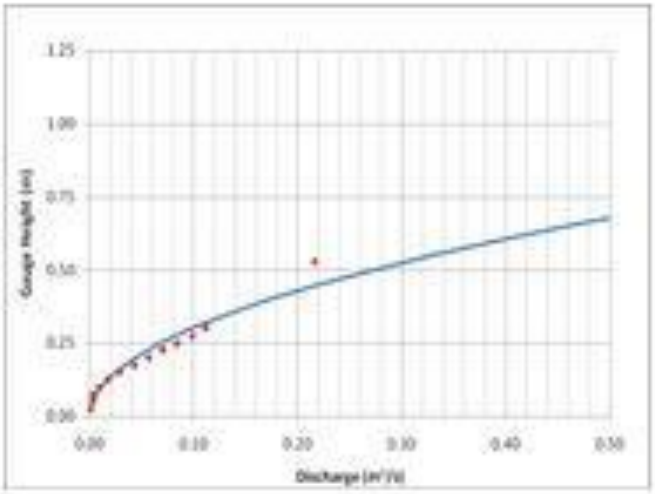
FINAL REPORT

Government of Nepal
MINISTRY OF IRRIGATION
DEPARTMENT OF IRRIGATION
IWRMP
Jawalakhel, Lalitpur



Calibration of Flow Control Structures of Mahakali Irrigation System under IWRMP in Phase I & II

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Table of Contents

1. Introduction

1.1 Background

Government of Nepal has received grant assistance from the World Bank for implementation of Irrigation and Water Resources Management Project (IWRMP). The IWRMP has been undertaken by DOI in order to support irrigation development in Nepal. The project is designed to improve the existing irrigation infrastructure, government and support organizations, and advance related policy development strategies and legislations that would lead towards providing reliable access to water to facilitate higher agricultural production and productivity. The IWRMP has the overall goal to contribute to reducing poverty of the rural community through improved integrated management of water resources development and rehabilitation of irrigation infrastructures of Farmers' Managed Irrigation Systems (FMISs) and management improvement and management transfer of Agency Managed Irrigation Systems (AMISs).

The project consists of major four components. Component A includes the modernization of Farmer Managed Irrigation systems (FMIS) in three western regions. Component B includes the transfer of management, operation & maintenance responsibilities of selected portions of large agency managed irrigation systems (AMISs) to the Water User Associations (WUAs) of the respective systems. Component C includes support to the Water and Energy Commission Secretariat (WECS) for its role in water regulatory authority. Component D comprises the activities on the integrated crop water management in the FMIS and AMIS system to support the agriculture sector for increase production including promotion of marketing and other assistances to the beneficiaries.

The overall objective of Component B is to improve irrigation service performance and service delivery to selected irrigation systems in the Terai through the completion and consolidation of Irrigation Management Transfer (IMT) to the relevant Water Users Association (WUAs). The main activities to achieve the overall objective of Component B are mostly focused on infrastructure development through Essential Structures Improvement, water management, and Institutional Development and mitigation measures for social and environmental impacts on the irrigation system. The expected output of the Irrigation Management Transfer (IMT) program through the implementation of the program objectives are efficient and equitable service delivery by financially and institutionally sustainable WUAs, Improved physical performance of the selected irrigation schemes, Reliable bulk water service delivery by Department of Irrigation (DOI) in line with the transfer agreement and Formation and strengthening of WUAs to become self-governing, self-financing and self-regulating organizations. For the efficient and reliable bulk water delivery, an appropriate water management practices through the development of the canal operation plan is envisioned.

1.2 Introduction

As a follow up action of the present agricultural strategy to increase agricultural production by raising unit yields and expanding higher cropped area from available irrigable area, the necessity to improve the irrigation water management practices is highly realized. In order to do so, some knowledge about resource being managed is required. This implies that water must be measured at strategic locations within the system. Irrigation and Water Resources Management Project (IWRMP) intends to to measure the discharge and calibrate the flow control structures or canal structures of Mahakali Irrigation System Stage I and II at different strategic locations in main and branch canals to improve water management practices and reduce conflicts among users through equitable distribution of available resources.

1.3 Objectives of Work

The overall objective of this study is to evaluate the hydraulic performance of the flow control structures. The specific objectives of the study are as follows:

- To measure the discharge through H/R and C/R at different strategic locations (24 in MIS both of stage-I and II, See on Annex A) in main and branch canals at different depth of flow.
- To prepare calibration chart of water delivery through above mentioned flow control structures of different canals.

1.4 Scope of Work

The specific objectives of the study are as follows:

- To review the reports and drawings of the control structures as built in;
- To identify the locations of measuring structures (points) in Main and Branch canals.
- To measure the discharge at minimum four different depths of flow at each location,
- To prepare the calibration chart for different flow conditions as far as practicable,
- To calibrate the gates, where there are appropriate measuring locations in canal systems

2. List of Structures Calibrated

Mahakali Irrigation System – Stage I

2.1. Bulk Water Delivery Points of Water Measurement as per IMT agreement, total-8 No.

Bulk Water Delivery Points	Name of Structure	Main Canal Chainage	Priority of Calibration
1	Head Regulator of Ultakham Distributary	9+524	First Priority
2	Head Regulator of Suda Branch	12+477	First Priority
3	Head Regulator of Sisaiya Branch	14+875	First Priority
4	Head Regulator of Daiji Minor	17+175	First Priority
5	Head Regulator of Gadda Minor	0+915	Second Priority (Optional)
6	Head Regulator of Bhujela Distributary	2+085	Second Priority (Optional)
7	Head Regulator of Basantpur Minor	2+519	Second Priority (Optional)
8	Head Regulator of Mahendranagar Distributary	5+172	Second Priority (Optional)

Mahakali Irrigation System – Stage II

2.2 Bulk Water Delivery Points of Water Measurement as per IMT agreement, Total-13 No.

2.2.1Along M3 Canal (Belauri Main Branch Canal), Total - 6 No.

Bulk Water Delivery Points	Chainage	Name of Structure	Block
1	4+586	HR-SLR (Salghari Branch) Canal	Block 7
2	4+591	HR-SLM (Salghari Minor) Canal	Block 7
3	8+404	HR-PUR (Pachoi Branch) Canal	Block 7
4	12+076	HR-KUR (Kunda Branch) Canal	Block 8
5	16+169	HR-SAR (Syali-A Branch) Canal	Block 8
6	16+176	HR-SYR (Syali-Y Branch) Canal	Block 8

2.2.2 Along Shivanagar Main Branch Canal, Total – 7 No.

Bulk Water Delivery Points	Chainage	Name of Structure	Block
1	0+579	HR-KAR (Kamari Branch) Canal	Block 7
2	1+011	HR-KHR (Khairighat Branch) Canal	Block 7
3	2+567	HR-Imiliya Minor Canal	Block 7
4	3+247	HR-BBR (Baibaha Branch) Canal	Block 7
5	4+129	HR-JHR (Jhilmila Branch) Canal	Block 7
6	15+185	HR-BHR (Bhuda Minor) Canal	Block 7
7	16+196	HR-BGR (Bhuda-Gauri) Canal	Block 8

2.3 Other points of water measurement, Total – 3 No

2.3.1 Cross-Regulator at Daiji, adjacent to Daiji Branch Canal

2.3.2 Head-Regulator, M3 Canal (Belauri Main Branch Canal)

2.3 .3 Head-Regulator, Shivanagar Main Branch Canal)

2.4 Summary

At stage I of Mahakali Irrigation three structures are not calibrated. The lists of structure are

- Majgaon Branch
- Bhagtpur Branch
- Chunariya Branch

The reason for Chunariya Branch is head regulator gate out of operation. Similarly Bagtpur branch is closed for the construction work in downstream so calibration is not possible. At Majgaon Branch the measuring structure flume is overtop by the canal water so unless the flume is reconstructed it is meaningless to calibrate structure. Beside the above mention structure the other structure were well calibrated and out coming result is satisfactory.

At Stage II of Mahakali Irrigation five structures are not calibrated. The lists of structure are

- Beldandi Branch along M3 canal
- Beldandi Minor along M3 canal
- Dakka Minor along M3 canal
- Belauri Branch alongM3 canal
- Gaurigaun Branch along Shivanagar Branch

The reason for the Beldandi Branch,Beldandi minor,Dakka Minor is the construction work undergoing in the downstream of the respective canal. At Belauri Branch the slab culvert of existing road have consoli-

dated obstructing the flow of canal due to which calibration is not possible at desired accuracy hence not performed. Gaurigaun Branch along Shivanagar Branch being the last branch there was not sufficient availability of water for flow measurement. Our current meter doesn't show any reading for longer duration so it was not calibrated. Beside above mention structure the other structures are calibrated and the out coming result is satisfactory.

Mahakali Irrigation System – Stage II

Fig:Map of Mahakali Irrigation Stage-II

3. Methodology and Approach

3.1 Measurement of Discharge

Measurement works has been carried out by following standard practices in hydrology and the DHM. Area-Velocity Method was applied to measure discharges of the River. A current meter can be used to measure the velocity at a point on a selected vertical of a cross section. The adopted procedures of discharge measurement at the site are as follows:

- Divide the measuring section into 20 to 30 verticals of equal width.
- Each vertical would not pass more than 10% of total discharge.
- The difference of velocities in the adjacent segments should not be more than 20%.
- Measure the distance from the initial point and the water depth for each vertical
- Measure the velocity at 0.8 depth (V0.8d) and 0.2 depth (V0.2d) in each vertical if depths are more than 1 meter.
- Measure the velocity, v, at 0.6 depth (V0.6d) near the bank where the depth is shallow (Whenever the depth is less than 1 m)
- Compute velocity using the current meter-rating table provided by the manufacturer. Continue for all the partial sections.
- Compute the partial discharge for all partial sections using the following equation

$$q_x = v_x \frac{b_{x+1} - b_{x-1}}{2} d_x \qquad (1)$$

- Use the following equations for the end sections

$$q_1 = v_1 \frac{b_2 - b_1}{2} d_1 \qquad (2)$$

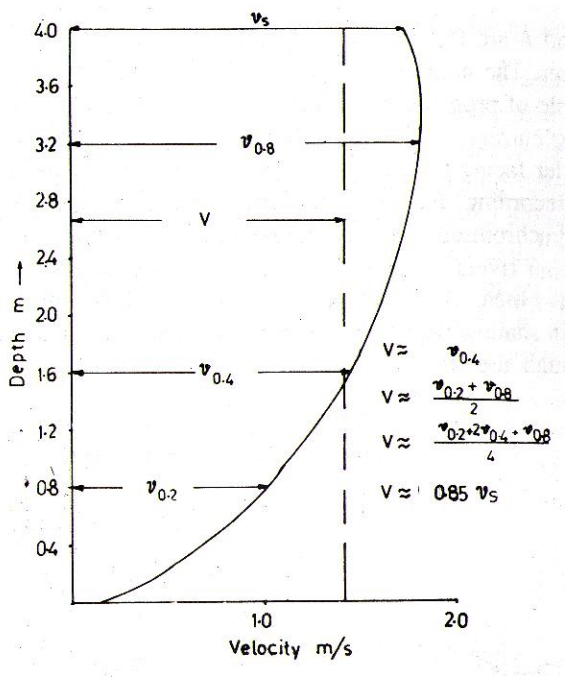


Figure: Velocity Profile along a River Depth

$$q_n = v_n \frac{b_x - b_{n-1}}{2} d_n \qquad (3)$$

- Compute the total discharge using the following expression

$$Q = \sum_{x=1}^{n} q_x \qquad (4)$$

3.2 Rating Curve (Stage Discharge Relation or Calibration of the station)

Continuous discharge measurement of a stream is very difficult and costly but the continuous record of river stage can be obtained easily. Hence to compute the daily flow, there should be an adequate correlation between stage and discharge.

Discharge ratings for gauging stations are usually determined empirically by means of periodic measurements of discharge and stage. The discharge measurements are usually made by current meter. Measured discharges are then plotted against concurrent stages on graph paper to define the rating curve.

The stage discharge relation at stream gauging station is defined by the complex interaction of the channel characteristics including cross-sectional areas, shape, slope and roughness. The combination of these effects is called control. A control is said to be permanent control if the stage-discharge relationship which is defined does not change with time. On the contrary, is known as either an impermanent of shifting control. The shifting control may be due to the effects of changing channel scour and silt in alluvial streams, back water, rapidly changing stage in the stream, variable channel storage, aquatic vegetation etc. after a gauging station has been established and sufficient discharge measurements have been to determine the stage-discharge relation, it becomes necessary to make additional measurements at various stages from time to time to know just how rapidly or how slowly the control is changing. A control should never be assumed permanent until it has been proved so by a number of measurements made after the passage of flood.

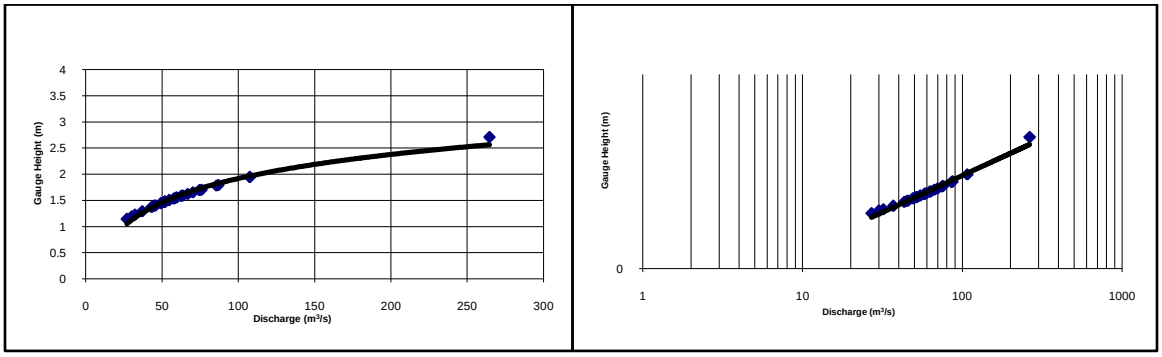


Figure Typical Rating Curve in Arithmetic Scale and Log-Log scale

If there are discharge measurements covering the entire range of stage experienced during a period of time, there will not be any problem in defining the stage-discharge relation. On the other hand, if the discharge measurements are lacking to define the upper end of the rating, the defined lower part of the rating curve must be extrapolated to the highest stage experienced. Such extrapolations are always subject to error, but the error may be reduced if the analyst has knowledge of the principles that govern the shape of the rating curves.

Stage-discharge relations are usually developed from a graphical analysis of the discharge measurements plotted on either rectangular co-ordinate or logarithmic plotting paper. In a preliminary step, the discharge measurements available for analysis are tabulated and summarized on a form by numbering consecutively in chronological order. Discharge is then plotted as the abscissa, corresponding gauge height is plotted as the ordinate, and a curve or line is fitted to the plotted points.

The use of logarithmic plotting paper is usually preferred for graphical analysis of the rating because in the usual situation of compound controls, changes in the slope of the logarithmically plotted rating identify the range in stage for which the individual controls are effective. Furthermore, the portion of the rating curve that is applicable to any particular control may be linearized for rational extrapolation or interpolation.

A rating curve or a segment of a rating curve that plots as a straight line in logarithmic paper has the equation:

$$Q = a(H - H_0)^b \qquad (1)$$

Where,

Q is discharge;

$H\text{-}H_0$ is head or depth of water on the control;

H is the gauge height of the water surface;

H_0 is the gauge height of zero flow;

a is a constant that is numerically equal to the discharge when the head $H\text{-}H_0$ equals unity;

b is the slope of the rating curve. Its value is influenced by the transverse profile of the streambed at the control section.

If the natural section control is essentially horizontal for the entire width of the control, the exponent b will be greater than 1.5, because of the increase in velocity of approach with stage. If the crest of the control has a roughly parabolic profile, as most natural controls have (greater depth on the control near midstream), the exponent b will be even larger because of the increase in width of the stream with stage. The value of b will almost always exceed 2.

4. CONSIDERATION

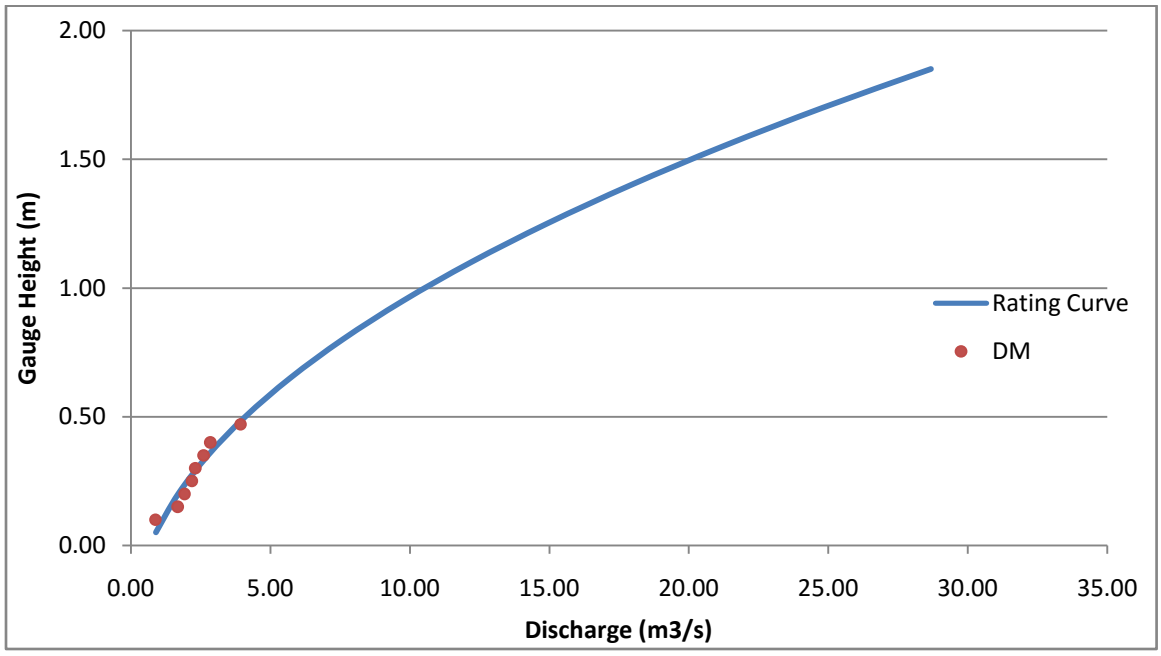
It is important to realize that some of the structures within this report were not specifically designed as flow measurement structures. Other structures herein, though designed as flow measurement structures, have been designed and constructed according to criteria that are sub-optimal by current uses and/or design methods. Thus, in many cases, the structures reported within this document can not measure the full range of desired flow rates with the degree of accuracy which could be obtained if designing and constructing a new structure. However, this report assumes that a calibrated structure, capable of flow measurement within recognized level of uncertainty, is preferable to an uncalibrated structure. The detailed reports for each structure contained within this document note the expected uncertainties for each structure throughout the entire range of calibrated flow rates. If the level of uncertainty is determined by the users to be unacceptable, then the options are to either restrict flows to the range of acceptable levels of uncertainty, or to modify the existing structure or construct a new structure which is capable of obtaining the required levels of accuracy. In many cases the existing structures could be modified to achieve greater accuracy at comparatively low cost.

