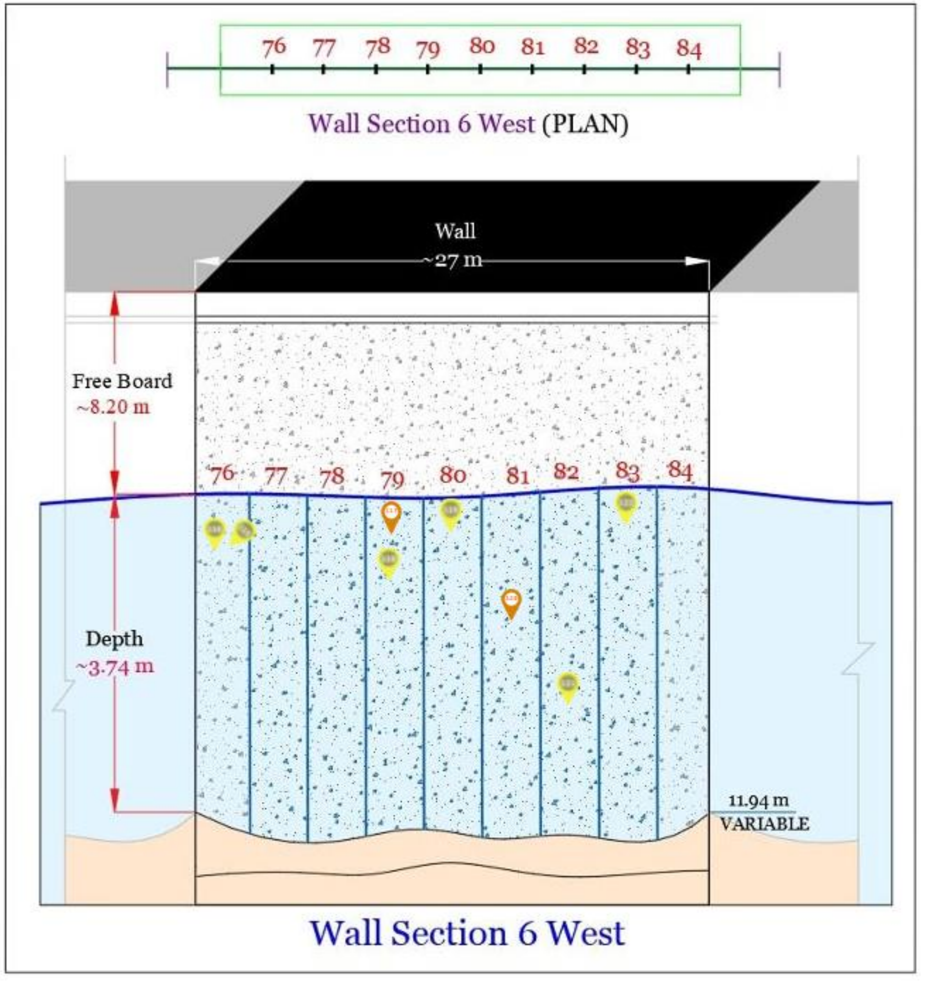


Figure 18: Heat map and Observations at Wall Section 6 West

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
O115	Cavity/Minor	Wall West76 & 9.91	42.45 X 21.53	

O116	Cavity/Minor	Wall West76 & 9.91	26.07 X 16.26	
O117	Cavity/Moderate	Wall West79 & 8.39	81.15 X 35.77	

O118	Cavity/Minor	Wall West79 & 8.84	63.96 X 30.49	
O119	Cavity/Minor	Wall West80 & 8.21	48.34 X 41.53	

O120	Cavity/Moderate	Wall West81 & 9.77	102.70 X 39.40	
O121	Surface Deformation/Minor	Wall West82 & 11.71	96.36 X 59.30	

O122	Pin Holes/Minor	Wall West83 & 8.60	31.93 X 22.17	

Table 17: Observation details at Wall Section 6 West

4.2.13 Heatmap of observations at Wall Bottom Section 16 - 30

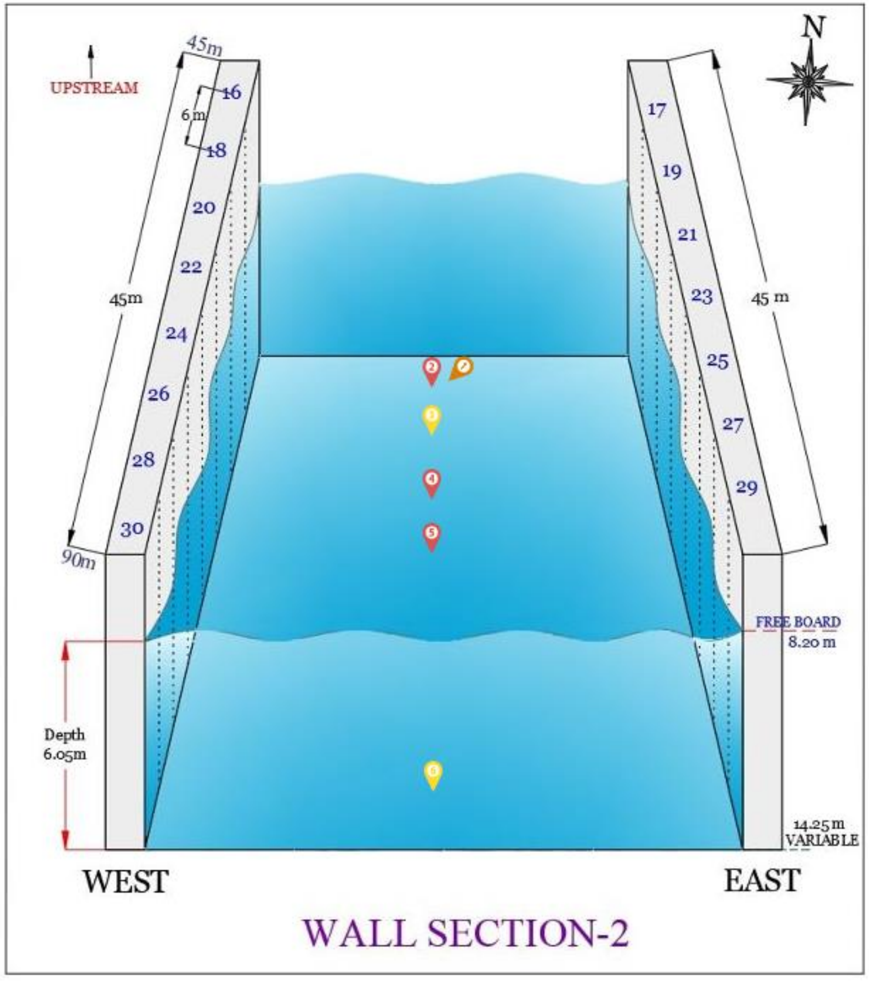


Figure 19: Heat map and Observations at Wall Bottom Section 16 - 30

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
B1	Cavity/Moderate	Wall Bottom 16	106.51 X 48.93	

B2	Rebar Protruding/Major	Wall Bottom 16	NA X NA	
B3	Surface Deformation/Minor	Wall Bottom 17	307.25 X 104.13	

B4	Surface Deformation/Major	Wall Bottom 20	306.88 X 143.52	
B5	Cavity/Major	Wall Bottom 22	195.05 X 142.98	

B6	Construction Debris/Minor	Wall Bottom 29	NA X NA	

Table 18: Observation details at Wall Bottom Section 16 - 30

4.2.14 Heatmap of observations at Wall Bottom Section 31 - 45

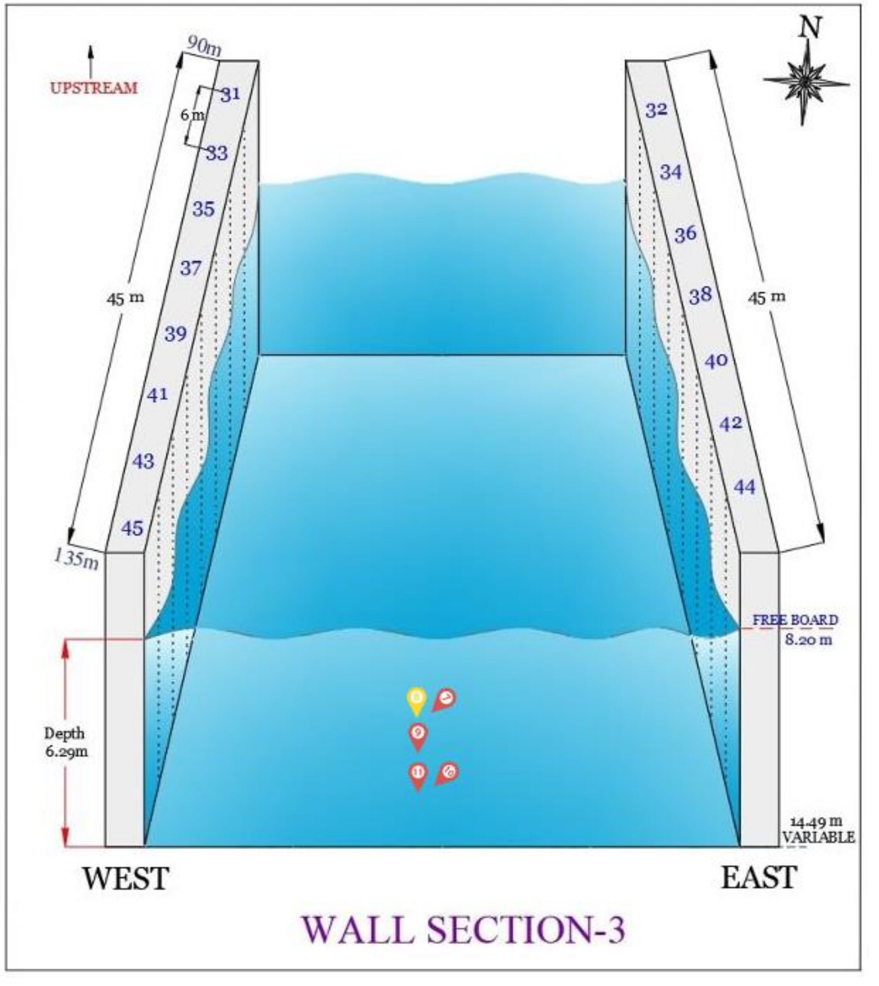


Figure 20: Heat map and Observations at Wall Bottom Section 31 - 45

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
B7	Rebar Protruding/Major	Wall Bottom 41	NA X NA	

B8	Fishing Net/Minor	Wall Bottom 41	NA X NA	
B9	Cavity/Major	Wall Bottom 42	379.86 X 178.09	

<table>
<tr><td>B10</td><td>Cavity/Major</td><td>Wall Bottom 43</td><td>247.08 X 144.57</td><td>
</td></tr>
<tr><td>B11</td><td>Cavity/Major</td><td>Wall Bottom 43</td><td>259.04 X 119.58</td><td>
</td></tr>
</table>

Table 19: Observation details at Wall Bottom Section 31 - 45

4.2.15 Heatmap of observations at Wall Bottom Section 46 - 60

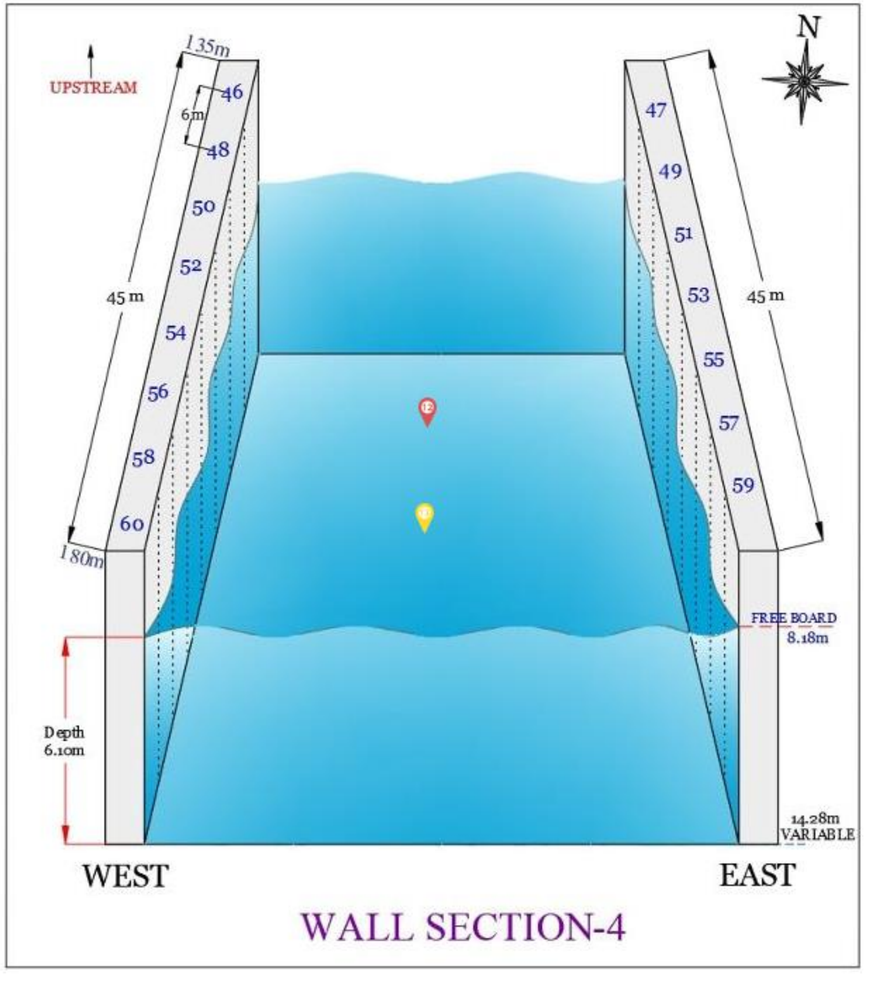
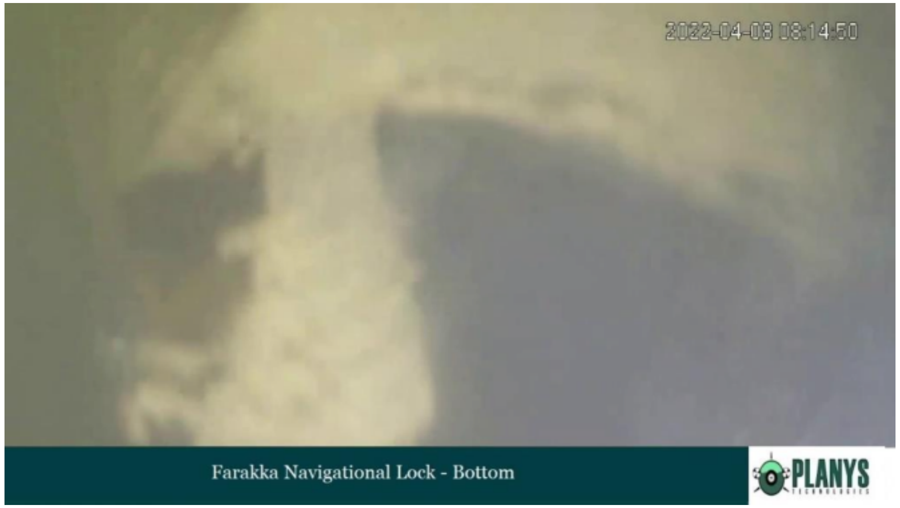


Figure 21: Heat map and Observations at Wall Bottom Section 46 - 60

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
B12	Rebar Protruding/Major	Wall Bottom 49	NA X NA	

B13	Construction Debris/Minor	Wall Bottom 52	NA X NA	

Table 20: Observation details at Wall Bottom Section 46 - 60

4.2.16 Heatmap of observations at Wall Bottom Section 61 - 75

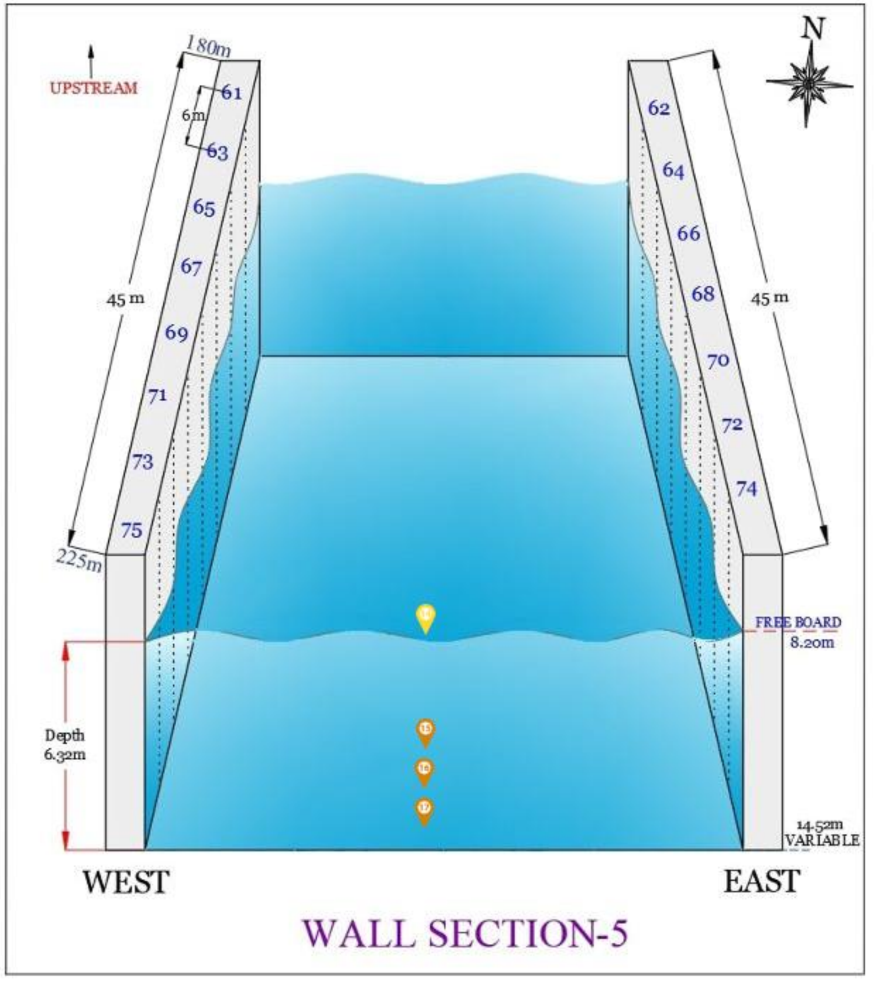
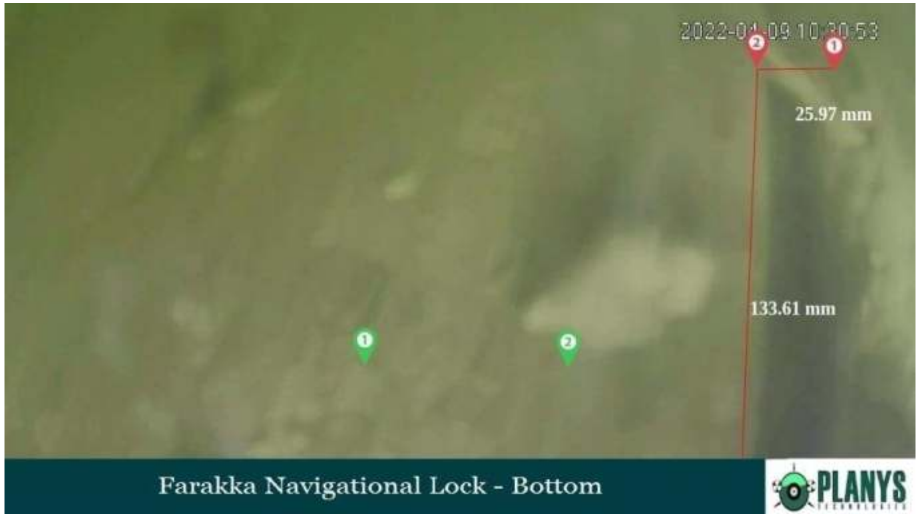


Figure 22: Heat map and Observations at Wall Bottom Section 61 - 75

ID	Observation Type	Observation Details		Observations
		Location & Depth(m)	Dimension of Observations (L x W) (mm)	
B14	Construction Debris/Minor	Wall Bottom 70	NA X NA	

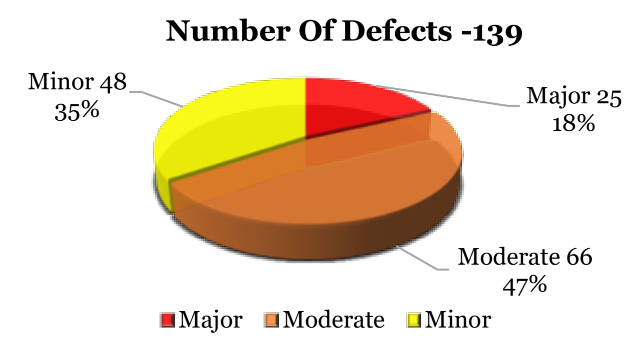
B15	Cavity/Moderate	Wall Bottom 73	75.32 X 72.17	
B16	Debonding Between Two Layers/Moderate	Wall Bottom 74	133.61 X 25.97	

B17	Cavity/Moderate	Wall Bottom 75	120.23 X 67.59	

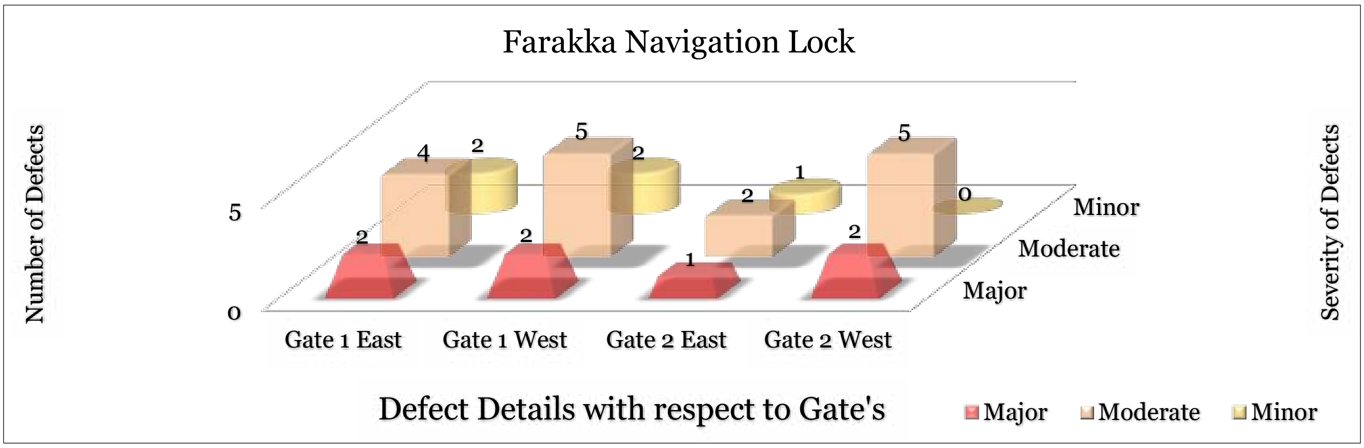
Table 21: Observation details at Wall Bottom Section 61 - 75

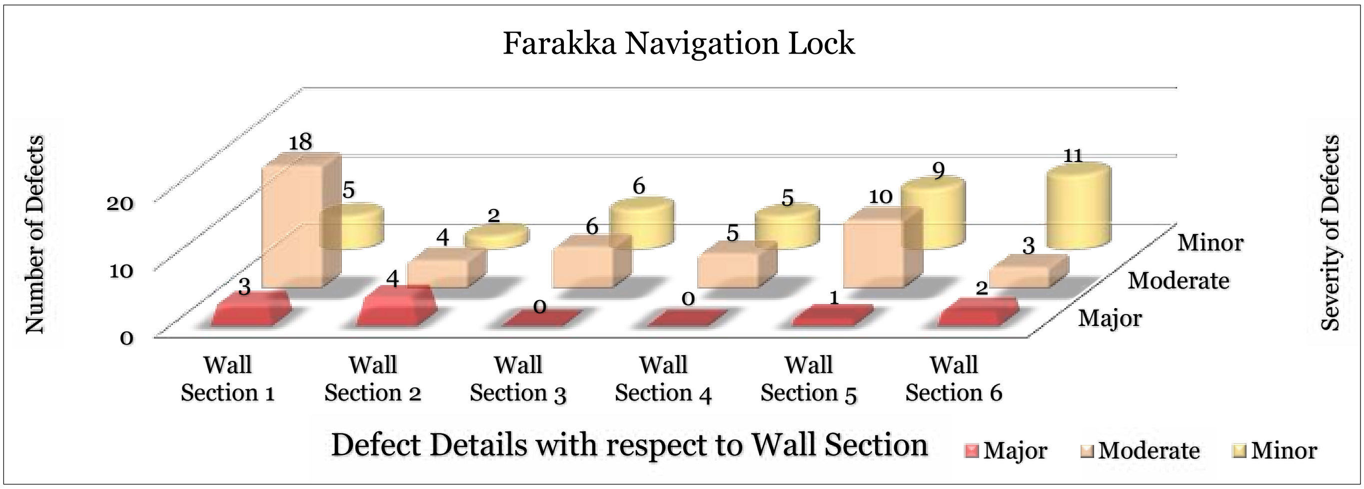
Visual Inspection Summary

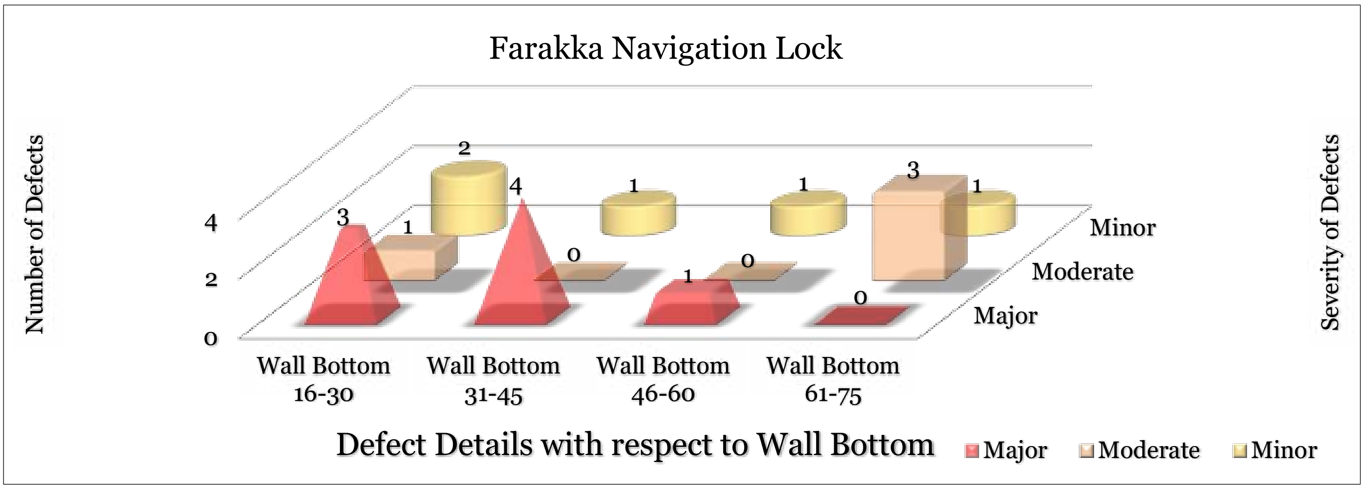
Area of interest		Structural Audit of Farakka Navigational Lock	
Inspection Method		1.Underwater Visual Inspection 2.UT test 3.UPV	
Equipment Used	ROV Beluga (Refer Appendix 7.B)	Date/Duration	30-03-2022 to 09-04-2022
Crew Size	6 members (Refer Appendix 7.A)	Underwater Visibility	Good



Category of Defect	Type of Defects Observed
Major	Cavity, Honeycomb
Moderate	Surface Deformation
Minor	Debris

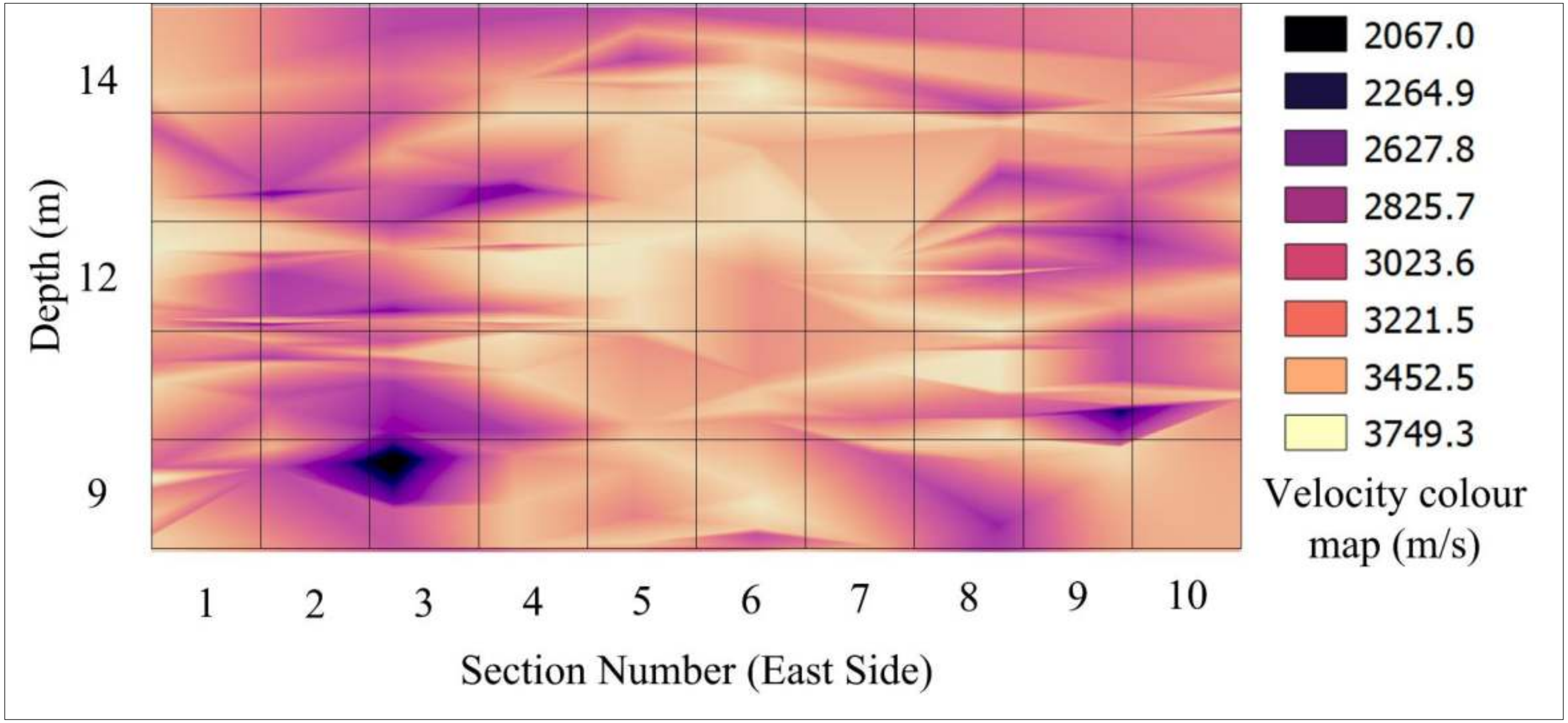




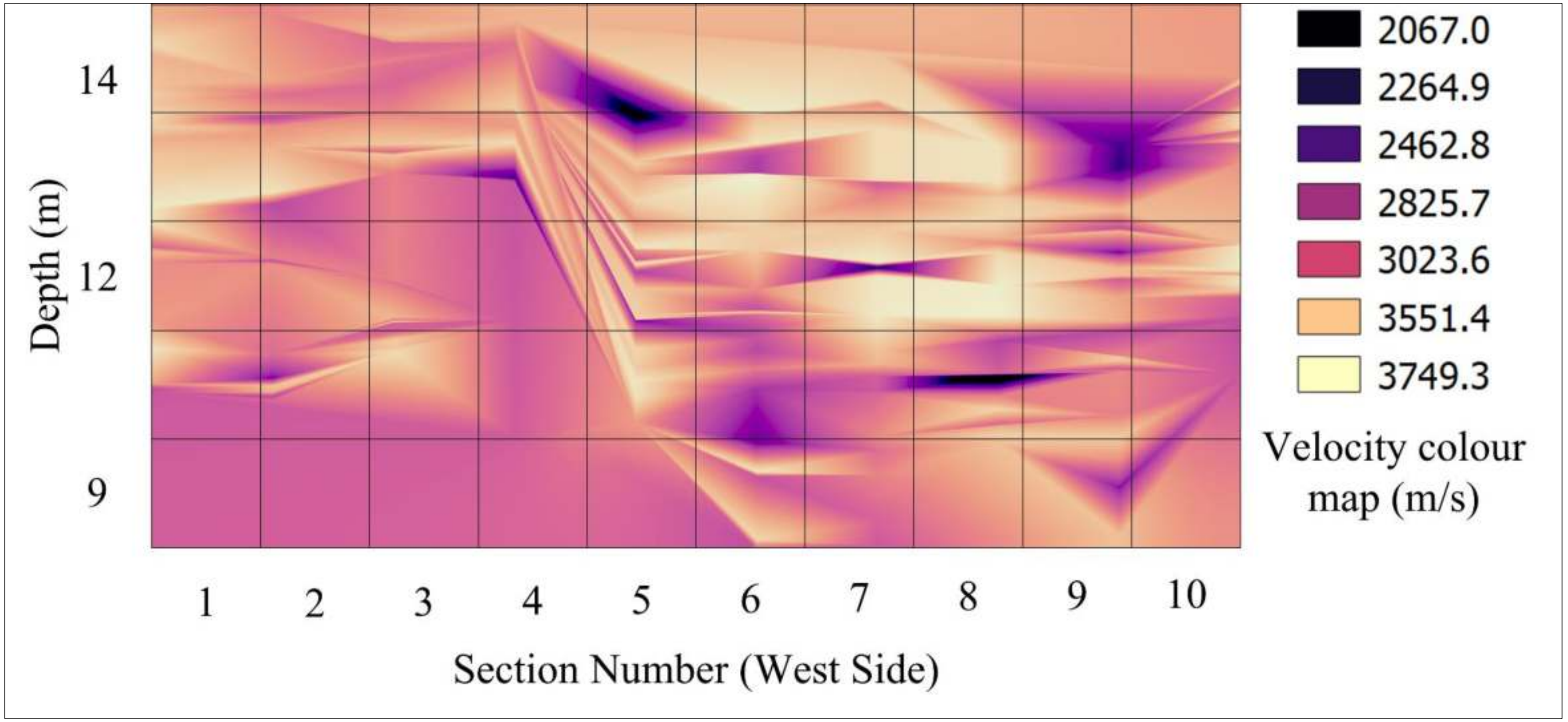

Farakka Navigation Lock
Number of Defects
Severity of Defects
0
2
4
3
1
2
4
0
1
1
0
1
0
3
1
Minor
Moderate
Major
Wall Bottom 16-30
Wall Bottom 31-45
Wall Bottom 46-60
Wall Bottom 61-75
Defect Details with respect to Wall Bottom
Major
Moderate
Minor

