Advance Instruments for Streamflow measurement – Case studies

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Why to measure a flow?

- The objective of the flow measurement in an irrigation system is to achieve better water management.

Main System

- \- Water budgeting
- \- Efficient water distribution
- \- Monitoring
- \- To evaluate system performance

- On farm system
  - Delivering right amount of water to users
  - Efficient on farm water application
- Applied research
  - Evaluation of irrigation methods
  - Conveyance efficiency of irrigation system
  - Checking carrying capacity of irrigation channels and verifying design parameters

- Socio Economic aspects
  - Water billing
  - Achieving equity of water distribution (ie., compensating losses in the system).
  - To ensure reliability of water supply
  - The increase confidence to users in an irrigation system

Canal system operation in India

Conventional operation involves the following basic procedure :

- Request demands are submitted by the water users
- A water schedule is formulated
- Flow changes are made at the head of the canal to meet the water schedule and
- The canal is operated manually to transfer these changes downstream, making adjustments at the canal-side turnouts and canal check structures en route.

Automation

- `Automation' is defined as *A procedure or control method used to operate a water system by* ***mechanical or electronic equipment*** *that takes the place of* ***human observation, effort and decision;*** *the condition of being automatically controlled or operated.*

Canal Automation in India

Canal automation is done in India on the following water resources projects:

- Chambal project in Madhya Pradesh,
- Khadakwasla project in Maharashtra,
- Majalgaon project in Maharashtra,
- RAJAD project in Rajasthan,
- Sardar Sarovar project in Gujarat and
- Tungabhadra project in Karnataka.

INTRODUCTION

- Stream flow is the only phase of the hydrological cycle in which the water is confined in well defined channels.

- The rate at which water is transported by a canal is called its discharge, and the maximum discharge that any canal can transport is canal capacity.

- Good water management is based on reliable stream flow information.

WHY ESTIMATING THE DISCHARGE

- Good irrigation management

- Discharges in canals should meet the demand for water from the farms.

- A poor flow division may result in discharges being too high in some canals and too low in others, and could lead to water disputes between farmers

Cross section of Canal

Trapezoidal section

- Trapezoidal section converted into semi circular Section due to sedimentation of canal

Necessity of Present Study

- To achieve efficient control,
- timely and reliable water delivery,
- modern irrigation practices employing automatic operation and telemetry arrangements are to be introduced on the canal system.
- To find out the transmission losses in canals
- Rating the canal
- To calibrate the canal structures

Field Studies

- Site selection for measurement
- Equipments for measurement
- Gauge stations

Acoustic Doppler Current Profiler (ADCP)

The Acoustic Doppler Current Profiler (ADCP) is an acoustic instrument designed to measure discharges in river/canal, three dimensional water currents, depths and bathymetry from a moving or stationary vessel.

Water-velocity measurements are made by transmitting sound at a known frequency into the water and measuring the Doppler shift, or change in sound frequency, from signals reflected off particles in the water.

Advantages of ADCP

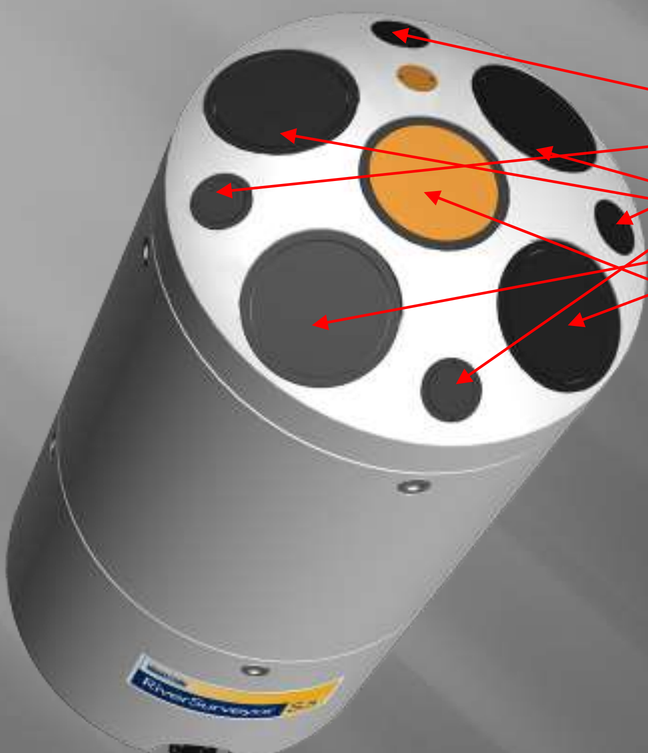
- Time required to complete a measurement is reduced
- The ADCP allows for data to be collected throughout most of the water column and cross section rather than at discrete points.
- The ADCP is deployed at the water surface appreciably reducing the chance of snagging by debris, the instrument can be boat-mounted thus, eliminating the installation, maintenance, and liability of costly manned cableways/cradle arrangement.