It is also extremely important to understand that many of the structures included within this document are potentially subject to changes in flow rates due downstream canal conditions that will, or potentially may, invalidate the calibration output included herein. All structures in this report have been calibrated under the assumption of properly maintained downstream canal conditions (i.e. canal beds and banks at design levels, no excessive vegetation, etc.). This was **not** the present case at a number of structures at the time of field measurements. In a number of cases the floors of measurement structures were observed to be well below the adjacent upstream and downstream bed levels of the canals due to the deposition of sediment. It would not be possible to calibrate some of these structures using the observed condition of the canals as input data. In other cases, though possible, it seemed most rational to calibrate the structures assuming the canal's design parameters rather than the observed, hopefully temporary, state. Therefore this has been done where necessary within thereportscompiledinthisdocument.

Report on Calibration of Structure

5.1 Stage I

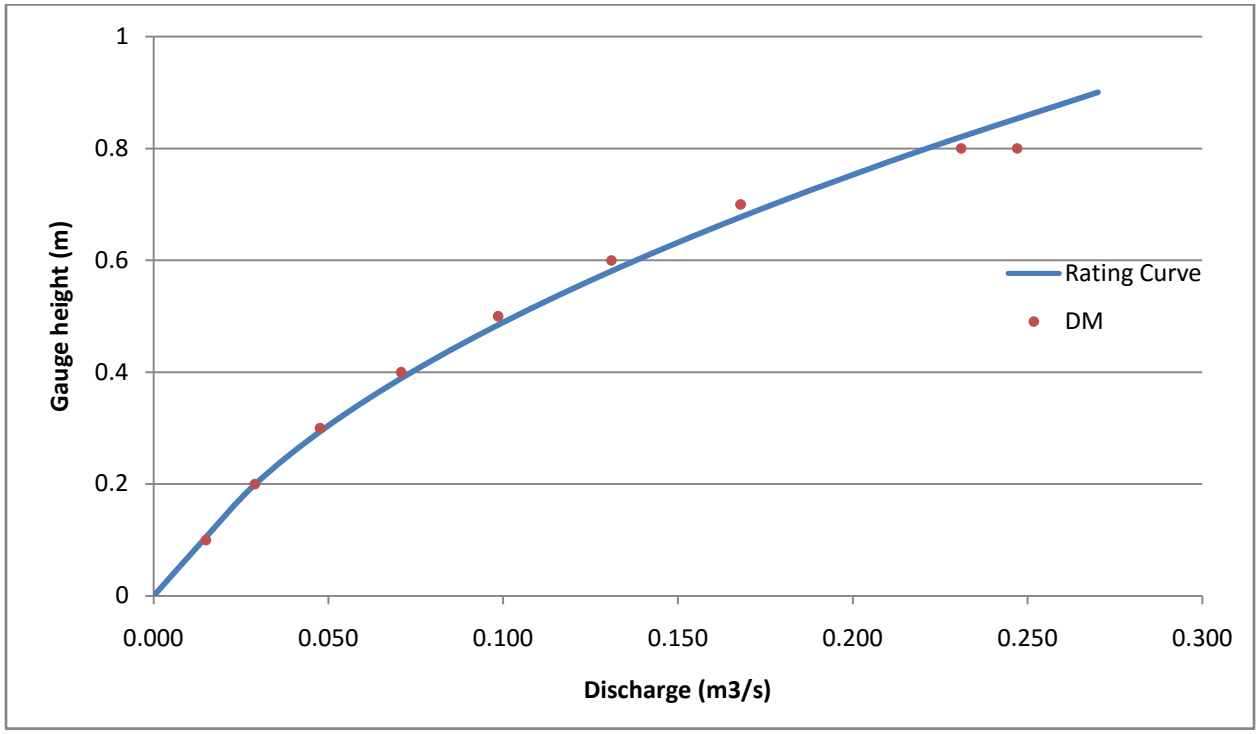
1. Main Branch Canal



Equation; $Q= 5.548(H+0.365)^{2.066}$

H	Q
1.85	28.69
1.70	24.82
1.55	21.24
1.40	17.94
1.25	14.94
1.10	12.21
0.95	9.77
0.80	7.61
0.65	5.72
0.50	4.11
0.35	2.77
0.20	1.71
0.05	0.90
0.00	0.00

2. Gadda Minor

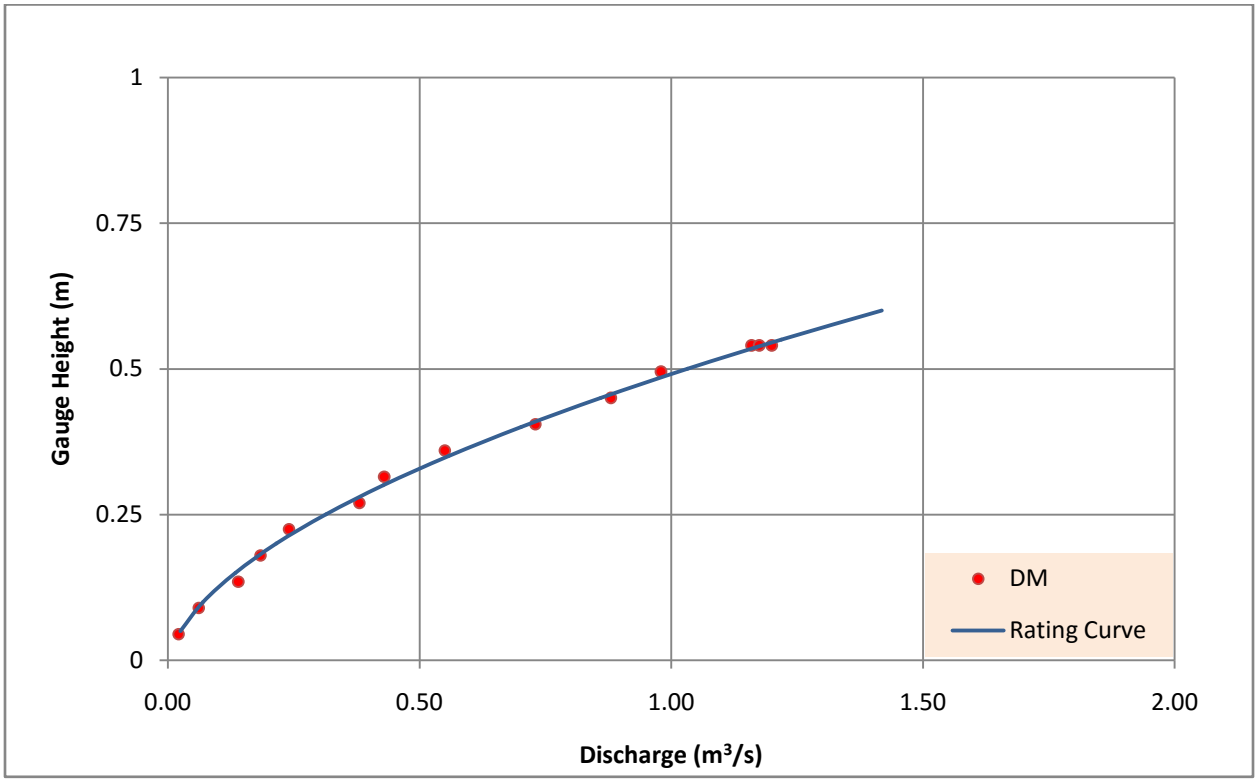


$Q=0.261*(H+0.16)^{2.023}$

H	Q
0	0.000
0.1	0.014
0.2	0.029
0.3	0.049
0.4	0.074
0.5	0.104
0.6	0.138
0.7	0.177
0.8	0.221
0.9	0.270

The location of measurement is 39m downstream from the head regulator. The structure calibrated is head regulator of Gadda minor. Gauge was placed at crest of head regulator during measurement.

3. Bhujela Distributary

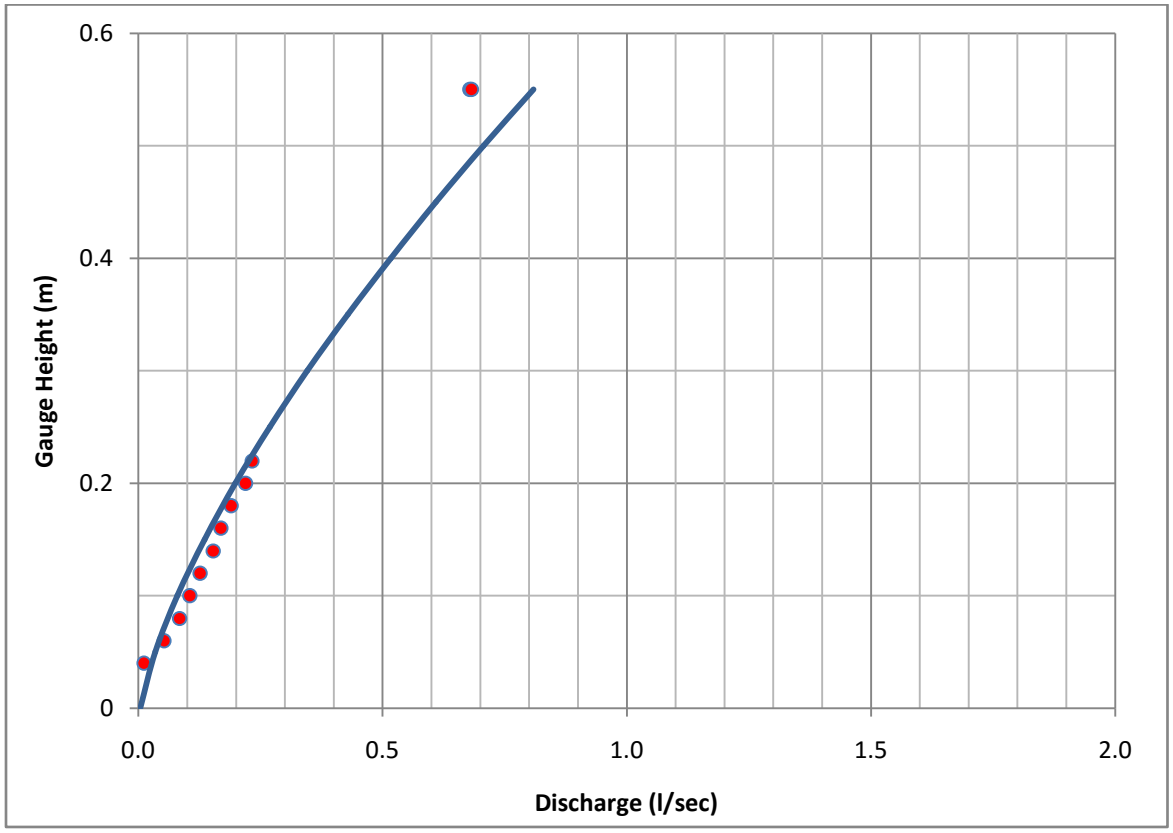


$Q=3.393*(H+0.013)^{1.782}$

H	Q
0.60	1.419
0.55	1.219
0.50	1.033
0.45	0.860
0.40	0.702
0.35	0.558
0.30	0.428
0.25	0.314
0.20	0.216
0.15	0.134
0.10	0.070
0.05	0.025

The location of measurement is 53 m downstream from the head regulator. The structure calibrated is head regulator of Bhujela Distributary. Gauge was placed at crest of flume during measurement.

4. Basantapur Minor

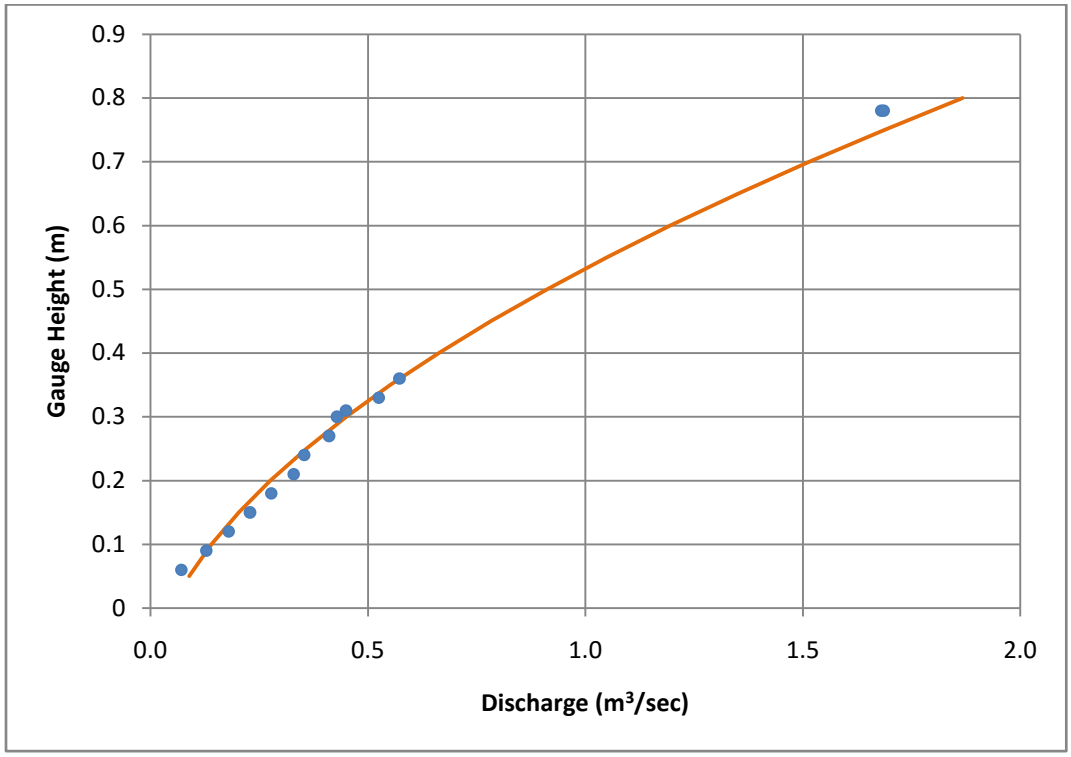


$Q=1.853*(H+0.015)^{1.452}$

H	Q
0.60	1.419
0.55	1.219
0.50	1.033
0.45	0.860
0.40	0.702
0.35	0.558
0.30	0.428
0.25	0.314
0.20	0.216
0.15	0.134
0.10	0.070
0.05	0.025

The location of measurement is 47m downstream from the head regulator. The structure calibrated is head regulator of Basantapur minor. Gauge was placed at crest of flume during measurement.

5. Mahendranagar Distributary

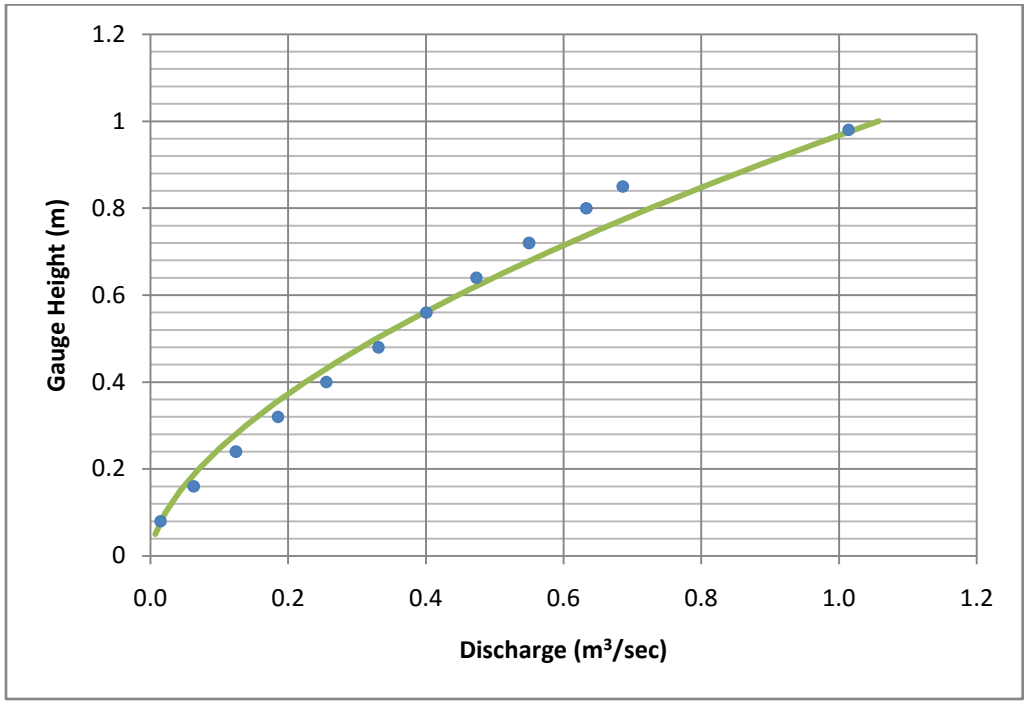


$Q=2.154(H+0.125)^{1.83}$

H	Q
0.80	1.868
0.75	1.687
0.70	1.515
0.65	1.351
0.60	1.196
0.55	1.049
0.50	0.911
0.45	0.782
0.40	0.662
0.35	0.552
0.30	0.450
0.25	0.358
0.20	0.275
0.15	0.203
0.10	0.141
0.05	0.089

The location of measurement is 28.4m downstream from the head regulator. The structure calibrated is head regulator of Mahendarnagar Distributary.Gauge was placed at crest of flume during measurement.