4.3 Observation from Above water UPV test

4.3.1 Consolidated points detail of East side



4.3.2 Consolidated points detail of West side



4.3.3 Heat Map of observations at Above water West 1 UPV

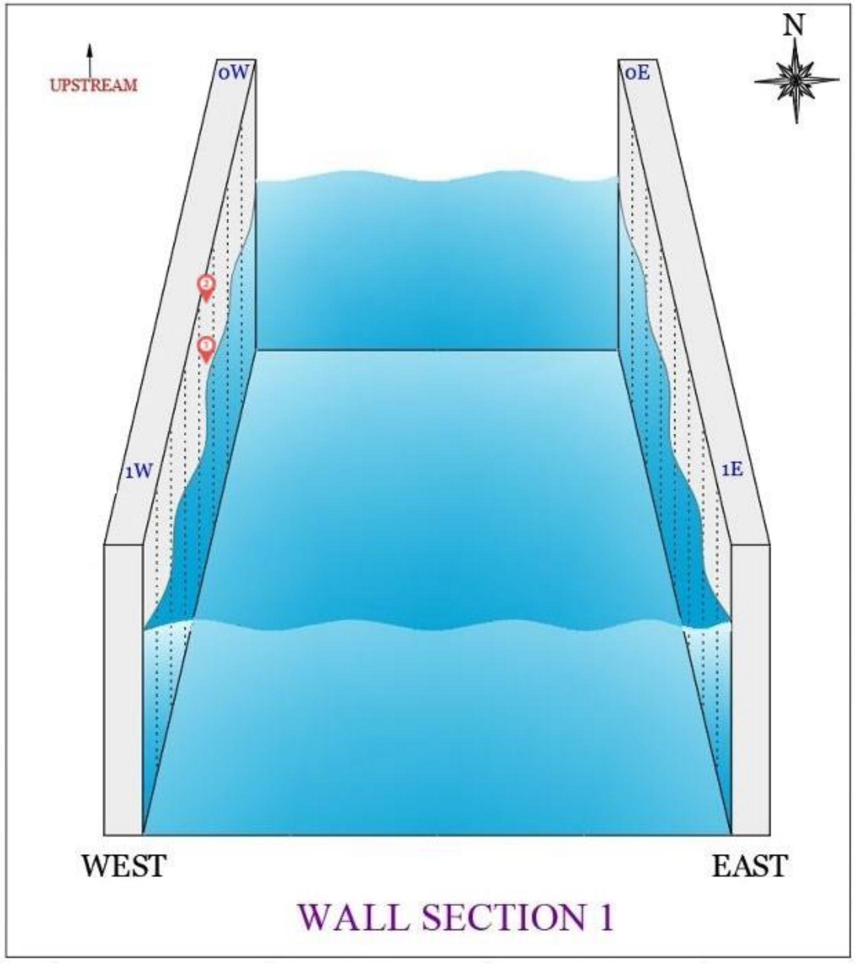


Figure 23: Heat map and Observations at Above water West 1 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
1	Between 0 to 1W	Bottom	2.71	Indirect	Doubtful
2	Between 0 to 1W	Top	2.83	Indirect	Doubtful

Table 22: Observation details at Above water West 1 UPV

4.3.4 Heat Map of observations at Above water East 1 UPV

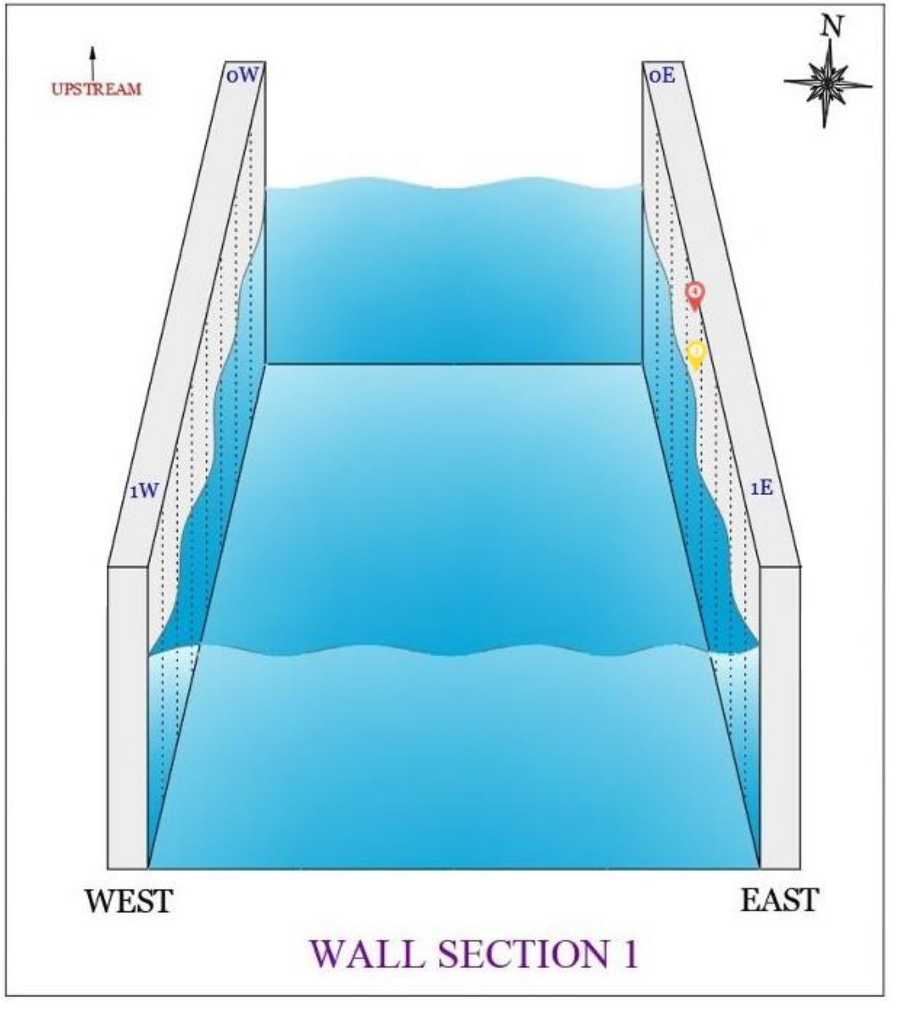


Figure 24: Heat map and Observations at Above water East 1 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
3	Between 0 to 1E	Bottom	3.56	Indirect	Good
4	Between 0 to 1E	Top	2.65	Indirect	Doubtful

Table 23: Observation details at Above water East 1 UPV

4.3.5 Heat Map of observations at Above water 1-2 UPV

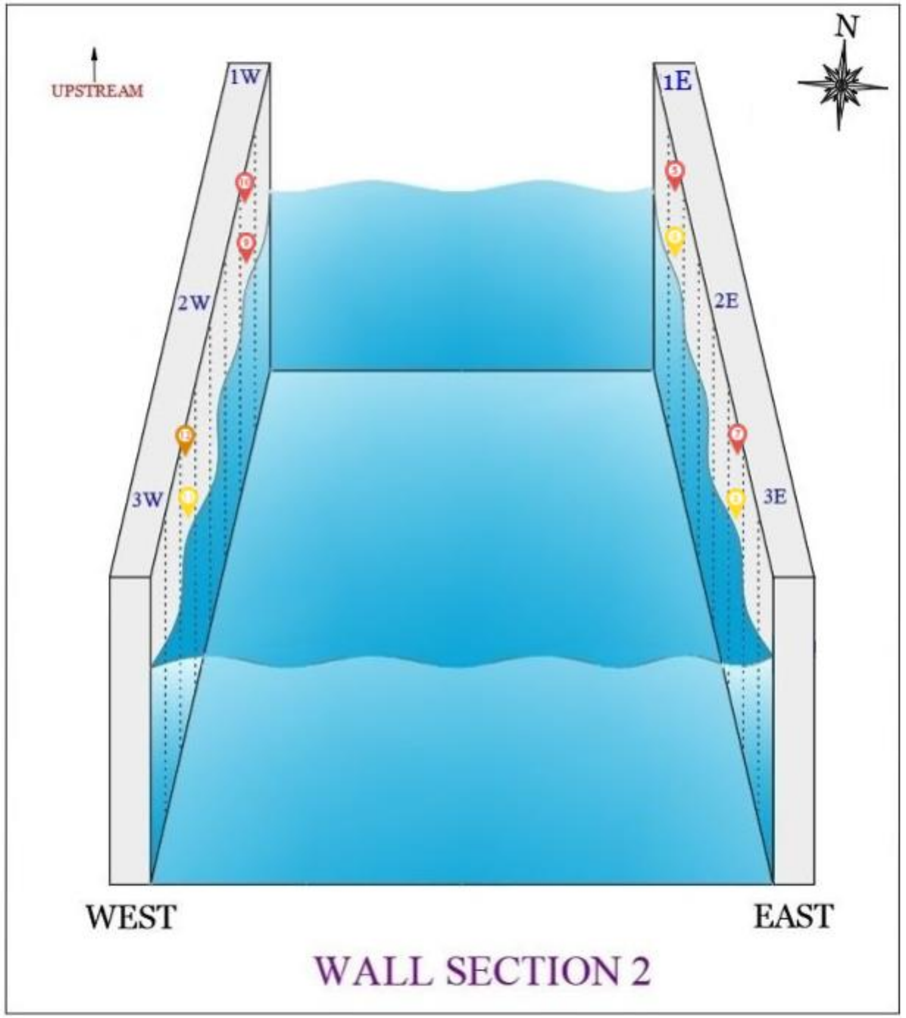


Figure 25: Heat map and Observations at Above water 1-2 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
5	Between 1E to 2E	Top	2.63	Indirect	Doubtful
6	Between 1E to 2E	Bottom	3.50	Indirect	Good
7	Between 2E to 3E	Top	2.82	Indirect	Doubtful
8	Between 2E to 3E	Bottom	3.55	Indirect	Good
9	Between 1W to 200	Bottom	2.61	Indirect	Doubtful
10	Between 1W to 200	Top	2.64	Indirect	Doubtful
11	Between 2w to 3w	Bottom	4.02	Indirect	Good
12	Between 2w to 3w	Top	3.20	Indirect	Medium

Table 24: Observation details at Above water 1-2 UPV

4.3.6 Heat Map of observations at Above water 3-4 UPV

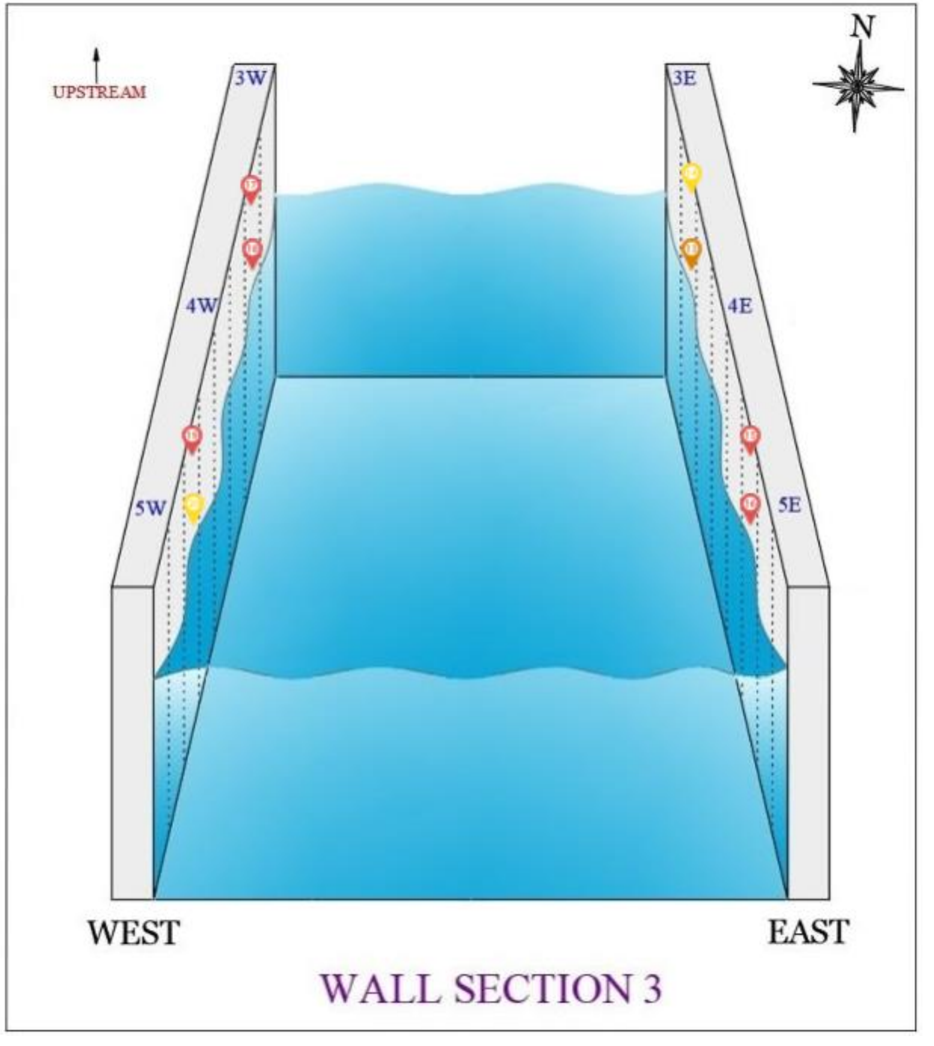


Figure 26: Heat map and Observations at Above water 3-4 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
13	Between 3E to 4E	Bottom	3.26	Indirect	Medium
14	Between 3E to 4E	Top	3.91	Indirect	Good
15	Between 4E to 5E	Top	2.82	Indirect	Doubtful
16	Between 4E to 5E	Bottom	2.86	Indirect	Doubtful
17	Between 3w to 4w	Top	2.57	Indirect	Doubtful
18	Between 3w to 4w	Bottom	2.64	Indirect	Doubtful
19	Between 4w to 5w	Top	2.58	Indirect	Doubtful
20	Between 4w to 5w	Bottom	3.75	Indirect	Good

Table 25: Observation details at Above water 3-4 UPV

4.3.7 Heat Map of observations at Above water 5-6 UPV

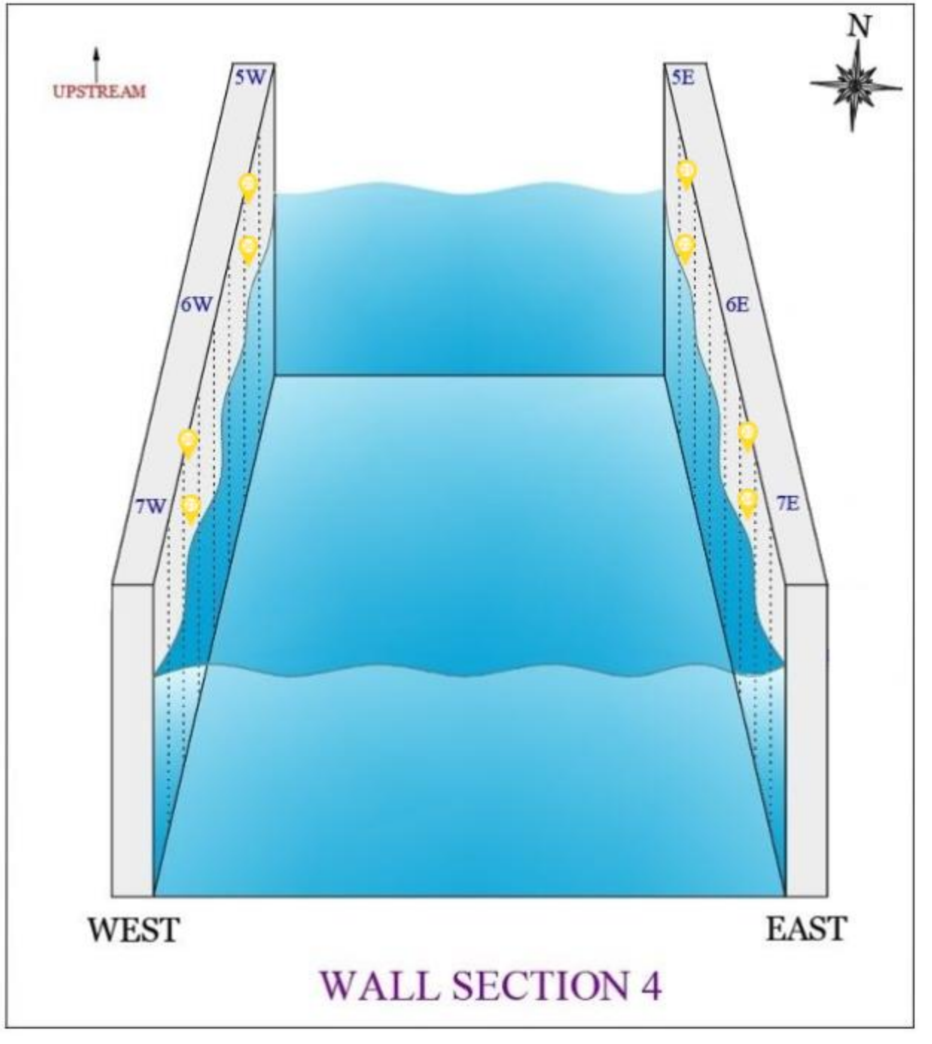


Figure 27: Heat map and Observations at Above water 5-6 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
21	Between 5E to 6E	Top	3.55	Indirect	Good
22	Between 5E to 6E	Bottom	3.51	Indirect	Good
23	Between 6E to 7E	Top	4.00	Indirect	Good
24	Between 6E to 7E	Bottom	3.93	Indirect	Good
25	Between 5w to 6w	Top	3.65	Indirect	Good
26	Between 5w to 6w	Bottom	3.73	Indirect	Good
27	Between 6w to 7w	Bottom	3.97	Indirect	Good
28	Between 6w to 7w	Top	3.56	Indirect	Good

Table 26: Observation details at Above water 5-6 UPV

4.3.8 Heat Map of observations at Above water 7-8 UPV

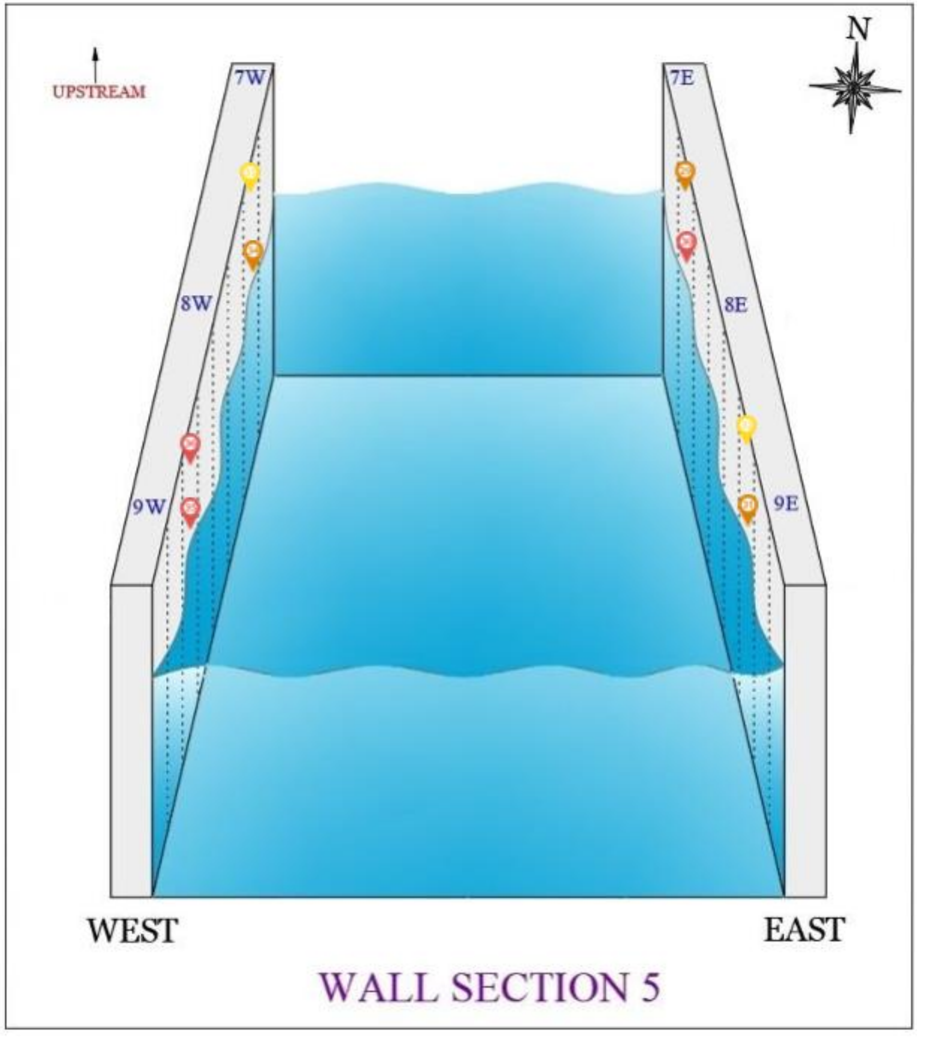


Figure 28: Heat map and Observations at Above water 7-8 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
29	Between 7E to 8E	Top	3.27	Indirect	Medium
30	Between 7E to 8E	Bottom	2.67	Indirect	Doubtful
31	Between 8E to 9E	Bottom	3.18	Indirect	Medium
32	Between 8E to 9E	Top	3.84	Indirect	Good
33	Between 7w to 8w	Top	4.00	Indirect	Good
34	Between 7w to 8w	Bottom	3.20	Indirect	Medium
35	Between 8w to 9w	Bottom	2.85	Indirect	Doubtful
36	Between 8w to 9w	Top	2.60	Indirect	Doubtful

Table 27: Observation details at Above water 7-8 UPV

4.3.9 Heat Map of observations at Above water West 9-10 UPV

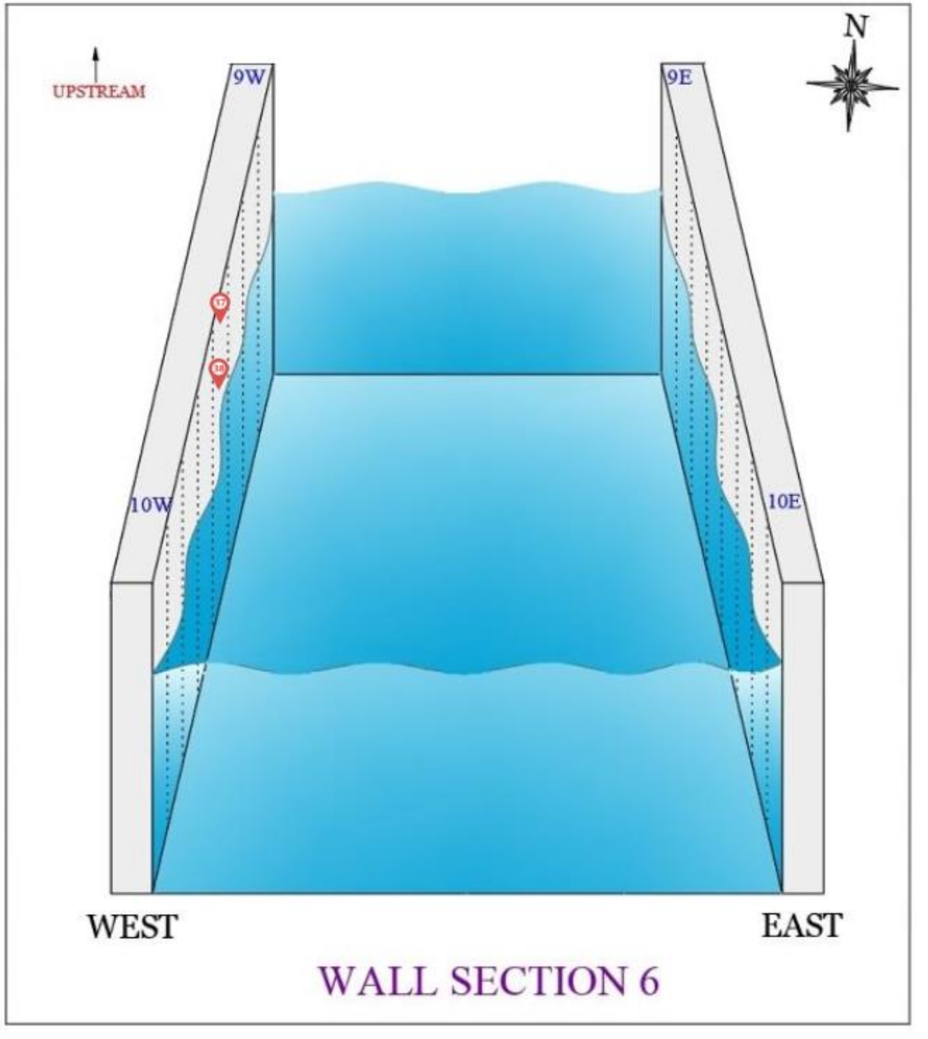


Figure 29: Heat map and Observations at Above water West 9-10 UPV

ID MARK	LOCATION	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
37	Between 9w to 10w	Top	2.88	Indirect	Doubtful
38	Between 9w to 10w	Bottom	3.53	Indirect	Good

Table 28: Observation details at Above water West 9-10 UPV

4.3.10 Heat Map of observations at Above water East 9-10 UPV

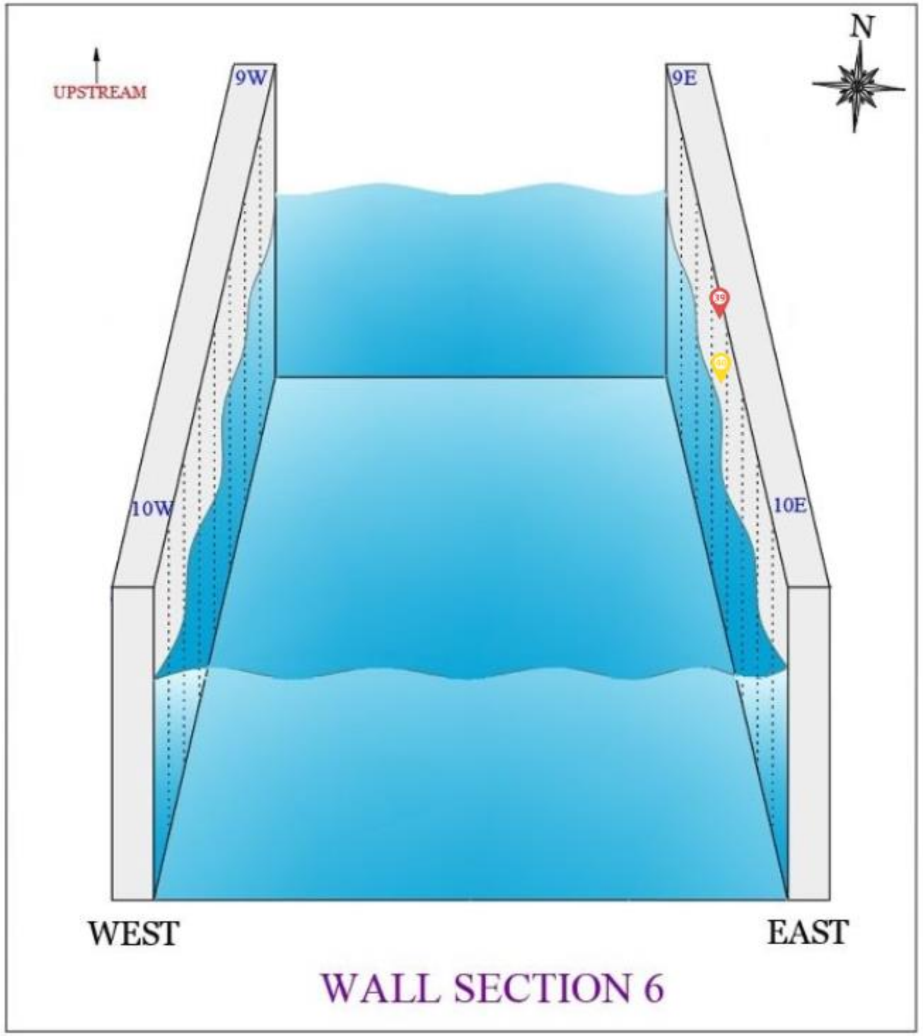


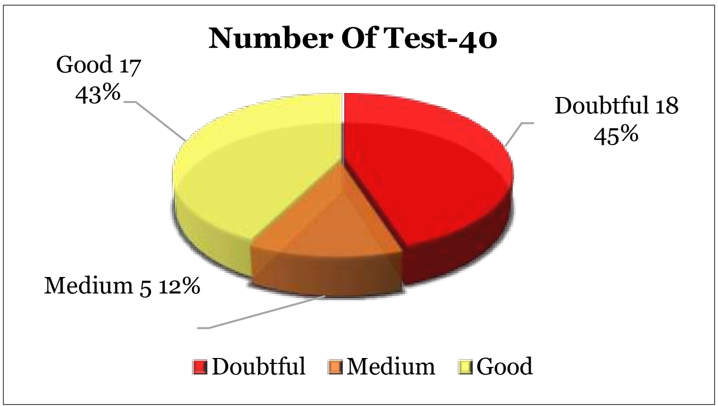
Figure 30: Heat map and Observations at Above water East 9-10 UPV

ID MARK	Member	LOCATION	CORRECTED VELOCITY (km/s)	PROBING METHOD	REMARKS
39	Between 9E to 10E	Top	2.70	Indirect	Doubtful
40	Between 9E to 10E	Bottom	2.76	Indirect	Doubtful

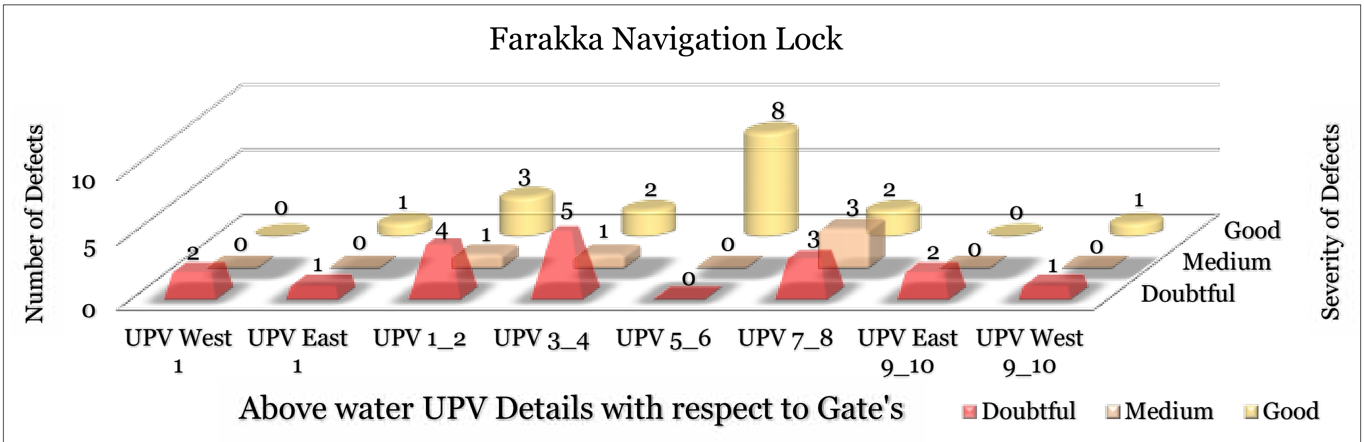
Table 29: Observation details at Above water East 9-10 UPV

Above Water UPV Test Summary

Area of interest		Above Water UPV on East and West Wall	
Inspection Method		Ultrasonic Pulse Velocity Method	
Equipment Used	Ultrasonic Pulse Velocity Equipment (Refer 7F)	Date/Duration	13-04-2022
Crew Size	6 members	Underwater Visibility	NA



Category of Observations	Number of Points
Doubtful	18
Medium	05
Good	17



4.4 Observation from Under water UPV test

4.4.1 Heat Map of observations at Underwater West 1 UPV

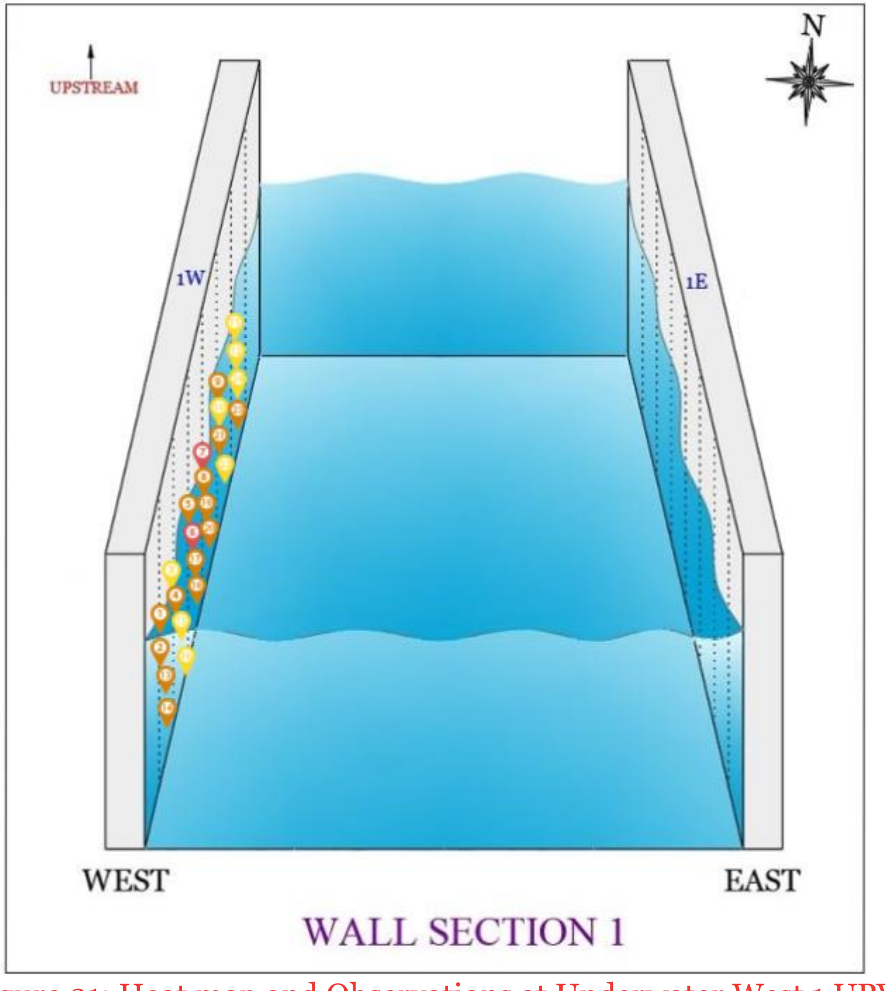


Figure 31: Heat map and Observations at Underwater West 1 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
1	West 1 Zone 1	12.03	3.203	Medium
2	West 1 Zone 1	12.12	3.417	Medium
3	West 1 Zone 1	11.31	3.683	Good
4	West 1 Zone 1	11.02	3.289	Medium
5	West 1 Zone 1	11.01	3.029	Medium
6	West 1 Zone 1	10.97	2.808	Doubtful
7	West 1 Zone 1	10.96	2.928	Doubtful
8	West 1 Zone 1	11.53	3.271	Medium
9	West 1 Zone 1	12.16	3.029	Medium
10	West 1 Zone 1	12.35	3.639	Good
11	West 1 Zone 1	12.48	3.705	Good
12	West 1 Zone 1	12.75	3.535	Good

13	West 1 Zone 2	12.91	3.475	Medium
14	West 1 Zone 2	13.05	3.361	Medium
15	West 1 Zone 2	13.16	3.555	Good
16	West 1 Zone 2	13.41	3.535	Good
17	West 1 Zone 2	13.37	3.494	Medium
18	West 1Zone 2	13.61	3.436	Medium
19	West 1 Zone 2	13.74	3.379	Medium
20	West 1 Zone 2	14.06	3.361	Medium
21	West 1 Zone 2	13.33	3.494	Medium
22	West 1 Zone 2	13.83	3.597	Good
23	West 1 Zone 2	13.5	3.455	Medium
24	West 1 Zone 2	13.26	3.597	Good

Table 30: Observation details at Underwater West 1 UPV

4.4.2 Heat Map of observations at Underwater East 1 UPV

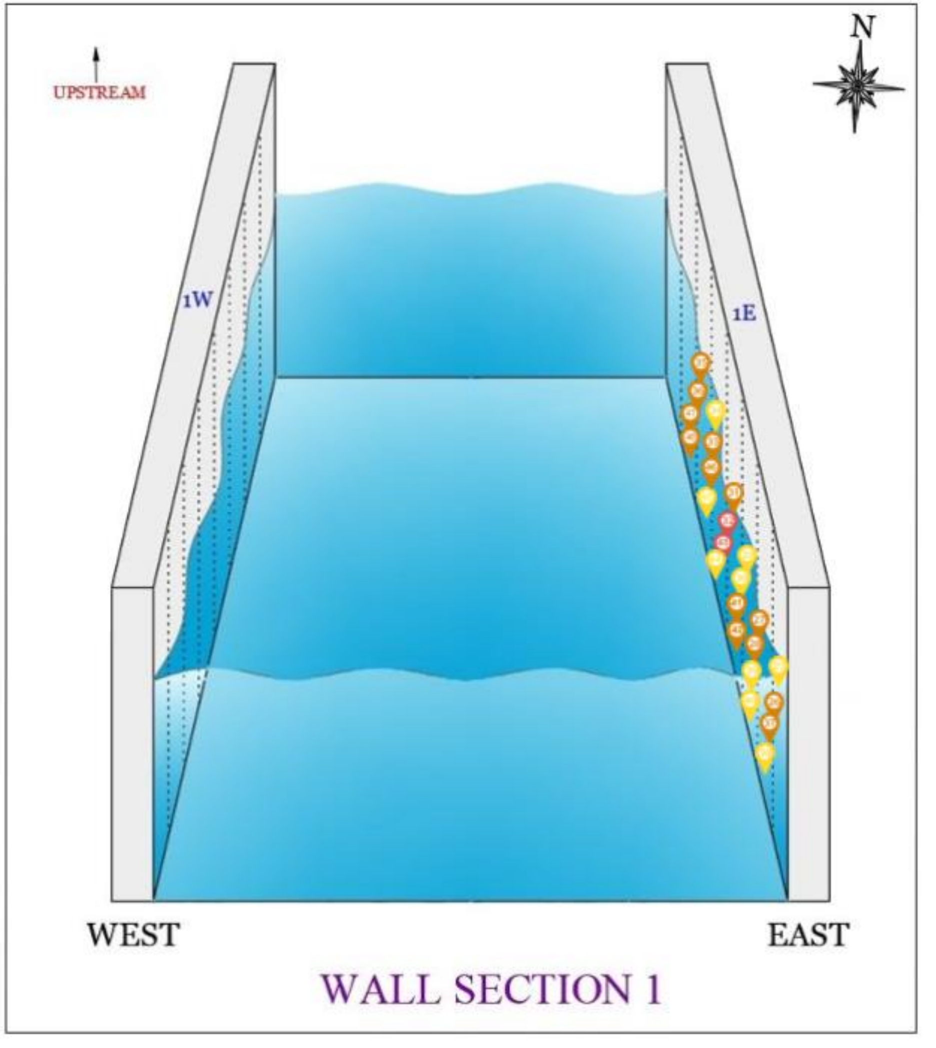


Figure 32: Heat map and Observations at Underwater East 1 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
25	East 1 Zone 1	9.79	3.535	Good
26	East 1 Zone 1	9.82	3.186	Medium
27	East 1 Zone 1	9.97	3.475	Medium
28	East 1 Zone 1	10.19	3.186	Medium
29	East 1 Zone 1	10.25	3.750	Good
30	East 1 Zone 1	10.29	3.750	Good
31	East 1 Zone 1	10.37	3.014	Medium
32	East 1 Zone 1	11.07	2.942	Doubtful
33	East 1 Zone 1	11.52	3.361	Medium
34	East 1 Zone 1	11.07	3.597	Good
35	East 1 Zone 1	11.17	3.237	Medium
36	East 1 Zone 1	11.24	3.137	Medium

37	East 1 Zone 2	11.59	3.271	Medium
38	East 1 Zone 2	11.92	3.576	Good
39	East 1 Zone 2	12.16	3.728	Good
40	East 1 Zone 2	12.47	3.597	Good
41	East 1 Zone 2	12.59	3.494	Medium
42	East 1 Zone 2	12.88	3.342	Medium
43	East 1 Zone 2	13.17	2.956	Doubtful
44	East 1 Zone 2	13.46	3.536	Good
45	East 1 Zone 2	11.78	3.514	Good
46	East 1 Zone 2	11.67	3.342	Medium
47	East 1 Zone 2	11.59	3.271	Medium
48	East 1 Zone 2	11.69	3.237	Medium

Table 31: Observation details at Underwater East 1 UPV

4.4.3 Heat Map of observations at Underwater East West 2 UPV

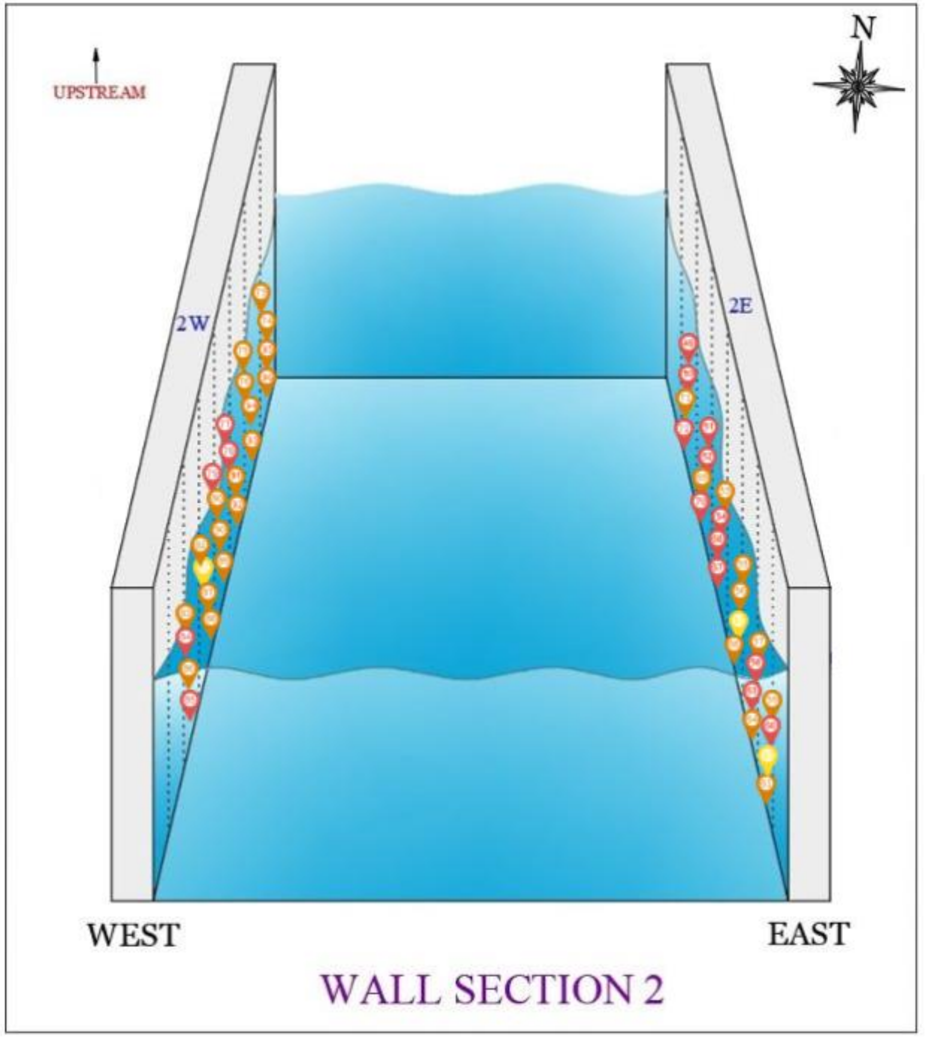


Figure 33: Heat map and Observations at Underwater East West 2 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
49	East 2 Zone 1	10.37	2.820	Doubtful
50	East 2 Zone 1	10.87	2.985	Doubtful
51	East 2 Zone 1	10.97	2.860	Doubtful
52	East 2 Zone 1	11.27	2.733	Doubtful
53	East 2 Zone 1	11.37	3.106	Medium
54	East 2 Zone 1	11.55	2.499	Doubtful
55	East 2 Zone 1	10.53	3.379	Medium
56	East 2 Zone 1	11.42	3.342	Medium
57	East 2 Zone 1	11.23	3.398	Medium
58	East 2 Zone 1	11.52	2.985	Doubtful
59	East 2 Zone 1	11.46	3.220	Medium
60	East 2 Zone 1	11.53	2.970	Doubtful

61	East 2 Zone 2	11.61	3.106	Medium
62	East 2 Zone 2	11.57	3.514	Good
63	East 2 Zone 2	11.97	2.733	Doubtful
64	East 2 Zone 2	12.17	3.121	Medium
65	East 2 Zone 2	12.32	3.514	Good
66	East 2 Zone 2	12.54	3.121	Medium
67	East 2 Zone 2	12.63	2.479	Doubtful
68	East 2 Zone 2	11.62	2.795	Doubtful
69	East 2 Zone 2	12.07	3.106	Medium
70	East 2 Zone 2	12.12	2.887	Doubtful
71	East 2 Zone 2	12.17	3.494	Medium
72	East 2 Zone 2	12.67	2.782	Doubtful
73	West 2 Zone 1	10.89	3.044	Medium
74	West 2 Zone 1	11.27	3.059	Medium
75	West 2 Zone 1	12.02	3.220	Medium

76	West 2 Zone 1	12.07	3.154	Medium
77	West 2 Zone 1	10.92	2.808	Doubtful
78	West 2 Zone 1	11.07	2.572	Doubtful
79	West 2 Zone 1	12.51	2.820	Doubtful
80	West 2 Zone 1	12.55	3.170	Medium
81	West 2 Zone 1	12.61	3.661	Good
82	West 2 Zone 1	10.96	3.379	Medium
83	West 2 Zone 1	11.01	3.455	Medium
84	West 2 Zone 1	12.04	2.887	Doubtful
85	West 2 Zone 2	13.24	2.770	Doubtful
86	West 2 Zone 2	13.1	3.254	Medium
87	West 2 Zone 2	12.98	3.379	Medium
88	West 2 Zone 2	13.35	3.170	Medium
89	West 2 Zone 2	14.09	3.186	Medium
90	West 2 Zone 2	12.57	3.306	Medium

91	West 2 Zone 2	13.16	3.220	Medium
92	West 2 Zone 2	13.41	3.075	Medium
93	West 2 Zone 2	13.26	3.254	Medium
94	West 2 Zone 2	13.17	3.106	Medium
95	West 2 Zone 2	13.43	3.106	Medium
96	West 2 Zone 2	13.53	3.324	Medium

Table 32: Observation details at Underwater East West 2 UPV

4.4.4 Heat Map of observations at Underwater East West 3 UPV

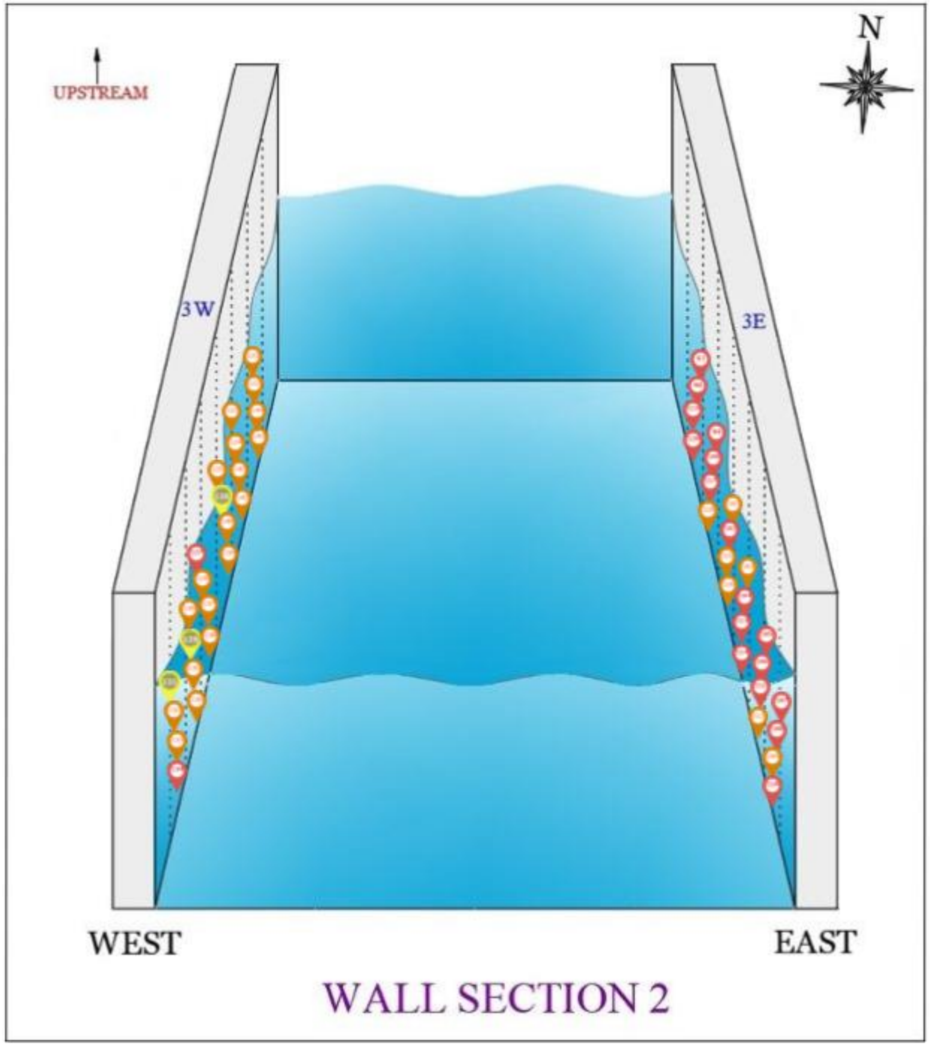


Figure 34: Heat map and Observations at Underwater East West 3 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
97	East 3 Zone 1	10.43	2.009	Doubtful
98	East 3 Zone 1	10.67	2.583	Doubtful
99	East 3 Zone 1	11.07	2.720	Doubtful
100	East 3 Zone 1	11.41	2.887	Doubtful
101	East 3 Zone 1	11.3	3.436	Medium
102	East 3 Zone 1	11.25	2.942	Doubtful
103	East 3 Zone 1	11.16	3.014	Medium
104	East 3 Zone 1	10.12	2.401	Doubtful
105	East 3 Zone 1	9.71	2.673	Doubtful
106	East 3 Zone 1	9.71	2.900	Doubtful
107	East 3 Zone 1	10.02	2.942	Doubtful
108	East 3 Zone 1	10.07	2.551	Doubtful

109	East 3 Zone 2	11.58	3.203	Medium
110	East 3 Zone 2	11.66	2.562	Doubtful
111	East 3 Zone 2	11.77	2.860	Doubtful
112	East 3 Zone 2	12.17	3.289	Medium
113	East 3 Zone 2	12.37	2.795	Doubtful
114	East 3 Zone 2	12.69	2.970	Doubtful
115	East 3 Zone 2	12.93	3.342	Medium
116	East 3 Zone 2	13.02	3.271	Medium
117	East 3 Zone 2	13.28	2.928	Doubtful
118	East 3 Zone 2	13.6	3.090	Medium
119	East 3 Zone 2	13.92	2.847	Doubtful
120	East 3 Zone 2	13.97	2.795	Doubtful
121	West 3 Zone 1	11.87	3.075	Medium
122	West 3 Zone 1	11.82	3.170	Medium
123	West 3 Zone 1	11.881	3.170	Medium

124	West 3 Zone 1	11.56	3.044	Medium
125	West 3 Zone 1	11.46	3.014	Medium
126	West 3 Zone 1	11.39	3.514	Good
127	West 3 Zone 1	11.53	2.985	Doubtful
128	West 3 Zone 1	11.57	3.398	Medium
129	West 3 Zone 1	11.54	3.535	Good
130	West 3 Zone 1	11.43	3.203	Medium
131	West 3 Zone 1	11.29	3.618	Good
132	West 3 Zone 1	11.32	3.494	Medium
133	West 3 Zone 2	12.92	3.494	Medium
134	West 3 Zone 2	12.94	2.999	Doubtful
135	West 3 Zone 2	13.27	3.170	Medium
136	West 3 Zone 2	13.75	3.075	Medium
137	West 3 Zone 2	13.01	3.494	Medium
138	West 3 Zone 2	13.67	3.075	Medium

139	West 3 Zone 2	13.7	3.170	Medium
140	West 3 Zone 2	13.51	3.014	Medium
141	West 3 Zone 2	13.84	3.029	Medium
142	West 3 Zone 2	13.91	3.417	Medium
143	West 3 Zone 2	13.86	3.306	Medium
144	West 3 Zone 2	12.77	3.154	Medium

Table 33: Observation details at Underwater East West 3 UPV

4.4.5 Heat Map of observations at Underwater East West 4 UPV

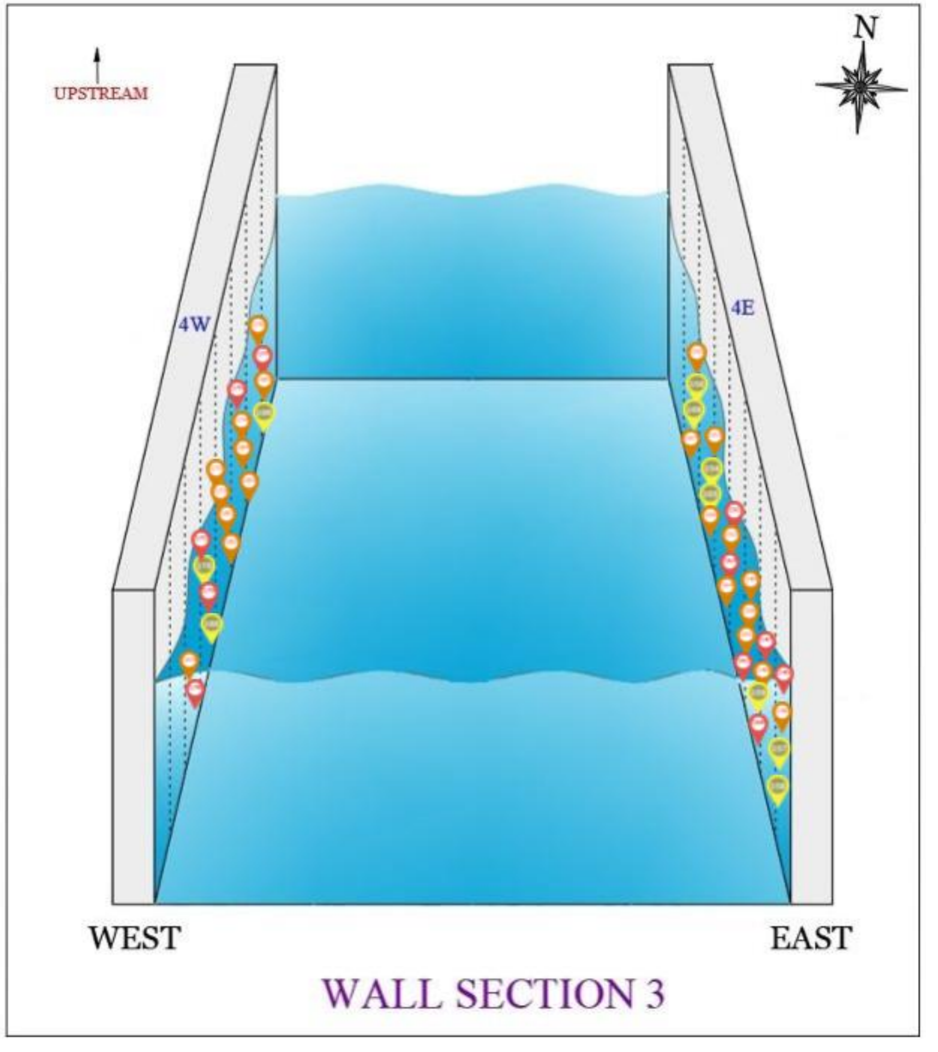


Figure 35: Heat map and Observations at Underwater East West 4 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
145	East 4 Zone 1	9.67	2.942	Doubtful
146	East 4 Zone 1	9.69	3.186	Medium
147	East 4 Zone 1	10.07	2.985	Doubtful
148	East 4 Zone 1	9.72	3.455	Medium
149	East 4 Zone 1	10.07	3.455	Medium
150	East 4 Zone 1	10.47	3.186	Medium
151	East 4 Zone 1	10.67	2.745	Doubtful
152	East 4 Zone 1	11.17	3.475	Medium
153	East 4 Zone 1	11.56	3.170	Medium
154	East 4 Zone 1	11.47	3.645	Good
155	East 4 Zone 1	11.49	3.379	Medium
156	East 4 Zone 1	11.13	3.555	Good

157	East 4 Zone 2	12.07	3.683	Good
158	East 4 Zone 2	11.57	3.705	Good
159	East 4 Zone 2	11.87	3.576	Good
160	East 4 Zone 2	12.2	2.942	Doubtful
161	East 4 Zone 2	12.37	3.494	Medium
162	East 4 Zone 2	12.67	2.469	Doubtful
163	East 4 Zone 2	12.77	2.887	Doubtful
164	East 4 Zone 2	11.67	3.075	Medium
165	East 4 Zone 2	12.13	3.705	Good
166	East 4 Zone 2	12.22	3.494	Medium
167	East 4 Zone 2	13.56	3.361	Medium
168	East 4 Zone 2	13.27	3.597	Good
169	West 4 Zone 1	10.88	3.203	Medium
170	West 4 Zone 1	11.53	3.535	Good
171	West 4 Zone 1	11.34	2.987	Doubtful

172	West 4 Zone 1	11.35	3.417	Medium
173	West 4 Zone 1	11.4	3.361	Medium
174	West 4 Zone 1	10.95	3.121	Medium
175	West 4 Zone 1	10.59	2.956	Doubtful
176	West 4 Zone 1	10.71	3.059	Medium
177	West 4 Zone 1	11.55	2.928	Doubtful
178	West 4 Zone 2	12.73	2.311	Doubtful
179	West 4 Zone 2	12.7	2.887	Doubtful
180	West 4 Zone 2	13.02	3.618	Good
181	West 4 Zone 2	13.15	3.271	Medium
182	West 4 Zone 2	14.03	3.379	Medium
183	West 4 Zone 2	13.84	3.079	Medium

184	West 4 Zone 2	13.53	3.237	Medium
185	West 4 Zone 2	13.28	3.342	Medium
186	West 4 Zone 2	13.31	3.535	Good

Table 34: Observation details at Underwater East West 4 UPV

4.4.6 Heat Map of observations at Underwater East West 5 UPV

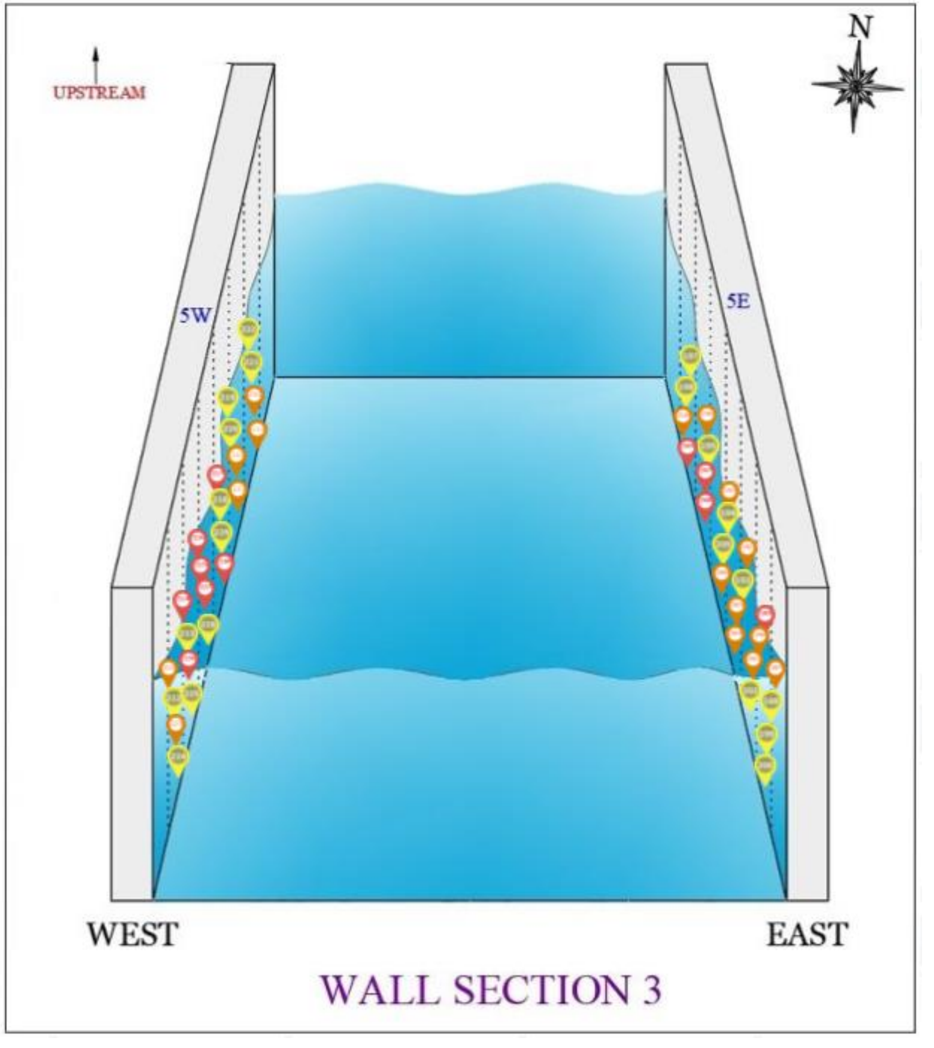


Figure 36: Heat map and Observations at Underwater East West 5 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
187	East 5 Zone 1	9.67	3.186	Medium
188	East 5 Zone 1	9.75	3.514	Good
189	East 5 Zone 1	10.37	2.440	Doubtful
190	East 5 Zone 1	9.97	3.154	Medium
191	East 5 Zone 1	10.37	3.342	Medium
192	East 5 Zone 1	10.57	3.514	Good
193	East 5 Zone 1	11.43	3.22	Medium
194	East 5 Zone 1	11.77	3.597	Good
195	East 5 Zone 1	11.57	3.618	Good
196	East 5 Zone 1	10.73	3.379	Medium
197	East 5 Zone 1	11.77	3.576	Good
198	East 5 Zone 1	11.87	3.639	Good

199	East 5 Zone 2	11.87	3.597	Good
200	East 5 Zone 2	12.22	3.683	Good
201	East 5 Zone 2	12.57	3.417	Medium
202	East 5 Zone 2	13.24	3.555	Good
203	East 5 Zone 2	13.47	3.417	Medium
204	East 5 Zone 2	13.52	3.222	Medium
205	East 5 Zone 2	13.57	3.535	Good
206	East 5 Zone 2	13.56	3.436	Medium
207	East 5 Zone 2	13.74	2.757	Doubtful
208	East 5 Zone 2	14.17	2.82	Doubtful
209	East 5 Zone 2	14.07	2.999	Doubtful
210	East 5 Zone 2	13.97	3.271	Medium
211	West 5 Zone 1	10.71	3.271	Medium
212	West 5 Zone 1	11.31	3.597	Good
213	West 5 Zone 1	11.56	3.597	Good

214	West 5 Zone 1	10.55	2.873	Doubtful
215	West 5 Zone 1	11.55	2.594	Doubtful
216	West 5 Zone 1	9.7	2.914	Doubtful
217	West 5 Zone 1	9.8	2.782	Doubtful
218	West 5 Zone 1	11.15	3.514	Good
219	West 5 Zone 1	11.6	3.537	Good
220	West 5 Zone 1	12.02	3.705	Good
221	West 5 Zone 1	11.05	3.683	Good
222	West 5 Zone 1	10.92	3.661	Good
223	West 5 Zone 2	11.81	3.494	Medium
224	West 5 Zone 2	12.15	3.683	Good
225	West 5 Zone 2	12.56	3.514	Good
226	West 5 Zone 2	12.05	2.928	Doubtful
227	West 5 Zone 2	11.95	2.770	Doubtful
228	West 5 Zone 2	12.55	3.576	Good

229	West 5 Zone 2	12.85	3.535	Good
230	West 5 Zone 2	13.25	2.015	Doubtful
231	West 5 Zone 2	12.87	3.494	Medium
232	West 5 Zone 2	12.75	3.306	Medium
233	West 5 Zone 2	12.35	3.220	Medium
234	West 5 Zone 2	12.13	3.237	Medium

Table 35: Observation details at Underwater East West 5 UPV

4.4.7 Heat Map of observations at Underwater East West 6 UPV

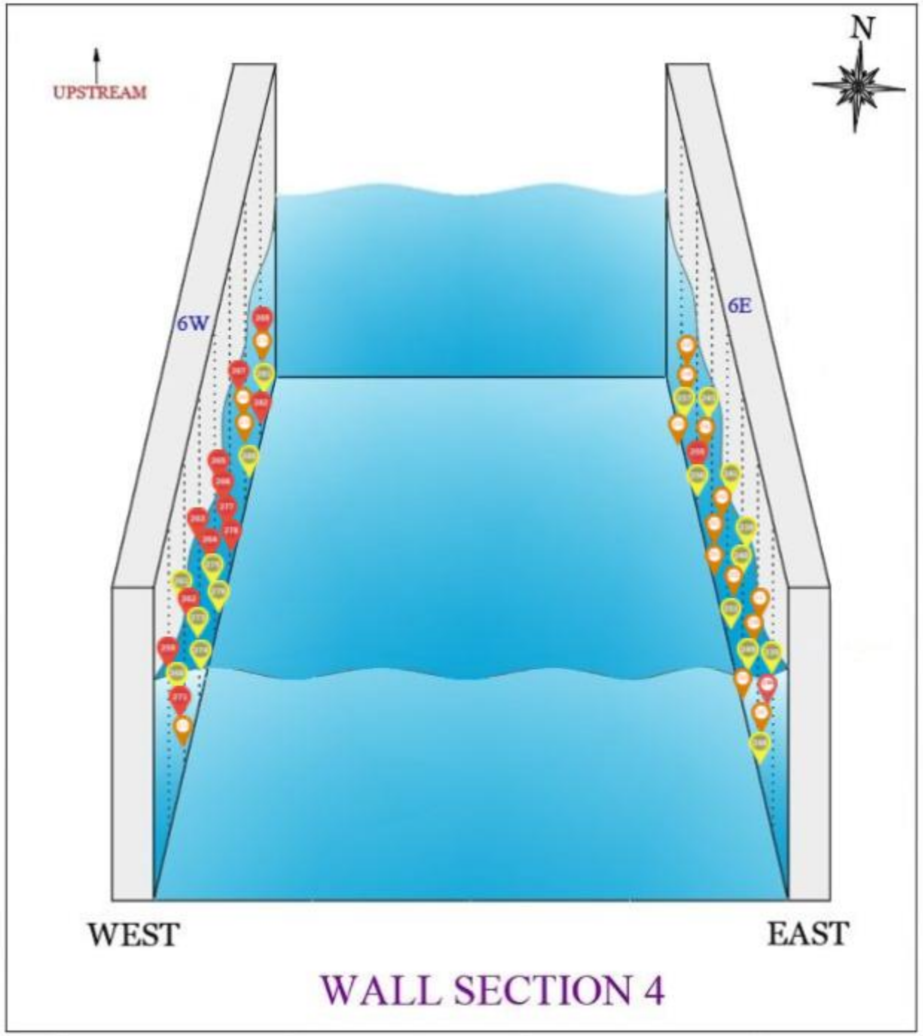


Figure 37: Heat map and Observations at Underwater East West 6 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
235	East 6 Zone 1	9.67	3.639	Good
236	East 6 Zone 1	9.82	2.847	Doubtful
237	East 6 Zone 1	9.69	3.014	Medium
238	East 6 Zone 1	9.72	3.029	Medium
239	East 6 Zone 1	9.87	3.514	Good
240	East 6 Zone 1	10.07	3.705	Good
241	East 6 Zone 1	10.17	3.597	Good
242	East 6 Zone 1	10.77	3.209	Medium
243	East 6 Zone 1	10.87	3.535	Good
244	East 6 Zone 1	11.07	3.289	Medium
245	East 6 Zone 1	11.01	3.475	Medium
246	East 6 Zone 1	11.12	3.22	Medium

247	East 6 Zone 2	11.97	3.224	Medium
248	East 6 Zone 2	12.37	3.618	Good
249	East 6 Zone 2	12.77	3.618	Good
250	East 6 Zone 2	12.97	3.475	Medium
251	East 6 Zone 2	13.04	3.342	Medium
252	East 6 Zone 2	13.57	3.683	Good
253	East 6 Zone 2	13.87	3.475	Medium
254	East 6 Zone 2	13.47	3.455	Medium
255	East 6 Zone 2	13.47	2.928	Doubtful
256	East 6 Zone 2	13.37	3.618	Good
257	East 6 Zone 2	13.47	3.728	Good
258	East 6 Zone 2	13.71	3.436	Medium
259	West 6 Zone 1	9.65	2.847	Doubtful
260	West 6 Zone 1	9.74	3.597	Good
261	West 6 Zone 1	10.30	3.683	Good