6. Ultakham Distributary

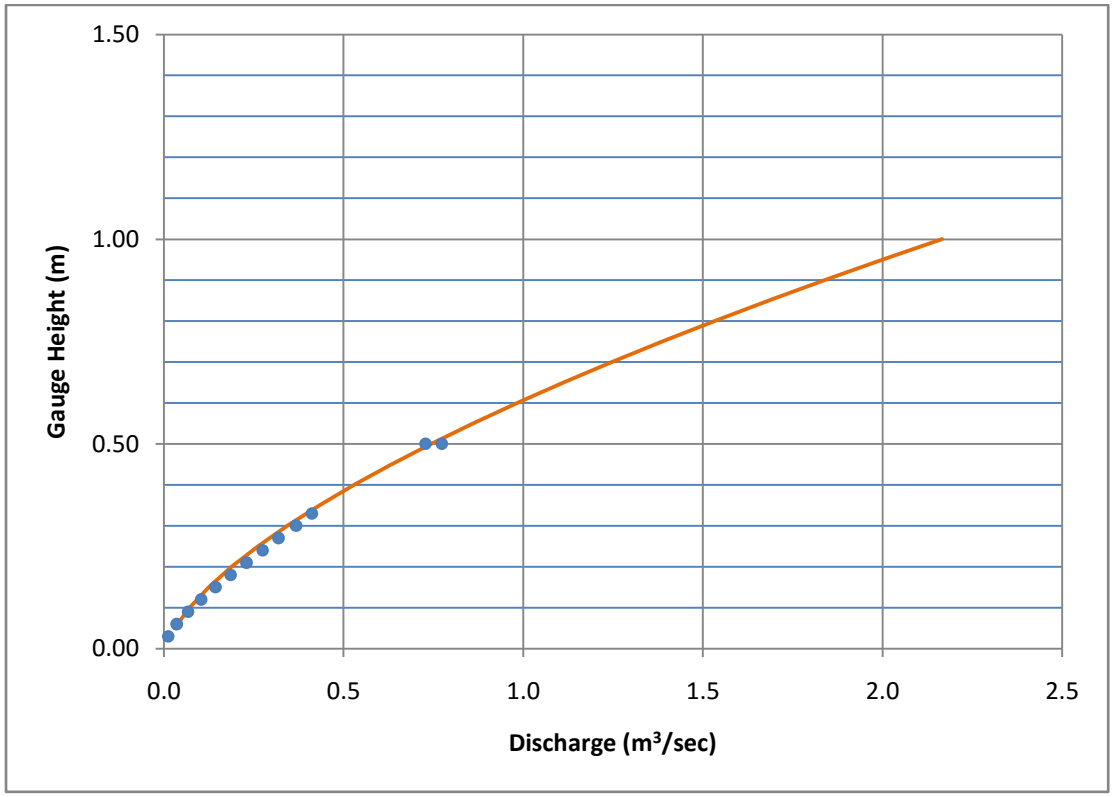


$Q=1.056(H+0.001)^{1.69}$

H	Q
1.00	1.058
0.95	0.970
0.90	0.885
0.85	0.804
0.80	0.726
0.75	0.651
0.70	0.579
0.65	0.511
0.60	0.447
0.55	0.386
0.50	0.328
0.45	0.275
0.40	0.225
0.35	0.180
0.30	0.139
0.25	0.102
0.20	0.070
0.15	0.043
0.10	0.022
0.05	0.007

The location of measurement is 54m downstream from the head regulator.The structure calibrated is head regulator of Ultakham Distributaory Gauge was placed at crest of flume during measurement.

7. Suda Branch

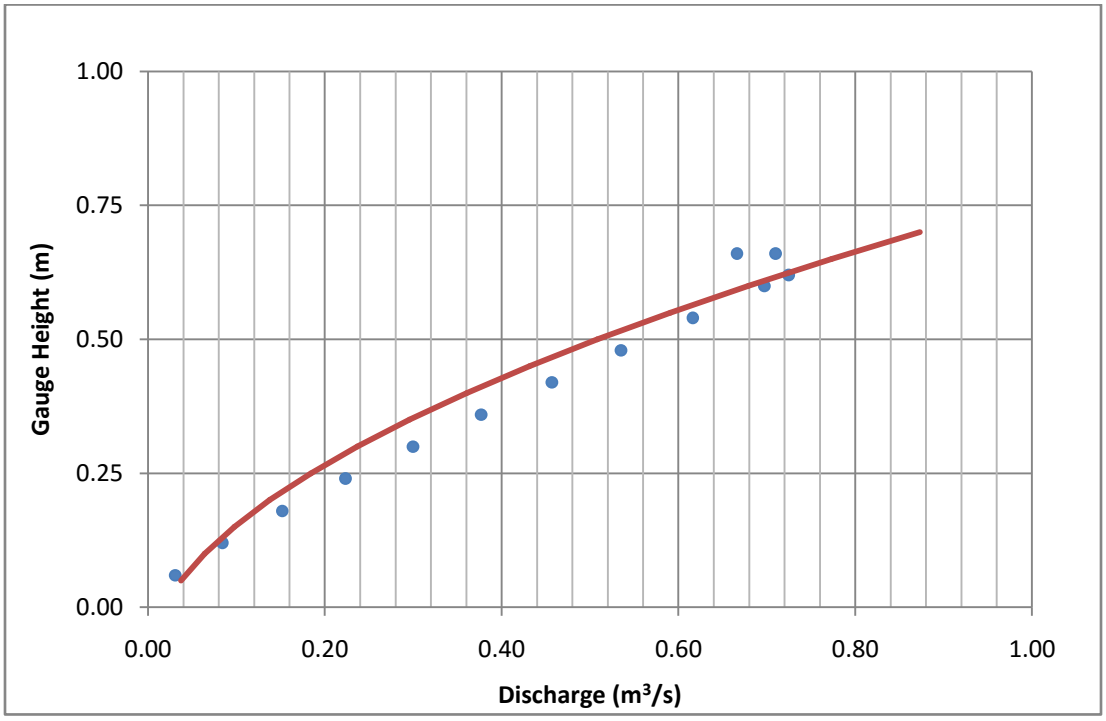


$Q = 1.65(H-0.012)^{1.239}$

H	Q
0.70	1.246
0.65	1.112
0.60	0.983
0.55	0.860
0.50	0.743
0.45	0.633
0.40	0.529
0.35	0.432
0.30	0.343
0.25	0.261
0.20	0.188
0.15	0.124
0.10	0.070
0.05	0.029

The location of measurement is 2.50 m upstream from the First drop Structure. The structure calibrated is First Drop Structure of Suda Branch. Gauge was placed at crest of Drop during measurement.

8. Sisaiya Branch

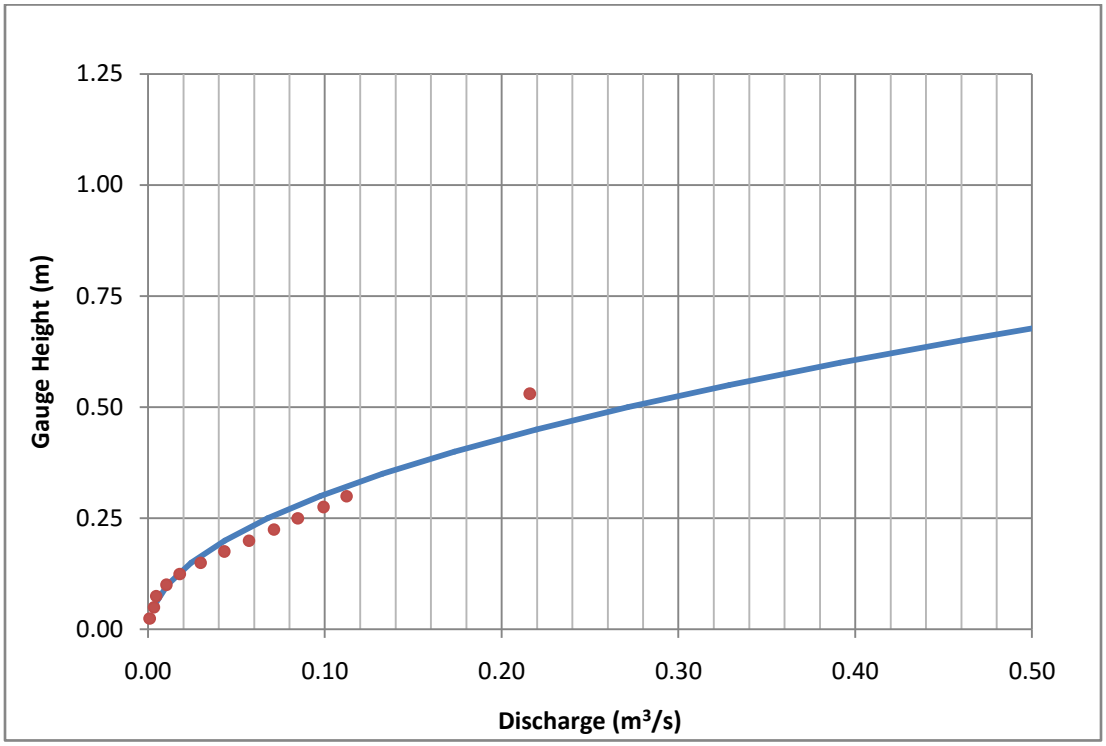


$Q= 1.331(H+0.099)^{1.879}$

H	Q
0.70	0.873
0.65	0.773
0.60	0.679
0.55	0.591
0.50	0.508
0.45	0.431
0.40	0.361
0.35	0.296
0.30	0.237
0.25	0.184
0.20	0.138
0.15	0.098
0.10	0.064
0.05	0.037

The location of measurement is 26.50m downstream from the head regulator.The structure calibrated is head regulator of Saisaya Branch .Gauge was placed at crest of flume during measurement.

9. Daiji Minor

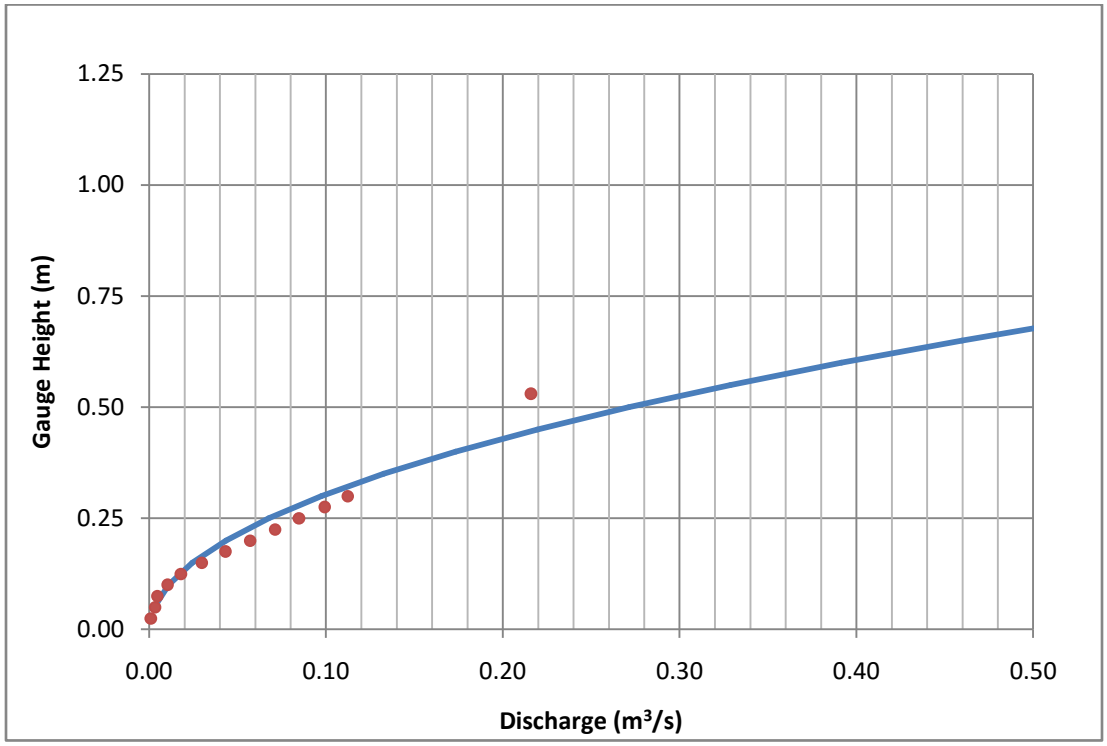


$Q = 1.088(H+0.003)^{2.021}$

H	Q
0.70	0.534
0.65	0.460
0.60	0.391
0.55	0.329
0.50	0.271
0.45	0.220
0.40	0.173
0.35	0.133
0.30	0.097
0.25	0.068
0.20	0.043
0.15	0.024
0.10	0.011
0.05	0.003

The location of measurement is 24.90m downstream from the head regulator. The structure calibrated is head regulator of Daiji minor.Gauge was placed at crest of head regulator during measurement.

10. Daiji Major



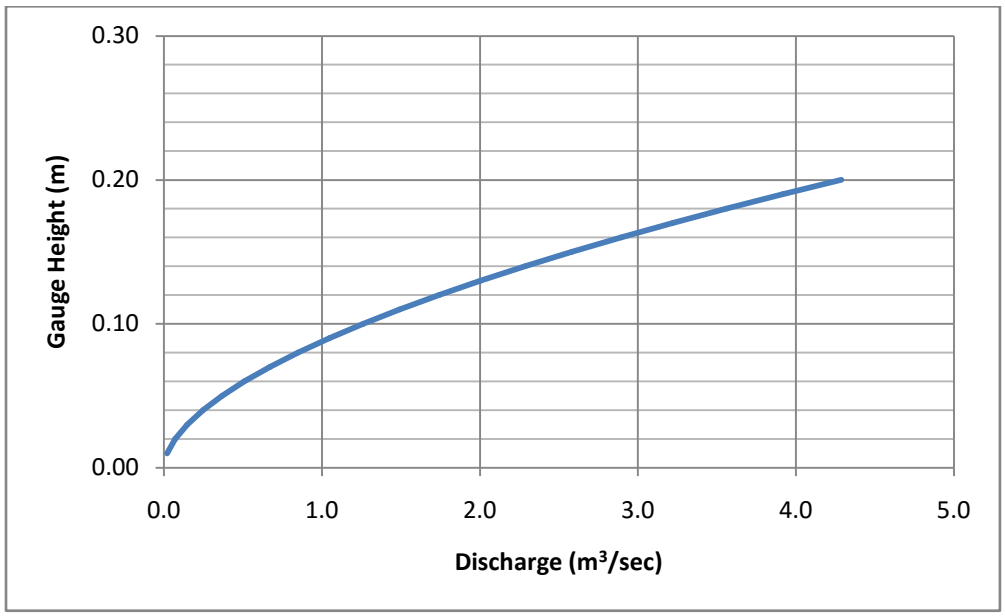
$Q=1.088*(H+0.003)^{2.021}$

H	Q
0.70	0.534
0.65	0.460
0.60	0.391
0.55	0.329
0.50	0.271
0.45	0.220
0.40	0.173
0.35	0.133
0.30	0.097
0.25	0.068
0.20	0.043
0.15	0.024
0.10	0.011
0.05	0.003

The location of measurement is 20m downstream from the Cross regulator. The structure calibrated is Cross Regulator of Daiji Major. Gauge was placed at crest of cross regulator during measurement.

5.2 Stage II along M3 Main Branch

1. M3 Main Canal

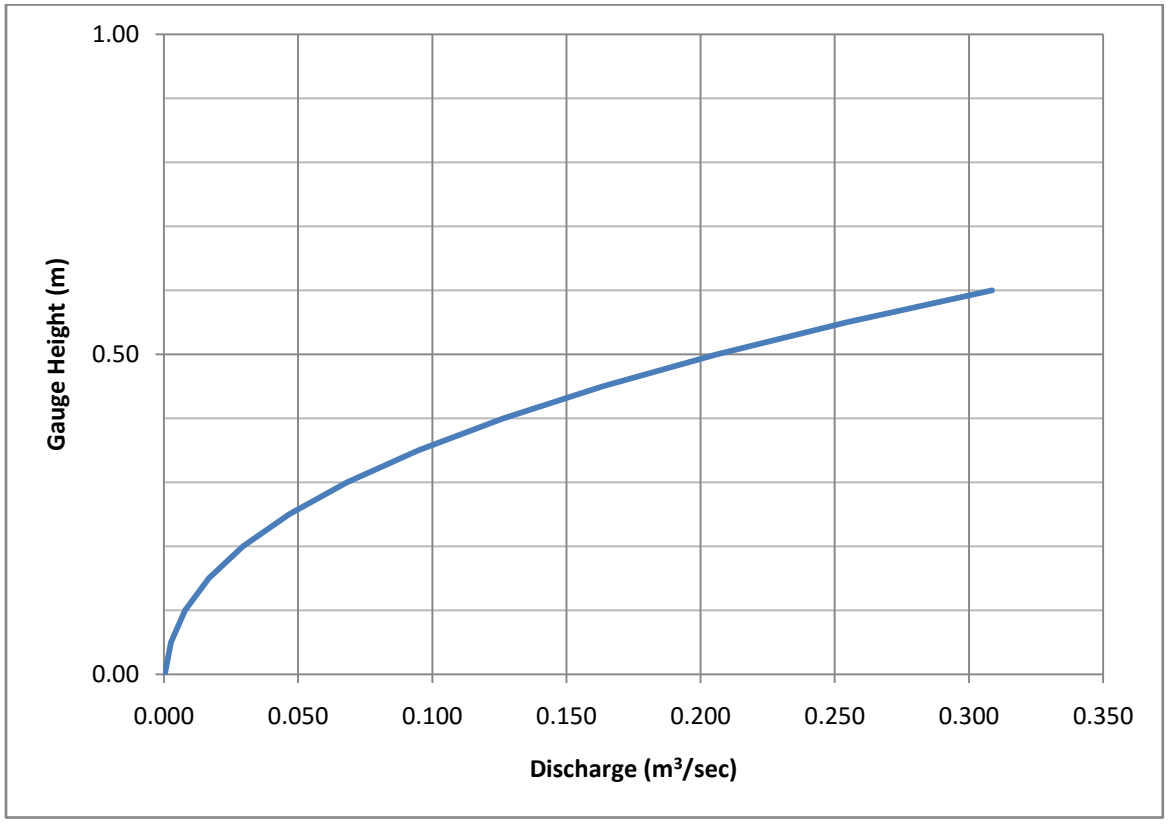


$Q = 72.796*(H-0.001)^{1.754}$

H	Q
0.20	4.288
0.19	3.918
0.18	3.561
0.17	3.220
0.16	2.893
0.15	2.582
0.14	2.285
0.13	2.005
0.12	1.740
0.11	1.492
0.10	1.260
0.09	1.046
0.08	0.848
0.07	0.669
0.06	0.508
0.05	0.367
0.04	0.246
0.03	0.146
0.02	0.070
0.01	0.019
0.00	0.000

The location of measurement is 18m downstream from the Cross regulator. The structure calibrated is Cross Regulator of M3 Canal. Gauge was placed at crest of head regulator during measurement.