262	West 6 Zone 1	10.55	2.469	Doubtful
263	West 6 Zone 1	10.26	2.900	Doubtful
264	West 6 Zone 1	10.98	2.697	Doubtful
265	West 6 Zone 1	11.30	2.808	Doubtful
266	West 6 Zone 1	11.49	2.833	Doubtful
267	West 6 Zone 1	11.64	2.86	Doubtful
268	West 6 Zone 1	11.60	3.059	Medium
269	West 6 Zone 1	11.40	2.887	Doubtful
270	West 6 Zone 1	11.15	3.121	Medium
271	West 6 Zone 2	11.60	2.708	Doubtful
272	West 6 Zone 2	11.81	3.220	Medium
273	West 6 Zone 2	11.62	3.555	Good
274	West 6 Zone 2	12.13	3.514	Good
275	West 6 Zone 2	12.3	3.535	Good
276	West 6 Zone 2	12.76	3.773	Good

277	West 6 Zone 2	12.77	2.733	Doubtful
278	West 6 Zone 2	12.90	2.757	Doubtful
279	West 6 Zone 2	13.25	3.436	Medium
280	West 6 Zone 2	13.01	3.683	Good
281	West 6 Zone 2	13.26	3.728	Good
282	West 6 Zone 2	12.96	2.900	Doubtful

Table 36: Observation details at Underwater East West 6 UPV

4.4.8 Heat Map of observations at Underwater East West 7 UPV

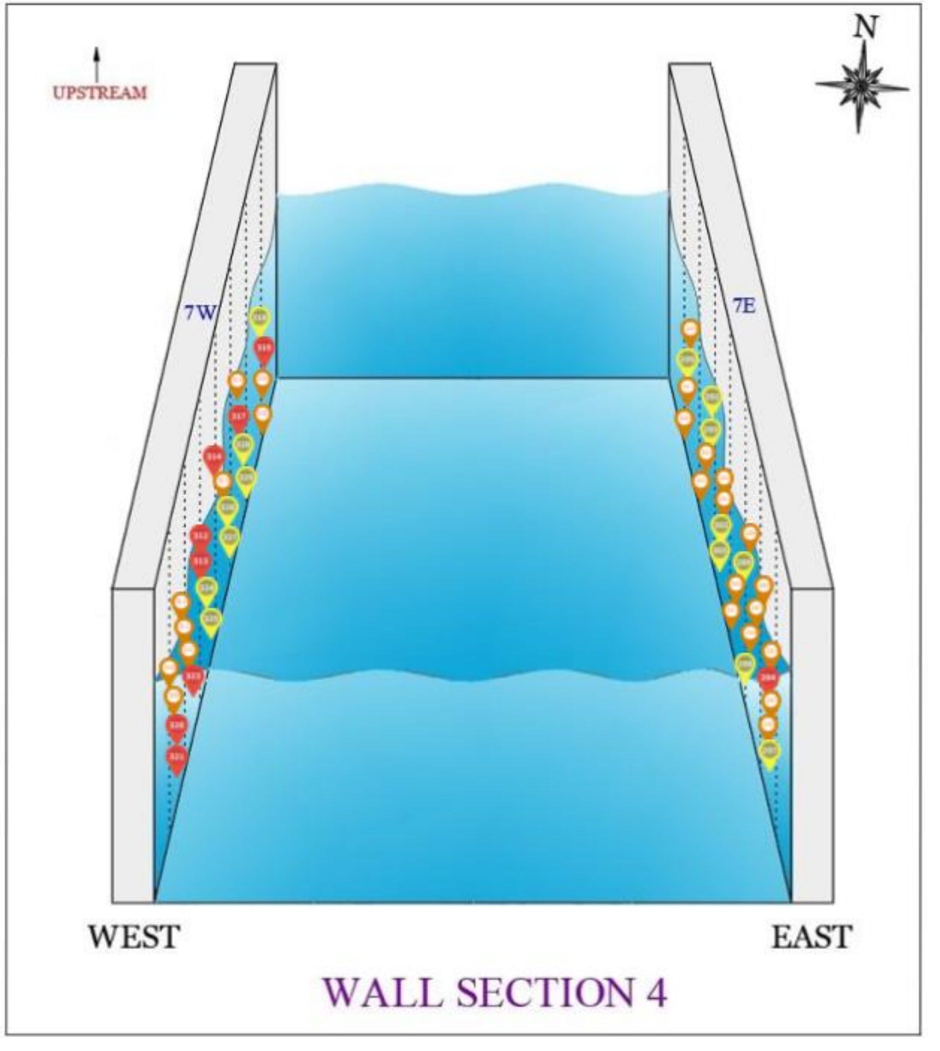


Figure 38: Heat map and Observations at Underwater East West 7 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
283	East 7 Zone 1	9.72	3.324	Medium
284	East 7 Zone 1	10.47	2.914	Doubtful
285	East 7 Zone 1	10.77	3.044	Medium
286	East 7 Zone 1	11.33	3.361	Medium
287	East 7 Zone 1	11.67	3.271	Medium
288	East 7 Zone 1	11.97	3.170	Medium
289	East 7 Zone 1	12.07	3.597	Good
290	East 7 Zone 1	11.77	3.417	Medium
291	East 7 Zone 1	11.92	3.494	Medium
292	East 7 Zone 2	11.97	3.705	Good
293	East 7 Zone 1	11.98	3.661	Good
294	East 7 Zone 1	11.50	3.324	Medium

295	East 7 Zone 1	11.90	3.514	Good
296	East 7 Zone 2	11.95	3.475	Medium
297	East 7 Zone 2	11.97	3.576	Good
298	East 7 Zone 2	11.98	3.121	Medium
299	East 7 Zone 2	11.96	3.535	Good
300	East 7 Zone 2	11.90	3.398	Medium
301	East 7 Zone 2	10.56	3.494	Medium
302	East 7 Zone 2	11.17	3.618	Good
303	East 7 Zone 2	11.67	3.576	Good
304	East 7 Zone 2	11.90	3.342	Medium
305	East 7 Zone 2	11.96	3.306	Medium
306	East 7 Zone 2	11.97	3.361	Medium
307	East 7 Zone 2	11.96	3.398	Medium
308	West 7 Zone 1	10.47	3.059	Medium
309	West 7 Zone 1	10.95	3.029	Medium

310	West 7 Zone 1	11.19	3.398	Medium
311	West 7 Zone 1	11.29	3.455	Medium
312	West 7 Zone 1	10.96	2.942	Doubtful
313	West 7 Zone 1	9.89	2.999	Doubtful
314	West 7 Zone 1	9.69	2.942	Doubtful
315	West 7 Zone 1	10.27	3.170	Medium
316	West 7 Zone 1	10.59	3.203	Medium
317	West 7 Zone 1	11.09	2.970	Doubtful
318	West 7 Zone 1	11.59	3.705	Good
319	West 7 Zone 1	11.19	2.627	Doubtful
320	West 7 Zone 2	11.92	2.355	Doubtful
321	West 7 Zone 2	11.99	2.219	Doubtful
322	West 7 Zone 2	12.58	3.154	Medium
323	West 7 Zone 2	12.69	2.942	Doubtful
324	West 7 Zone 2	11.92	3.683	Good

325	West 7 Zone 2	12.03	3.728	Good
326	West 7 Zone 2	12.29	3.514	Good
327	West 7 Zone 2	12.71	3.618	Good
328	West 7 Zone 2	13.13	3.618	Good
329	West 7 Zone 2	13.39	3.597	Good
330	West 7 Zone 2	13.76	3.475	Medium
331	West 7 Zone 2	13.34	3.220	Medium

Table 37: Observation details at Underwater East West 7 UPV

4.4.9 Heat Map of observations at Underwater East West 8 UPV

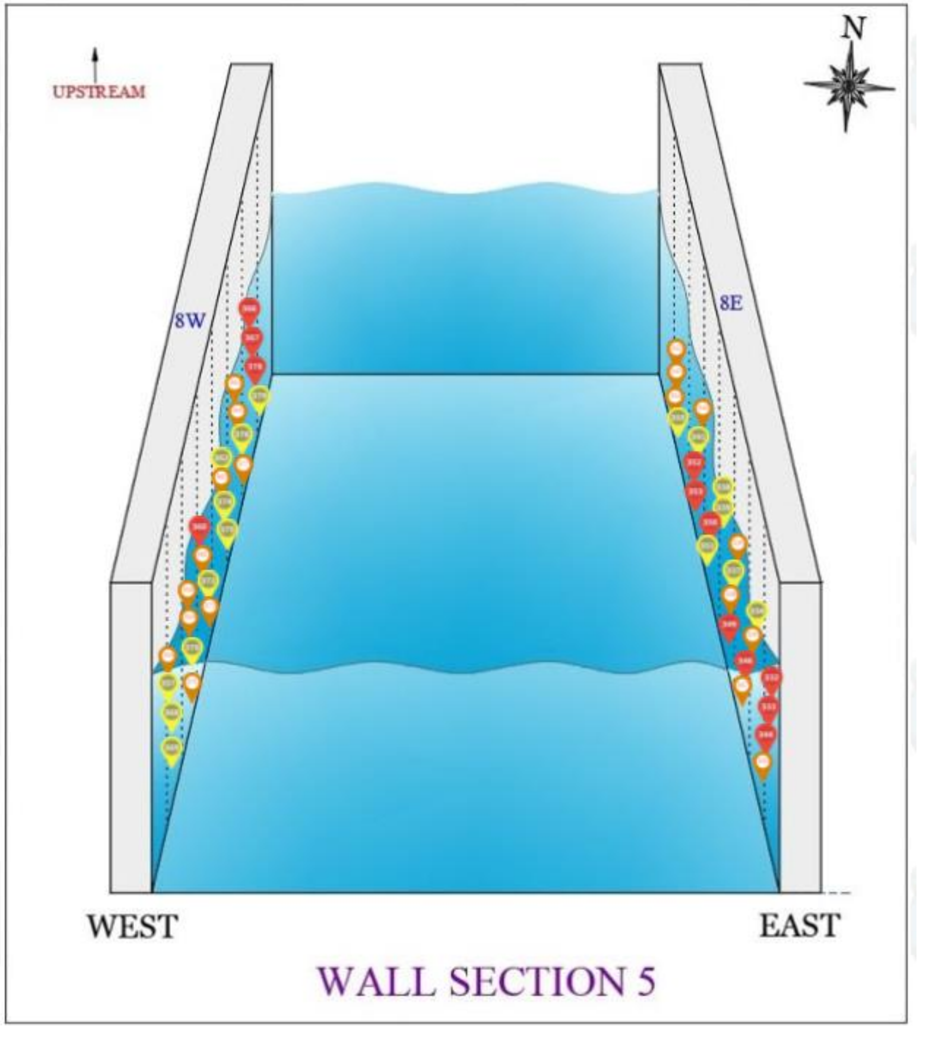


Figure 39: Heat map and Observations at Underwater East West 8 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
332	East 8 Zone 1	9.89	2.639	Doubtful
333	East 8 Zone 1	10.79	2.956	Doubtful
334	East 8 Zone 1	11.01	3.661	Good
335	East 8 Zone 1	11.35	3.09	Medium
336	East 8 Zone 1	11.41	3.417	Medium
337	East 8 Zone 1	11.54	3.661	Good
338	East 8 Zone 1	11.47	3.618	Good
339	East 8 Zone 1	11.33	3.683	Good
340	East 8 Zone 1	10.96	3.137	Medium
341	East 8 Zone 1	10.62	3.639	Good
342	East 8 Zone 1	10.42	3.271	Medium
343	East 8 Zone 1	10.75	3.455	Medium

344	East 8 Zone 2	12.01	2.873	Doubtful
345	East 8 Zone 2	12.22	3.324	Medium
346	East 8 Zone 2	11.91	2.942	Doubtful
347	East 8 Zone 2	12.42	3.417	Medium
348	East 8 Zone 2	12.93	3.220	Medium
349	East 8 Zone 2	13.33	2.757	Doubtful
350	East 8 Zone 2	11.95	2.847	Doubtful
351	East 8 Zone 2	11.97	3.639	Good
352	East 8 Zone 2	12.33	2.900	Doubtful
353	East 8 Zone 2	12.78	2.733	Doubtful
354	East 8 Zone 2	13.16	3.306	Medium
355	East 8 Zone 2	13.21	3.535	Good
356	West 8 Zone 1	10.54	3.455	Medium
357	West 8 Zone 1	10.60	3.555	Good
358	West 8 Zone 1	10.57	3.417	Medium

359	West 8 Zone 1	11.44	3.044	Medium
360	West 8 Zone 1	11.11	2.985	Doubtful
361	West 8 Zone 1	10.69	3.014	Medium
362	West 8 Zone 1	10.82	3.576	Good
363	West 8 Zone 1	10.85	3.398	Medium
364	West 8 Zone 1	10.68	3.324	Medium
365	West 8 Zone 1	10.93	3.154	Medium
366	West 8 Zone 1	11.38	2.770	Doubtful
367	West 8 Zone 1	11.09	1.643	Doubtful
368	West 8 Zone 2	11.59	3.750	Good
369	West 8 Zone 2	11.84	3.728	Good
370	West 8 Zone 2	12.11	3.597	Good
371	West 8 Zone 2	12.24	3.398	Medium
372	West 8 Zone 2	12.40	3.555	Good
373	West 8 Zone 2	12.590	3.436	Medium

374	West 8 Zone 2	12.99	3.661	Good
375	West 8 Zone 2	12.56	3.535	Good
376	West 8 Zone 2	12.40	3.597	Good
377	West 8 Zone 2	12.19	3.220	Medium
378	West 8 Zone 2	12.99	2.782	Doubtful
379	West 8 Zone 2	12.69	3.661	Good

Table 38: Observation details at Underwater East West 8 UPV

4.4.10 Heat Map of observations at Underwater East West 9 UPV

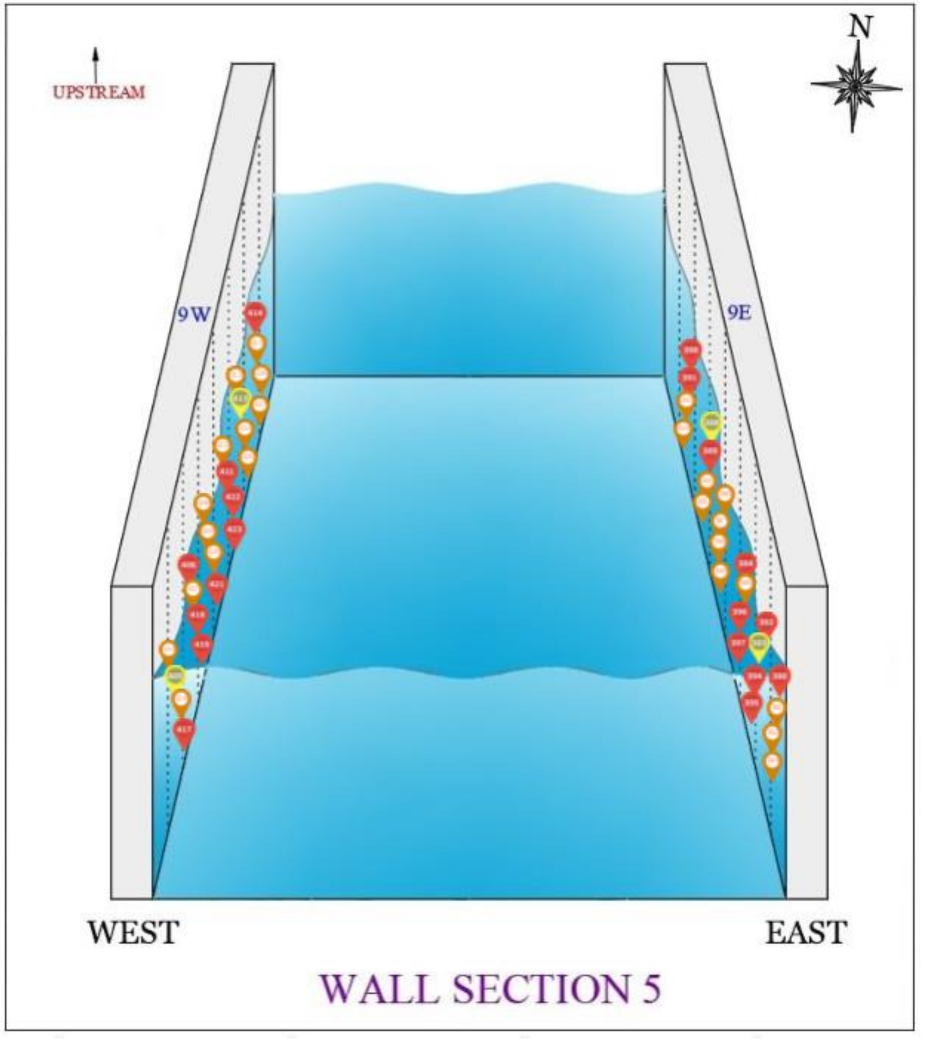


Figure 40: Heat map and Observations at Underwater East West 9 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
380	East 9 Zone 1	11.09	2.833	Doubtful
381	East 9 Zone 1	10.89	3.203	Medium
382	East 9 Zone 1	10.56	2.860	Doubtful
383	East 9 Zone 1	10.39	3.555	Good
384	East 9 Zone 1	10.84	2.211	Doubtful
385	East 9 Zone 1	11.01	3.342	Medium
386	East 9 Zone 1	11.07	3.044	Medium
387	East 9 Zone 1	10.89	3.09	Medium
388	East 9 Zone 1	10.53	3.597	Good
389	East 9 Zone 1	10.88	2.900	Doubtful
390	East 9 Zone 1	11.35	2.860	Doubtful
391	East 9 Zone 1	11.49	2.820	Doubtful

392	East 9 Zone 2	11.69	3.306	Medium
393	East 9 Zone 2	11.79	3.306	Medium
394	East 9 Zone 2	12.04	2.86	Doubtful
395	East 9 Zone 2	12.27	2.627	Doubtful
396	East 9 Zone 2	12.36	2.733	Doubtful
397	East 9 Zone 2	12.63	2.956	Doubtful
398	East 9 Zone 2	12.85	3.237	Medium
399	East 9 Zone 2	13.00	3.237	Medium
400	East 9 Zone 2	13.09	3.417	Medium
401	East 9 Zone 2	13.39	3.289	Medium
402	East 9 Zone 2	13.10	3.342	Medium
403	East 9 Zone 2	12.99	3.289	Medium
404	West 9 Zone 1	9.77	3.455	Medium
405	West 9 Zone 1	10.59	3.514	Good
406	West 9 Zone 1	10.17	2.605	Doubtful

407	West 9 Zone 1	10.39	3.220	Medium
408	West 9 Zone 1	10.76	3.170	Medium
409	West 9 Zone 1	11.22	3.494	Medium
410	West 9 Zone 1	11.55	3.361	Medium
411	West 9 Zone 1	11.15	2.942	Doubtful
412	West 9 Zone 1	11.13	3.203	Medium
413	West 9 Zone 1	11.25	3.514	Good
414	West 9 Zone 1	11.46	2.847	Doubtful
415	West 9 Zone 1	11.26	3.170	Medium
416	West 9 Zone 2	12.29	3.398	Medium
417	West 9 Zone 2	11.89	2.956	Doubtful
418	West 9 Zone 2	12.06	2.982	Doubtful
419	West 9 Zone 2	12.31	2.860	Doubtful
420	West 9 Zone 2	12.46	3.417	Medium
421	West 9 Zone 2	12.81	2.294	Doubtful

422	West 9 Zone 2	12.99	2.337	Doubtful
423	West 9 Zone 2	12.11	2.562	Doubtful
424	West 9 Zone 2	12.04	3.0900	Medium
425	West 9 Zone 2	11.98	3.436	Medium
426	West 9 Zone 2	11.74	3.324	Medium
427	West 9 Zone 2	11.92	3.417	Medium

Table 39: Observation details at Underwater East West 9 UPV

4.4.11 Heat Map of observation s at Underwater East 10 UPV

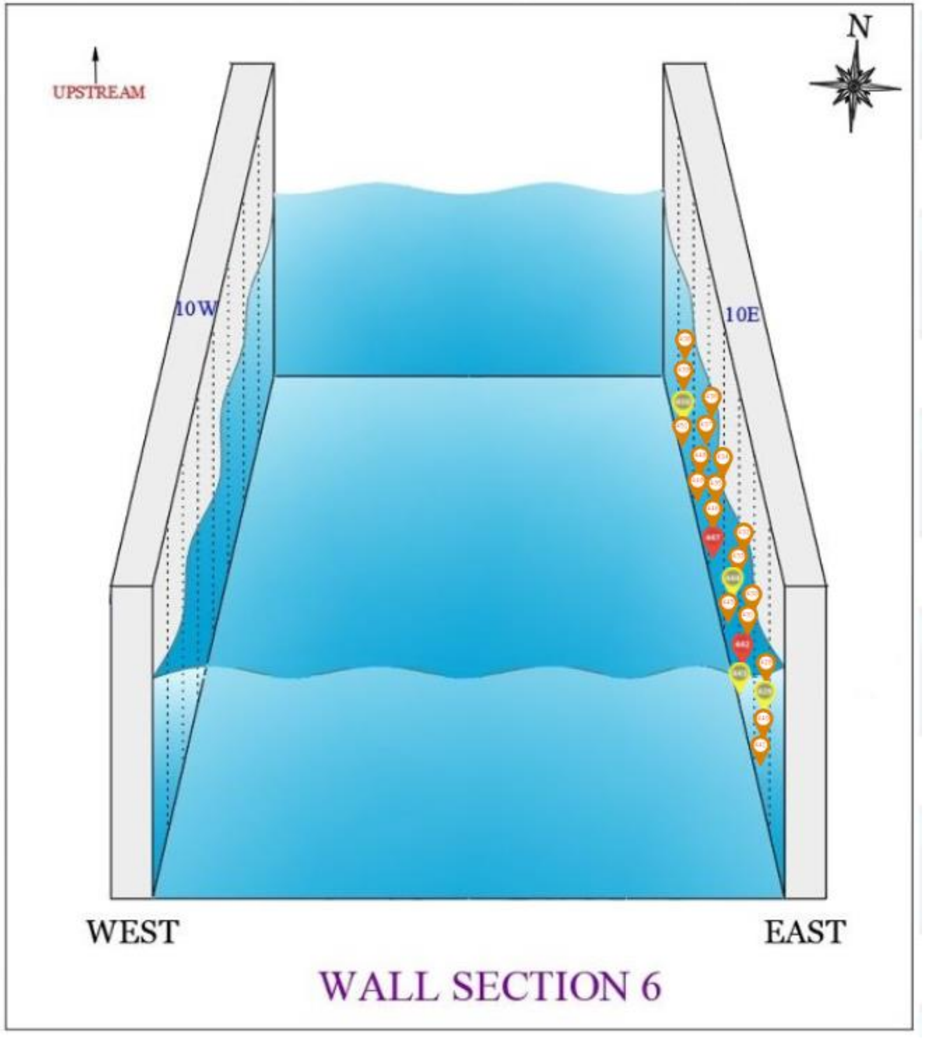


Figure 41: Heat map and Observations at Underwater East 10 UPV

S.No	Location	Depth(m)	Velocity(km/sec)	Remark
428	East 10 Zone 1	10.93	3.186	Medium
429	East 10 Zone 1	10.97	3.535	Good
430	East 10 Zone 1	10.95	3.494	Medium
431	East 10 Zone 1	11.02	3.137	Medium
432	East 10 Zone 1	11.37	3.271	Medium
433	East 10 Zone 1	11.26	3.289	Medium
434	East 10 Zone 1	11.43	3.306	Medium
435	East 10 Zone 1	11.56	3.121	Medium
436	East 10 Zone 1	12.07	3.029	Medium
437	East 10 Zone 1	12.00	3.186	Medium
438	East 10 Zone 1	11.91	3.455	Medium
439	East 10 Zone 1	12.55	3.455	Medium

440	East 10 Zone 2	12.93	3.17	Medium
441	East 10 Zone 2	13.10	3.379	Medium
442	East 10 Zone 2	13.16	2.928	Doubtful
443	East 10 Zone 2	13.20	3.639	Good
444	East 10 Zone 2	13.46	3.75	Good
445	East 10 Zone 2	13.32	3.289	Medium
446	East 10 Zone 2	13.37	3.324	Medium
447	East 10 Zone 2	13.47	2.999	Doubtful
448	East 10 Zone 2	13.67	3.154	Medium
449	East 10 Zone 2	13.52	3.475	Medium
450	East 10 Zone 2	13.43	3.639	Good
451	East 10 Zone 2	12.88	3.059	Medium

Table 40: Observation details at Underwater East 10 UPV

4.4.12 Heat Map of observations at Underwater West 10 UPV

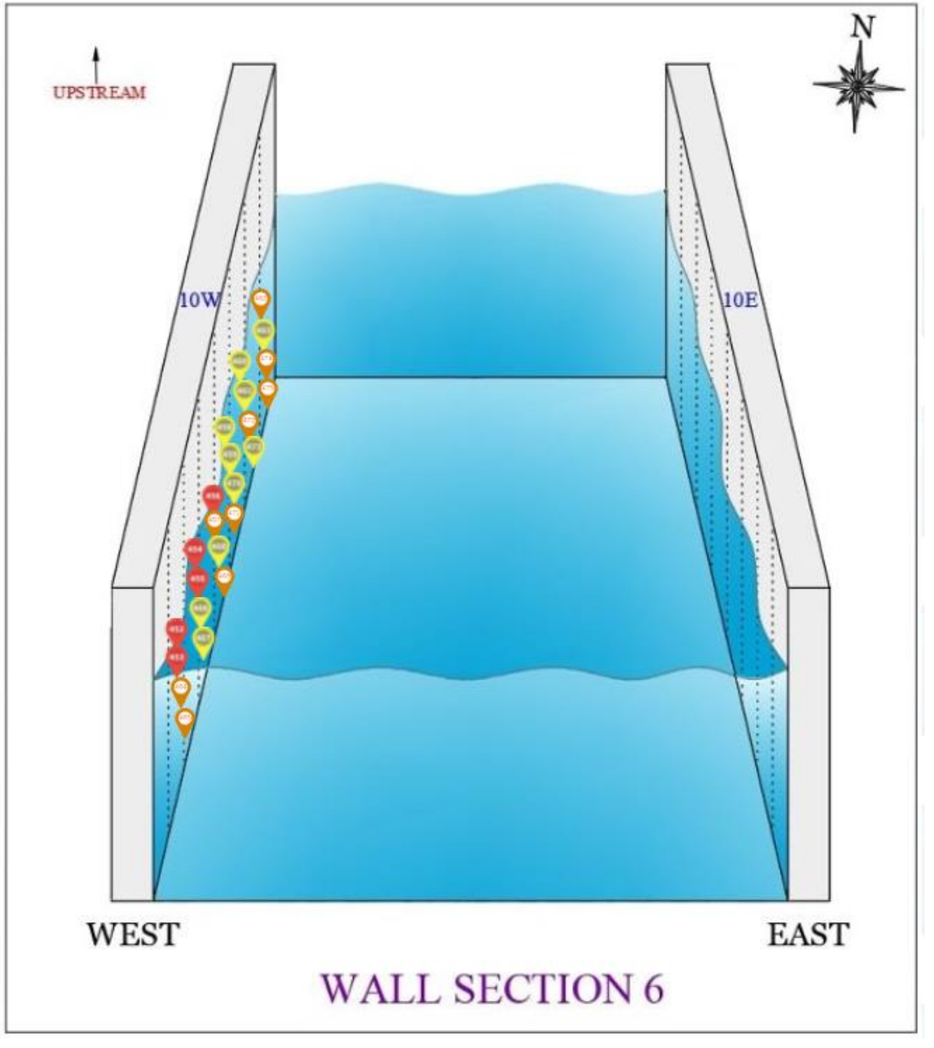


Figure 42: Heat map and Observations at Underwater West 10 UPV

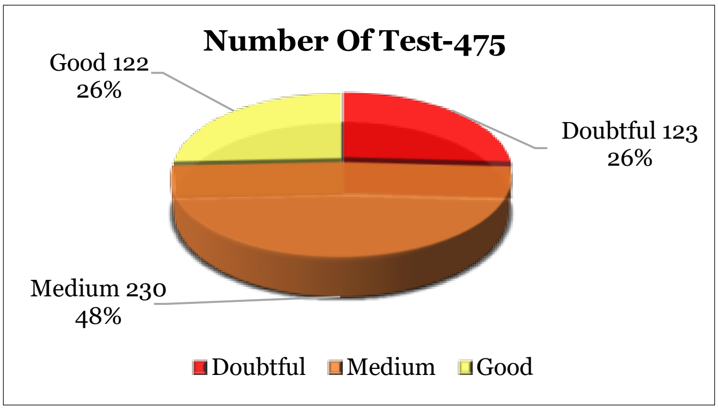
S.No	Location	Depth(m)	Velocity(km/sec)	Remark
452	West 10 Zone 1	11.11	2.914	Doubtful
453	West 10 Zone 1	11.57	2.847	Doubtful
454	West 10 Zone 1	11.59	2.914	Doubtful
455	West 10 Zone 1	11.74	2.970	Doubtful
456	West 10 Zone 1	11.57	2.820	Doubtful
457	West 10 Zone 1	11.93	3.289	Medium
458	West 10 Zone 1	11.80	3.514	Good
459	West 10 Zone 1	11.86	3.683	Good
460	West 10 Zone 1	11.97	3.728	Good
461	West 10 Zone 1	11.92	3.618	Good
462	West 10 Zone 1	12.18	3.436	Medium
463	West 10 Zone 1	12.17	3.661	Good

464	West 10 Zone 2	13.01	3.09	Medium
465	West 10 Zone 2	13.12	3.154	Medium
466	West 10 Zone 2	13.13	3.514	Good
467	West 10 Zone 2	13.17	3.618	Good
468	West 10 Zone 2	13.26	3.576	Good
469	West 10 Zone 2	13.57	3.271	Medium
470	West 10 Zone 2	13.52	3.576	Good
471	West 10 Zone 2	13.49	3.075	Medium
472	West 10 Zone 2	13.34	3.203	Medium
473	West 10 Zone 2	13.04	3.576	Good
474	West 10 Zone 2	12.85	3.254	Medium
475	West 10 Zone 2	13.08	3.237	Medium

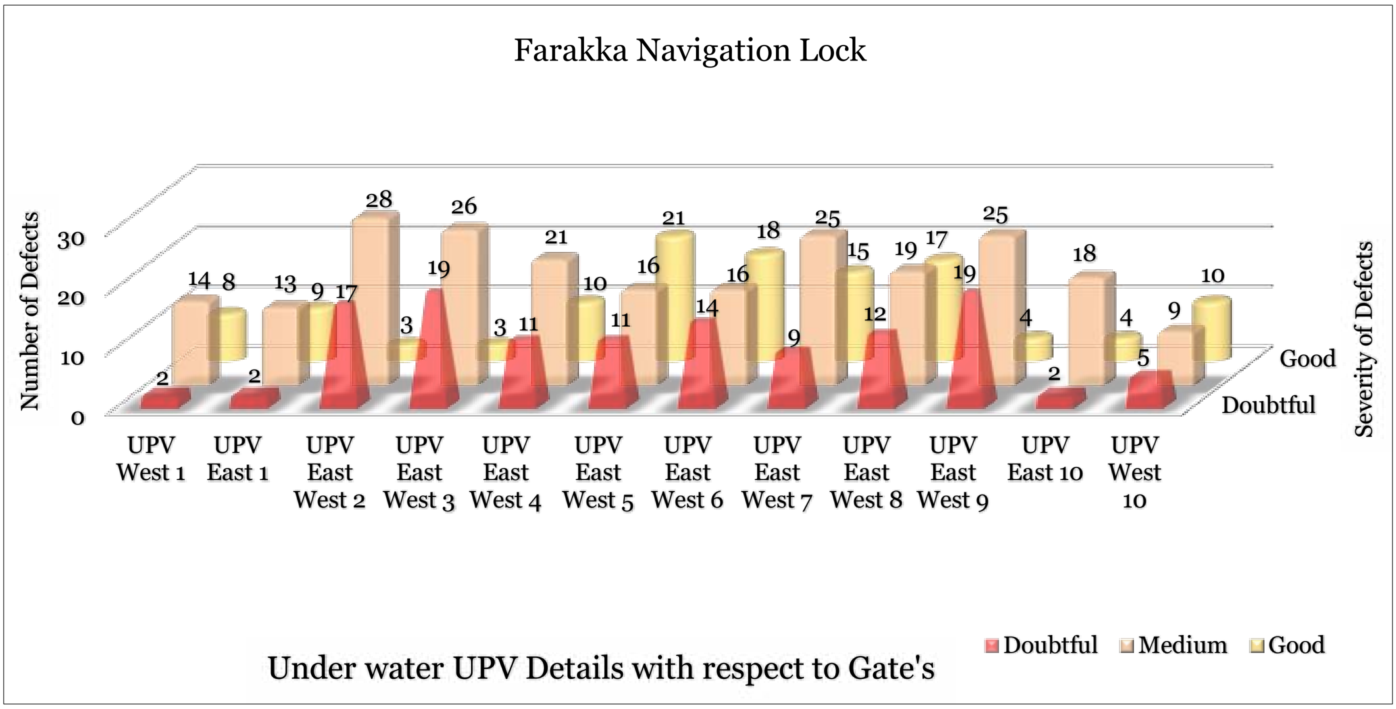
Table 41: Observation details at Underwater West 10 UPV

Under Water UPV Test Summary

Area of interest		Under Water UPV on East and West Wall	
Inspection Method		Ultrasonic Pulse Velocity Method	
Equipment Used	Ultrasonic Pulse Velocity Equipment (Refer 7F)	Date/Duration	31-03-2022 to 04-04-2022
Crew Size	6 members	Underwater Visibility	NA