2. Salghari Branch

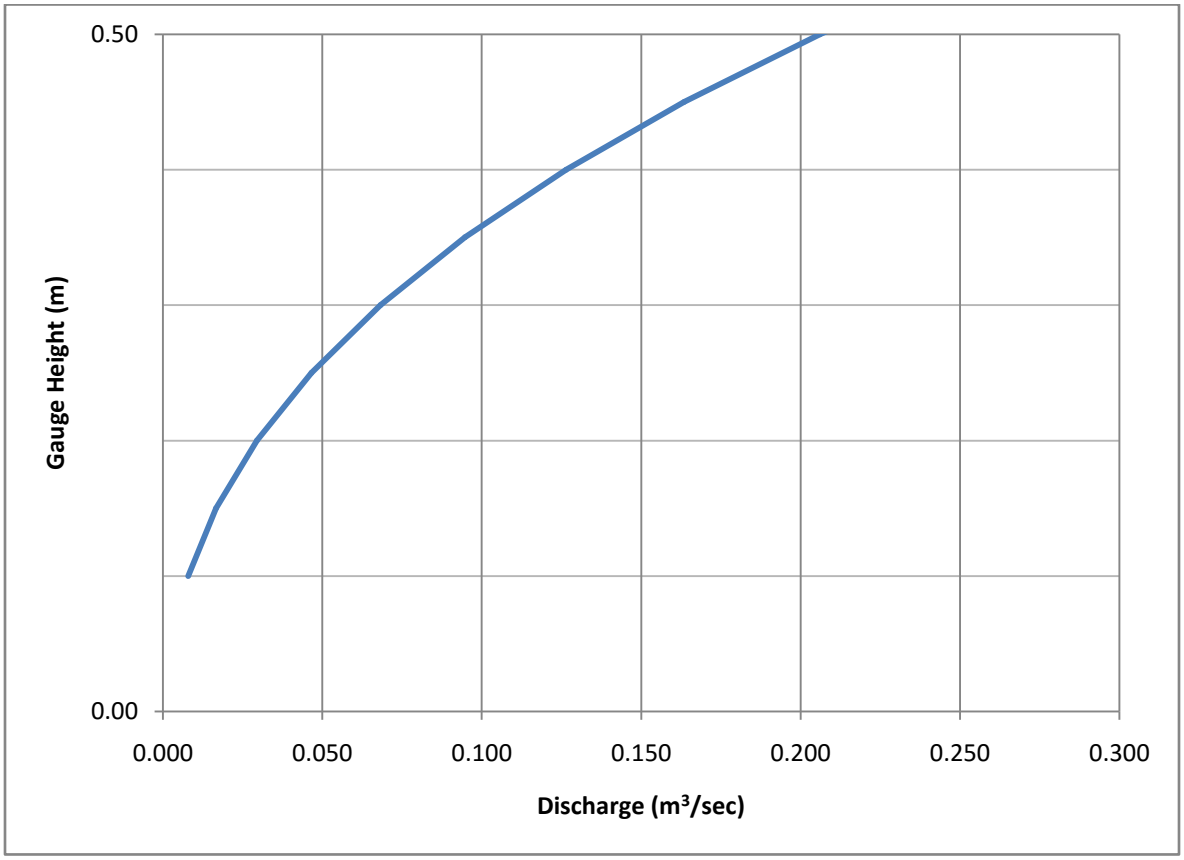


$Q = 0.905*(H+0.032)^{2.345}$

H	Q
0.60	0.309
0.55	0.254
0.50	0.206
0.45	0.163
0.40	0.126
0.35	0.095
0.30	0.068
0.25	0.047
0.20	0.029
0.15	0.017
0.10	0.008
0.05	0.003
0.00	0.000

The location of measurement is 26m downstream from the head regulator. The structure calibrated is head regulator of Salghari Branch.Gauge was placed at crest of head regulator during measurement.

3. Salghari Minor

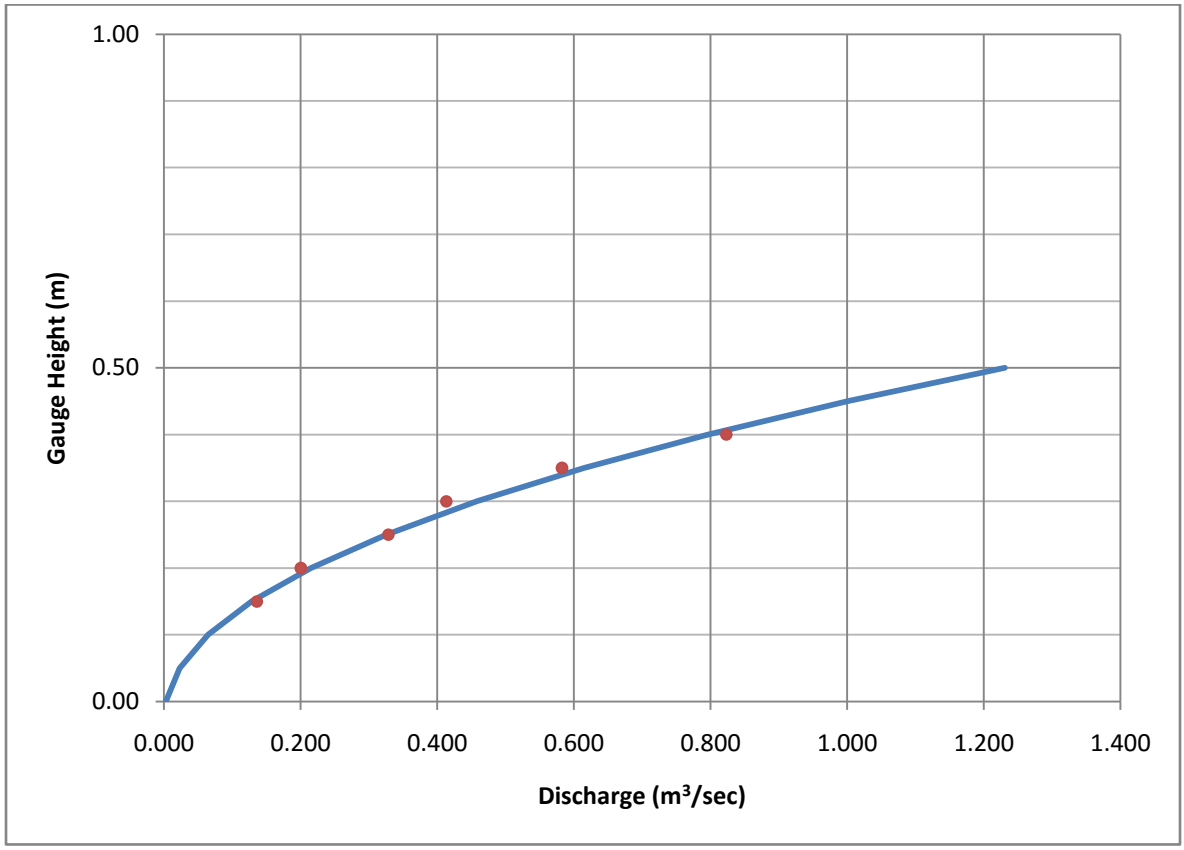


$Q = 0.533*(H+0.038)^{2.32}$

H	Q
0.50	0.127
0.45	0.101
0.40	0.079
0.35	0.059
0.30	0.043
0.25	0.030
0.20	0.019
0.15	0.011
0.10	0.005
0.05	0.002
0.00	0.000

The location of measurement is 28 m downstream from the head regulator. The structure calibrated is head regulator of Salghar Minor.Gauge was placed at crest of head regulator during measurement.

4. Pachoi Branch

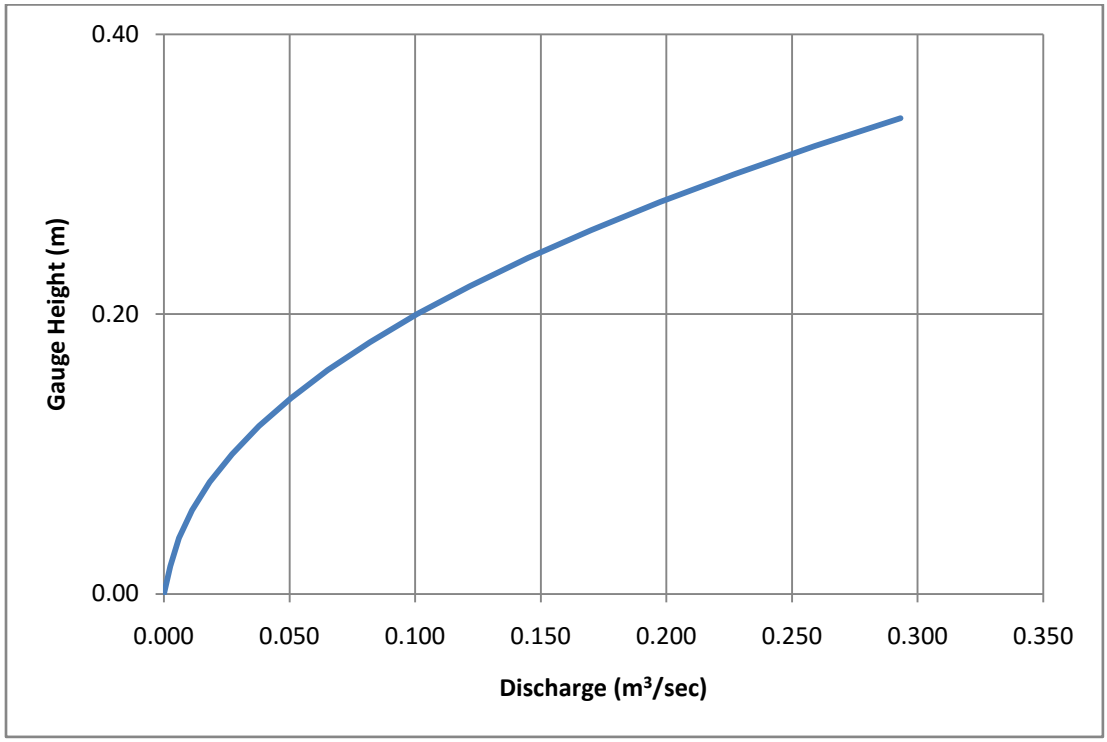


$Q = 4.641*(H+0.027)^{2.072}$

H	Q
0.50	1.231
0.45	1.001
0.40	0.796
0.35	0.615
0.30	0.458
0.25	0.325
0.20	0.215
0.15	0.128
0.10	0.065
0.05	0.023
0.00	0.003

The location of measurement is 30 m downstream from the head regulator. The structure calibrated is head regulator of poachi Branch.Gauge was placed at crest of head regulator during measurement.

5. Kunda Branch

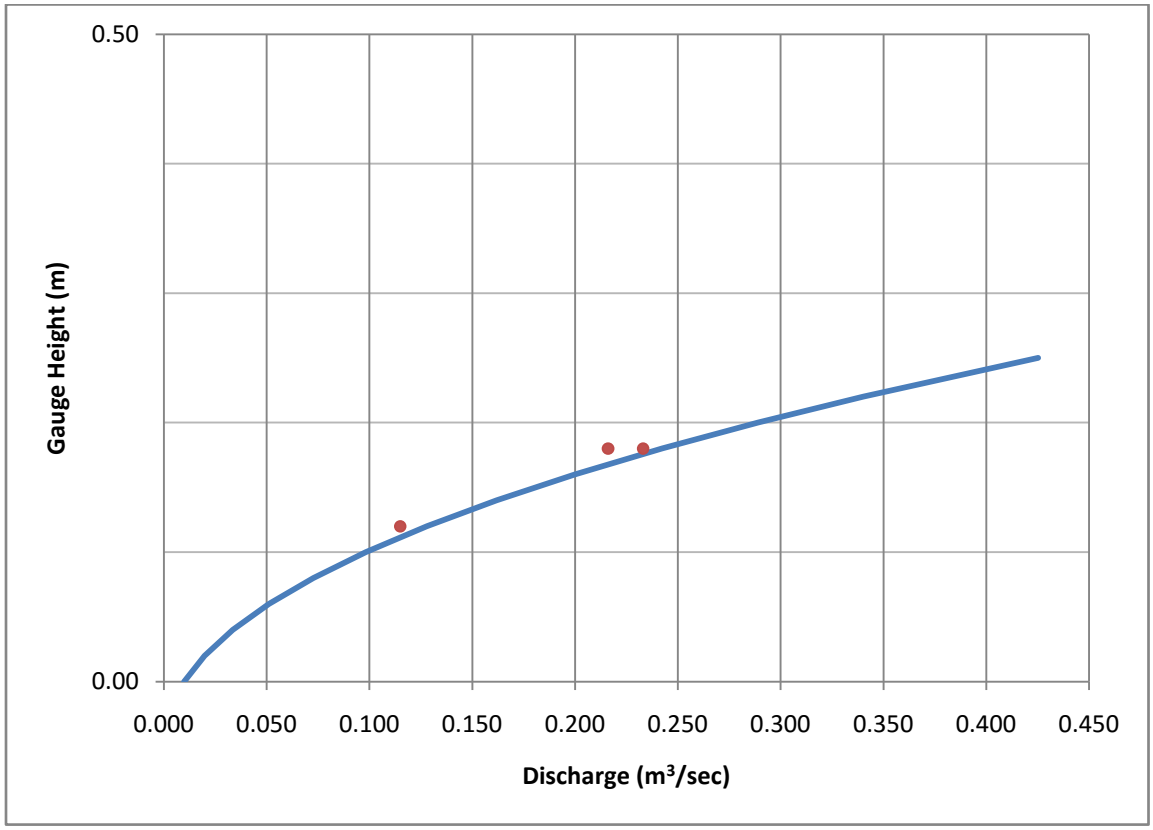


$Q=2.686*(H+0.02)^{2.168}$

H	Q
0.34	0.293
0.32	0.259
0.30	0.227
0.28	0.197
0.26	0.170
0.24	0.145
0.22	0.122
0.20	0.101
0.18	0.082
0.16	0.065
0.14	0.051
0.12	0.038
0.10	0.027
0.08	0.018
0.06	0.011
0.04	0.006
0.02	0.003
0.00	0.000

The location of measurement is 17m downstream from the head regulator. The structure calibrated is head regulator of Kunda Branch.Gauge was placed at crest of head regulator during measurement.

6. Syali –A Branch

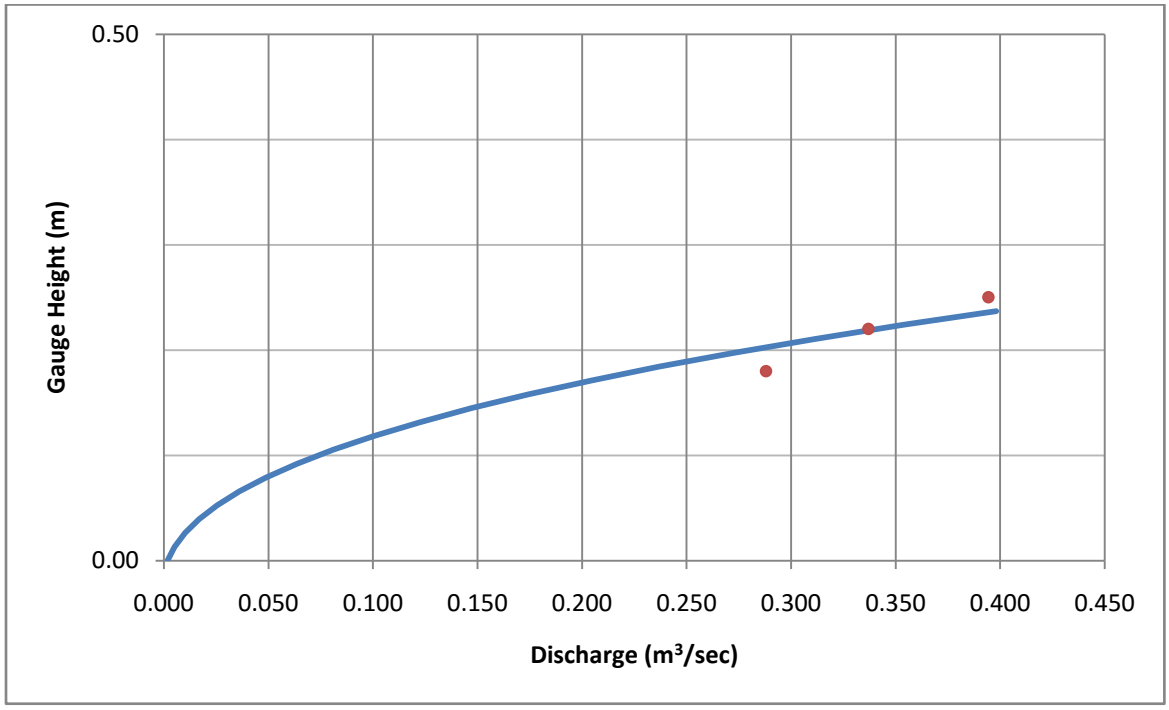


$Q = 5.447*(H+0.051)^{2.124}$

H	Q
0.25	0.425
0.22	0.340
0.20	0.289
0.18	0.242
0.16	0.200
0.14	0.162
0.12	0.128
0.10	0.098
0.08	0.073
0.06	0.051
0.04	0.034
0.02	0.020
0.00	0.010

The location of measurement is 25m downstream from the head regulator. The structure calibrated is head regulator of Syali-A Branch.Gauge was placed at crest of head regulator during measurement.

7. Syali-Y Branch



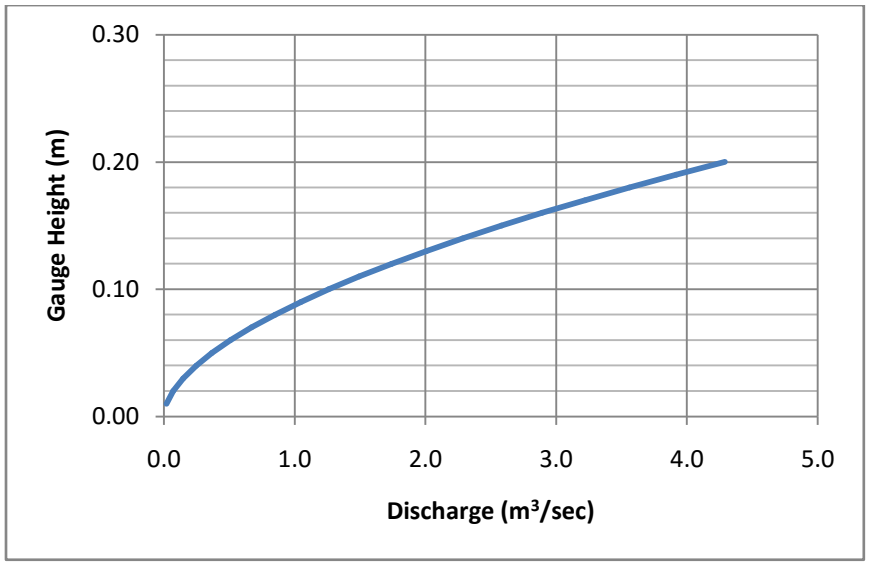
$Q=2.258*(H+0.134)^{1.698}$

H	Q
0.25	0.387
0.24	0.370
0.22	0.354
0.20	0.324
0.18	0.310
0.16	0.283
0.14	0.271
0.12	0.248
0.09	0.227
0.08	0.217
0.05	0.199
0.03	0.110
0.01	0.024
0.00	0.000

The location of measurement is 18 m downstream from the head regulator. The structure calibrated is head regulator of Syali-Y Branch.Gauge was placed at crest of head regulator during measurement.