Category of Observations	Number of Points
Doubtful	123
Medium	230
Good	122



Under water UPV Details with respect to Gate's

4.5 Observation from Underwater UT test

4.5.1 Heat Map of observations at UT 1

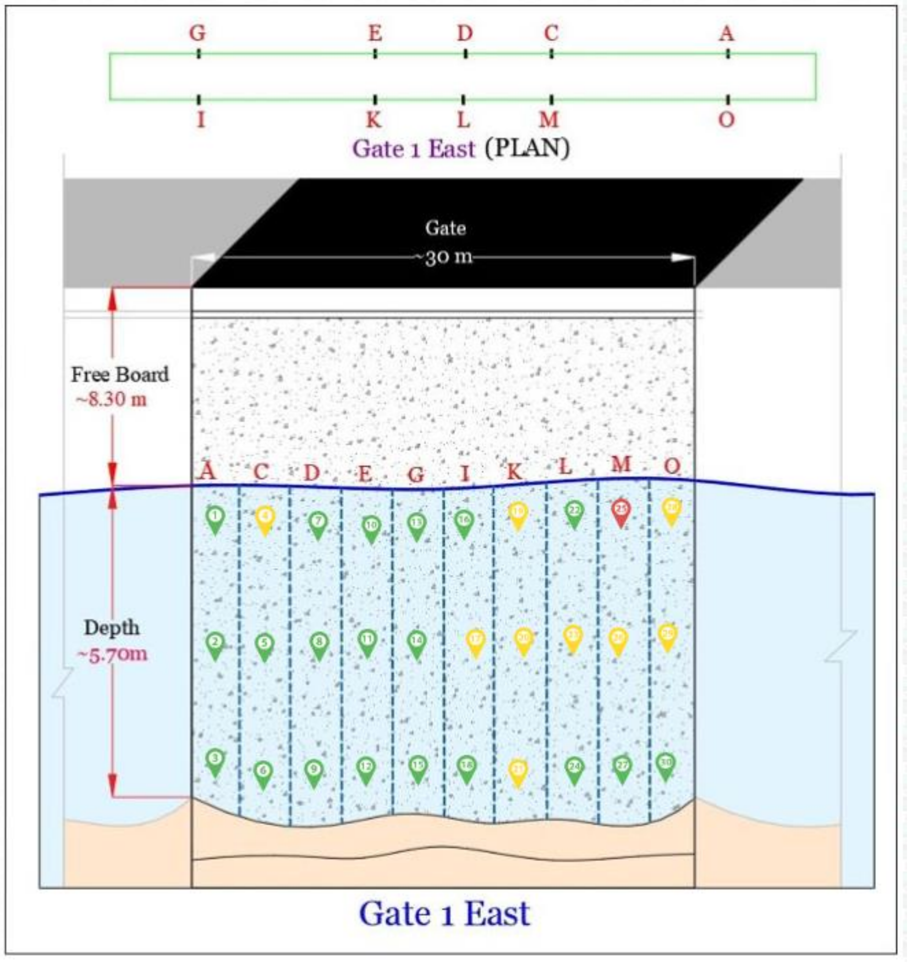


Figure 43: Heat map and Observations at UT 1

S.No	Location	Depth(m)	R1(mm)	R2(mm)	R3(mm)	R4(mm)	R5(mm)	R6(mm)	Average(mm)
1	A1	9.35	20.30	18.85	19.40	18.75	18.70	18.70	19.12
2	A2	11.42	22.00	22.00	22.00	22.00	22.00	22.00	22.00
3	A3	12.97	22.00	17.80	17.30	22.00	22.00	22.00	20.52
4	C1	9.43	17.55	17.90	17.85	17.80	19.75	19.60	18.41
5	C2	11.42	22.00	22.00	22.00	22.00	22.00	22.00	22.00
6	C3	12.99	22.00	22.00	22.00	22.00	22.00	22.00	22.00
7	D1	9.30	17.55	18.00	20.90	20.30	17.85	20.75	19.23
8	D2	10.70	21.50	21.45	22.00	22.00	22.00	22.00	21.83
9	D3	13.01	17.85	17.90	22.00	17.85	15.40	21.50	18.75
10	E1	9.50	20.10	20.00	20.15	19.50	17.50	NA	19.45
11	E2	11.28	22.00	22.00	22.00	22.00	22.00	NA	22.00
12	E3	13.05	22.00	22.00	22.00	22.00	22.00	22.00	22.00

13	G1	9.30	20.90	20.90	19.50	19.00	18.95	17.85	19.52
14	G2	11.30	22.00	22.00	22.00	22.00	22.00	22.00	22.00
15	G3	13.30	22.00	22.00	22.00	22.00	NA	NA	22.00
16	I1	8.98	12.00	12.00	12.00	12.00	12.00	NA	12.00
17	I2	11.62	17.15	17.25	17.00	18.85	17.25	17.35	17.48
18	I3	12.74	22.00	21.75	21.80	22.00	22.00	22.00	21.93
19	K1	9.14	7.13	6.65	9.00	12.00	12.00	NA	9.36
20	K2	11.42	17.10	15.85	16.00	16.80	17.25	14.55	16.26
21	K3	12.44	22.00	17.50	17.15	17.00	17.50	17.30	18.08
22	L1	9.10	9.95	9.70	12.00	8.90	10.85	12.00	10.57
23	L2	11.45	17.00	17.65	16.70	16.65	16.80	16.05	16.81
24	L3	12.60	22.00	22.00	22.00	22.00	22.00	22.00	22.00
25	M1	9.01	6.00	6.30	8.50	8.75	9.40	6.00	7.49
26	M2	11.27	15.75	15.15	16.40	16.40	16.25	16.15	16.02
27	M3	12.65	20.85	20.70	19.00	22.00	22.00	22.00	21.09

28	O1	9.03	10.65	10.75	10.56	6.15	6.00	NA	8.82
29	O2	11.23	17.05	15.50	16.95	17.00	16.95	16.85	16.72
30	O3	12.45	22.00	22.00	16.85	20.00	16.85	16.86	19.09

Table 42: Observation details at UT 1

4.5.2 Heat Map of observations at UT 2

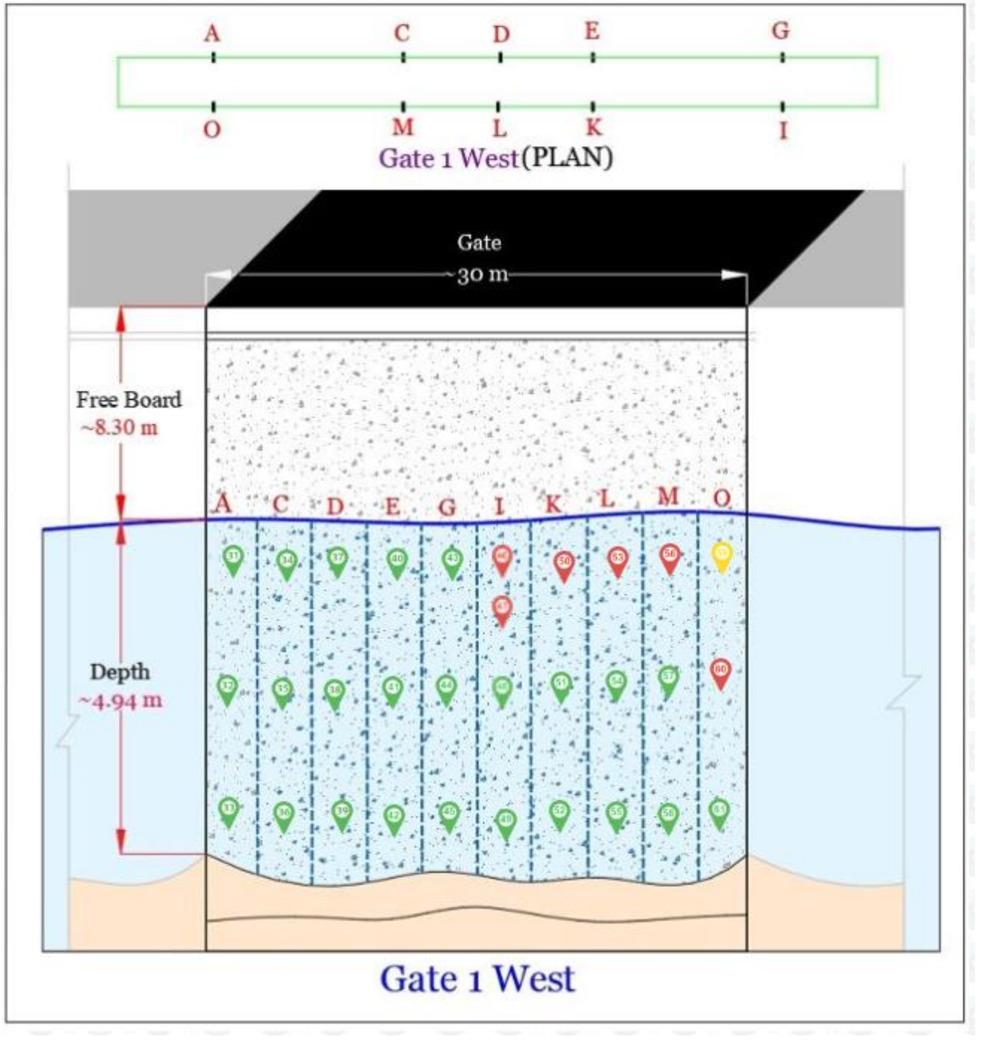


Figure 44: Heat map and Observations at UT 2

S.No	Location	Depth(m)	R1(mm)	R2(mm)	R3(mm)	R4(mm)	R5(mm)	R6(mm)	Average(mm)
31	A1	9.56	22.00	21.15	21.20	21.25	20.10	NA	21.14
32	A2	11.39	22.00	22.00	22.00	22.00	22.00	NA	22.00
33	A3	12.97	16.55	17.95	21.40	22.00	22.00	NA	19.98
34	C1	9.62	19.95	19.65	18.04	17.55	NA	NA	18.80
35	C2	11.03	22.00	22.00	22.00	22.00	22.00	NA	22.00
36	C3	12.99	22.00	22.00	17.90	22.00	22.00	22.00	21.32
37	D1	9.91	17.85	22.00	22.00	22.00	22.00	22.00	21.31
38	D2	10.93	22.00	22.00	22.00	22.00	22.00	NA	22.00
39	D3	12.44	22.00	22.00	22.00	22.00	22.00	NA	22.00
40	E1	9.38	20.00	22.00	19.95	17.65	19.15	NA	19.75
41	E2	11.23	22.00	22.00	22.00	22.00	22.00	NA	22.00

42	E3	13.26	22.00	22.00	22.00	22.00	22.00	NA	22.00
43	G1	9.56	21.35	19.65	20.15	17.95	20.80	20.95	20.14
44	G2	10.41	22.00	17.80	17.45	22.00	22.00	22.00	20.54
45	G3	12.74	22.00	22.00	22.00	22.00	22.00	NA	22.00
46	I1	9.28	5.90	5.90	8.30	NA	NA	NA	6.70
47	I1	9.57	5.40	NA	NA	NA	NA	NA	5.40
48	I2	11.13	16.00	12.00	16.00	16.00	16.00	NA	15.20
49	I3	12.70	22.00	22.00	22.00	22.00	22.00	NA	22.00
50	K1	9.50	8.80	5.90	5.90	5.95	11.91	NA	7.69
51	K2	11.12	12.00	16.00	9.10	16.00	16.00	16.00	14.18
52	K3	12.80	22.00	22.00	22.00	22.00	22.00	NA	22.00
53	L1	9.40	11.00	11.80	8.80	10.00	11.90	11.80	10.88
54	L2	11.20	12.00	16.00	14.30	16.00	16.00	13.00	14.55
55	L3	12.50	22.00	22.00	22.00	22.00	22.00	22.00	22.00

56	M1	9.50	5.95	11.80	11.80	6.90	8.70	8.30	8.91
57	M2	10.80	15.40	16.00	16.00	16.00	16.00	15.30	15.78
58	M3	12.90	22.00	22.00	22.00	22.00	22.00	22.00	22.00
59	O1	9.40	11.90	12.00	9.60	11.80	NA	NA	11.33
60	O2	11.30	12.50	17.50	15.70	14.30	NA	NA	15.00
61	O3	12.90	22.00	22.00	22.00	22.00	22.00	22.00	22.00

Table 43: Observation details at UT 2

4.5.3 Heat Map of observations at UT 3

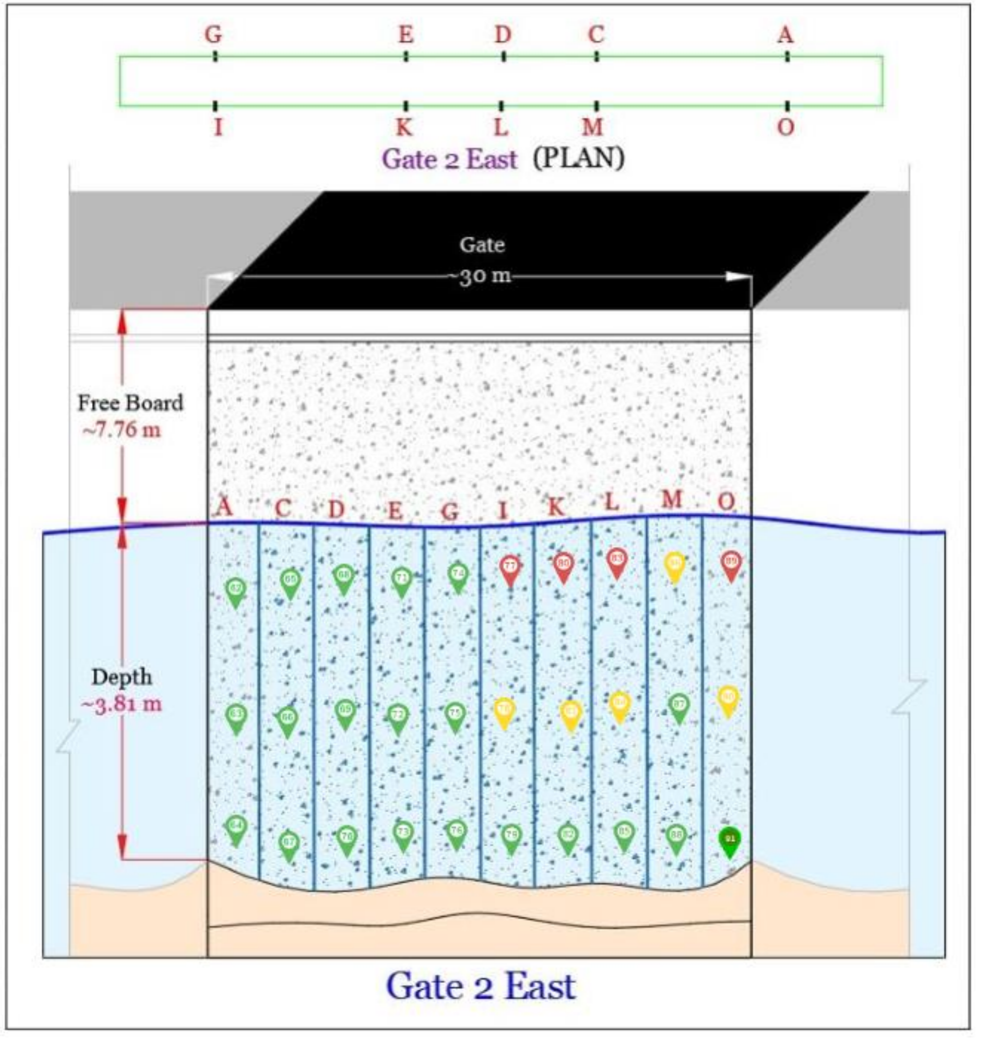


Figure 45: Heat map and Observations at UT 3

S. No	Location	Depth(m)	R1(mm)	R2(mm)	R3(mm)	R4(mm)	R5(mm)	R6(mm)	Average(mm)
62	A1	8.36	16.00	16.00	16.00	16.00	16.00	16.00	16.00
63	A2	9.17	14.75	16.00	16.00	15.55	16.00	16.00	15.72
64	A3	10.77	22.00	15.35	22.00	22.00	22.00	22.00	20.89
65	C1	8.46	16.00	16.00	16.00	16.00	16.00	16.00	16.00
66	C2	9.91	22.00	22.00	22.00	22.00	17.75	17.80	20.59
67	C3	10.95	22.00	22.00	21.45	22.00	22.00	NA	21.89
68	D1	8.72	16.00	16.00	16.00	16.00	16.00	16.00	16.00
69	D2	10.00	18.25	22.00	17.25	22.00	22.00	20.05	20.26
70	D3	10.99	3.31	21.85	22.00	22.00	22.00	22.00	18.86
71	E1	8.61	16.00	16.00	16.00	16.00	16.00	16.00	16.00
72	E2	9.08	16.00	16.00	16.00	16.00	16.00	16.00	16.00

73	E3	10.77	22.00	22.00	22.00	22.00	22.00	22.00	22.00
74	G1	8.32	16.00	12.00	16.00	16.00	16.00	16.00	15.33
75	G2	9.57	16.75	22.00	17.85	22.00	22.00	22.00	20.43
76	G3	11.07	22.00	22.00	22.00	22.00	22.00	22.00	22.00
77	I1	8.79	12.00	15.10	15.20	15.15	13.20	NA	14.13
78	I2	9.79	16.95	17.00	16.95	16.90	16.85	NA	16.93
79	I3	11.02	22.00	22.00	22.00	22.00	18.15	NA	21.23
80	K1	9.02	12.05	17.85	12.00	17.00	17.80	15.65	15.39
81	K2	9.72	15.05	16.65	17.15	17.15	17.25	12.50	15.96
82	K3	10.91	22.00	22.00	17.65	22.00	22.00	22.00	21.28
83	L1	8.26	10.85	16.85	12.00	15.75	17.75	16.80	15.00
84	L2	10.15	16.80	16.70	16.90	17.90	18.30	NA	17.32
85	L3	10.81	22.00	17.65	22.00	22.00	22.00	22.00	21.28
86	M1	8.79	15.30	16.25	16.70	16.95	12.05	NA	15.45

87	M2	10.15	17.75	22.00	22.00	22.00	22.00	22.00	21.29
88	M3	10.87	20.90	22.00	22.00	22.00	22.00	22.00	21.82
89	O1	8.50	12.00	9.65	9.50	9.80	14.60	15.90	11.91
90	O2	9.92	17.75	17.65	17.75	17.60	17.55	16.50	17.47
91	O3	10.97	22.00	22.00	22.00	22.00	22.00	22.00	22.00

Table 44: Observation details at UT 3

4.5.4 Heat Map of observations at UT 4

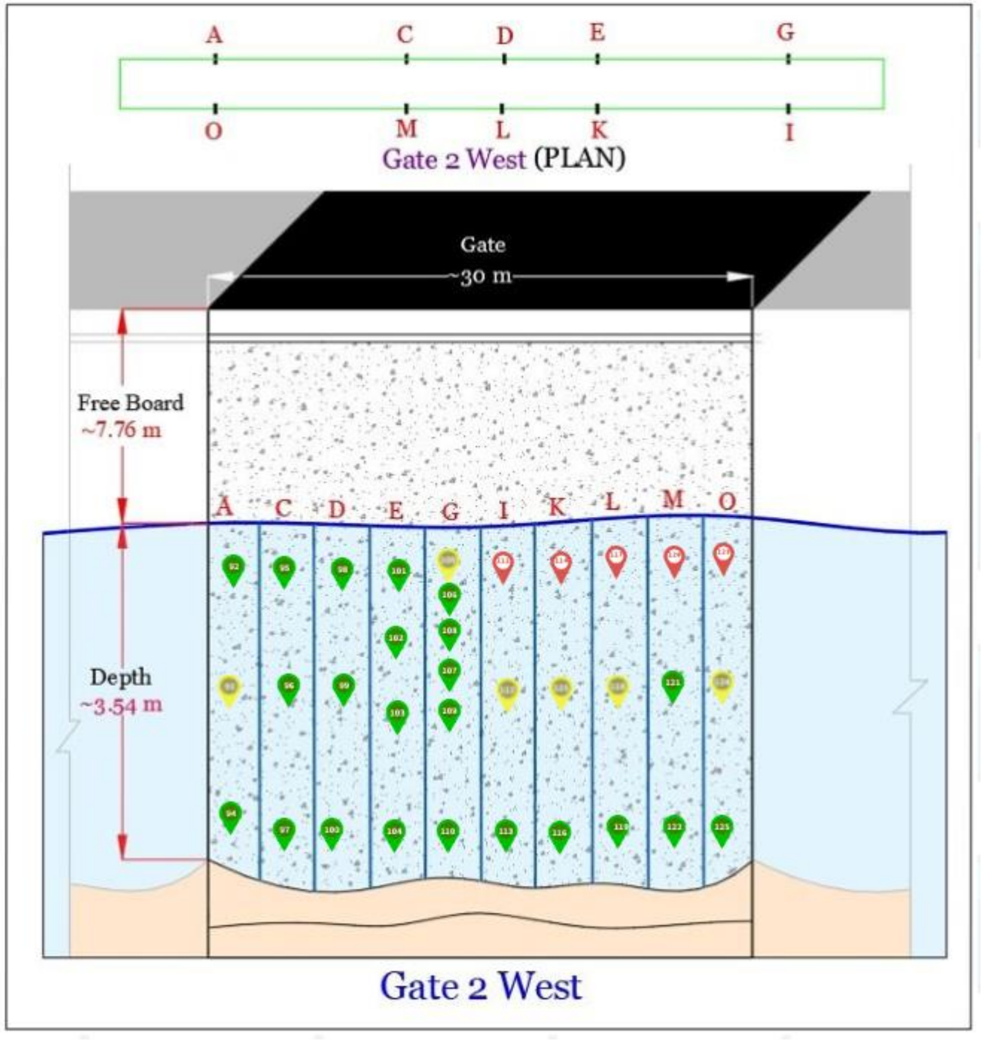


Figure 46: Heat map and Observations at UT 4

S.No	Location	Depth(m)	R1(mm)	R2(mm)	R3(mm)	R4(mm)	R5(mm)	R6(mm)	Average(mm)
92	A1	8.59	16.00	12.00	16.00	16.00	14.75	16.00	15.13
93	A2	9.61	22.00	22.00	15.75	15.05	17.85	17.75	18.40
94	A3	10.58	22.00	22.00	22.00	22.00	21.50	22.00	21.92
95	C1	8.55	16.00	16.00	16.00	16.00	16.00	16.00	16.00
96	C2	9.39	16.00	16.00	16.00	16.00	16.00	16.00	16.00
97	C3	10.49	17.90	17.90	17.80	17.85	22.00	22.00	19.24
98	D1	8.15	16.00	16.00	16.00	16.00	16.00	16.00	16.00
99	D2	9.20	16.00	16.00	10.95	14.80	16.00	16.00	14.96
100	D3	10.18	22.00	22.00	22.00	22.00	22.00	22.00	22.00
101	E1	8.28	16.00	16.00	16.00	16.00	16.00	16.00	16.00
102	E2	9.18	16.00	16.00	16.00	16.00	16.00	16.00	16.00

103	E3	10.22	22.00	22.00	22.00	22.00	22.00	NA	22.00
104	E3	10.73	22.00	17.75	17.85	NA	NA	NA	19.20
105	G1	8.37	12.00	7.85	16.00	16.00	10.15	10.05	12.01
106	G1	8.79	16.00	16.00	NA	NA	NA	NA	16.00
107	G1	9.41	11.45	11.80	16.00	16.00	16.00	16.00	14.54
108	G2	9.16	22.00	22.00	22.00	22.00	22.00	22.00	22.00
109	G2	11.12	16.00	10.55	16.00	16.00	16.00	16.00	15.09
110	G3	10.29	17.95	22.00	22.00	22.00	22.00	22.00	21.33
111	I1	8.43	12.30	12.00	12.05	9.00	12.05	11.45	11.48
112	I2	9.18	17.60	17.45	17.95	15.65	18.15	17.20	17.33
113	I3	10.74	22.00	22.00	22.00	22.00	22.00	22.00	22.00
114	K1	9.05	6.55	17.45	17.40	18.95	8.70	17.85	14.48
115	K2	10.03	17.20	17.05	16.75	13.25	22.00	15.65	16.98
116	K3	10.88	22.00	22.00	22.00	22.00	22.00	22.00	22.00

117	L1	9.05	12.00	9.95	12.00	9.00	16.45	9.85	11.54
118	L2	9.95	17.50	16.05	17.60	17.35	13.95	NA	16.49
119	L3	11.17	22.00	22.00	22.00	17.75	22.00	19.50	20.88
120	M1	8.78	7.50	7.80	6.80	12.00	8.56	8.70	8.56
121	M2	9.87	17.25	22.00	22.00	22.00	22.00	NA	21.05
122	M3	10.97	22.00	22.00	22.00	22.00	22.00	22.00	22.00
123	O1	8.98	15.55	10.50	16.65	11.75	9.35	9.85	12.28
124	O2	9.72	17.30	17.20	17.25	17.05	17.15	17.30	17.21
125	O3	10.98	22.00	22.00	22.00	22.00	22.00	22.00	22.00

Table 45: Observation details at UT 4

4.6 Observations from site inspection

4.6.1 Mitre Gates

During visual survey it was observed that the submerged portion of gates have significant leakages from bottom and front portion and structural components of these portion were found to be severally corroded (Figure 47). The wooden and rubber seals were found to be damaged and not effectively sealing openings/gaps between the structure and skin plates from both ends (b/w gates and b/w gate and corners (Figure 48)

Figure 47: Mitre Gates of Farakka Lock

Figure 48: Condition of Seals of Mitre Gate of Farakka Lock

The embedded parts of gate groove could not be inspected due to restricted access and presence of water during the site visit however the condition of the visible areas is not inducing confidence and rusting in exposed parts can be seen. The opening and closing of the gates were demonstrated to the team and the operation periods of the lock gates are noted as below.

Mitre Gate: Opening time: Appx. 10 minutes
Closing time: Appx. 10 minutes

These timings are quite high compared to the proposed Opening/Closing Time of 3-5 min for new lock's Mitre Gates and the operational capability and reliability of present mechanism is doubtful in future if the traffic across the Lock is further increased. During the operation of the gates, it was noted that top hinges of both gates are almost in the end period of their use and significant part of them is corroded with noise being observed for some period of operations from top bearings (Figure 49). It was noted that the greasing arrangement for the bearing is abandoned and has never been used. Hinges of one of the gate was damaged and subsequently replaced in 2020.

Figure 49: Top Bearing of Mitre Gates of Farakka Lock

Figure 50: Operating Mechanism of Mitre Gates of Farakka Lock

The operating mechanism (Figure 50) of the mitre gates is found to be based on old technology principles and the components and consumables are in dire need of replacement. The rope dismantles from the guides during operation and has to be put back on guides manually. The double rope guided pulley mechanism is not dependable and can create operation hazard/bottlenecks easily. The opening and closing time of the gate cannot be speeded up with this operating system. There is no automatic supervisory control mechanism for mitre gate operation and human intervention/interpretation is required to assess the U/S and D/S water level at gate and to decide the right time for closing and opening operation.

4.6.2 Cassion Gates

Two set of cassion Gates were provided for use to isolate the mitre gate for their inspection and maintenance. The gates are of size 26.05 m (H) X 4.0 m (B) X 0.8 m (W). However, due to the gate groove being not constructed properly during the initial stages, the gates were never lowered and hence have been abandoned with little to no care for their structural elements and operating mechanism (Figure 51).

The gates are in a dilapidated condition and heavily corroded. They are kept at the side of the lock presently and deeply embedded in silt (See Figure 51). The overall condition of the gates is rundown and is not in a position to be used presently or in the future. Further, the gates are kept anchored at the side of lock structure as no provision for parking was made at the time of original construction of the lock. These gates cannot be used at any point in future also as their gate grooves are not proper and they cannot be lowered in position to stop water. Also, the current position of gates is not right and suitable parking mechanisms and structure needs to be created at site.

Figure 51: Cassion Gates for Mitre Gate Maintenance at Farakka Lock

4.2.3 Radial Gates

To facilitate equalisation of water levels at opening and closing of lock, 4 Nos. of radial gates (2 Nos each at U/S and D/S end) are provided. These gates were manually operated for long duration. However; the mechanism was changed to electrically operated rope drum hoist. The radial Gates of the Lock are found in reasonably good physical condition but in need of rehabilitation. Bare minimum maintenance has been performed on the radial gates due to non-functioning of bulkhead gates.

Some structural members are found to be corroded and misaligned. Due to misalignment in the trunnions, it has caused the gate structure to rub against the piers causing some damage to both. The seals of most of the gates are not functioning properly and are worn out due to normal use and not having been replaced since long time. Radial Gates of Farakka Lock and Lifting brackets and limb arms of radial Gates are shown in Figure 52.

Figure 52: Lifting brackets and limb arms of Radial Gates

The embedded parts of these gates could not be inspected due to lack of access and most of structure being underwater.

The operation time of the radial gates as observed is given below:

Radial Gate: Opening time: Appx. 4 minutes

Closing time: Appx. 4 minutes

These durations are considered to be on higher side compared to the proposed Opening/Closing Time of 1 min for New Lock's radial gates. The operating mechanism of these gates is electrically operated rope drum hoist of old technology. Also, the operating equipment i.e., hoists, motors, ropes are found to be in poor condition and the system has not been properly maintained (Figure 53).

Figure 53: Operating System of Radial Gates

4.2.4 Bulkhead Gates

To isolate the existing radial gates for inspection and maintenance 8 Nos Bulkhead gates (2 Nos for each radial gate at its U/S and D/S) have been provided (Figure 54). These gates are critical to proper functioning of the Lock as they are necessary for maintenance and upkeep of radial gate and reduce the risk of failure. These are fixed wheel type vertical lift gates. Bulkhead Gates for Radial Gate Maintenance are shown in Figure 54. All gates were observed and also reported to be of different dimensions with not all of them being interchangeable. Most of the gates were kept outside in open atmosphere.

All structural members of the bulkheads were visually inspected and were found to be heavily corroded and beyond any chances of use in operation and not in a position of rehabilitation. The seals of all gates are in damaged conditions (Figure 54 and 55). The filling valve arrangement of gates are also in dilapidated state with corrosion on all sides (Figure 56). The Wheels are jammed and not rotating freely, greasing system was not functioning and bearings need to be replaced. The lifting assembly is shown in Figure 57.

Figure 54: Bulkhead Gates for Radial Gate Maintenance

Figure 55: Heavy corrosion in Bulkhead Gates

Figure 56: Deteriorated equalizing valve of Bulkhead Gates

Figure 57: Lifting Assembly of Bulkhead Gates

4.2.5 Filling / Emptying Systems

The lock is filled using filling water conductors running either side of the upstream mitre gates, with inlets on each side of the lock head structure, and outlets in the walls inside the chamber and downstream of the mitre gates. These water conductors are controlled using radial gates and are shown in Figure 58.

Similarly the lock is emptied using emptying water conductors running either side of the downstream mitre gates, with inlets inside the chamber and outlets in the walls downstream of the downstream mitre gates.

The filling/emptying (f/e) system appeared to operate at an adequate speed, and the lock levelling process (filling or emptying) took about 6.5 minutes including the time required for opening the radial gates. The hydraulic conditions created by the f/e system, i.e. currents and turbulence, appeared to provide acceptable conditions for vessels moored in the lock. No changes to the designs of the filling/emptying water conductors are recommended.

It was not possible to inspect the condition of the f/e culverts, which could have deteriorated due to erosion caused by water flows or mechanical damage from abrasion and impact of water-borne sediments and debris. The f/e water conductors could not be inspected even with the underwater robots due to the limited size of the opening at inlet and outlet points. As such an inspection is necessary under dry conditions. The water conductors along with filling / empting system should be inspected in dry condition when rehabilitation is undertaken in the lock structure.

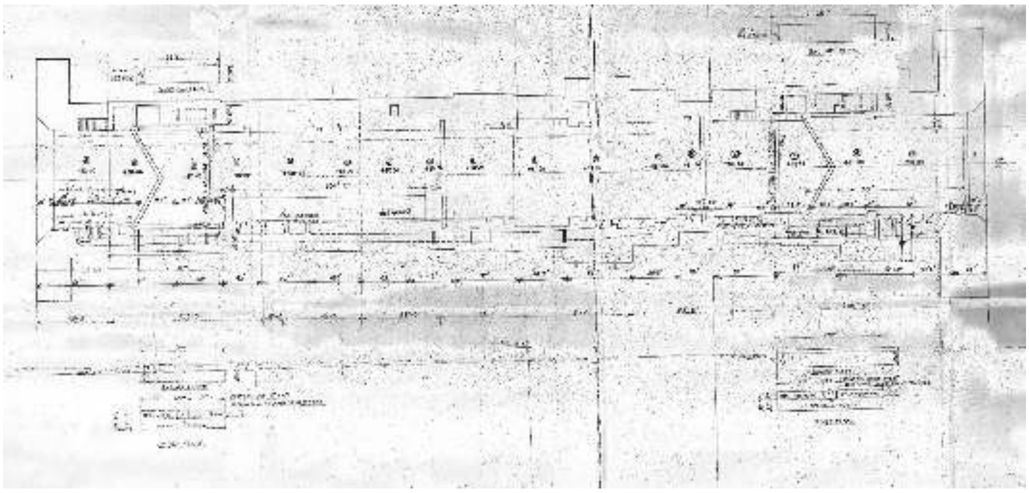


Figure 58: Navigational lock layout with filling/emptying system

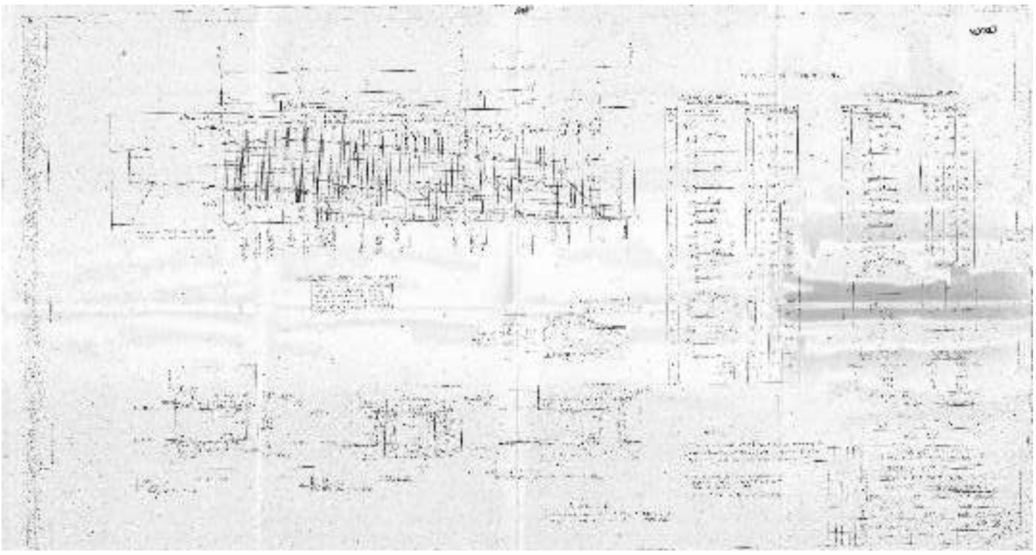


Figure 59: Details of filling/emptying system

4.2.6 Mooring Equipment

Conventional moorings systems viz. floating and fixed bollards are in place in the navigational lock. There are Bollards – eight (8) numbers floating type (four (4) on each bank) and fourteen (14) numbers fixed type (seven (7) on each bank). Most of the floating bollards are non-functional and even few of the fixed type bollards are damaged.

Figure 60: Floating Type Bollards

Figure 61: Damaged Fixed Type Bollard

4.2.7 Control Room Building

A G+4-storey central control room building is on the left bank of the existing navigational lock (Figure 62 and 63).

Figure 62: Control room building

Figure 63: Control room building (Close-up view)

Figure 64: Present Condition of interiors of Control room building

The structural condition of the Control room building is good but the building lacks basic amenities or the amenities are in very poor condition like lift, water supply, sanitation, lighting, etc. as shown in Figure 64.

4.2.8 Mechanical and Electrical Equipment

In addition to the various gates, the mechanical and electrical equipment includes the following Items:

- Mitre gate operating systems;
- Radial Gate operating systems;
- Bulkhead lifting beams;
- Ballasting/de-ballasting systems within the caisson gates;

- Two cable bridges spanning the lock at the upstream and downstream ends.