4.3 Stage II along Shivanagar Main Branch

1. Shivanagar Main Branch

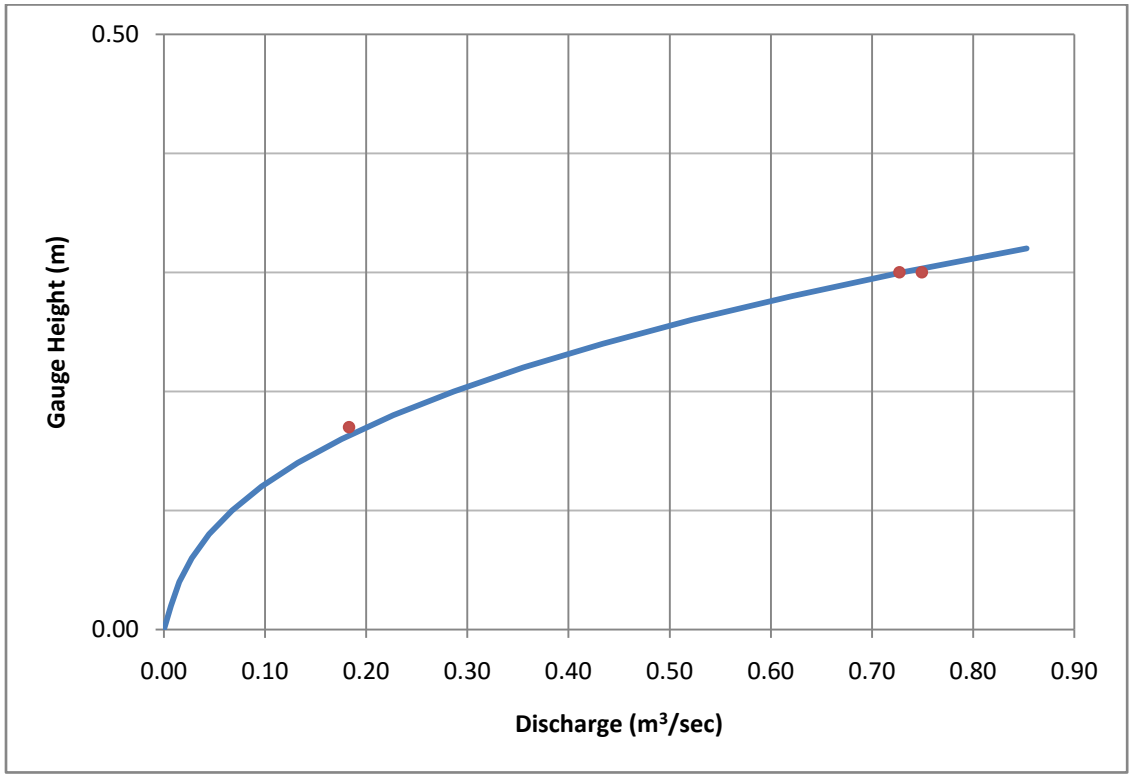


$Q = 72.796*(H-0.001)^{1.754}$

H	Q
0.20	4.288
0.19	3.918
0.18	3.561
0.17	3.220
0.16	2.893
0.15	2.582
0.14	2.285
0.13	2.005
0.12	1.740
0.11	1.492
0.10	1.260
0.09	1.046
0.08	0.848
0.07	0.669
0.06	0.508
0.05	0.367
0.04	0.246
0.03	0.146
0.02	0.070
0.01	0.019
0.00	0.000

The location of measurement is 38m downstream from the Cross regulator. The structure calibrated is Cross Regulator of Shivanagar Main Branch.Gauge was placed at crest of head regulator during measurement.

2. Kamari Branch

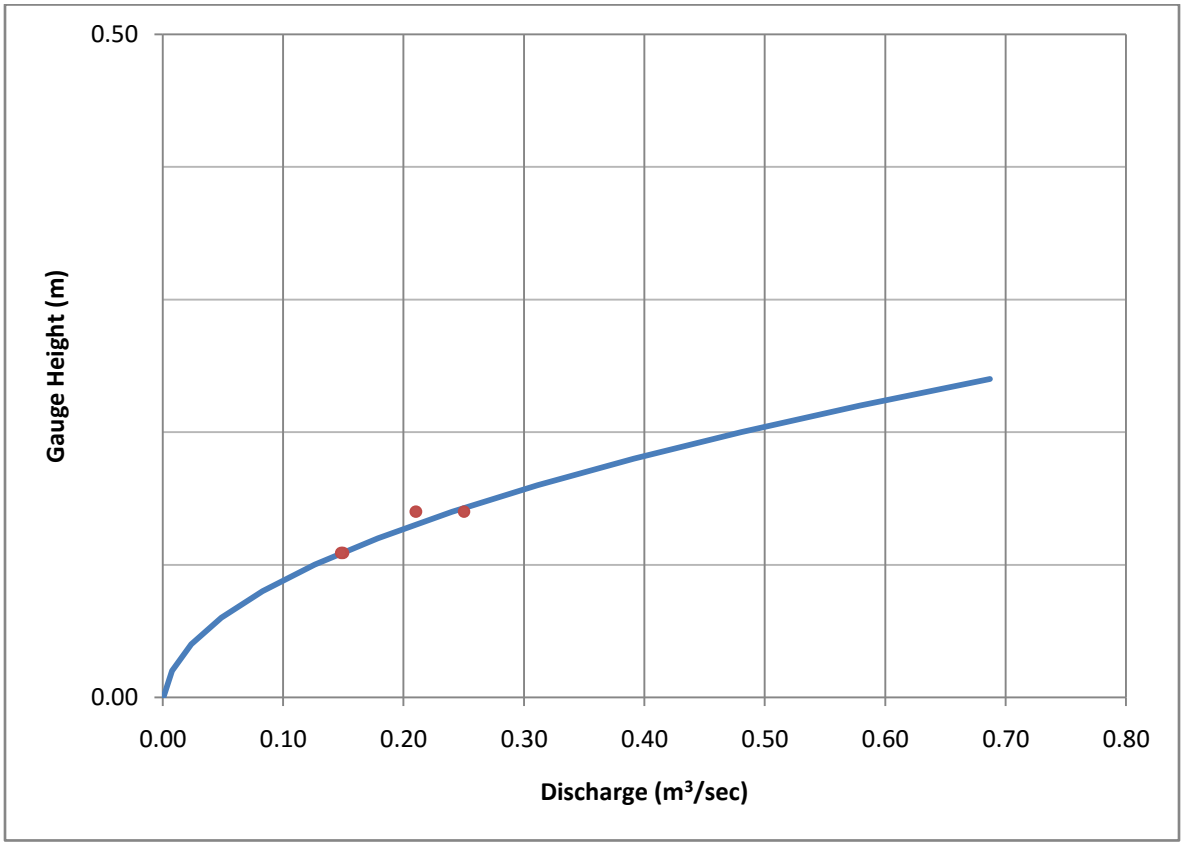


$Q = 13.354*(H+0.041)^{2.7}$

H	Q
0.32	0.853
0.30	0.731
0.28	0.621
0.26	0.522
0.24	0.434
0.22	0.355
0.20	0.286
0.18	0.227
0.16	0.175
0.14	0.132
0.12	0.096
0.10	0.067
0.08	0.045
0.06	0.027
0.04	0.015
0.02	0.007
0.00	0.000

The location of measurement is 36 m downstream from the head regulator. The structure calibrated is head regulator of Kamari Branch.Gauge was placed at crest of head regulator during measurement.

3. Khairighat Branch

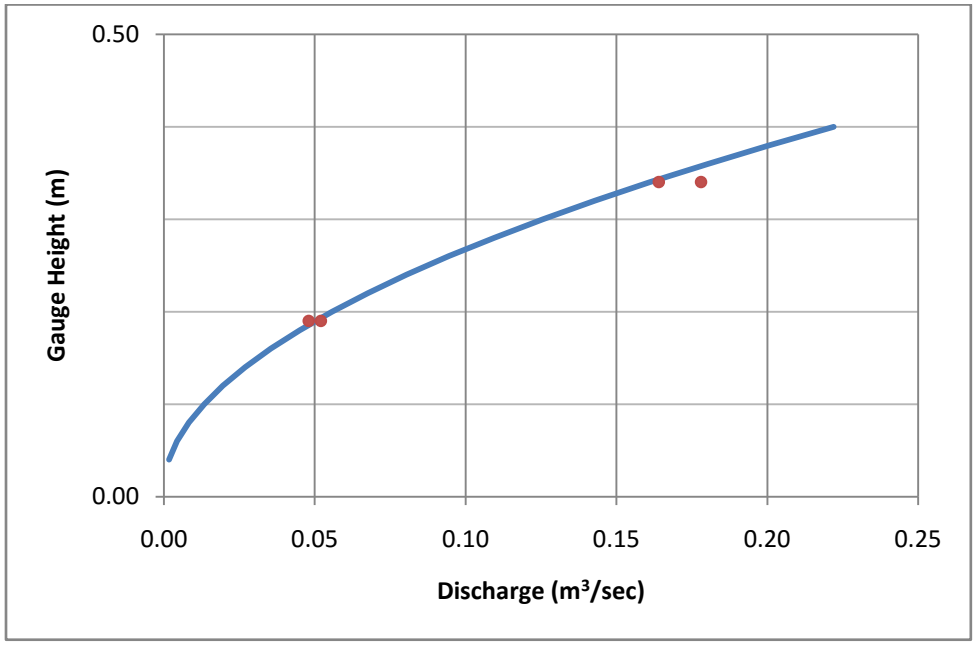


$Q = 11.576*(H+0.006)^{2.014}$

H	Q
0.24	0.687
0.22	0.579
0.20	0.480
0.18	0.391
0.16	0.311
0.14	0.240
0.12	0.179
0.10	0.126
0.08	0.083
0.06	0.049
0.04	0.023
0.02	0.007
0.00	0.000

The location of measurement is 40 m downstream from the head regulator. The structure calibrated is head regulator of Khairighat Branch.Gauge was placed at crest of head regulator during measurement.

4. Imiliya Minor Canal

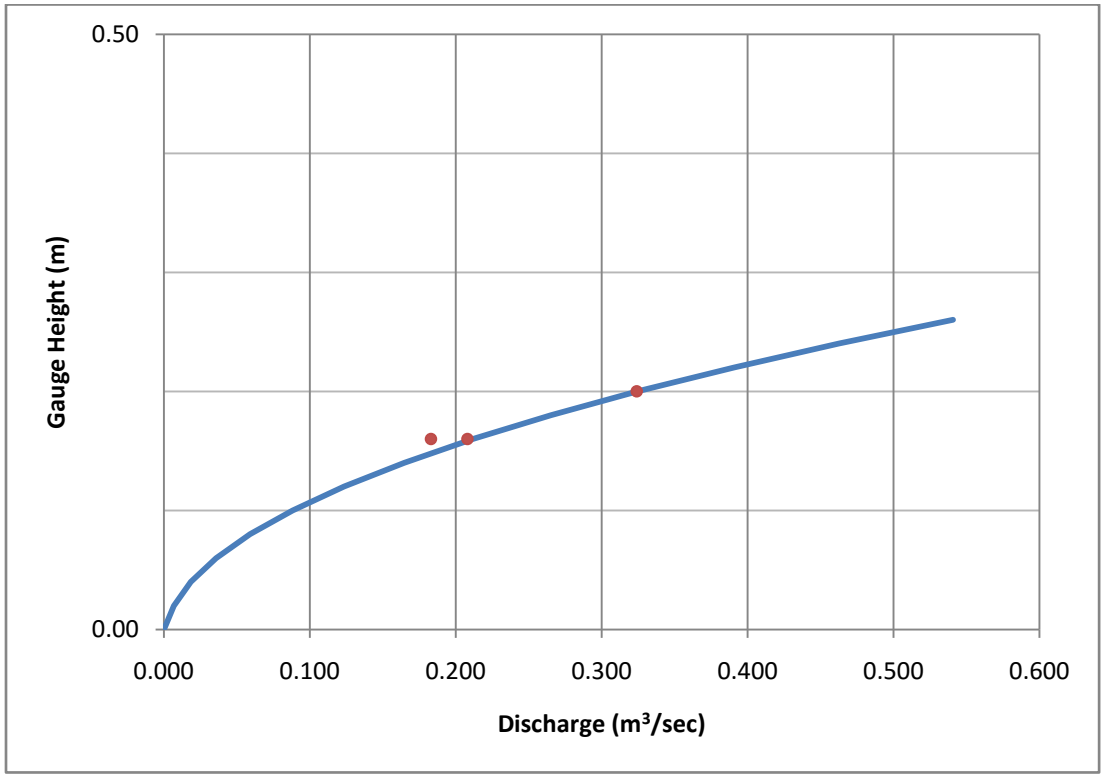


$Q = 1.36*(H-0.009)^{1.93}$

H	Q
0.40	0.222
0.38	0.201
0.36	0.180
0.34	0.161
0.32	0.143
0.30	0.126
0.28	0.109
0.26	0.094
0.24	0.080
0.22	0.068
0.20	0.056
0.18	0.045
0.16	0.035
0.14	0.027
0.12	0.020
0.10	0.013
0.08	0.008
0.06	0.004
0.04	0.002

The location of measurement is 20.7m downstream from the head regulator. The structure calibrated is head regulator of Imiliya Minor.Gauge was placed at crest of head regulator during measurement.

5. Baibaha Branch

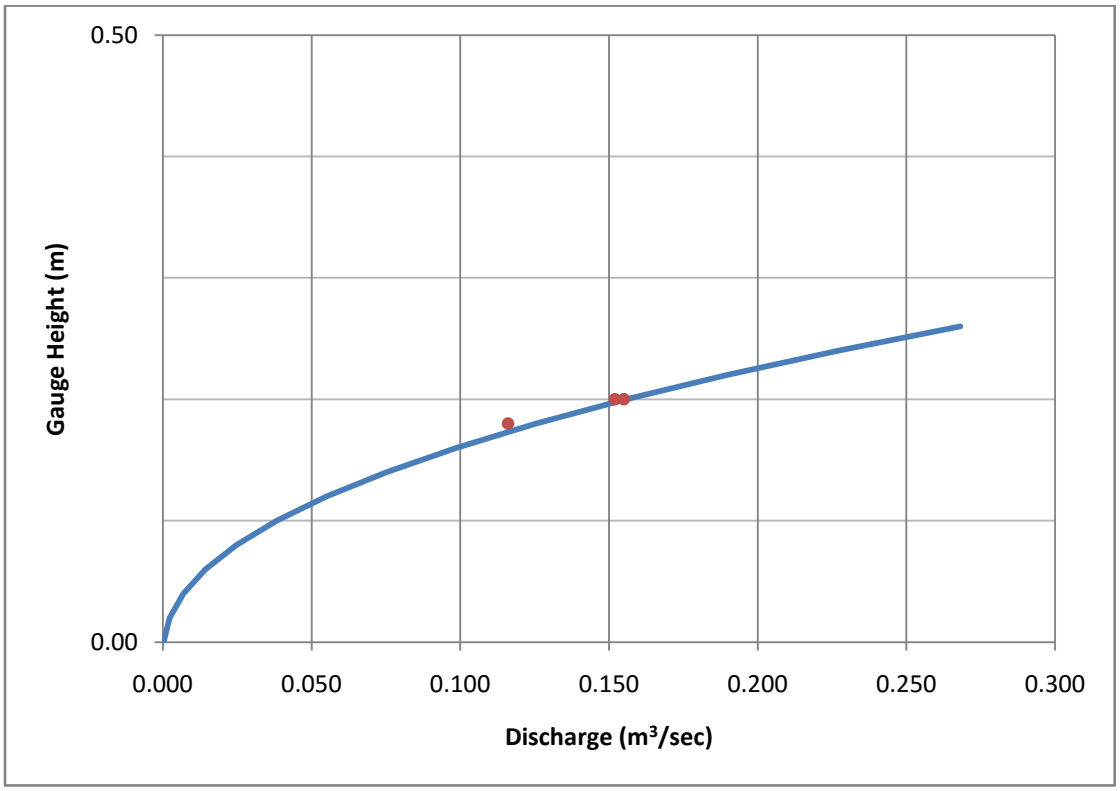


$Q = 7.73*(H+0.012)^{2.043}$

H	Q
0.26	0.541
0.24	0.463
0.22	0.391
0.20	0.325
0.18	0.265
0.16	0.212
0.14	0.165
0.12	0.123
0.10	0.088
0.08	0.059
0.06	0.036
0.04	0.018
0.02	0.007
0.00	0.000

The location of measurement is 28 m downstream from the head regulator. The structure calibrated is head regulator of Baibaha Branch.Gauge was placed at crest of head regulator during measurement.

6. Jhilmila Branch

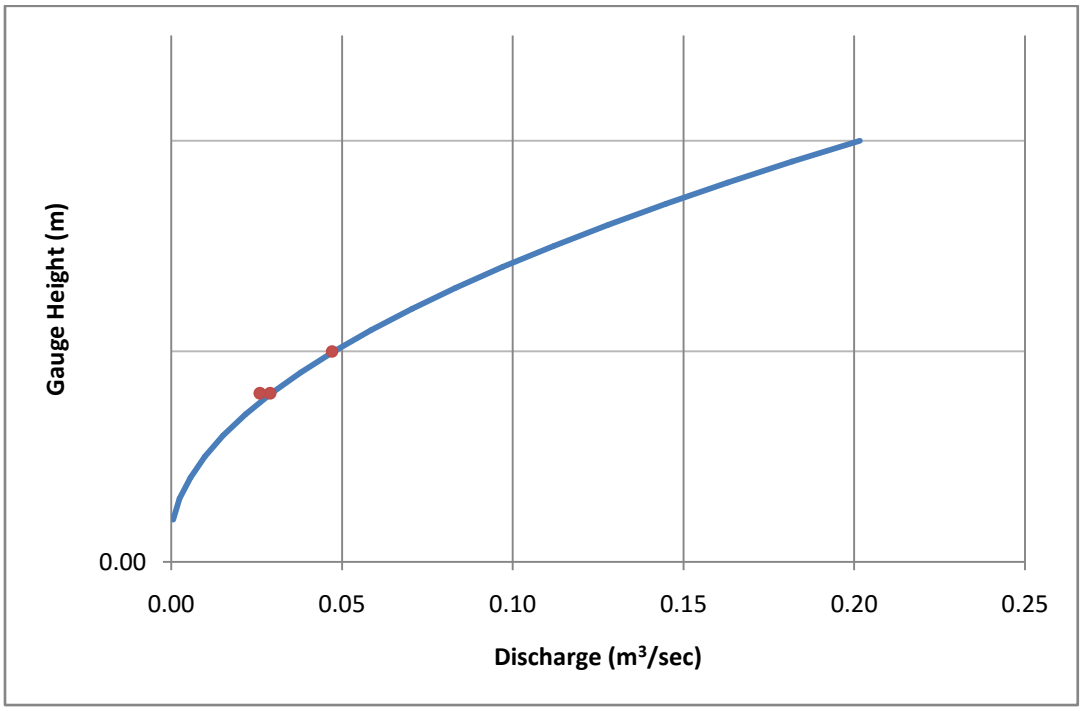


$Q = =4.535*(H+0.009)^{2.154}$

H	Q
0.26	0.268
0.24	0.227
0.22	0.190
0.20	0.156
0.18	0.125
0.16	0.099
0.14	0.075
0.12	0.055
0.10	0.038
0.08	0.025
0.06	0.014
0.04	0.007
0.02	0.002
0.00	0.000

The location of measurement is 27 m downstream from the head regulator. The structure calibrated is head regulator of Jhilmila Branch.Gauge was placed at crest of head regulator during measurement.