In the gate operating equipment listed here, the current state of the equipment has been dealt with along with the gates with which it is associated.

The earlier arrangement of power supply was using underground electrical ducts. But the overall electrical power and control system failed to work at some point of time which led to abandoning it. Subsequently a new direct power supply was separately taken to each electric motor drive contactor. This new arrangement did not use the existing underground electrical ducts and instead used two over-ground steel lattice cable bridges (one each at u/s ant d/s mitre gate) through which the electrical cables were dragged and supported (Figure 65). Both the cable bridges are corroded and are also vulnerable to collision.

Figure 65: Steel lattice type cable bridges

The electrical arrangements on the left side of the navigational lock are through the cable trench as shown in Figure 66. The trenches look essentially intact, but clearly need cleaning out. Some concrete covers are missing, or broken.

Figure 66: Cable trench for power cables

4.2.9 Control Systems

The original installation came complete with a push-button operating system with desks in houses at each end of the lock, on the left hand side. The electrical drawings indicate a sensible system based on direct-on-line starting of synchronous electric motors. Two control buildings exist, a central control building and a secondary control building at the upstream gates. These were built at the same time as the lock but it is not clear whether they were ever fully commissioned, or had originally been commissioned but have subsequently fallen into a state of dilapidation.

There are no working limit-switches for end of travel shut down and a series of stones are placed which are being used to indicate end of gate travel positions to the operators (Figure 67).

Figure 67: Temporary position indicator used to control gate opening

The gates were originally fitted with a push-button control system complete with end of travel limit switches and safety devices. This system has completely failed and the gates are now operated by persons directly closing the respective motor starter contactors (by placing their hands into a live electrical control box and using a stick) while somebody else manually over-rides the brake (Figure 68). This practice is dangerous as it exposes people to potentially fatal voltages.

Figure 68: Local control system of u/s Mitre and Radial Gate

4.2.10 Instrumentation

There are no instrumentation systems for water levels or head differences across the gates or flow monitoring in the lock. Fixed water level gauge boards exist at locations upstream and downstream of each of the sets of mitre gates, but these are in the ladder recesses and are not readily visible to the lock operators. Some of the gauge boards have been damaged and do not cover all operating water levels (Figure 69).

Figure 69: Fixed water level gauge in ladder recess

4.2.11 Power Supplies

Power comes onto the site via an 11kV substation inside the perimeter walls. The substation is outside of the scope of the survey, but looks in poor condition. It provides a 440 V 3-phase plus neutral supply via a single, overhead, 16 mm^2 (according to the OandM manual) cable which emerges at the downstream mitre gate power distribution house. 80 kA, 415 V, HRC in-line fuse links are in position. The power is distributed around the site via covered trenches and or overhead lines.

Figure 70: 11 kV to 415 V Transformer

Figure 71: Electrical sub-station distribution board

Figure 72: Electrical Control Room

All electrical equipment inspected was barely serviceable and in a dangerous condition whereby three-phase electricity can be directly touched. There is an alternative power source in the form of a DG set (Figure 73) which is in good shape.

Figure 73: DG Set

4.2.12 Communications Systems

There are no installed systems of communications at the lock complex and it appears that communications are primarily by voice.

4.2.13 Lighting and Signaling Equipment

There are a small number of low capacity street lamps along the lock chamber and two high mast lights (Figure 74). Night navigation is not operational at present.

Figure 74: Lighting system at the lock site

There is no signalling system or equipment in place. The current system of signalling is manual using flag and hooter.

4.2.14 Safety Equipment including Fender Arrangement

There does not appear to be any safety equipment installed at the lock, other than the ladders installed at intervals along the walls of the lock chamber. The positions of these ladders could usefully be highlighted by painting them white.

Provisions for fenders in the form of wooden logs and hanging tyres are provided in the lock chamber. There are 25 wooden fenders on each wall of dimension 6 in x 4 in and variable height. The wooden fenders are in poor condition with some fenders not in place while some are damaged. The rubber tyre fenders are also in dilapidated condition (Figure 75).

Figure 75: Wooden and rubber tyre fender arrangement

Safety equipment at navigation locks should include lifebuoys at intervals along each side of the lock. These should be in prominent positions at identified high-risk areas and at intervals of not more than 100 m. Lifelines should be attached to lifebuoys and a separate throwing line should be provided.

It is normally assumed that the fire brigade would be responsible for fire-fighting at locks, although detailed contingency plans should be agreed with the fire brigade for different types of fire (e.g. buildings, ships), particularly if hazardous or inflammable cargoes are passing through the lock. Armed guards are present at the upstream and downstream ends of the lock chamber. The whole lock site is surrounded by a security wall and the public are not allowed to enter. The wall is evidently maintained to a high standard and repainted regularly.

4.2.15 Stocks of Spares

There do not appear to be any stocks of spare equipment installed at the lock. Storage space is apparently available in the control room building.

4.2.16 Maintenance Equipment

Stocks of maintenance equipment and supplies do not appear to be kept at the lock; except for grease and oil for lubrication of some of the equipment.

4.2.17 Lock Operation Manuals (SOP's) and Existing Technical Records

A copy of the Lock Operations and Maintenance Manual was provided which includes brief details of the various lock components and the process to operate the various components of the lock viz. cassion gates, mitre gates, radial gates, bulkhead gates, mooring bits etc. for movement of vessel in the u/s to d/s and vice versa direction. A set of as-built drawings of the navigational lock chamber, cassion gates, mitre gates, radial gates, bulkhead gates and other ancillary components were provided. Detailed technical specifications of the structures and equipment do not appear to be available.

4.2.18 Maintenance Records

No records of previous break-downs and repairs were available. No log of maintenance operations is available with the barrage team.

5.0 Condition Survey Indicators

5.1 Performance Indicators

The information gathered from condition survey type of inspection is used to calculate a condition index (CI). The Condition Index (CI) is a snapshot look at the condition of a part or component of the infrastructure. The field measurement data is representative of the current state of the structure. The condition index (CI) is a numerical measure used to rate the current state of the equipment / structure. The ratings are based primarily on physical deterioration as determined by distresses that can be seen or measured.

The Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program of the U.S. Army Corps of Engineers has developed a condition index which is a numerical scale, ranging from a low of 0 to a high of 100. The numbers indicate the relative need to perform REMR work because of deteriorating characteristics of the structure. Condition index provided by U.S. Army Corps of Engineers has been used to assess the present condition of the navigation lock and its various appurtenances. For management purposes, the CI scale is also calibrated to group structures into three basic categories or zones (Table 46).

The functional condition index is generated using expert analysis and judgement of field data. The experts take many factors into account as they evaluate the functional condition index like:

a) Its performance at normal and below-normal service conditions on a day-to-day basis.
b) Subjective Safety

A series of critical measurements have been made on each gate to quantify the functional condition index. The functional condition index is quantified by

$$Functional\ CI = 100(0.4)^{X/X_{max}}$$

where X_{max} *is the limiting value of X.*

Zone	Condition Index (CI)	Condition Description	Recommended Action
1	85 to 100	**Excellent:** No noticeable defects. Some aging or wear may be visible	
	70 to 84	**Good:** Only minor deterioration or defects are evident	
2	55 to 69	**Fair:** Some deterioration or defects are evident, but function is not significantly affected	Economic analysis of repair alternatives is recommended to determine appropriate action
	40 to 54	**Marginal:** Moderate deterioration. Function is still adequate	
3	25 to 39	**Poor:** Serious deterioration in at least some portions of the structure. Function is inadequate	Detailed evaluation is required to determine the type of repair, rehabilitation or reconstruction. Safety evaluation recommended
	10 to 24	**Very Poor:** Extensive deterioration. Barely functional	
	0 to 9	**Failed:** No longer functions. General failure or complete failure of a major structural component	

Table 46: Condition index scale and zones

According to the previous description of action zones, X_{max} is defined as the point at which the functional condition index is 40, that is, the dividing point between Zones 2 and 3.

Figure 76 illustrates the equation and zones from Table 46. If X is 0, that is, no distress, the condition index is 100.

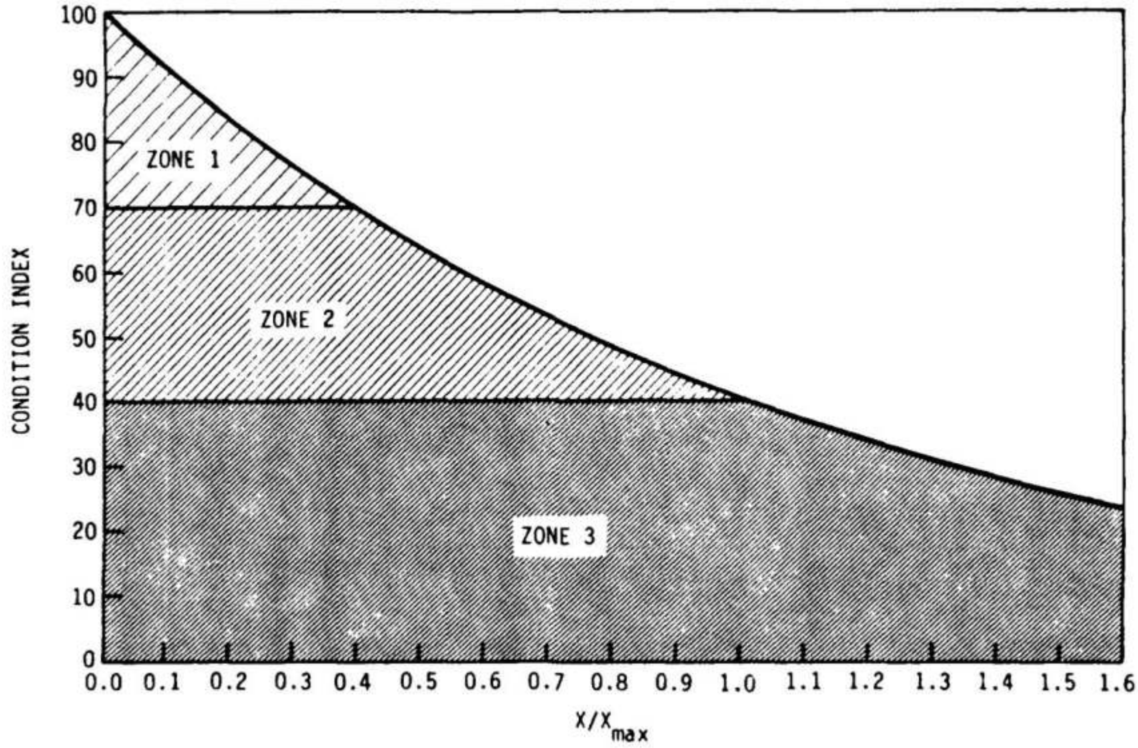


Figure 76: Functional condition index (CI) related to X/Xmax

Notes

1. If a structure is designed and constructed properly, it has an initial condition index of 100.
2. The functional condition index never quite reaches 0.
3. The judgment for X_{max} is based on serviceability or subjective safety considerations. The mix and weight of serviceability versus safety are incorporated.

The functional condition index of Cassion Gates, Mitre Gates, Radial Gates, Bulkhead Gates, Navigation Lock Chamber, Mooring Equipment and Electrical equipment is given in Tables 47-56.

5.2Functional Condition Index

Cassion Gates								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate, Girder and Stiffner	Crack	No	4	20	50	10	24.00	Replace the skin plate areas
	Corrosion	No	4	10	20	2		
	Strength (Thickness)	No	4	40.00	20	8.00		
	Dents	No	3	40	10	4		
Equalizing System	Operation	Yes	4	20	100	20	20	Replace the Equalizing System
Seals	Leakage	Yes	4	20	100	20	20	Replace the Seals
Operating Mechanism	Noise/Vibration	Could not be checked	NA	NA	NA	NA	23.3	Replace the operating system
	Maintenance Easiness	Yes	3	30	33	9.9		
	Operation	Yes	3	20	34	6.8		
	Synchronization	Yes	3	20	33	6.6		

Table 47: Functional Condition Index of Cassion Gates of Existing Farakka Navigational Lock

Upstream Mitre Gate (East Leaf)								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation & Ultrasonic Thickness Testing (UT)**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate, Girders and Stiffeners	Crack	Yes	4	40	50	20	50.65	Replace the underwater portion and 1.0 m above the HFL in splash zone
	Corrosion	Yes	4	40	20	8		
	Strength (Thickness)	Yes	2	63.25	20	12.65		
	Dents	No	0	100	10	10		
Wooden and Rubber Seals	Leakage	Yes	4	20	100	20	20	Replace the wooden and rubber seals
Operating Mechanism	Noise/Vibration	Yes	3	30	25	7.5	30	Replace the operating system
	Maintenance Easiness	Yes	3	30	25	7.5		
	Operation	Yes	3	30	25	7.5		
	Synchronization	Yes	3	30	25	7.5		

Table 48: Functional Condition Index of Upstream Mitre Gate (East Leaf) of Existing Farakka Navigational Lock

Upstream Mitre Gate (West Leaf)								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation & Ultrasonic Thickness Testing (UT)**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate, Girders and Stiffeners	Crack	Yes	4	40	50	20	48.06	Replace the underwater portion and 1.0 m above the HFL in splash zone
	Corrosion	Yes	4	40	20	8		
	Strength (Thickness)	Yes	3	50.30	20	10.06		
	Dents	No	0	100	10	10		
Wooden and Rubber Seals	Leakage	Yes	4	20	100	20	20	Replace the wooden and rubber seals
Operating Mechanism	Noise/Vibration	Yes	3	30	25	7.5	30	Replace the operating system
	Maintenance Easiness	Yes	3	30	25	7.5		
	Operation	Yes	3	30	25	7.5		
	Synchronization	Yes	3	30	25	7.5		

Table 49: Functional Condition Index of Upstream Mitre Gate (West Leaf) of Existing Farakka Navigational Lock

Downstream Mitre Gate (East Leaf)								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation & Ultrasonic Thickness Testing (UT)**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate, Girders and Stiffeners	Crack	Yes	4	40	50	20	50.65	Replace the underwater portion and 1.0 m above the HFL in splash zone
	Corrosion	Yes	4	40	20	8		
	Strength (Thickness)	Yes	1	63.25	20	12.65		
	Dents	No	0	100	10	10		
Wooden and Rubber Seals	Leakage	Yes	4	20	100	20	20	Replace the wooden and rubber seals
Operating Mechanism	Noise/Vibration	Yes	3	30	25	7.5	30	Replace the operating system
	Maintenance Easiness	Yes	3	30	25	7.5		
	Operation	Yes	3	30	25	7.5		
	Synchronization	Yes	3	30	25	7.5		

Table 50: Functional Condition Index of Downstream Mitre Gate (East Leaf) of Existing Farakka Navigational Lock

Downstream Mitre Gate (West Leaf)								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation & Ultrasonic Thickness Testing (UT)**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate, Girders and Stiffeners	Crack	Yes	4	40	50	20	50.65	Replace the underwater portion and 1.0 m above the HFL in splash zone
	Corrosion	Yes	4	40	20	8		
	Strength (Thickness)	Yes	1	63.25	20	12.65		
	Dents	No	0	100	10	10		
Wooden and Rubber Seals	Leakage	Yes	4	20	100	20	20	Replace the wooden and rubber seals
Operating Mechanism	Noise/Vibration	Yes	3	30	25	7.5	30	Replace the operating system
	Maintenance Easiness	Yes	3	30	25	7.5		
	Operation	Yes	3	30	25	7.5		
	Synchronization	Yes	3	30	25	7.5		

Table 51: Functional Condition Index of Downstream Mitre Gate (West Leaf) of Existing Farakka Navigational Lock

Radial Gates								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate	Crack	No	0	100	50	50	84.30	Repair the skin plate areas
	Corrosion	No	2	63.246	20	12.649		
	Strength (Thickness)	No	2	63.25	20	12.65		
	Dents	No	0	100	10	10		
Arms	Joint assembly	Yes	4	20	100	20	20	Repair the arms/joint assembly
Rubber Seals	Leakage	Yes	4	20	100	20	20	Replace the rubber seals
Operating Mechanism	Noise/Vibration	Yes	1	90	25	22.5	45	Replace the operating system
	Maintenance Easiness	Yes	3	30	25	7.5		
	Operation	Yes	3	30	25	7.5		
	Synchronization	Yes	3	30	25	7.5		

Table 52: Functional Condition Index of Radial Gates of Existing Farakka Navigational Lock

Bulkhead Gates								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Skin Plate, Girder and Stiffner	Crack	No	3	40	50	20	44.06	Replace the skin plate areas
	Corrosion	No	4	20	20	4		
	Strength (Thickness)	No	3	50.30	20	10.06		
	Dents	No	0	100	10	10		
Equalizing Valve	Operation	Yes	4	20	100	20	20	Replace the Equalizing valve
Roller Assembly	Jammed	Yes	4	20	100	20	20	Replace the roller assembly
Operating Mechanism	Noise/Vibration	Could not be checked	NA	NA	NA	NA	30	Replace the operating system
	Maintenance Easiness	Yes	3	30	33	9.9		
	Operation	Yes	3	30	34	10.2		
	Synchronization	Yes	3	30	33	9.9		

Table 53: Functional Condition Index of Bulkhead Gates of Existing Farakka Navigational Lock

Lock Chamber and Approach Structure								
Items	**Critical Parameter**	**Defect based on Visual Inspection/ Estimation & Ultrasonic Pulse Velocity Testing (UPV)**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Side Walls	Crack	Yes	1	63.25	25	15.811	63.46	Repair the wall surface
	Bar Exposure	Yes	1	90	25	22.5		
	Honeycombing	Yes	3	50.30	25	12.57		
	Quality	Yes	3	50.30	25	12.574		
Side Walls	Crack	Yes	1	63.25	25	15.811	60.96	Repair the Base slab surface
	Bar Exposure	Yes	1	80	25	20		
	Honeycombing	Yes	3	50.30	25	12.57		
	Quality	Yes	3	50.30	25	12.574		

Table 54: Functional Condition Index of Lock Chamber of Existing Farakka Navigational Lock

Mooring Equipment								
Items	**Critical Parameter**	**Defect based on Visual Inspection/**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Fixed Bollard	Crack	Yes	3	50.30	100	50.3	50.3	Replace the Fixed Bollard
Floating Bollard	Corrosion	Yes	2	63.25	50	31.6	41.6	Replace the Floating Bollard
	Movement	Yes	4	20	50	10		

Table 55: Functional Condition Index of Mooring Equipment of Existing Farakka Navigational Lock

Electrical Equipment								
Items	**Critical Parameter**	**Defect based on Visual Inspection**	**Count/ Severity**	**CI**	**Weightage (%)**	**Weight * CI**	**Functional CI**	**Remarks**
Underground Electrical Ducts	Access	Yes	4	20	50	10	32.5	Repair the Underground Electrical Ducts
	Civil Structure	Yes	3	50.30	50	22.5		
Steel Lattice Cable Bridge	Corrosion	Yes	2	63.25	100	63.25	63.25	Repair the Steel Lattice Cable Bridge

Table 56: Functional Condition Index of Electrical Equipment's of Existing Farakka Navigational Lock

Sl. No.	Item	Design Life (Yrs) as per IS Codes*	Residual Life Without Renovation and Replacement (Yrs)	Working Life With Renovation and Replacement (Yrs)
1	Cassion Gate	30-35	Nil	30-35
2	Cassion Gate Operating System	15	Nil	15
3	Mitre Gate	30-35	Nil	30-35
4	Mitre Gate Operating System	15	Nil	15
5	Radial Gate	30-35	10-15	20-25
6	Radial Gate Operating System	15	Nil	15
7	Bulkhead Gate	30-35	Nil	30-35
8	Bulkhead Operating System	15	Nil	15
9	Lock Chamber and Approach Structure	100	30-40	50
10	Filling/Emptying System	100	30-40	50
11	Mooring Equipment	30-35	Nil	30-35
12	Electrical Equipment’s	30-35	15-20	25-30
13	Control System	15	Nil	15
14	Power Supply	30-35	5-10	30-35
15	Lighting Equipment	30-35	10-15	25-30
16	Fender Arrangement	30-35	Nil	30-35

Table 57: Operational working life with or without renovation

* IS: 10210, IS: 456, IS: 14223, IS: 2060, etc.

6.0 Findings and Recommendations

6.1 Introduction

The condition survey shows clearly that the existing mechanical, electrical and control equipment at the Farakka Lock is in poor state and beyond its life in terms of condition and reliability. Each area of the equipment is discussed separately below in terms of the need and potential to refurbish and improve or to replace completely. The condition of all of the concrete structures in the lock complex has been affected with deterioration in homogeneity and honeycombing along with cracks and cavity formation.

6.2 Cassion Gates

The health of the cassion gates is very poor in zone 3 with overall condition index falling in the range of 10-24. It is recommended to replace both the cassion gates. The complete system of cassion gates and the operating system needs to be replaced. The gate groves and embedded parts of existing lock may be suitably modified to accommodate the new cassion gates.

However, as a viable alternative, and since use of Cassion Gates will be very infrequent in both existing as well as under construction lock for maintenance of mitre gate or lock structure, the feasibility of utilizing the cassion gates being fabricated for use at the new (under construction) lock structure in the existing lock may be explored during the construction phase.

This resource sharing can be beneficial to the project from both time and cost aspects during the rehabilitation of existing lock structure. The feasibility of using the new lock caisson gates at existing lock structure can be explored along with possible modifications in the new caisson gates for provision of movement of the gates using tug boat.

6.2.1 Possible Performance Improvements

The new cassion gates shall comprise of deck, bulkheads, face plates so that various tanks and chambers can be arranged for ballasting and de-ballasting required for sinking and raising operations of the gate. The structural arrangement of the gate shall be of adequate strength and stiffness along with anti-corrosive coting to enhance the life. Proper sealing arrangements shall be provided with vertical and horizontal face of the lock chamber. Sill and side walls at gate grooves shall be made of polished granite. Electrically operated capstan including starters, cables, fuse sockets etc. shall be fitted with necessary foundation for positioning and shifting the caisson on both side of lock floor.

6.3 Mitre Gates

The health of the gate leaf portion of the mitre gates above water is good whereas, for the underwater portion and area in the splash zone, the health is marginal in zone 2 with functional condition index falling in the range of 40-54. It is recommended to carry out minor repairs in the above water portion and replace the skin plate and damaged components of underwater and splash zone portion of the mitre gates. Further the embedded parts along with the wooden and rubber seals also need replacement.

The health of the operating mechanism of the mitre gates is poor in zone 3 with functional condition index falling in the range of 25-39. Overall, all the components of the mitre gates under water and splash zone should be replaced and the above water gate leaf portion and components can continue with repairs.

6.3.1 Possible Performance Improvements

The existing operating mechanism needs to be replaced with a hydraulic system with axial-piston pumps and cylinders for quick operation speeds and durable components. The replacement of the current rope operating system with an alternative involving a hydraulic system with axial-piston pumps and cylinders would enable overload protection and incorporate gate holding properties. A cross-head which is a guided bearing attaches to the mitre gate leaf via a push-rod to give it smoother operation. This also has the advantage of protecting the hydraulic cylinder from the possibility of direct impact from a vessel. Such an arrangement will be needed at Farakka. The hydraulic operating cylinder will also bring down the operating time (opening and closing time) of the mitre gate substantially and improve the performance of the old navigational lock.

6.3.2 Suggested state-of-the-art Technology

Modern Hydraulic power packs units are envisaged to use axial pumps with hydraulic cylinders. The hydraulic system shall include hydraulic power units using variable displacement, axial-piston pumps, manifolds, stainless steel reservoirs, hydraulic cylinders, piping etc. as well as safety and instrumentation system. The system components shall be designed as per IS: 10210. A remote control operation of the gate is envisaged from central control and also local control room. The conceptual drawing of the proposed system is given in Figure 77.

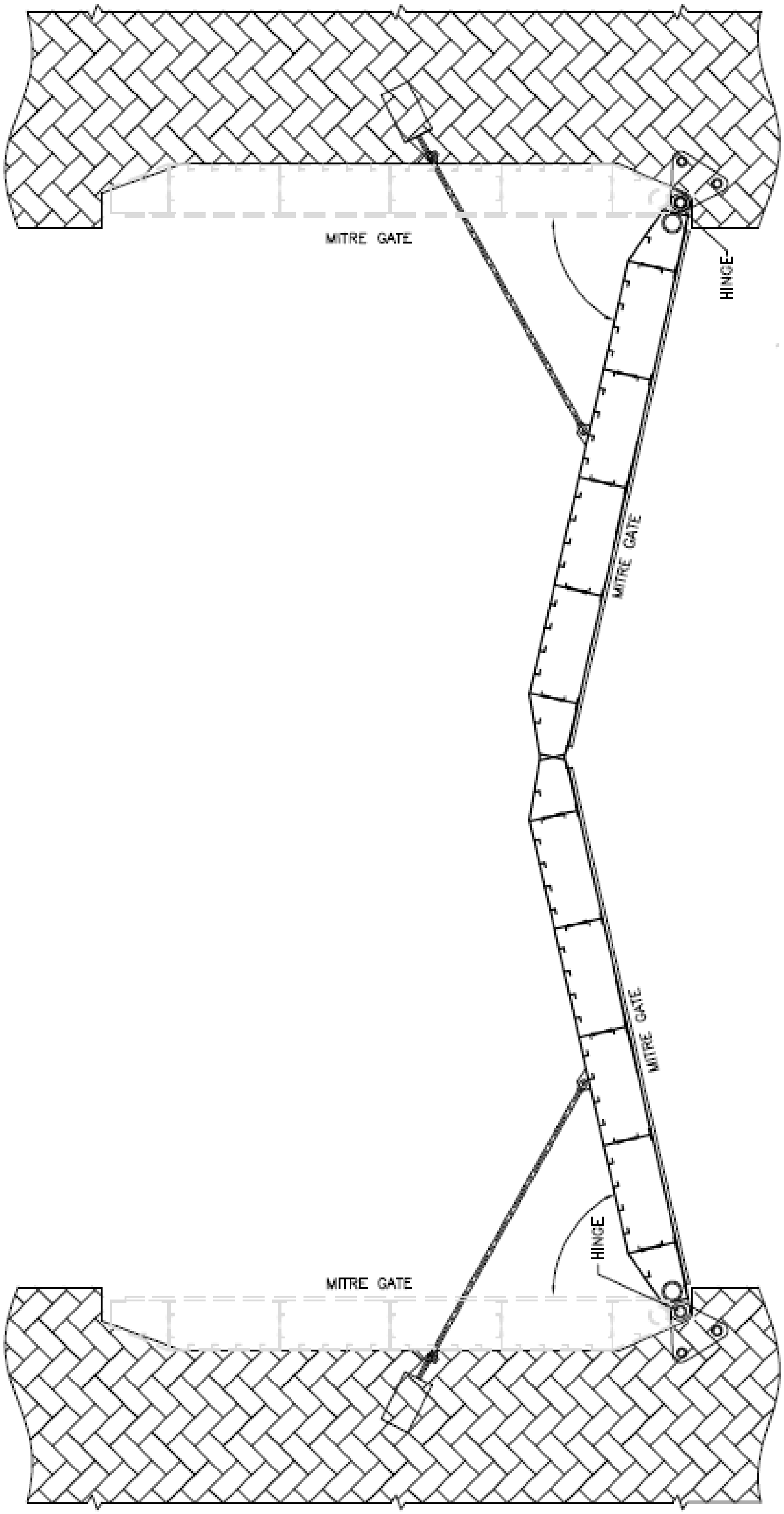


Figure 77: Conceptual drawing of Mitre gate with hydraulic system

6.4 Radial Gates

The health of the radial gates skin plate is good in zone 1 with functional condition index falling in the range of 70-84. It is recommended to carry out required repairs in the components of the radial gates. However, the rubber seals and other severely damaged parts need to be replaced.

The health of the operating mechanism of the radial Gates is marginal in zone 2 with functional condition index falling in the range of 40-54. However, as there is some misalignment of trunnion assembly and improper operation of radial Gates, it is suggested to re-align and attend any other issues after isolating these radial Gates so that smooth and trouble-free operation of radial Gates can be ensured. Thorough cleaning by sand/grit blasting and painting after repair of skin plate and other structural parts needs to be carried out.

6.4.1 Possible Performance Improvements

The existing operating mechanism needs to be replaced with a hydraulic system with axial-piston pumps and cylinders for quick operation speeds and durable components. The replacement of the current wheel operating system to an alternative involving a hydraulic system with axial-piston pumps and cylinders will bring down the operating time (opening and closing time) of the radial gate substantially and improve the performance of the radial gates as well as the old navigational lock.

6.4.2 Suggested state-of-the-art Technology

Modern Hydraulic power packs units are envisaged to use axial pumps with hydraulic cylinders. The hydraulic system shall include hydraulic power units using variable displacement, axial-piston pumps, manifolds, stainless steel reservoirs, hydraulic cylinders, piping etc. as well as safety and instrumentation system. The system components shall be designed as per IS: 10210. A remote control operation of the gate is envisaged from central control and also local control room. The conceptual drawing of the proposed system is given in Figure 78.

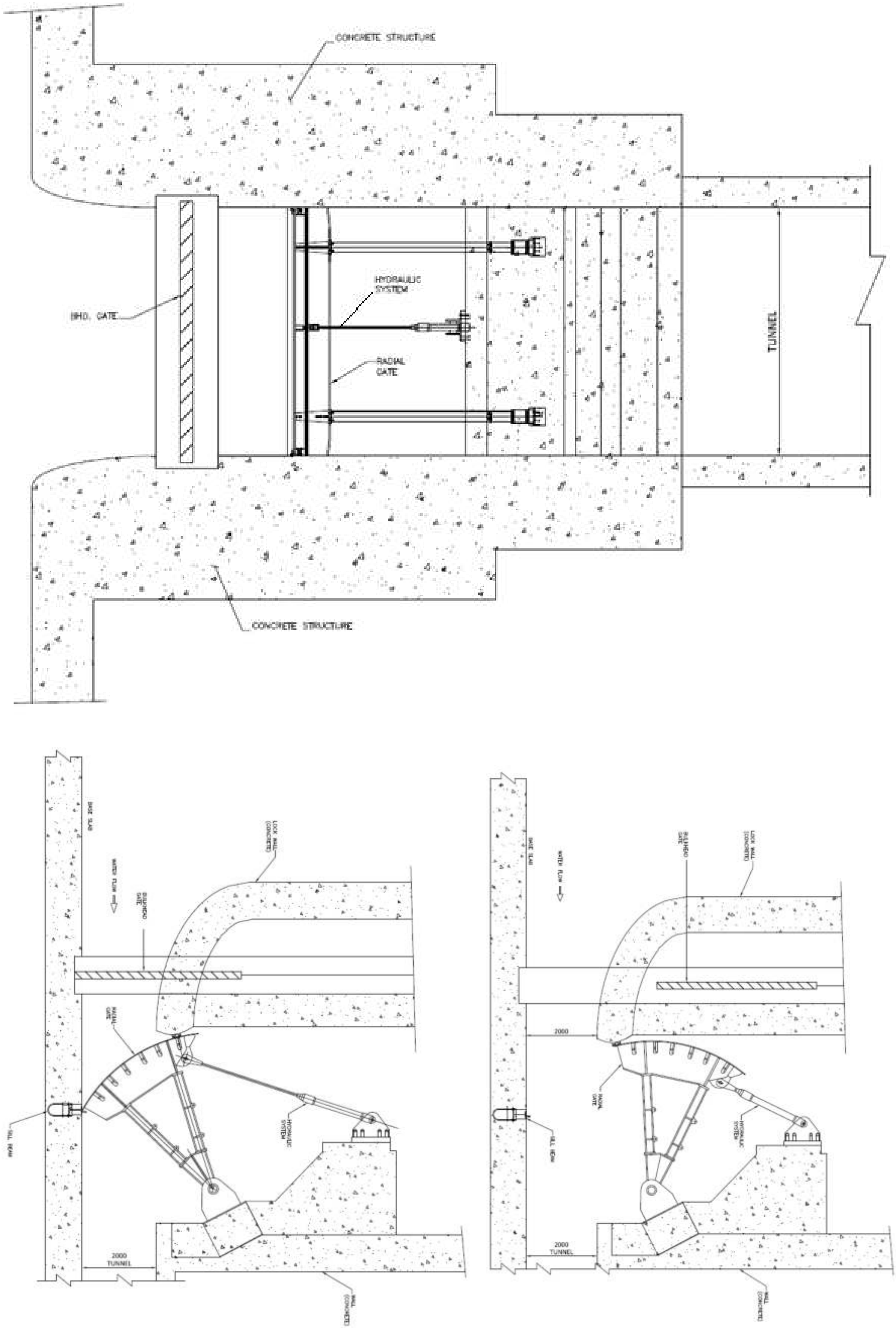


Figure 78: Conceptual drawing of radial gate with hydraulic system

6.5 Bulkhead Gates

As per the condition survey, the health of the bulkhead gates in general including skin plate and its supporting members is marginal in zone 2 with functional condition index falling in the range of 40-54. The Gates are pitted; rusted and heavily corroded. It is recommended to replace the skin plate and supporting steel members of the bulkhead gates. All filling valves of the bulkhead gates are also badly damaged and non-functional. All rollers are jammed along with rusted pins and bearings. These gates have not been operated since decades. Further, besides the roller assembly and equalizing valve, embedded parts and rubber seals also need to be replaced. Almost the entire gate is unusable and difficult to repair. It is recommended to provide 8 new bulkhead gates, one individual gate for each of the grooves.

The present lifting arrangement of bulkhead gates is totally inadequate and the condition of the operating mechanism of the bulkhead gates is in zone 3 (poor) with functional condition index falling in the range of 25-39. The critical embedded parts and its critical dimensions need to be checked and matched with the new bulkhead gates suggested to be provided. Overall, all the 8 Bulkhead gates need to be replaced.

6.5.1 Possible performance improvements

The existing operating mechanism needs to be replaced with a new individual fixed Winch type hoist (of suitable capacity) for each bulkhead gate along with dogging arrangement. The replacement of the current operating system to an alternative involving a fixed Monorail hoist will allow for regular maintenance of the radial gates and filling/emptying system.

6.5.2 Suggested state-of-the-art Technology

Fixed Monorail / winch hoist units (of suitable capacity) are envisaged for each of the 8 Bulkhead Gate along with dogging arrangement. The conceptual drawing of the proposed system is given in Figure 79 and 80.

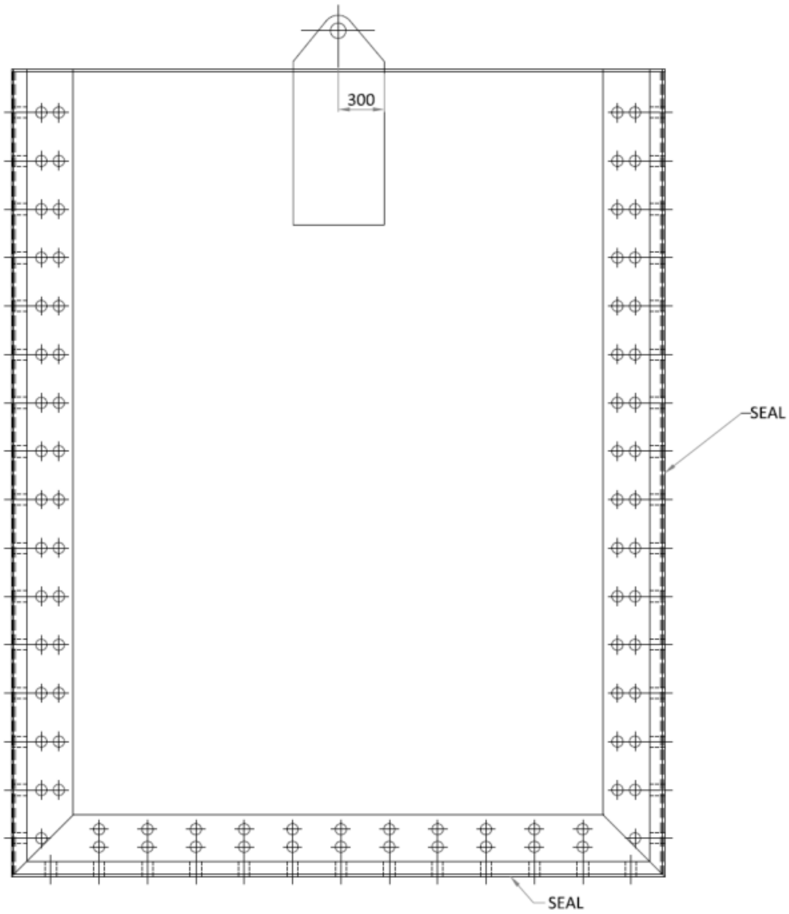


Figure 79: Conceptual drawing of Bulkhead gate

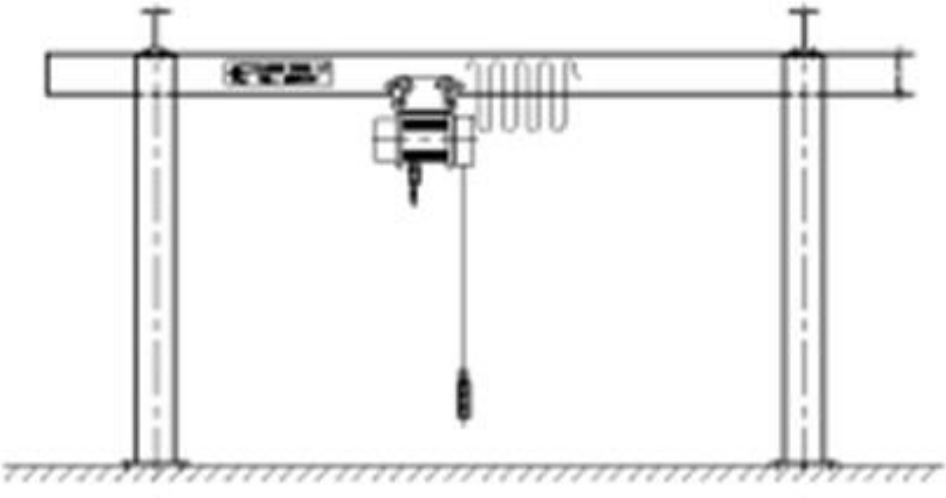


Figure 80: Conceptual drawing of Bulkhead gate operating system

6.6 Lock Chamber and Approach including Filling/Emptying System

The structural health of the navigation lock chamber which includes the side walls and base slab is fair and categorized in zone 2 with functional condition index falling in the range of 50-69 as per the condition survey. However, concrete has been affected with deterioration in homogeneity and honeycombing along with cracks and cavity formation. It is recommended to carry out major repairs in the side walls as well as the base slab. Major repairs in the approach wing walls, water conductor system, etc. also needs to be undertaken.

6.6.1 Possible performance improvements

The repair of the concrete in the navigational lock structure will enhance the service life of the structure.

6.6.2 Suggested state-of-the-art Technology

Concrete / Epoxy Bonded Concrete shotcrete (guniting) with compressor has been proposed. Shotcrete is defined as pneumatically applied concrete or mortar placed directly on to a surface. The shotcrete shall be placed by either the *dry mix* or *wet mix process*.

The *dry mix* process (Figure 81) shall consist of

- Thoroughly mixing the dry materials,
- Feeding of these materials into mechanical feeder or gun,
- Carrying the materials by compressed air through a hose to a special nozzle,
- Introducing water at nozzle point and intimately mixing it with other ingredients at the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete.

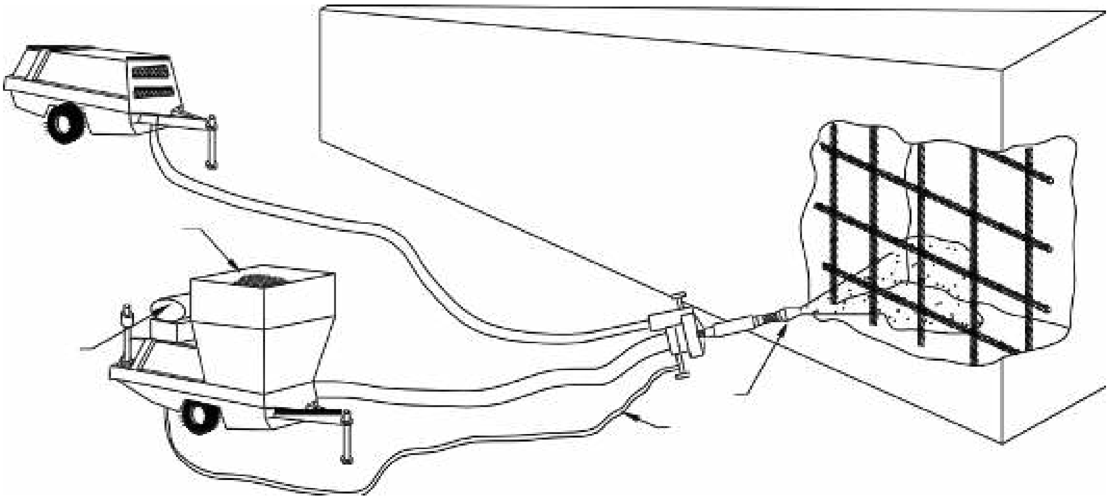


Figure 81: Dry Mix Shortcrete

The *wet-mix* process shall consist of

- Thoroughly mixing all the ingredients with the exception of the accelerating admixture, if used;
- Feeding the mixture into the delivery equipment;
- Delivering the mixture by positive displacement or compressed air to the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete.

If specified, fibres of steel, poly propylene or other material, as may be specified, would also be used together with the admixtures to modify the structural properties of the concrete/mortar being placed in position.

Epoxy Bonded Concrete is defined as freshly mixed portland cement concrete that is placed over epoxy resin bond coat on existing hardened concrete. This method is used when the depth of repair is 40 mm or greater. It will be necessary to provide suitable reinforcement as per design requirement. In addition, epoxy bonded shear keys may also be used for shear transfer through the interface.

6.7 Mooring Equipment

The health of the Mooring Equipment is marginal in zone 2 with functional condition index falling in the range of 40-54. The floating bollards are rusted and some are non-functional while few of the fixed bollards have been detached from the lock structure. It is suggested to replace all the fixed and floating bollards.

6.7.1 Possible performance improvements

The replacement of the Mooring Equipment in the navigational lock structure will enhance the safety of the vessels during operations.

6.7.2 Suggested state-of-the-art Technology

The Floating moorings conventional systems and magnetic moorings have been considered. The conventional system is adopted because of following advantages:

1. Magnetic moorings fail to work properly in silt conditions. Silt is likely in our case hence conventional floating moorings having been adopted.
2. Easy or no maintenance is required, unlike the magnetic moorings.
3. These are also economical.

6.8 Control Room Building

The health of the control room building is good but it lacks the necessary operational facilities like lift, water supply, drinking water, water purifier, sanitation, etc. Also, the exterior look is very shabby as it has not been painted for many years. It is proposed to renovate the building with all the latest features as well as safety equipment.

6.8.1 Possible performance improvements

The repair of the control room building will improve the usability and serviceability.

6.8.2 Suggested state-of-the-art Technology

The existing G+4-storied building will be used as master control room. The second and third floor should be fitted with full width glass view in the front of the control room so that the movement of the vessels in U/S and D/S direction in the approach channels and in the Lock can be viewed by the operator sitting in his chair. The control room building shall be provided with vitreous non-skid tiles in the flooring of the control room.

Control Room comprises of following equipment:

- Switchgear room on the Ground Floor shall be housing Metering Panel of WBSEDCL, Transformers, Diesel Generator set, 11 kV HT Switchgear Panel, 415 V Power Control Center (PCC) and various distribution Boards etc.
- Two store rooms for spare parts (one for general electric items and other for specialized components) shall be on the first floor.
- Operating cum programming station, server station, PLC panels, UPS and 32” LED Screen, CCTV Terminals, Third party control system for field instruments, conference room and various utilities rooms at second and third floor. The floors shall be equipped with Rest Room, Pantry and Toilet.
- The fourth floor shall be housing two numbers of Guest Rooms with attached toilet facility.
- The building shall be fitted with a lift.
- The building shall be fitted with firefighting systems.

6.9 Mechanical and Electrical Equipment

The existing electrical and control cable shafts are in dilapidated condition and requires overhaul. The existing Steel Lattice Cable Bridge also requires repair.

6.9.1 Possible performance improvements

The repair of the cable shaft as well as cable bridge will improve the reliability and serviceability during operations of the vessels. ‘

6.9.2 Suggested state-of-the-art Technology

The electrical shafts shall be equipped with latest safety and evacuation facilities for smooth operation of the navigation lock.

6.10 Control Systems

The existing control system of the navigation lock components and mainly the mitre and radial gates is completely manual and in piece-meal. The condition of the control system is also very poor and prone to accidents at site.

6.10.1 Possible performance improvements

The existing manual operating system needs to be totally replaced with a new control system and using a distributed Programmable Logic Controller (PLC) control system with a fibre optic or twisted pair loop connection. This shall significantly improve the performance of the lock and reduce the vessel movement time. Control would be available as follows:

1. From a remote single point in the upper floor of the (currently) disused control room building. This would become the central operating room (mission control) via a computerized SCADA system with monitors and fully interlocked and operated through the PLCs.
2. From a local Human-Machine Interface (HMI) point adjacent to each mitre gate, on the near side, which could operate the mitre gate pair via the PLC control system and fully interlocked.
3. From a point adjacent to each mitre gate via a hard wired push-button system on the local control panel, on the left hand side of the lock and by-passing interlocks. This would only be available via key-switch for use by specially trained, senior staff. The control panel would incorporate a "push to run" push-button directly operating the pump motors which would enable operation of the gates via direct manual operation of the hydraulic solenoid valves.

The following interlocks should be provided:

- Only one pair of mitre gates can be open at the same time
- Only one set of radial gates can be open at the same time

6.10.2 Suggested state-of-the-art Technology

The Control system shall be installed to ensure safe and reliable operation of Lock Gates and other facilities. PLC system shall read the inputs, perform all system logic, conduct online diagnostics, sequencing control and control the outputs. The processor based central control system is envisaged to control and monitor the Lock operations in the old Navigation Lock so as to carry out the operation in an integrated mode from "Control Room".

The Control Network shall be used for providing Automation functions, Opening and closing of mitre and radial gates, monitoring and supervisory functions from Control Room.

The core of the system shall consist of an Operating cum Programming Terminal and Server station (all the computers shall be latest version of the Industrial PCs - IPC as on the date of bidding) with printer and along with centralized real –time redundant PLC system (One online and the other in hot standby excluding I/O modules), sharing a RAID 6 (redundant array of independent disk) data storage system and a data network, with shared high-capacity data backup and off-site data archiving.

The control system would incorporate all safety interlocks to ensure complete safety to operating personnel and to avoid any damage to equipment due to malfunctioning.

6.11 Power Supplies

The existing source of Power at 11 kV is made available up to a DP (Double Pole) Structure within the Project boundary by West Bengal State Electricity Distribution Company Limited (WBSEDCL). Power at 11 kV received at the input of HT Switchgear is stepped down to 415 V through a transformer. This 415 V power shall be supplied to various LT Loads such as mitre gates, radial gates, Submersible Pump, Motors etc.

The existing power distribution system is past the end of its useful life. The following improvements are needed:

1. Refurbish the electrical sub-station at the boundary of the lock site adjacent to the road.
2. Renew the main incoming power supply cable from the electrical sub-station.

3. Evaluate the use of the under-lock electrical tunnel. If possible, de-commission the cable bridges, which are difficult to maintain and are vulnerable to impact with passing vessels.
4. Provide local distribution isolation panels adjacent to each mitre gate leaf as well as centralized operating point in the existing control building.

6.11.1 Possible performance improvements

The main power requirement for electrical load in the old Navigation Lock is on account of mitre gates, radial gates, Submersible Pump, Motors, etc. Other infrastructure such as general lighting, power for auxiliary services like Automatic Data Acquisition System (ADAS) etc. will also need their share of electric power. Power will also be needed for air- conditioning and lighting of control room building. The total power requirement shall be met through the existing dedicated power supply. Also, standby power source in the form of DG set of suitable capacity should be in place as alternative power source for smooth operations in case of power failures.

6.11.2 Suggested state-of-the-art Technology

For operational power, all the installed loads like mitre gates, radial gates and Submersible Pump, Motors etc. will not be operating simultaneously and will not draw maximum power at the same time. Taking all such aspects and applying suitable diversity factors, the computation for estimated connected power and demand load calculations shall be carried out during the design phase, and given in draft DPR. All Electrical and controls equipment shall be designed for an ambient temperature of 45°C.

6.12 Fender Arrangement

The existing fenders of wooden log and hanging tyres as provided in the lock chamber are in very poor condition and require replacement.

6.12.1 Possible performance improvements

The replacement of the wooden and rubber tyre fenders shall enhance the safety of the lock walls as well as vessels during the movement of the vessels through the lock.

6.12.2 Suggested state-of-the-art Technology

The wooden as well as rubber fenders which can withstand extreme climate as well as alternate wetting and drying are proposed to be used.

6.13 Electrical Ancillaries

The following systems could be included:

1. A lock lighting system, dimmable and suitable for navigational use at night.
2. A site electrical lighting system enabling safe access by staff at night.
3. Navigational lights at each side of the lock for guiding vessels
4. Fire alarm sensors in each oil hydraulic power unit compartment.
5. Water level sensors with output readings in the central operating room
6. The electrical control system would maintain a rolling record of one week of signals, alarms and warnings so that any incident could be subsequently investigated.

6.14 Non Electrical Ancillaries

The following should be included:

1. Port and Starboard markers at each end of the lock
2. Radio and other communications systems.
3. Life belts, in suitable locations, on each side of the lock.
4. Wall stripes to mark safe upstream and downstream mooring limits in the chamber.

6.15 Instrumentation

To monitor and ensure safety of the existing lock structure during construction and operation, the following monitoring instruments are proposed at existing lock:

- Piezometers – 05 Nos (along the right bank wall)
- Settlement gauges – 03 Nos (on right bank)
- Inclinometers – 02 Nos (on right bank)
- Water level Indicators – 03 Nos (one each in U/S and D/S approach channels and one within the lock chamber)

If any settlement / inclination of the lock wall is observed, remedial measures to check the structural safety will be taken. During operation, readings / data from the instrument's data loggers will be available at a central location in the control room.

Sl. No.	Item	Renovate/ Replace/ Modernize	Suggested Modifications
1	**Cassion Gate**	Replace	Replace the existing dilapidated gates with new ones along with the embedded parts.
2	**Cassion Gate Operating System**	Replace	Replace the existing system with capstan motors system for movement.
3	**Mitre Gate**	Renovate	Replace the underwater portion and repair the above water portion for corrosion protection
4	**Mitre Gate Operating System**	Replace and Modernize	Replace the existing wire rope system with modern hydraulic power packs with axial pumps and hydraulic cylinders
5	**Radial Gate (Skin Plate)**	Renovate	Renovate the skin plate for corrosion protection
6	**Radial Gate Operating System**	Replace and Modernize	Replace the existing wheel movement system with modern hydraulic power packs with axial pumps and hydraulic cylinders
7	**Bulkhead Gate**	Replace	Replace the existing dilapidated gates with new ones along with the embedded parts.
8	**Bulkhead Operating System**	Replace and Modernize	Fixed Monorail hoist units for each of the 8 bulkhead gates
9	**Lock Chamber and Approach Structure**	Renovate	Renovate the base slab, retaining walls, guide walls using concrete shotcrete or epoxy treatment

10	**Filling/Emptying System**	Renovate	Renovate the water conduit using concrete shotcrete or epoxy treatment
11	**Control Room Building**	Renovate and Modernize	Replace the floor with non-vitreous tiles and provide necessary amenities along with lift and fire fighting system
12	**Mooring Equipment**	Replace	Replace the floating and fixed bollards
13	**Electrical Equipment**	Renovate and Modernize	Renovate the electrical shaft as well as electrical cable
14	**Control System**	Replace and Modernize	Centralized command and control room for remote operations using PLCs
15	**Power Supply**	Renovate and Modernize	Renovate the existing power supply and distribution network along with cable trenches. Modernize as per the requirements of the proposed operating systems
16	**Lighting Equipment**	Renovate and Modernize	Renovate for safety and night navigation requirements
17	**Fender Arrangement**	Replace	Replace using strong and durable wooden and rubber fenders
18	**Instrumentation**	Modernize	Latest Instruments for monitoring the operational as well as safety requirement of the navigation lock have been proposed

Table 58: Renovate/ Replace/ Modernize strategy with suggested modifications

Sl No.	Equipment	Technical Specifications	Cost Implica-tion (Rs. in Lakh)
1	**Cassion Gate**	The new cassion gates comprising of deck, bulkheads, face plates for various tanks and chambers for ballasting and de-ballasting required for sinking and raising operations of the gate as per BS-6349: Part 3, BS-5400: Part 3 or any equivalent Indian Standards.	1500
2	**Cassion Gate Operating System**	As per new lock cassion gates and Sill and side walls at gate grooves should be made of polished granite as per IS: 14223 (Part-I). Electrically operated capstan including starters, cables, fuse sockets etc. with necessary foundation for positioning and shifting the caisson.	250
3	**Mitre Gate**	Double leaf hinged type mitre gates	300
4	**Mitre Gate Operating System**	Electro-hydraulic system. The hydraulic system shall include hydraulic power units using variable displacement, axial-piston pumps, manifolds, stainless steel reservoirs, hydraulic cylinders, piping etc. as well as safety and instrumentation system. The system components shall be designed as per IS: 10210. A remote control operation of the gate is envisaged from central control and also local control room.	400
5	**Radial Gate Operating System**	Electro-hydraulic system. The hydraulic system shall include hydraulic power units using variable displacement, axial-piston pumps, manifolds, stainless steel reservoirs, hydraulic cylinders, piping etc. as well as safety and instrumentation system. The system components shall be designed as per IS: 10210. A remote control operation of the gate is envisaged from central control and also local control room.	300

6	**Bulkhead Gate**	The gate frame consists of bearing plate/roller tracks, seal seats, girder and guides and the structure shall be welded construction. The gate frames, gate leaf and embedded parts shall be fabricated from structural steel as per IS: 2062.	500
7	**Bulkhead Operating System**	Electrically operated Fixed Monorail hoist shall be designed and manufactured as per IS: 6938.	150
8	**Lock Chamber & Approach Structure**	Concrete / Epoxy Bonded Concrete shotcrete	125
9	**Filling/ Emptying System**	Concrete / Epoxy Bonded Concrete shotcrete	25
10	**Control Room Building**	Replace the floor with non-vitreous tiles and provide necessary amenities along with glass view, lift and fire fighting system	300
11	**Mooring Equipment**	Cast steel bollards of 30 T capacity complete with base plate and H.T. anchor bolts of appropriate length, nuts washers, etc.	50
12	**Control System**	Centralized command and control room for remote operations using PLCs	500
13	**Power Supply**	Power distribution at 11 kV shall be done through 11 kV (E), XLPE, stranded Aluminium conductor, armoured, overall FRLS PVC sheathed cable laid on cable trays, ducts, and in trenches, etc. as per site requirement. LT power distribution to various Gates and services such as illumination, fire-fighting, air conditioning, water supply etc. shall be done through 1.1 kV grade XLPE insulated, stranded Aluminium conductor, armoured, overall FRLS PVC	150

		sheathed power cables. Internal wiring shall be done in recessed PVC conduit or on surface with GI conduit and single core PVC insulated FRLS copper wire.	
14	**Lighting Equipment**	HPSV twin lamp and Flood Light, weather proof, Heavy duty High Mast (30 m) in die cast Aluminium alloy housing. Single Arm Street light poles of 3.5m height above boundary wall with 30W LED luminaires @ 15m distance. Additionally, wherever required poles of suitable height with fittings shall be installed for outdoor lighting of the buildings.	100
15	**Fender Arrangement**	High quality timber and AN 800 E 3.0 grade rubber fender	50
16	**Instrumentation**	Monitoring Instruments based on relevant Indian Standards	200
17	**Bank Protection Systems**	As per relevant IS Codes and Manuals	1000
18	**Office cum Guest House Complex**	As per relevant IS Codes and Manuals	500
19	**Others**	As per relevant Indian/International Standards and Manuals	1500
		Cost Implication	**7900**
		Contingencies (5%)	**395**
		Total Cost Implication	**8295**

Table 59: Equipment to be repaired/ replaced/ modernized along with technical specifications and cost implications

The cost implication has been estimated based on block estimates (lump sum) considering the rates in the DPR of the new Farakka navigational lock and past DPR of renovation/modernization of old navigation lock at Farakka. The cost estimation is preliminary which shall be firmed up during the design phase and final cost estimates will be given in the Draft DPR.

7.0 Hydraulic Balance Imbalance Assessment

7.1 Introduction

The phenomenon of parallel flow behaviour is of interest for the re-design, modernization and operation of parallel locks. In the present study a two parallel lock channels setup is analysed for hydraulic balance/imbalance (Figure 82).

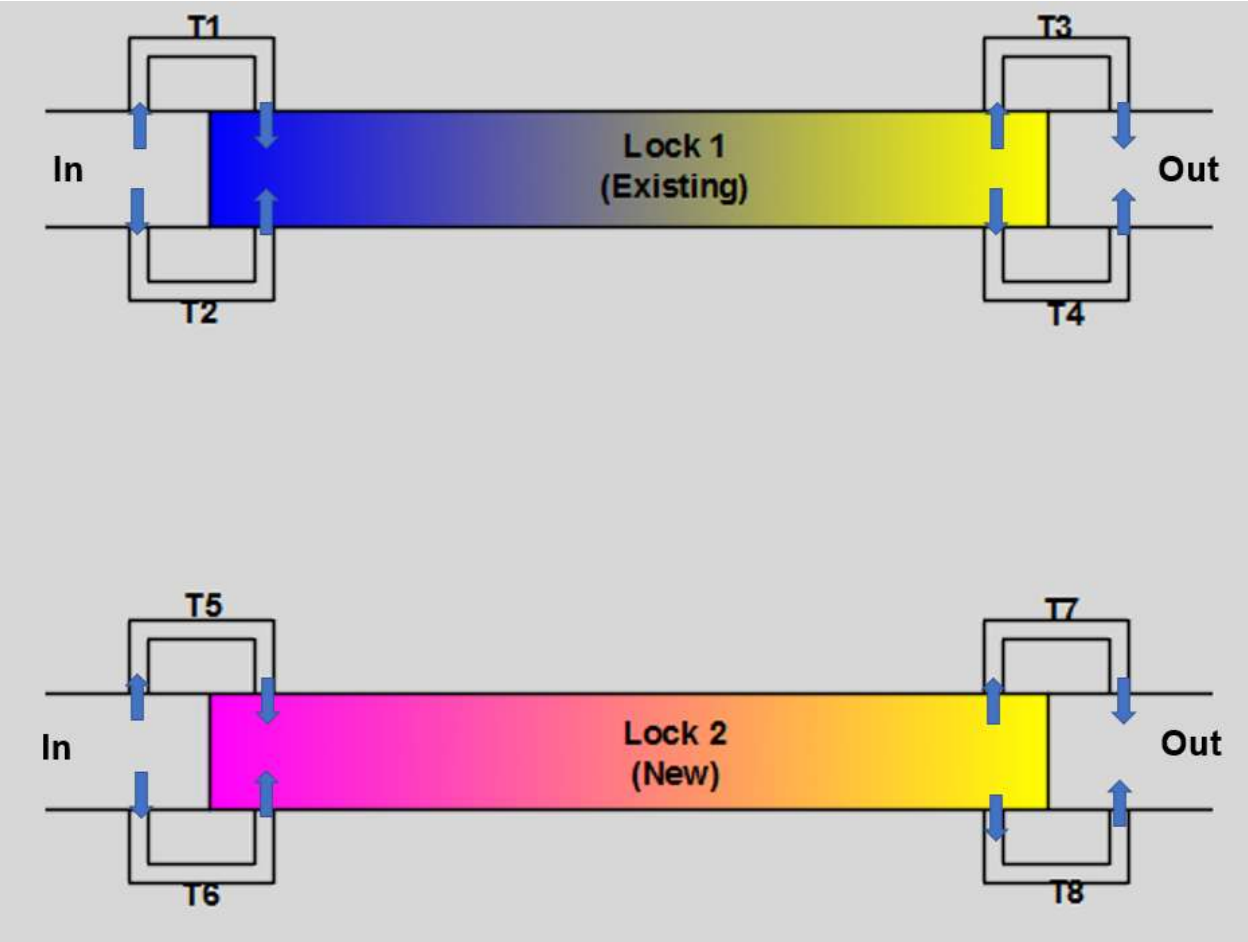


Figure 82: Plan of Lock System (Not to Scale)

Each lock system consists of four tunnels to carry water in/from the lock. Two tunnels are present in the upstream side (T1, T2 in Lock 1 and T5, T6 in Lock 2) to fill the lock system. Two tunnels are present in the downstream side (T3, T4 in Lock 1 and T7, T8 in Lock 2) to empty the lock system.

7.2 Hydraulic Balance/Imbalance

In the current situation one navigational lock is present to guide the flow through T1 and T2 to fill the Lock 1 and T3 and T4 to empty the system. Both the system is used in isolation as per requirement of ship to move either up to down or down to up. After completion of Lock 2, the operation of different tunnel systems may create behaviour change of hydraulic characteristics. For a smoother and coherent operation of parallel system, we have to analyse the cases where the simultaneous working of tunnel systems affects the hydraulic behaviours.

7.3 Collection of Data

All data is collected related to hydraulic study of channel and associated system from the past reports, operation manuals and DPR drawings.

Table 60: Lock 1 System (From Operation Manual)

Features	Value
Lock Width	25.145 m
Lock Length	179.800 m (Mitre Gate to Mitre Gate)
Mitre Gate Leaf Length	15.354 m
Mitre Gate Top Width	1.300 m
Mitre Gate Height (U/S)	11.880 m
Mitre Gate Height (D/S)	10.110 m
Mitre Gate Bottom Level (U/S)	15.545 m above MSL
Mitre Gate Bottom Level (D/S)	15.240 m above MSL
Mitre Gate Weight	85 ton (D/S) to 90 Ton (U/S)
Mitre Gate Angle from U/S wall at Full Closure	60 Degree
Radial Gate Bottom Level (U/S and D/S)	15.545 m above MSL
Radial Gate Opening Height (U/S and D/S)	2.210 m
Radial gate Movement Angle to full open	45 Degree 29 Minutes
Radial Gate Radius	3.26 m

Radial Gate Weight	20.2 ton
Cassion Gate Length	26.05 m
Cassion Gate Width	4.000 m to 0.800 m
Cassion Gate Weight	240.5 Ton
Bulk Head Gates (A)	L=4.138 m B =0.322 m and H=2.5 m
Bulk Head Gates (B)	L=3.478 m B =0.322 m and H=2.5 m
Bulk Head Gates (CC)	L=2.690 m B =0.322 m and H=2.5 m
Datum Level	15.400 m above MSL
Depth of Lock	18.89 m at U/S to 10.89 m D/S
Lock Bed Level	15.34 to 15.64 m above MSL

Table 61: Lock 2 System (From DPR Drawing)

Features	Value
Lock Width	25.150 m
Lock Length	179.000 m (Mitre Gate to Mitre Gate)
Mitre Gate Leaf Length	15.354 m
Mitre Gate Top Width	1.300 m
Mitre Gate Height (U/S)	11.880 m
Mitre Gate Height (D/S)	10.110 m
Mitre Gate Bottom Level (U/S)	14.800 m above MSL
Mitre Gate Bottom Level (D/S)	14.500 m above MSL
Mitre Gate Weight	85 ton (D/S) to 90 Ton (U/S)
Mitre Gate Angle from U/S wall at Full Closure	60 Degree
Radial Gate Bottom Level (U/S and	14.800 m above MSL (U/S)

D/S)	13.000 m above MSL (D/S)
Radial Gate Opening Height (U/S and D/S)	2.500 m
Width of Tunnel	4 m
Slope of Tunnel	1:24
Length of Tunnel	36.000 m
HWL at Radial Gate	26.800 m above MSL (24.38 for D/S)
HWL at Radial Gate	18.288 m above MSL (for Both U/S and D/S)
Radial gate Movement Angle to full open	45 Degree 29 Minutes
Radial Gate Radius	3.26 m
Radial Gate Weight	20.2 ton
Cassion Gate Length	26.05 m
Cassion Gate Width	4.000 m to 0.800 m
Cassion Gate Weight	240.5 Ton
Bulk Head Gates (A)	L=4.138 m B =0.322 m and H=2.5 m
Bulk Head Gates (B)	L=3.478 m B =0.322 m and H=2.5 m
Bulk Head Gates (CC)	L=2.690 m B =0.322 m and H=2.5 m
Datum Level	13.000 m above MSL
Depth of Lock	18.89 m at U/S to 10.89 m D/S
Lock Bed Level	15.34 to 15.64 m above MSL

7.4 Case Studies

To analyse the different scenario, several case will be studied. The following cases are evolved to understand the flow behaviour near lock system during site visits and subsequent experts' discussions.

Table 62: Proposed Scenarios for Hydraulic Balance Imbalance Study

Scenario	Scenario Details
C-1	T1 and T2 Opened, Rest Tunnels Closed
C-2	T1, T2, T5, T6 Opened, Rest Tunnels Closed
C-3	T1, T2, T7, T8 Opened, Rest Tunnels Closed
C-4	T3, T4, T5, T6 Opened, Rest Tunnels Closed
C-5	T5and T6 Opened, Rest Tunnels Closed
C-6	T3 and T4 Opened, Rest Tunnels Closed
C-7	T7 and T8 Opened, Rest Tunnels Closed
C-8	All Tunnels Closed

7.5 Additional Data Required for Balance Imbalance study

Bathymetry Data in upstream and downstream section is needed to perform Balance imbalance Study. Bathymetry survey data is required from the diversion point (off river to approach channel) to conversion point (approach channel to feeder canal). Bathymetry Data is required at 100 m c/c as well as l-section to study the hydraulic characteristics.

7.6 Creation of Model

Model of the lock system will be created using the integration of system components data (as mentioned in Section 7.3) and bathymetry data. Creation of model requires the following data

1.Geometry Data: Geometry Data is created using lock component specifications and upstream and downstream sections using bathymetric data.

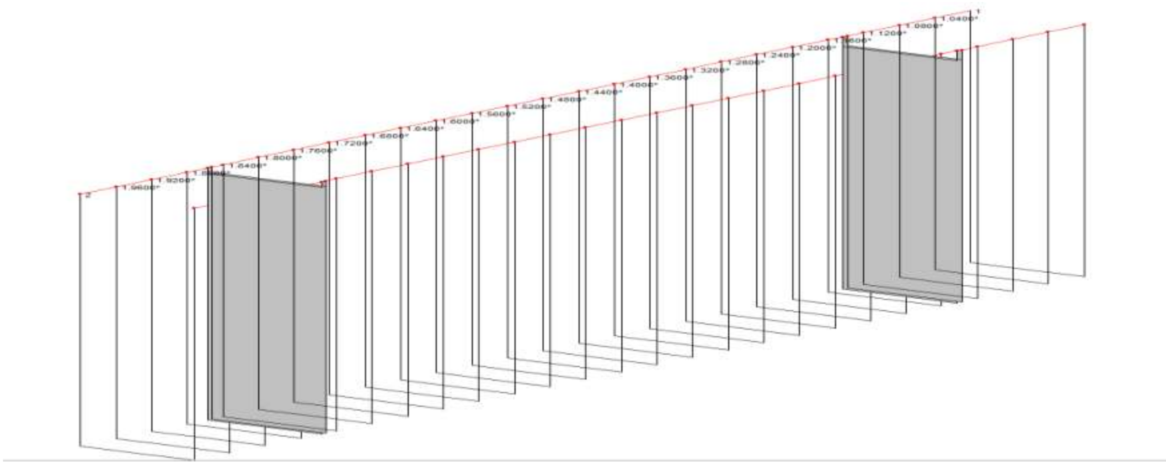


Figure 83: Sample Geometry Data of Lock and Gate

2.Flow Resistance Parameters: Roughness of Bed Profiles in river and lock will be used to estimate the model parameters.

3.Flow Parameters: Flow parameters like discharge conditions will be also be required to prepare model.

4.Gate Opening Parameters: Gate opening parameters needed to simulate the flow condition under single lock and combined lock system.

8.0 Appendix

8.A. Personnel

The following personnel were involved in the operation

Date	Location	Name	Responsibility
30th, Mar 2022 to 12th, Apr 2022	West Bengal, India	Mr. Nazeer	ROV Supervisor
		Mr. Guruteshwar	ROV Pilot
		Mr. Ashish	PD Technician
		Mr. Arun	PD Technician
		Mr. Vishnu	PD Technician
		Mr. Krishnaraj	PD Technician

Table 63: Personnel Details

8.B. Equipment Details

- 1 x RORV Beluga
- 1 x Tether Management System
- 1 x Petrol Electric Generator
- Command Module
    - 1 x LCD Screen
    - 1 x Control Station Processing Unit
    - 1 x Wireless Router
    - 1 x Remote Control Joystick
    - 1 x Laptop

8.C. Weather Conditions

Date	Temperature	Weather	Time of Operation
30-03-2022	35°C – 27°C	Sunny	10:00am to 6:00pm
31-03-2022	35°C – 27°C	Sunny	10:00am to 6:00pm
01-04-2022	34°C – 27°C	Sunny	10:00am to 6:00pm
02-04-2022	34°C – 28°C	Sunny	10:00am to 6:00pm
03-04-2022	35°C – 27°C	Sunny	10:00am to 6:00pm
04-04-2022	34°C – 28°C	Sunny	10:00am to 6:00pm

05-04-2022	34°C – 27°C	Sunny	10:00am to 6:00pm
06-04-2022	35°C – 26°C	Sunny	10:00am to 6:00pm
07-04-2022	36°C – 27°C	Sunny	10:00am to 6:00pm
08-04-2022	35°C – 25°C	Sunny	10:00am to 6:00pm
09-04-2022	35°C – 27°C	Sunny	10:00am to 6:00pm

Table 64: Weather Details

Source: https://www.accuweather.com/en/in/742212/742212/april-weather/541945pc?year=2022

8.D. Equipment Details of Inspection vehicle

Inspection vehicle for underwater inspection

Underwater inspection vehicle RORV Beluga developed by the inspecting agency **Planys Technologies** with the following specifications as mentioned in table below, was used to carry out the inspection.