7. Bhuda Minor

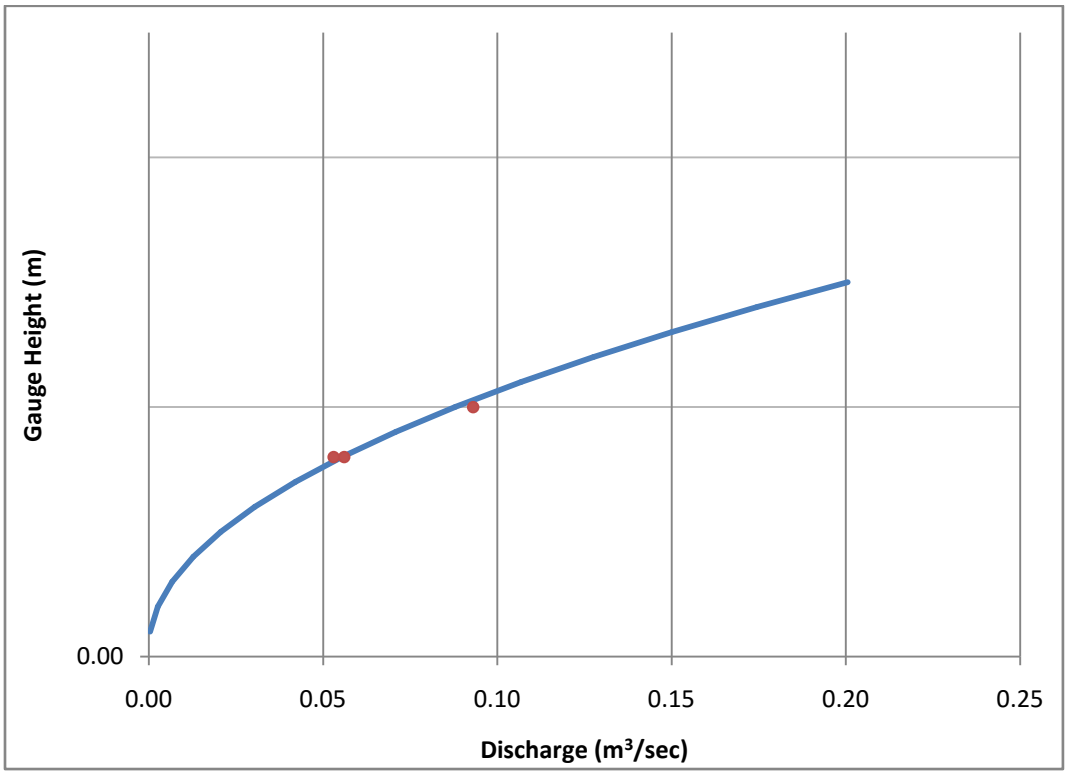


$Q = 4.893*(H-0.011)^{1.914}$

H	Q
0.20	0.202
0.19	0.182
0.18	0.163
0.17	0.145
0.16	0.128
0.15	0.112
0.14	0.097
0.13	0.083
0.12	0.070
0.11	0.059
0.10	0.048
0.09	0.038
0.08	0.029
0.07	0.022
0.06	0.015
0.05	0.010
0.04	0.006
0.03	0.002
0.02	0.001
0.00	0.000

The location of measurement is 64 m downstream from the head regulator. The structure calibrated is head regulator of Bhuda minor.Gauge was placed at crest of head regulator during measurement.

8. Bhuda Gauri



$Q = 8.827*(H-0.004)^{1.967}$

H	Q
0.15	0.200
0.14	0.174
0.13	0.150
0.12	0.128
0.11	0.107
0.10	0.088
0.09	0.071
0.08	0.056
0.07	0.042
0.06	0.030
0.05	0.021
0.04	0.013
0.03	0.007
0.02	0.003
0.01	0.000

The location of measurement is 39m downstream from the head regulator. The structure calibrated is head regulator of Bhuda-Gauri Branch.Gauge was placed at crest of head regulator during measurement.

5. Annex

6.1Velocity Profile

6.1.1 Stage I

1. Main Branch Canal

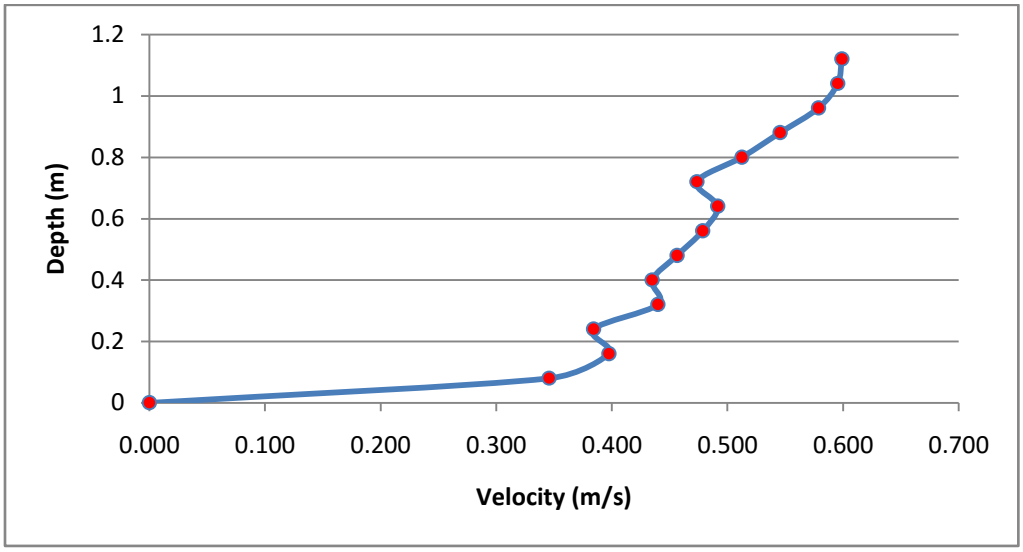


Fig: Vertical Velocity distribution

2. Mahendaranagar Distributary

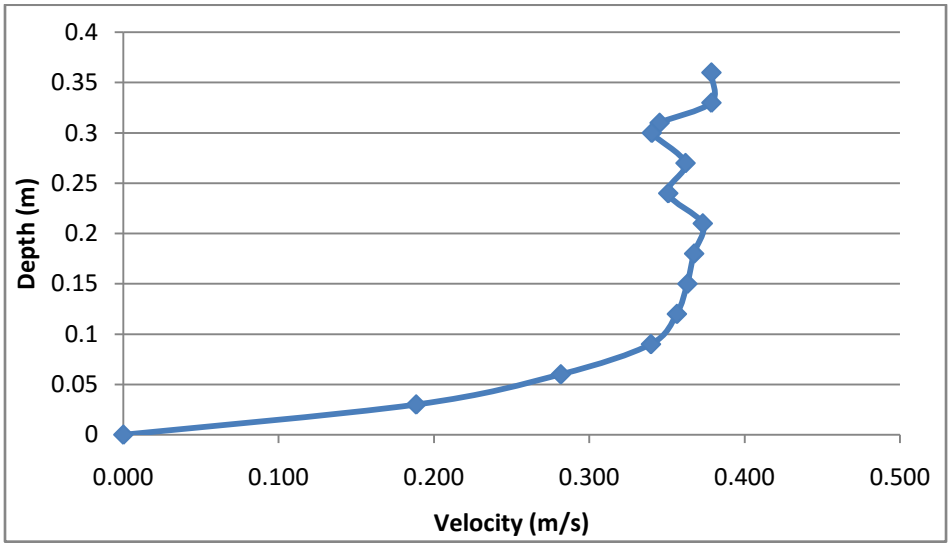


Fig: Vertical Velocity distribution

3. Bhagtpur Minor

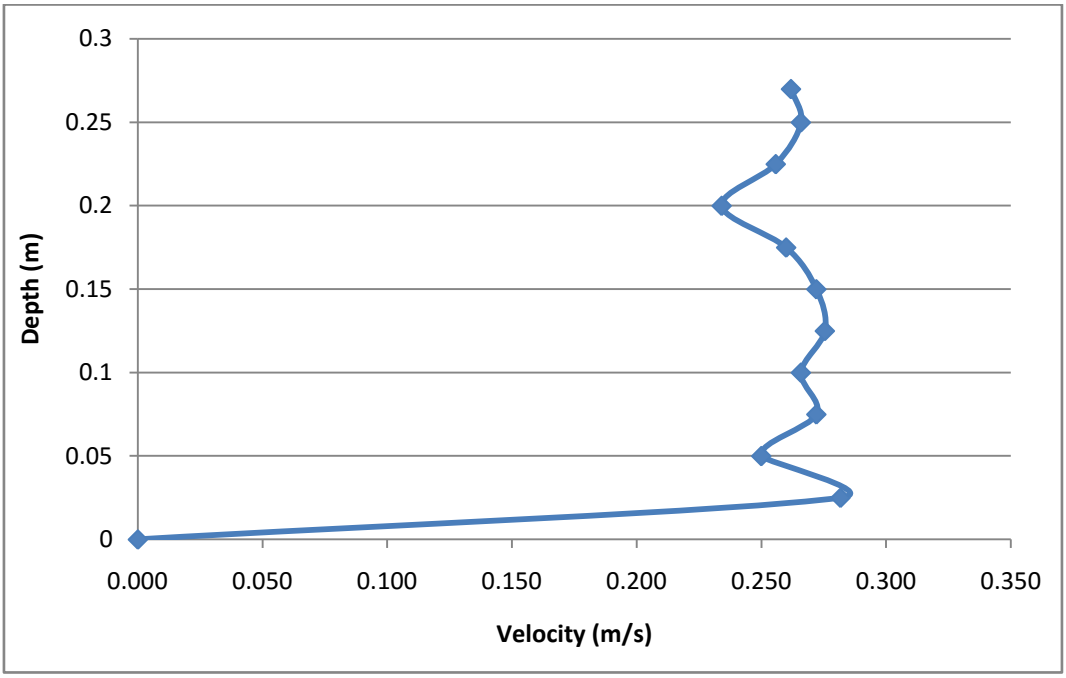


Fig: Vertical Velocity distribution

4. Ultakham Distributary

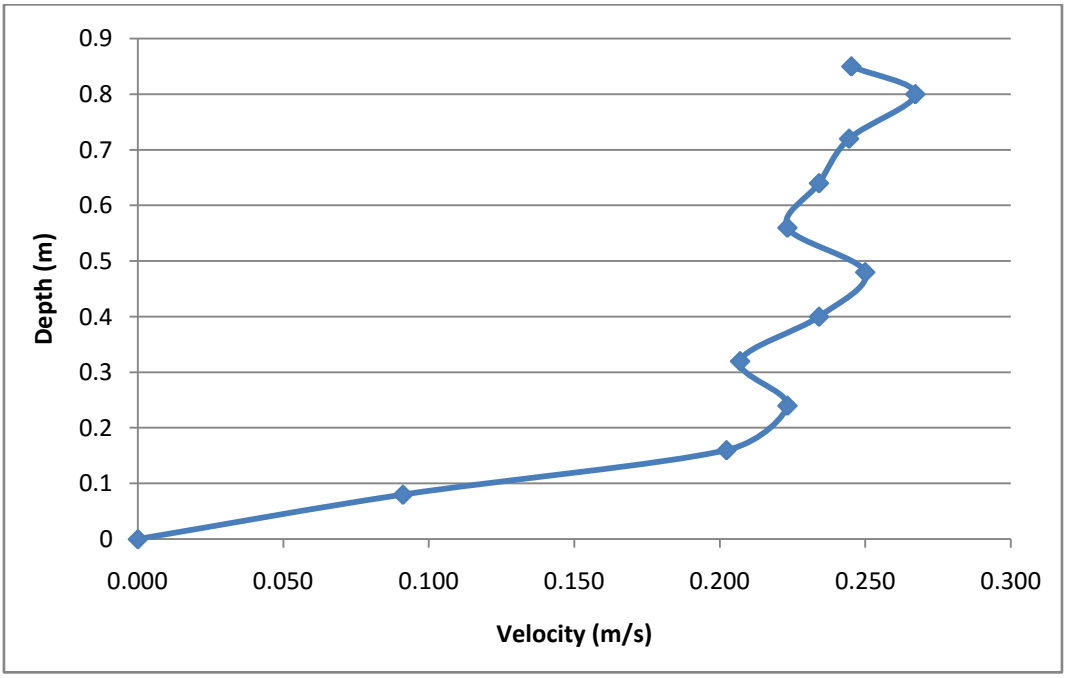


Fig: Vertical Velocity distribution

5. Suda Branch

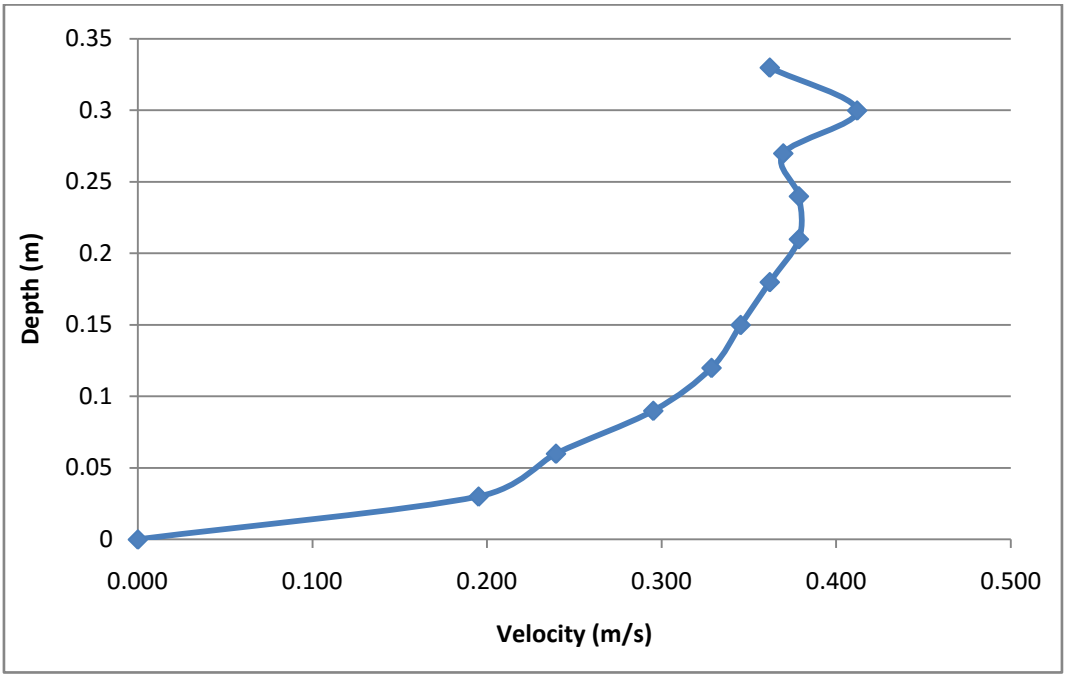


Fig: Vertical Velocity distribution

6. Sisaiya Branch

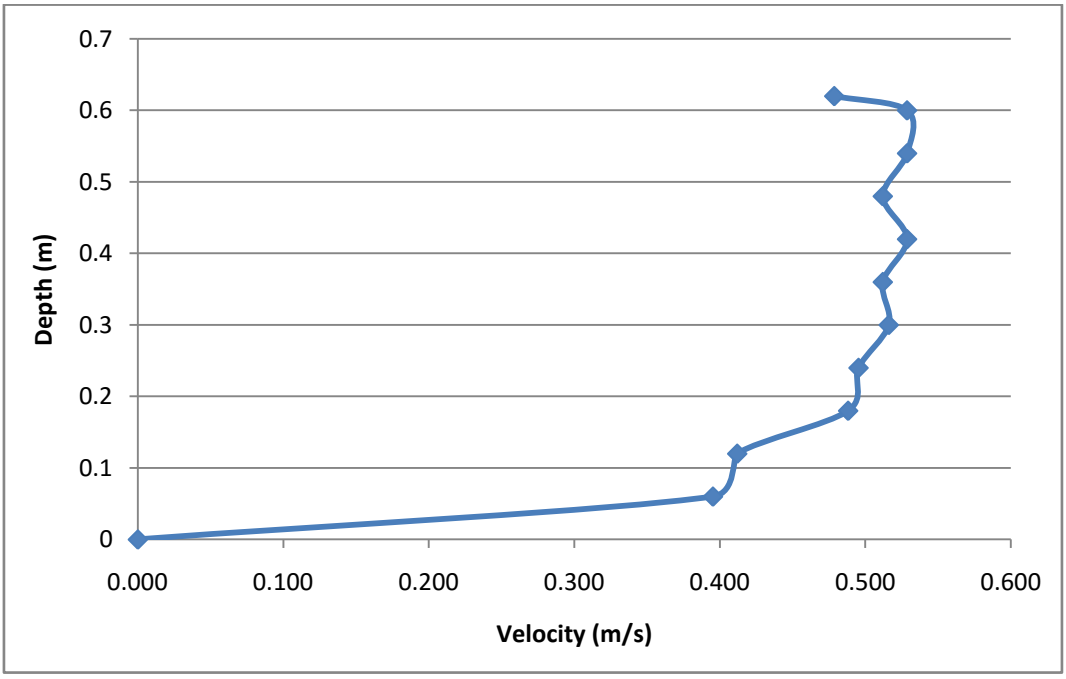


Fig: Vertical Velocity distribution

7. Daiji Minor

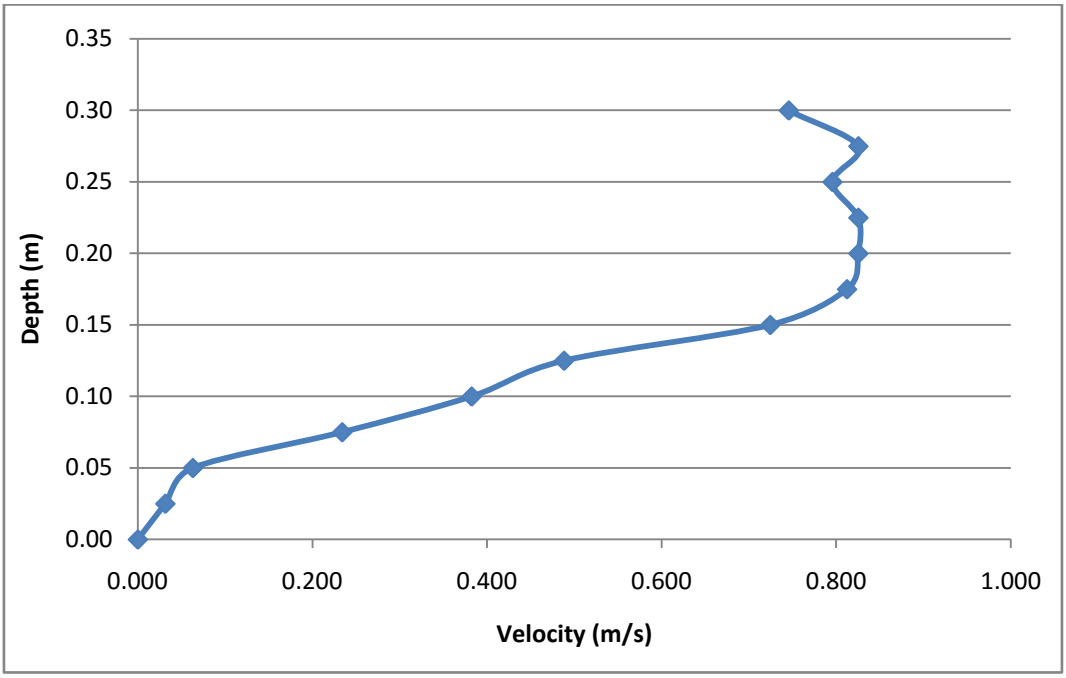


Fig: Vertical Velocity distribution

8. Daiji Major

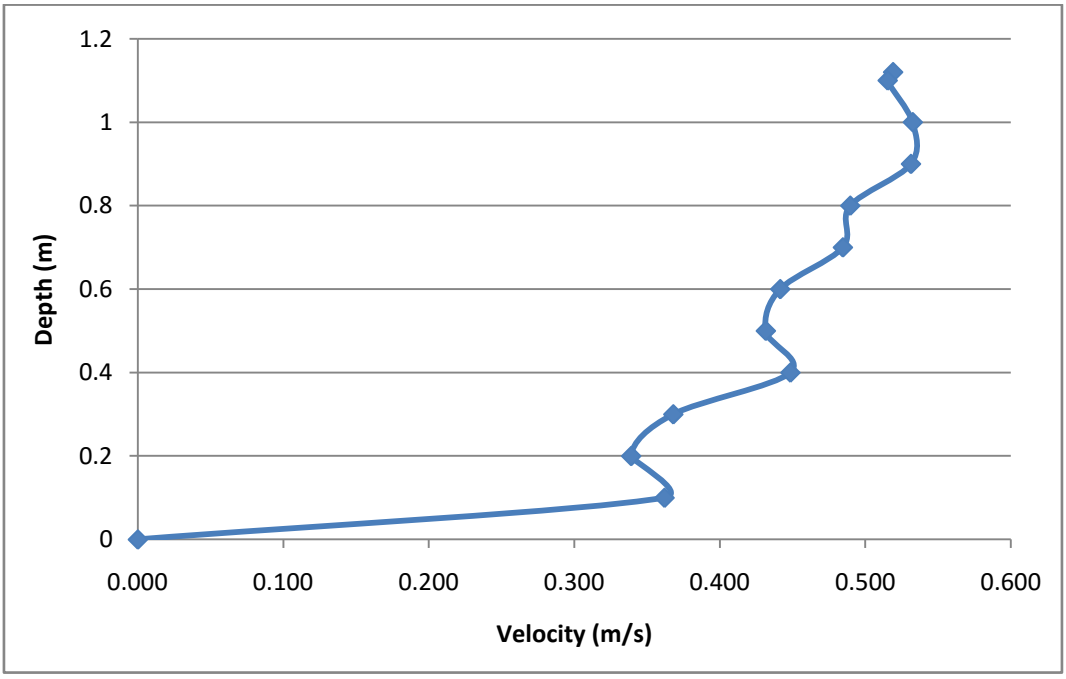


Fig: Vertical Velocity distribution

6.1.2 Stage II M3 Canal

1. M3 Canal

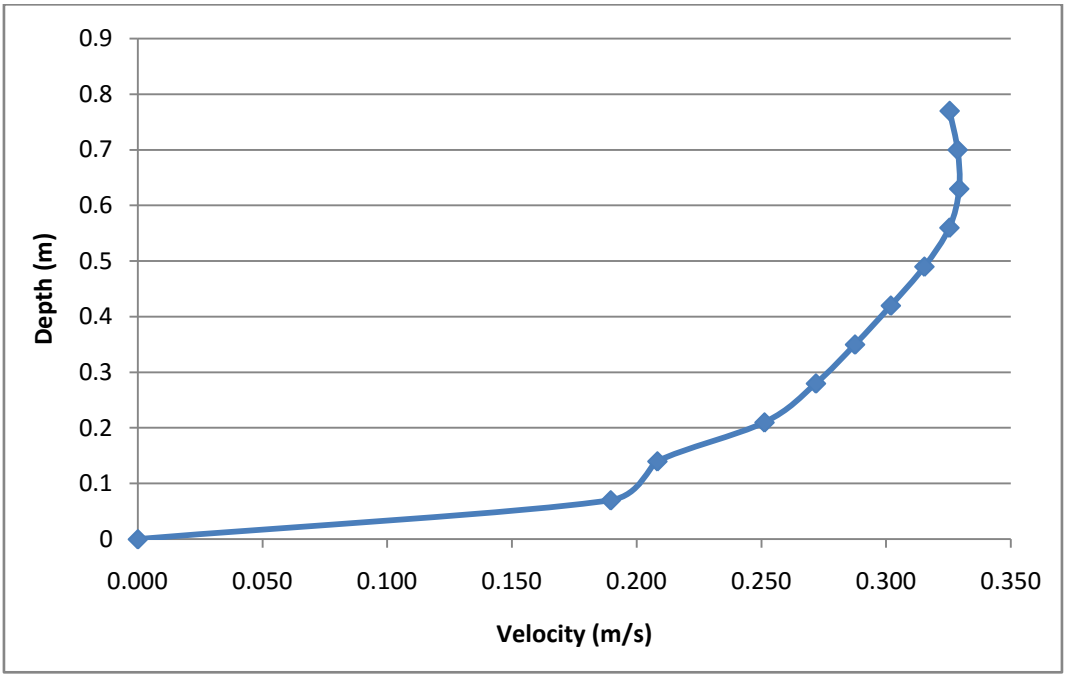


Fig: Vertical Velocity distribution

2. Salghari Branch

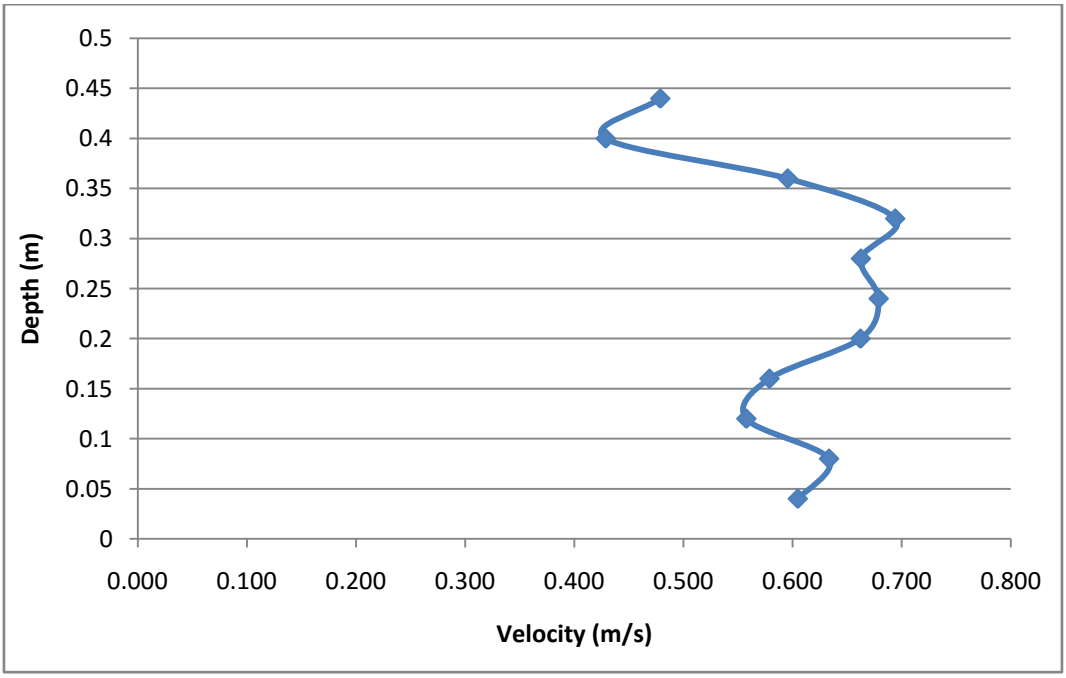


Fig: Vertical Velocity distribution

3. Salghari Minor

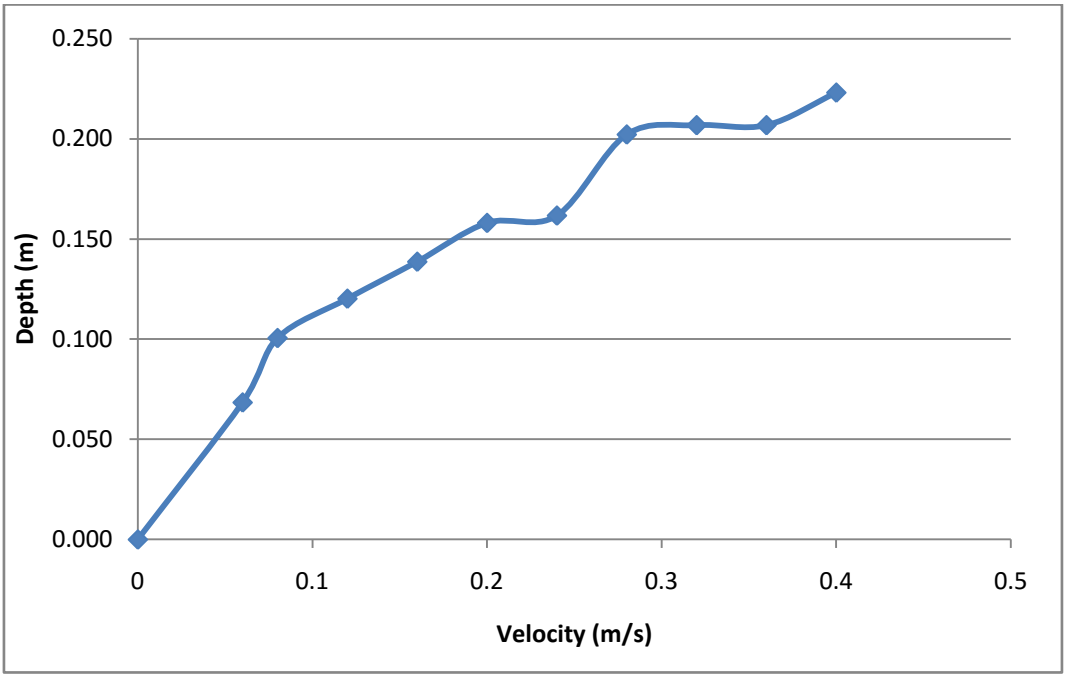


Fig: Vertical Velocity distribution

4. Pochoi Branch

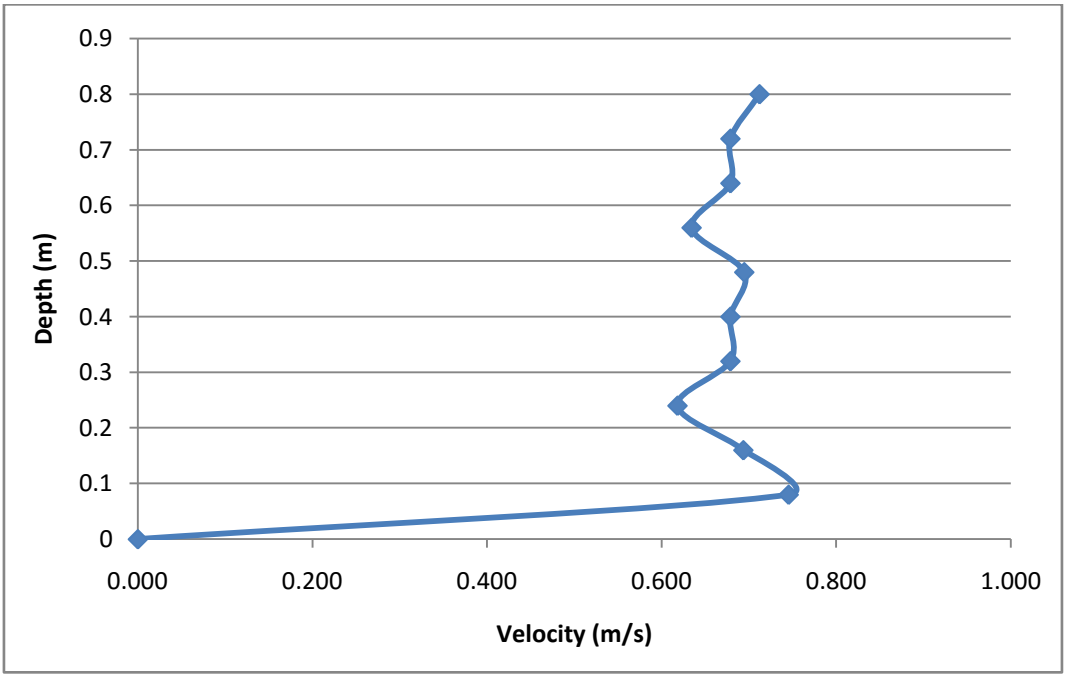


Fig: Vertical Velocity distribution

5. Kunda Branch

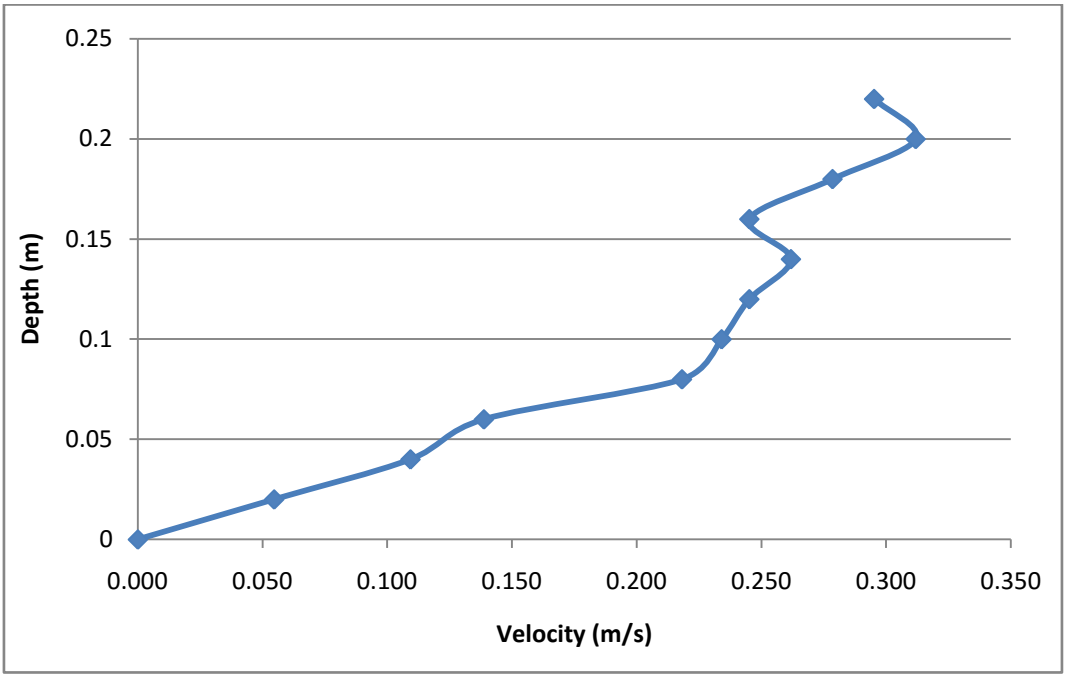


Fig: Vertical Velocity distribution

6. Syali-A Branch

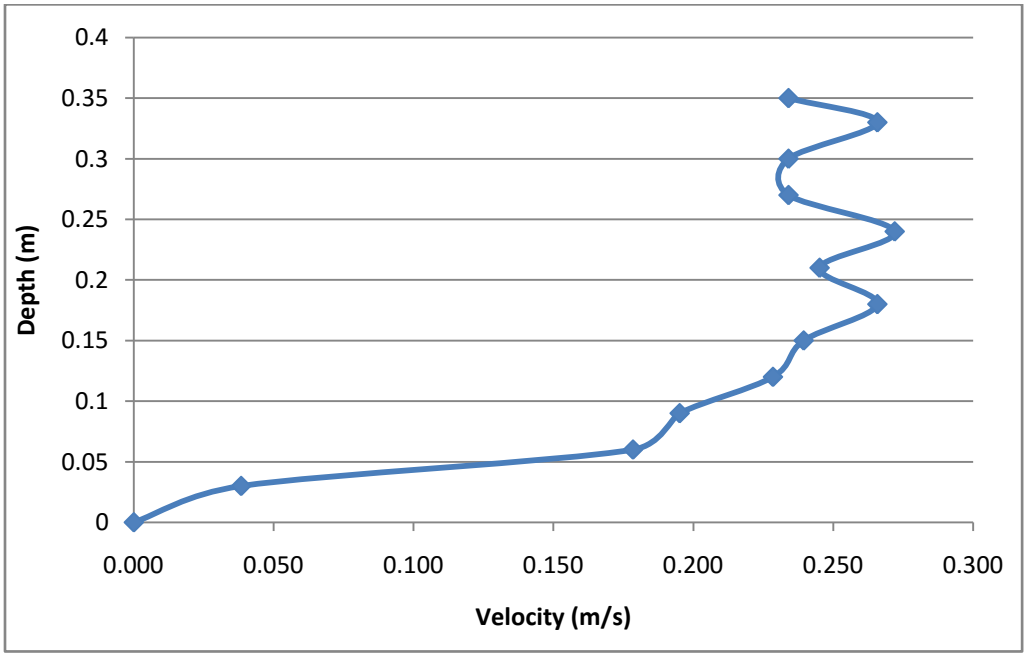


Fig: Vertical Velocity distribution

7. Syali-Y Branch

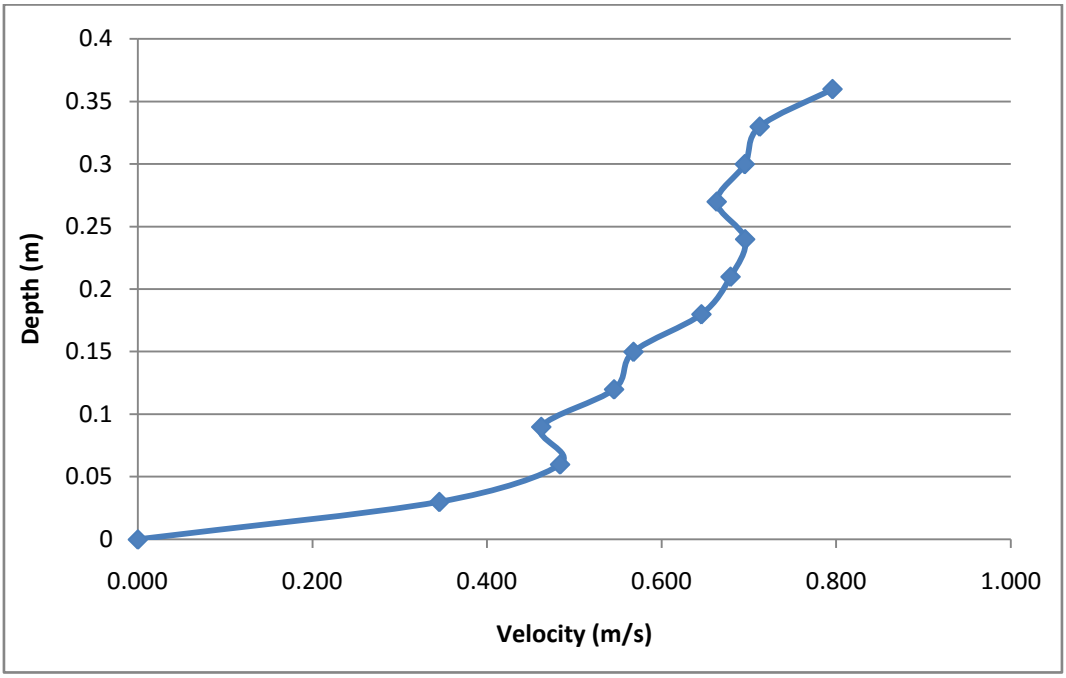
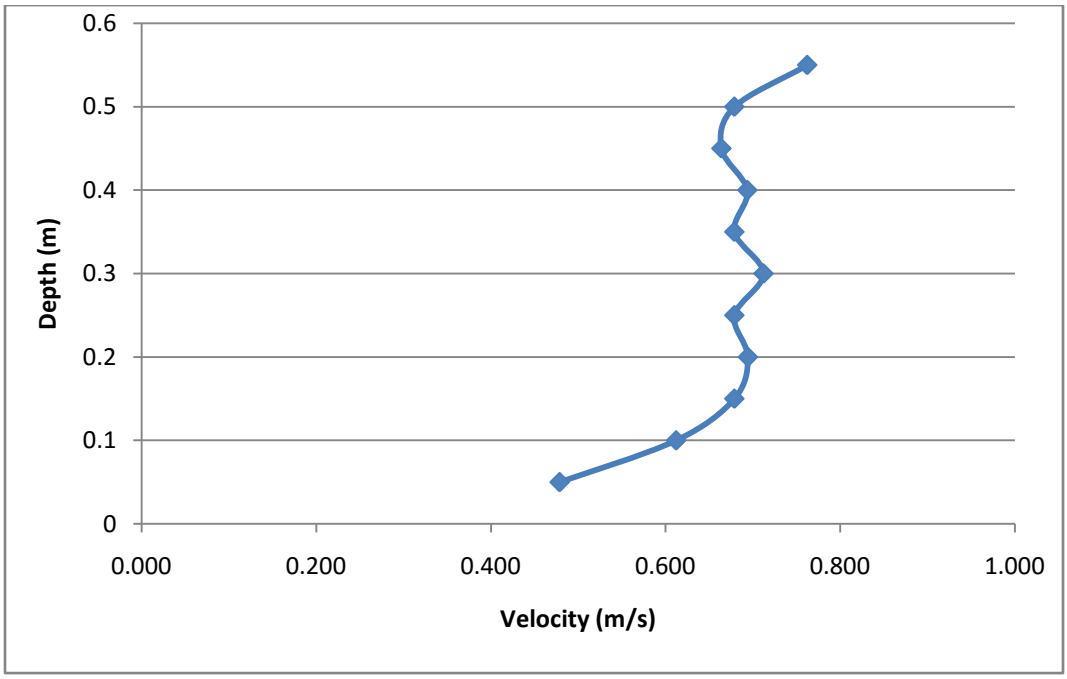


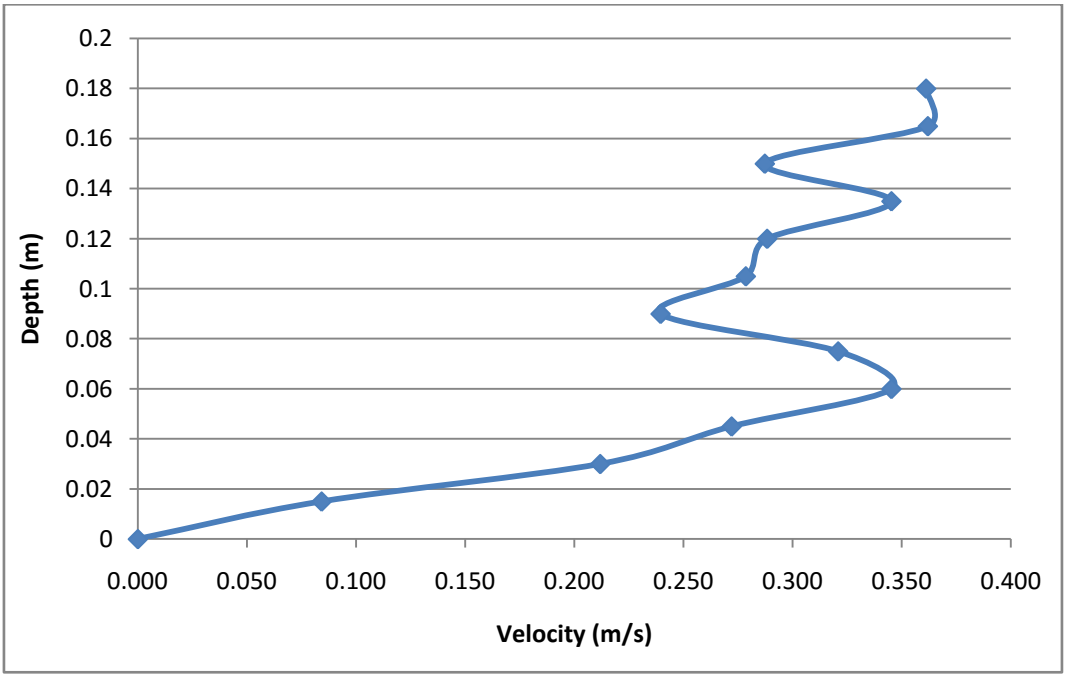
Fig: Vertical Velocity distribution

6.1.3 Stage II Shivanagar Main Branch

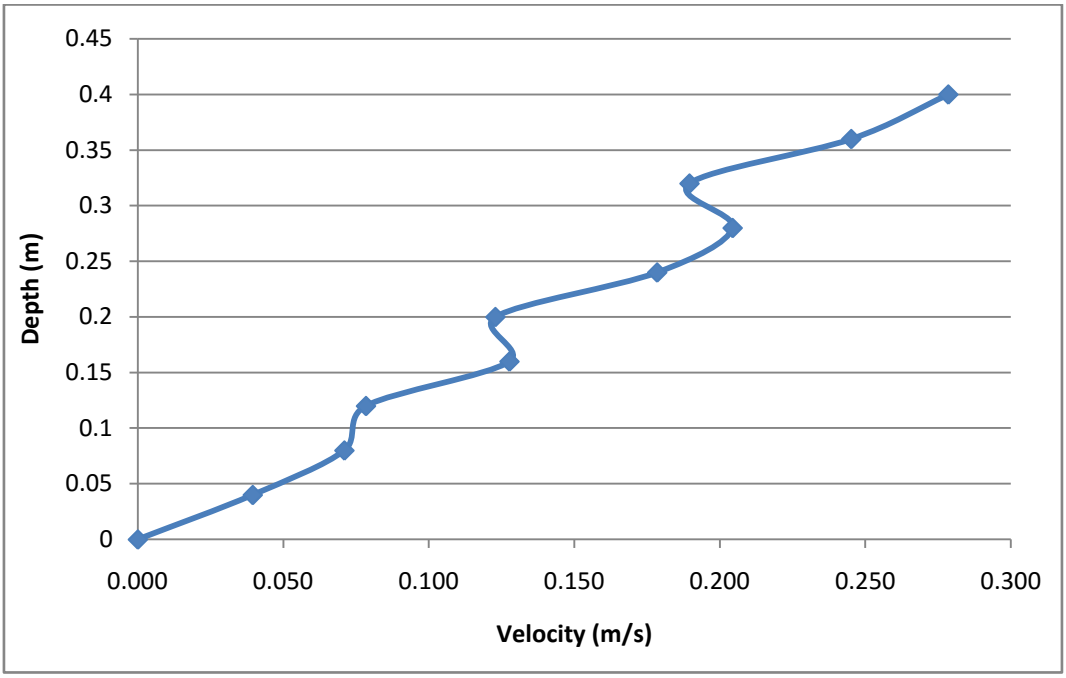
1. Khairighat Branch



2. Imiliya Minor



3. Bhuda Minor



6.2Measurement Sheet

6.2.1 Stage I

1. Main Branch Canal

Date	Gauge	Width	Velocity	Area	Discharge
	0.47	24.3	0.332	11.83	3.93
	0.40	24.2	0.330	8.63	2.85
	0.35	24.1	0.313	8.32	2.60
	0.30	24.0	0.288	8.01	2.31
	0.25	23.9	0.282	7.77	2.19
	0.20	23.8	0.260	7.41	1.93
	0.15	23.7	0.238	7.05	1.68
	0.10	23.6	0.173	5.10	0.88
	0.05	23.5	0.087	2.54	0.22

2. Gadda Minor

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.80	6.00	1.32	0.187	0.247	
2			0.80	6.00	1.40	0.159	0.231	0.239
			0.1				0.015	
			0.2				0.029	
			0.3				0.048	
			0.4				0.071	
			0.5				0.099	
			0.6				0.131	
			0.7				0.168	

3. Bhujela Distributary

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.54	8	2.94	0.408	1.20	
2			0.54	8	2.94	0.394	1.16	1.180
			0.54				1.20	
			0.50				0.98	
			0.45				0.88	
			0.40				0.73	
			0.35				0.55	
			0.30				0.43	
			0.27				0.38	
			0.23				0.24	
			0.18				0.18	
			0.14				0.14	
			0.09				0.06	

4. Basantapur Minor

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.55	3.5	1.60	0.424	0.678	
2			0.55	3.5	1.59	0.424	0.682	
			0.22		0.64	0.364	0.232	
			0.20		0.58	0.379	0.220	
			0.18		0.52	0.364	0.190	
			0.16		0.46	0.364	0.169	
			0.14		0.41	0.379	0.154	
			0.12		0.35	0.364	0.127	
			0.10		0.29	0.364	0.106	
			0.08		0.23	0.364	0.085	
			0.06		0.17	0.300	0.052	
			0.04		0.12	0.095	0.011	

5. Ultakham Distributary

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
			0.98	6.00	3.28	0.31	1.014	
			0.850	4.00	3.40	0.202	0.686	
			0.800	4.00	3.20	0.198	0.633	
			0.720	4.00	2.88	0.191	0.550	
			0.640	4.00	2.56	0.185	0.474	
			0.560	4.00	2.24	0.179	0.401	
			0.480	4.00	1.92	0.172	0.331	
			0.400	4.00	1.60	0.160	0.255	
			0.320	4.00	1.28	0.145	0.185	
			0.240	4.00	0.96	0.129	0.124	
			0.160	4.00	0.64	0.098	0.063	
			0.080	4.00	0.32	0.046	0.015	

6. Suda Branch

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)
1			0.50	6.75	2.56	0.285	0.728
2			0.50	6.75	2.57	0.301	0.773
			0.33	4.80	1.58	0.260	0.411
			0.30	4.80	1.44	0.255	0.368
			0.27	4.80	1.30	0.246	0.319
			0.24	4.80	1.15	0.238	0.274
			0.21	4.80	1.01	0.228	0.230
			0.18	4.80	0.86	0.214	0.185
			0.15	4.80	0.72	0.199	0.143
			0.12	4.80	0.58	0.180	0.104
			0.09	4.80	0.43	0.155	0.067
			0.06	4.80	0.29	0.123	0.035
			0.03	4.80	0.14	0.083	0.012

7. Sisaiya Branch

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.66	6.00	2.64	0.252	0.666	
2			0.66	6.00	2.60	0.274	0.710	
			0.62	4.00	2.48	0.270	0.669	
			0.60	4.00	2.40	0.268	0.644	
			0.54	4.00	2.16	0.263	0.569	
			0.48	4.00	1.92	0.257	0.494	
			0.42	4.00	1.68	0.251	0.422	
			0.36	4.00	1.44	0.242	0.348	
			0.30	4.00	1.20	0.231	0.277	
			0.24	4.00	0.96	0.215	0.206	
			0.18	4.00	0.72	0.194	0.140	
			0.12	4.00	0.48	0.161	0.077	
			0.06	4.00	0.24	0.119	0.028	

8. Daiji Minor

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.53	1.80	0.68	0.320	0.216	