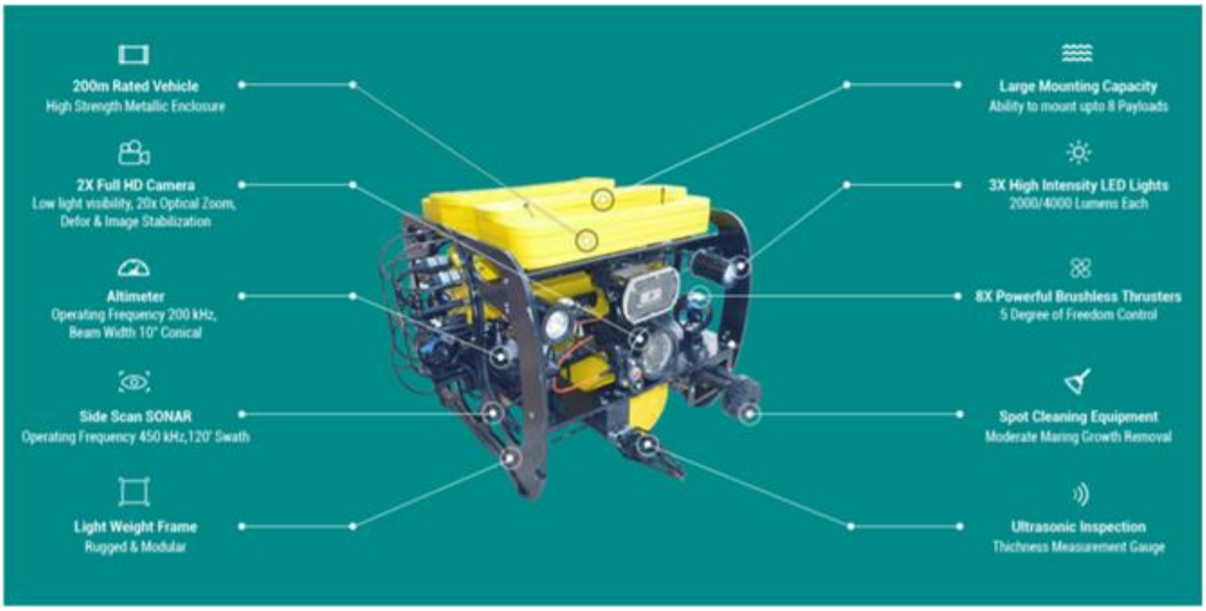


Figure 84: Photograph of RORV Beluga

Parameter	Specification
Product	53 Kgs
Dimensions (mm)	1200 x 500 x 500 mm
Weight in air (Without Payloads)	53 Kgs
Propulsion	5 DOF control using 7kg-F DC Brushed DC Thrusters
Camera	2 x (2M 1920x1080, 30fps) x 1((4x Zoom) (1080P 30fps))
Lights	3 x high intensity LED lights 2000/4000 lumens each
Sensors	Submersible Pressure sensor, Absolute, 190 PSI
Power Rating	1.6 KW
Communication	Tethered, with 200 m tether length
Payloads	1 x Laser Ranging Equipment
Sounding Equipment	High-frequency Altimeter (>200 kHz), min. range 0.1 m

Table 65: Details of Inspection Vehicle

Command Module

The RORV pilot used a Command Module for controlling the vehicle. The module was equipped with an LCD screen which displayed a Graphical User Interface (GUI) for assisting the pilot. The GUI displayed live feed from various cameras on the RORV as well as relayed various system parameters such as orientation, depth and speed of the vehicle in different directions. This helped the pilot in efficiently controlling the vehicle.

Pressure Sensor

High-accuracy silicon strain gauge pressure transducer from Omega Engineering, rated for 200 PSI of absolute pressure, was used for depth measurements by RORV Beluga least count of the depth sensor is 0.01m.

Laser Ranging

Laser ranging device with 650nm diodes was used for measuring the distance between any two points on the structure with high accuracy.

8.E. Guidelines for Defects Severity

Observations	Guidelines
Biofouling	1.Value of X and Y < 70mm is Minor 2. Value of X or Y between 70mm to 150mm is Moderate. 3.Value of X or Y >150mm is Major.
Cavity	1.Value of X and Y < 70mm & Depth range of Cavity <3cm is Minor 2. Value of X or Y between 70mm to 150mm & Depth range of cavity between 3cm to 6cm is Moderate. 3.Value of X or Y >150mm & Depth range of Cavity >8cm is Major
Cavity and Honeycomb Formation	1.Value of X and Y < 70mm & Depth range of Cavity <3cm is Minor 2. Value of X or Y between 70mm to 150mm & Depth range of cavity between 3cm to 6cm is Moderate. 3.Value of X and Y > 150mm & Depth range of Cavity >8cm is Major
Corrosion	Value of X and Y < 70mm is Minor 2. Value of X or Y between 70mm to 150mm is Moderate. 3.Value of X and Y >150mm is Major
Crack	1.Value of X and Y < 70mm is Minor 2. Value of X or Y between 70mm to 150mm is Moderate. 3.Value of X or Y >150mm is Major
Debonding Between Two Layers	1.Value of X and Y < 70mm & Depth range of Debonding <3cm is Minor 2. Value of X or Y between 70mm to 150mm & Depth range of Debonding between 3cm to 6cm is Moderate. 3.Value of X and Y >150mm & Depth range of Debonding >6cm is Major
Debris	Generally, Debris will be termed as Minor Observation
Honeycomb Formation	1.Value of X and Y < 100mm is Minor 2. Value of X or Y between 100mm to 200mm is Moderate. 3.Value of X and Y >200mm is Major
Marine Growth	1.Value of X and Y < 100mm is Minor 2. Value of X or Y between 100mm to 200mm is Moderate. 3.Value of X or Y >200mm is Major
Pin Holes	Generally Pin holes will be termed as Minor Observation
Rebar Exposed	Generally, Rebar Exposing will be termed as Major Observation
Rebar Protruding	Generally, Rebar Protruding from structure will be termed as Minor
Gap Between Stones	1.Value of X and Y < 250mm is Minor 2. Value of X or Y between 250mm to 500mm is Moderate. 3.Value of X and Y >500mm is Major
Surface Deformation	1.Value of X and Y < 100mm is Minor 2. Value of X or Y between 100mm to 250mm is Moderate. 3.Value of X or Y >250mm is Major.

Table 66: Observations Guidelines

8.F. Ultrasonic Pulse Velocity Equipment Details

Parameter	Specification
Product	Ultra-Sonic Pulse Velocity
Dimensions	180mm length
Velocity	2770m/s
Time	65 µs
Oscilloscope	Digital
Model No.	UCT UX 4600L

Table 67: Equipment details of UPV test

8.G. Guidelines for UPV test

REMARK: IS 13311-Part 1 clause 5.4.1: Surface probing in general gives lower pulse velocity than in case of cross probing and depends on number of parameters, the different could be of the order of about 1 km/sec. Wherever surface probing was done, velocity values increased by 1 km/sec as per above clause.

Pulse Velocity by Cross probing, Km/Sec	Concrete Quality grading
Above 4.5	Excellent
3.5 – 4.5	Good
3.0-3.5	Medium
Below 3.0	Doubtful

"Non-Destructive test measures parameter of concrete, which are corelated to properties we are interested in these measurements are influenced by many factors. It necessary to interpret NDT results judiciously taking into taking into consideration these factors and other information related to the structural member under investigation"

Disclaimer: Non-Destructive tests measures parameters of concrete, which are correlated to properties we are interested in these measurements are influenced by many factors. It is necessary to interpret NDT results judiciously taking into consideration these factors and other information related to the structural member under investigation.

8.H. Dive Details:

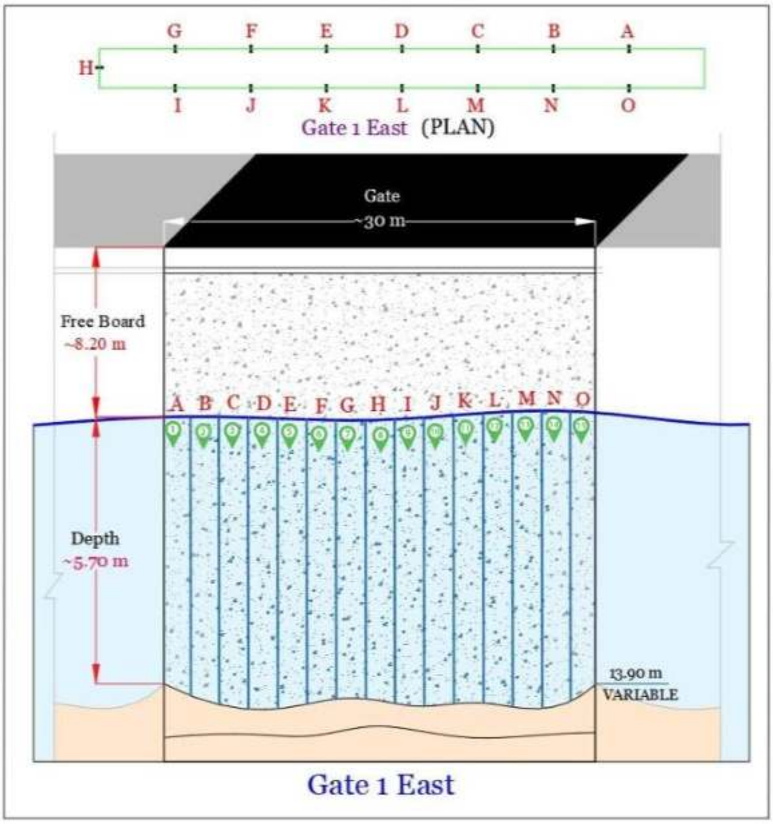


Figure 85: Dive details at Gate1 East

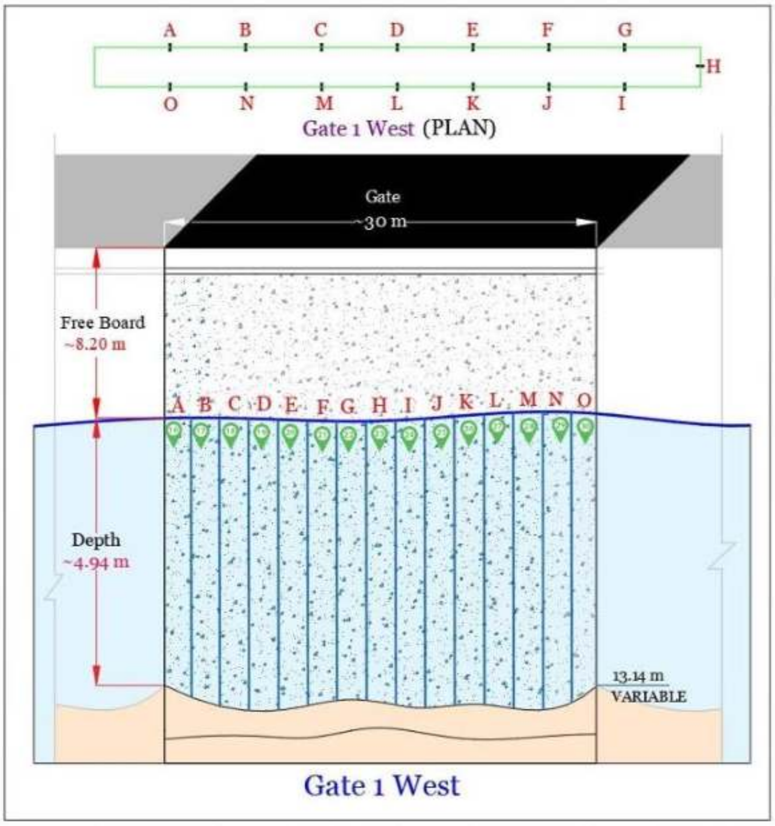


Figure 86: Dive details at Gate1 West

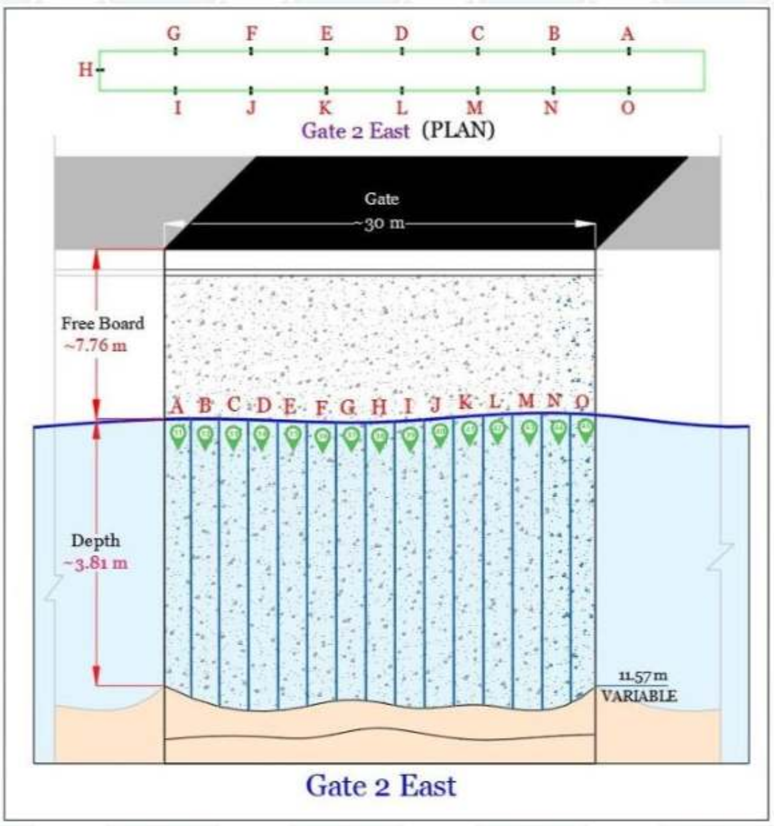


Figure 87: Dive details at Gate2 East

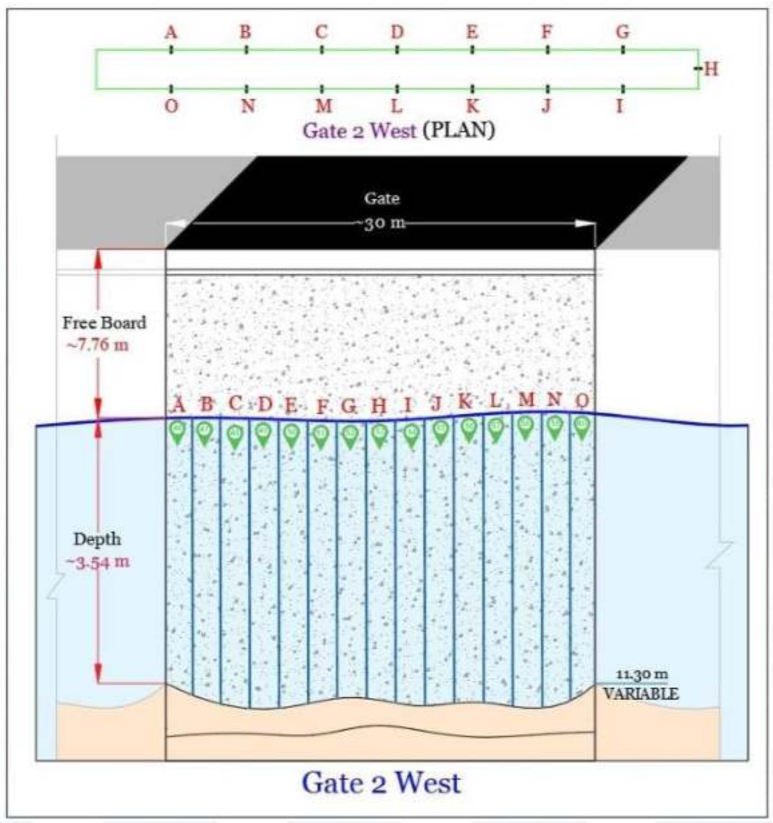


Figure 88: Dive details at Gate2 West

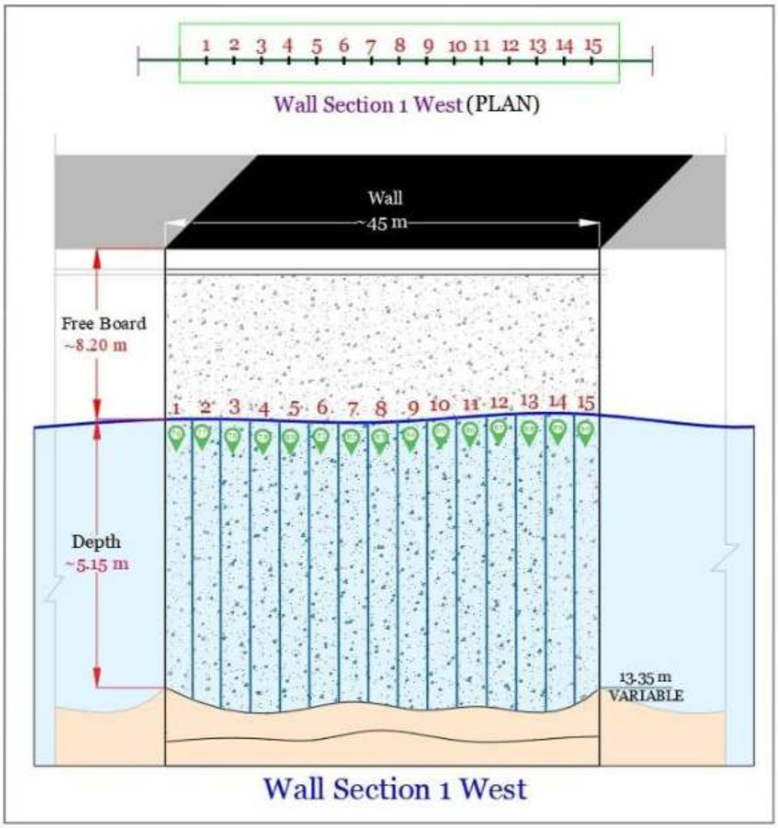


Figure 89: Dive details at Wall Section 1 West

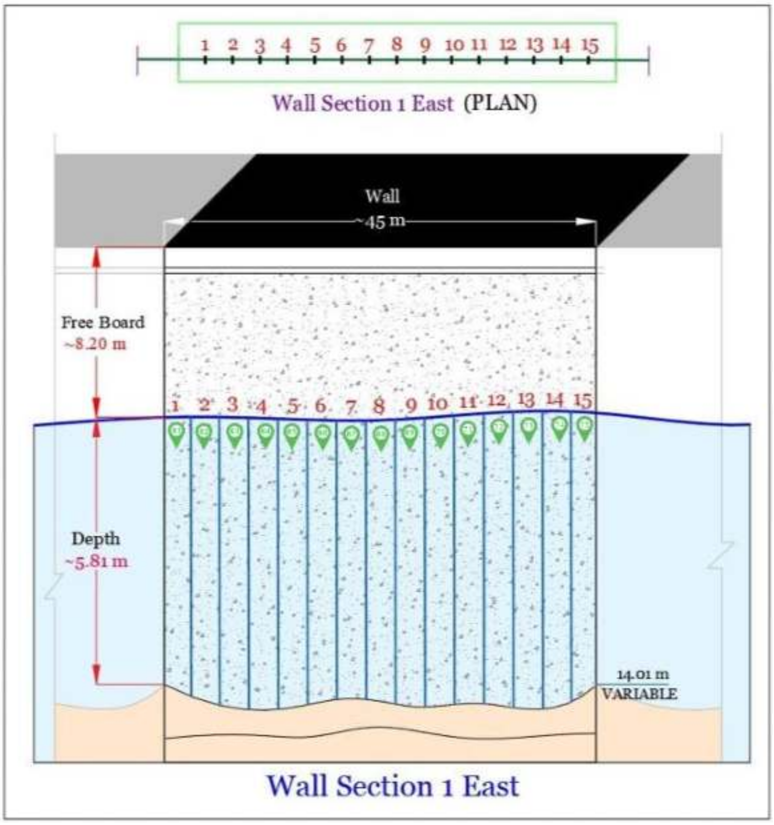


Figure 90: Dive details at Wall Section 1 East

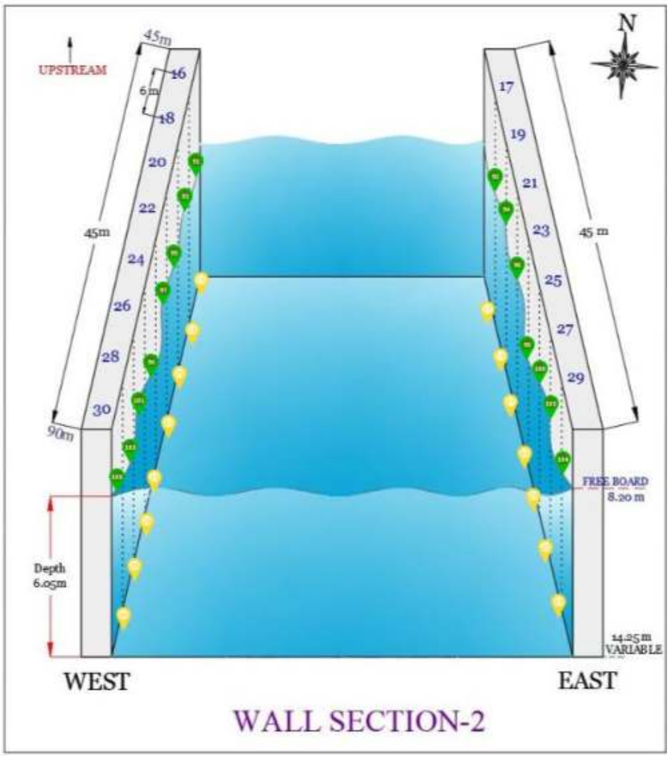


Figure 91: Dive details at Wall Section 2 East & West

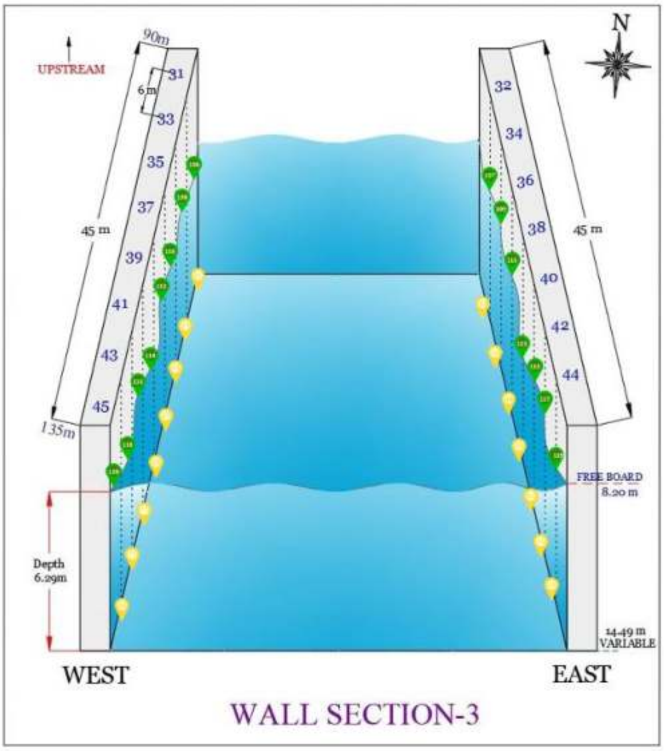


Figure 92: Dive details at Wall Section 3 East & West

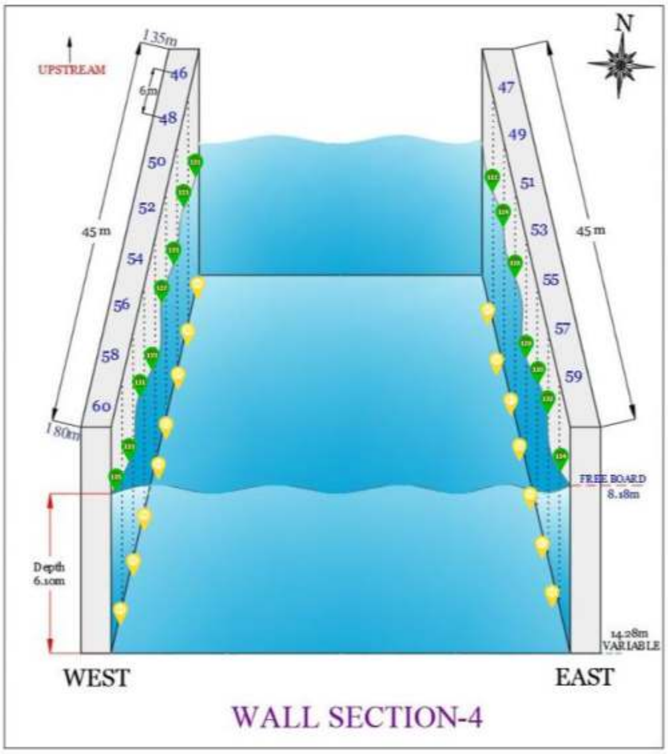


Figure 93: Dive details at Wall Section 4 East & West

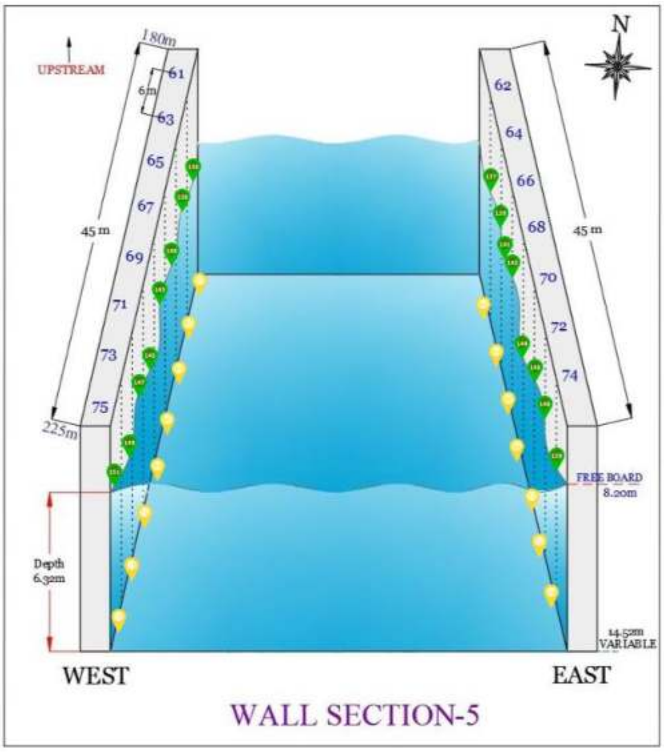


Figure 94: Dive details at Wall Section 5 East & West

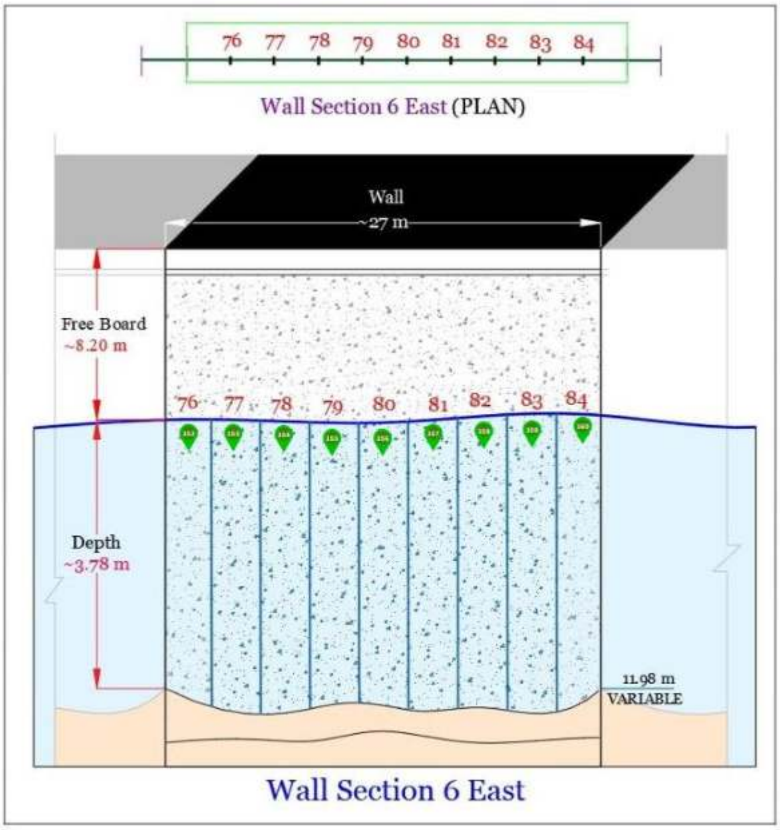


Figure 95: Dive details at Wall Section 6 East

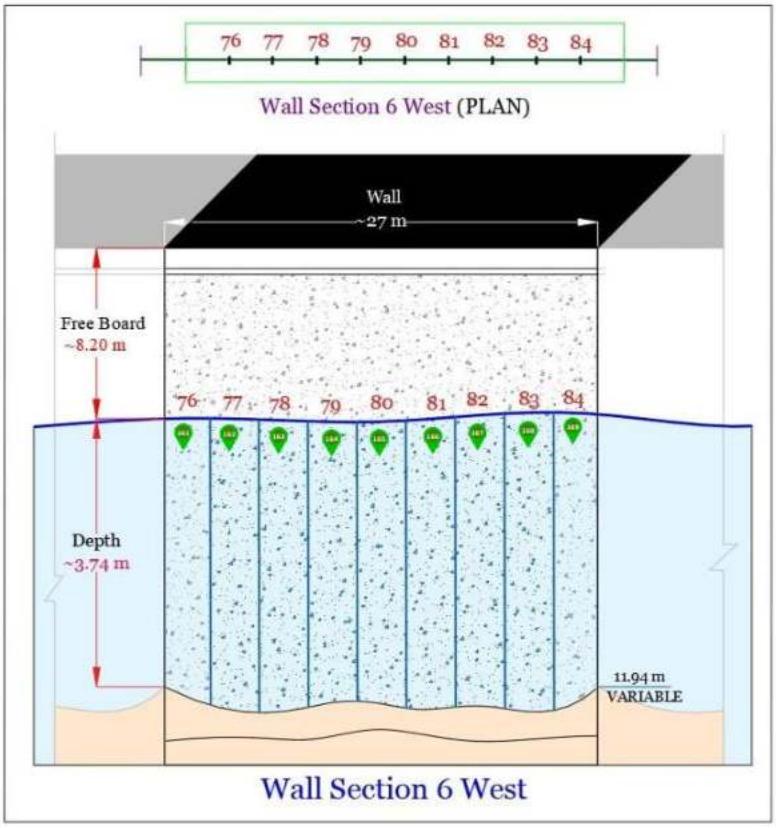


Figure 96: Dive details at Wall Section 6 West

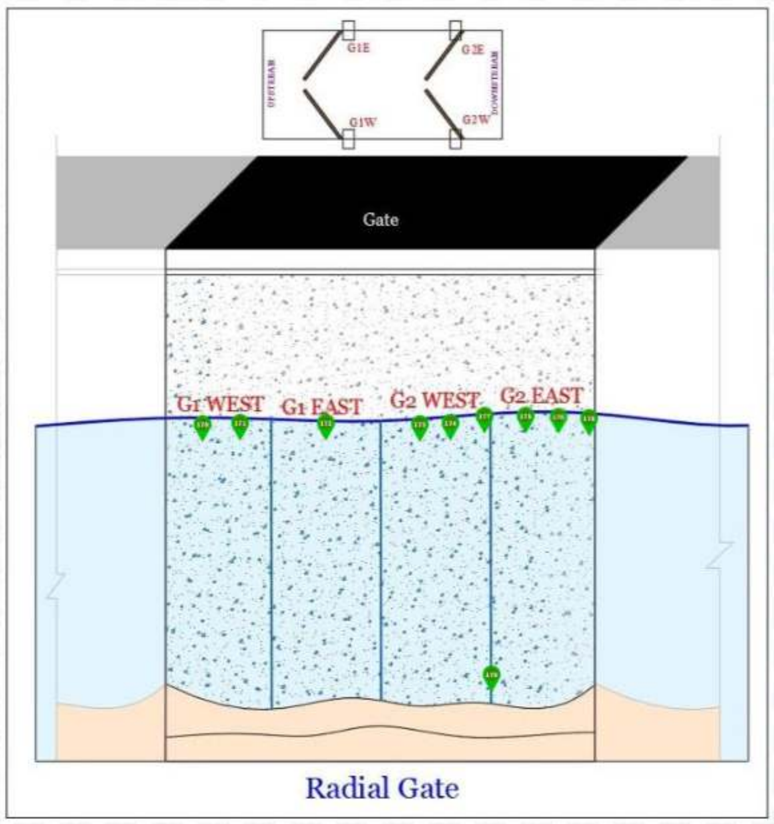


Figure 97: Dive details at Radial Gate

Annexure-8.1

COMMENTS AND COMPLIANCES

Comment

a. The proposal mentioned in the report regarding using of cassion gates of new navigational lock (which is under construction) is not based on the actual construction of the cassion gates of the new navigational lock.

Compliance

Based on the Condition Survey it has been recommended to replace both the cassion gates. It is found that the existing gates are in a very dilapidated state and the complete system of cassion gates and the operating system needs to be replaced.

However, since use of Cassion Gates will be very infrequent in both existing as well as under construction lock for maintenance of mitre gate purposes, the feasibility of utilizing the cassion gates being fabricated for use at the new (under construction) lock structure to be used in the existing lock as well may be explored during the construction phase. It will require some modifications to the existing civil structure of the present lock and some minor modifications to the gate as detailed in para below.

Comment

b. The details with respect to the size (length, width and height) including bottom level of the lock chamber of both the locks shall be compared and clearly mentioned. It shall also be checked whether the grooves provided in the old navigational lock are suitable for placing of cassion gates being constructed for new navigation lock.

Compliance

It has been recommended to replace of both caisson gates with new gates along with the complete system operation. However, the feasibility of utilizing the cassion gates being fabricated for use at the new (under construction) lock structure in the existing lock can be explored. The detailing for this whereby the dimensions and levels are to be checked is being done at the DPR stage. The suitability of the grooves in the wall section and bottom seating arrangement will also be checked in the DPR.

Comment

c. The mechanism for transfer of the cassion gates from the new navigational lock chamber to old navigation lock chamber shall also be mentioned duly examining the mechanism being provided in those cassion gates for their relocation. If any change in design of cassion gate of new navigation lock is required for its transfer, same shall be clearly mentioned. The expenditure and time required for such changes shall also be estimated.

Compliance

Using the gates being provided at the new lock at existing lock structure also, will require provision of a tug boat to tow the gates from the new lock to the old lock and place it in position at the existing lock. It will also require some minor modifications to the gate to make it suitable for towing with the tug boat which will be assessed at the DPR stage.