2			0.30	1.20		0.312		
			0.28	1.20		0.300		
			0.25	1.20		0.283		
			0.23	1.20		0.263		
			0.20	1.20		0.237		
			0.18	1.20		0.205		
			0.15	1.20		0.165		
			0.13	1.20		0.120		
			0.10	1.20		0.085		
			0.08	1.20		0.049		
			0.05	1.20		0.054		
			0.03	1.20		0.032		
			0.00	1.20		0.000		

9. Daiji Major

10. MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			1.12	8.00	8.96	0.420	3.765	
2			1.10	8.00	8.80	0.350	3.081	
			1.00	8.00	8.00	0.342	2.737	
			0.90	8.00	7.20	0.331	2.384	
			0.80	8.00	6.40	0.318	2.034	
			0.70	8.00	5.60	0.305	1.710	
			0.60	8.00	4.80	0.290	1.393	
			0.50	8.00	4.00	0.276	1.104	
			0.40	8.00	3.20	0.258	0.825	
			0.30	8.00	2.40	0.227	0.545	
			0.20	8.00	1.60	0.199	0.318	
			0.10	8.00	0.80	0.154	0.123	
			0.00	8.00	0.00	0.000	0.000	

6.2.2 Stage II M3 Canal

1. Syali –A Branch

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.18	4.50	1.70	0.137	0.233	
2			0.18	4.50	1.35	0.160	0.216	
			0.12	2.50	0.63	0.183	0.115	

2. Syali-Y Branch

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.22	3.00	1.19	0.284	0.337	
2			0.18	3.00	1.05	0.275	0.288	
			0.25	1.20	0.30	0.000	0.394	

6.2.3 Stage II Shivanagar Main Branch

1. Khairighat Branch

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.14				0.210	
2			0.14				0.250	
3			0.11				0.149	
4			0.11				0.148	

2. Imiliya Minor Canal

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.34				0.164	
2			0.34				0.178	
			0.19				0.052	
			0.19				0.048	

3. Baibaha Branch

4. MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.16				0.183	
2			0.16				0.208	
3			0.20				0.324	

5. Bhuda Minor

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.08				0.026	
2			0.08				0.029	
			0.10				0.047	

6. Bhuda Gauri

MN	Date	Measuring Party	Gauge Height (m)	Width (m)	Area (m^2)	Average Velocity (m/s)	Discharge (m^3/s)	Remarks
1			0.08				0.056	
2			0.08				0.053	
			0.10				0.093	

6.3Photographs

5.3.1 Stage I

1. Gadda Minor

Fig: Information Board at Gadda Minor

Fig: Installation of Gauge

Fig: Flow measurement of Gadda Minor

2. Bhujela Distributary

Fig: Information Board at Bhujela Distributary

Fig: Installation of Gauge at Flume

Fig: Flow Measurement of Bhujela Distributary

3. Basantpur Minor

Fig: Information Board at Basantapur Minor

Fig: Installation of Gauge at Flume

Fig: Flow Measurement of Basantapur Minor

4. Majhgaon Minor

Fig: Information Board at Majhgaon Minor

Fig: Placement of Gauge

Fig: Flow Measurement of Majgaon Minor

5. Mahendranagar Distributory

Fig: Information Board

Fig: Flow Measurement

Fig: Installation of Gauge at Flume of Mahendranagar Distributary

6. BhagtpurMinor

Fig: Information Board

Fig: Bhagtpur Minor

7. UltakhamDistributary

Fig: Flow Measurement

Fig: Installation of Gauge at Flume of Ultakham Distributary

8. Suda Branch

Fig: Installation of Gauge at drop of suda branch

Fig: Flow Measurement at Suda Branch

9. Sisaiya Branch

Fig: Measurement of cross-section through level machine

Fig: Flow Measurement of Sisaiya Branch

10. Daiji Minor

Fig: Placement of Gauge

Fig: Cross-section Measurement ofDaiji Minor

6.3.2 Stage II Shivanagar Main Branch

1. Shivanagar Main Branch

Fig: Information Board

Fig: Flow Measurement

Fig:Gauge Placement at Shivanagar Main Branch

2. Khamari Branch

Fig: Information Board

Fig: Flow Measurement

Fig: Gauge Placement at Khamari Branch

3. Khairighat Branch

Fig: Information Board

Fig: Flow Measurement

Fig: Placement of gauge at Kharighat Branch

4. Imiliya Minor

Fig: Information Board

Fig: Placement of Gauge

Fig: Flow Measurement of Imiliya Minor

5. Baibaha Minor

Fig: Information Board

Fig: Placement of Gauge at Baibaha Minor

6. Jhilmila branch

Fig: Placement of Gauge at Jhilmila Branch

7. Bhuda Minor

Fig: Information Board

Fig: Placement of Gauge at Buda Minor

8. Bhuda Gauri

Fig: Information Board

Fig; placement of Gauge

9. Gaurigaun Branch

Fig: Information Board

Fig: placement of Gauge at Buda Gauri

6.3.3 M3 Canal

1. Beldandi minor

Fig: Information Board

Fig: Placement of gauge at Beldandi Minor

2. Dhakka minor

Fig: Installation of Gauge at Dhakka Minor

3. Salghari branch

Fig: Flow measurement of Salghari Branch

4. Salghari Minor

Fig: Flow Measurement of Salghar Minor

5. Pachoi branch

Fig: Flow Measurement of Pochai Branch

6. Kunda Branch

Fig: Flow measurement Kunda Branch

7. Singhpur Branch

Fig: Flow Measurement of Singhpur Branch

8. Syali-A Branch

Fig: information Board

Fig: Gauge Placement at Syali-A Branch

9. Syali-Y Branch

Fig: Information Board

Fig: Gauge placement at Syali-Y Branch