M9 Acoustic Doppler Profilers

- Integrated acoustic vertical beam transducers – for depth.
- Internal recorder (8 Gb) - Discharge processing and data storage is done inside the ADP – not in software – faster sampling rates and no data lost to telemetry drops.
- Onsite discharge calculations, real-time data quality checking, on-line summary tables, etc…
- bottom tracking.

RiverSurveyor

"M9" Mid-Range system



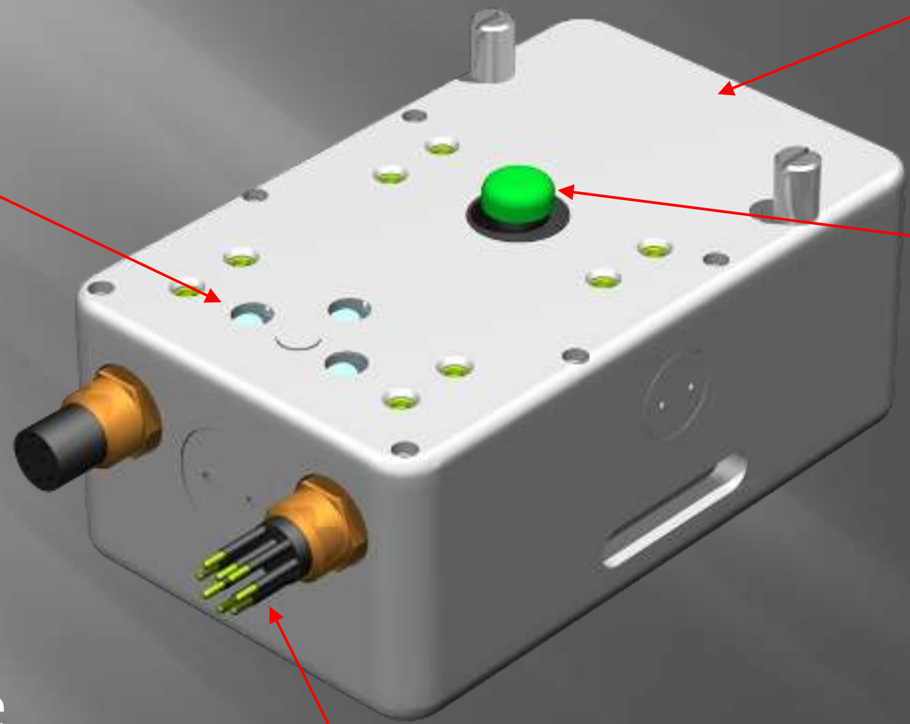
- 9 beams, tri-frequency, dual Janus array
  - 4 beam Janus for velocity (3.0Mhz)
  - 4 beam Janus for velocity (1.0 MHz)
  - 1 vertical beam (0.5 MHz)
- Velocity profiling range (0.06 m – 40.0 m*)
- Vertical beam range (80m)
- Discharge measurement range
  - 0.3 to 40m referencing bottom-track

* Max profiling range can vary depending on conditions

Power & Communications Module (PCM)

Battery Compartment

System/status lights



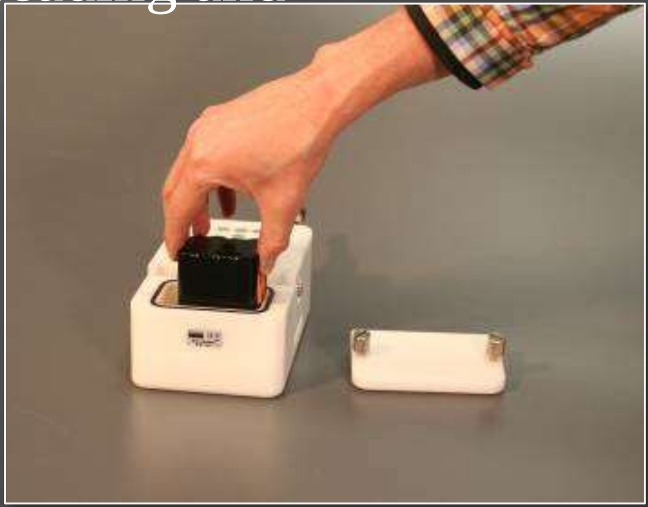
On/off button (w status light)

Connector to power/com cable or dummy plug

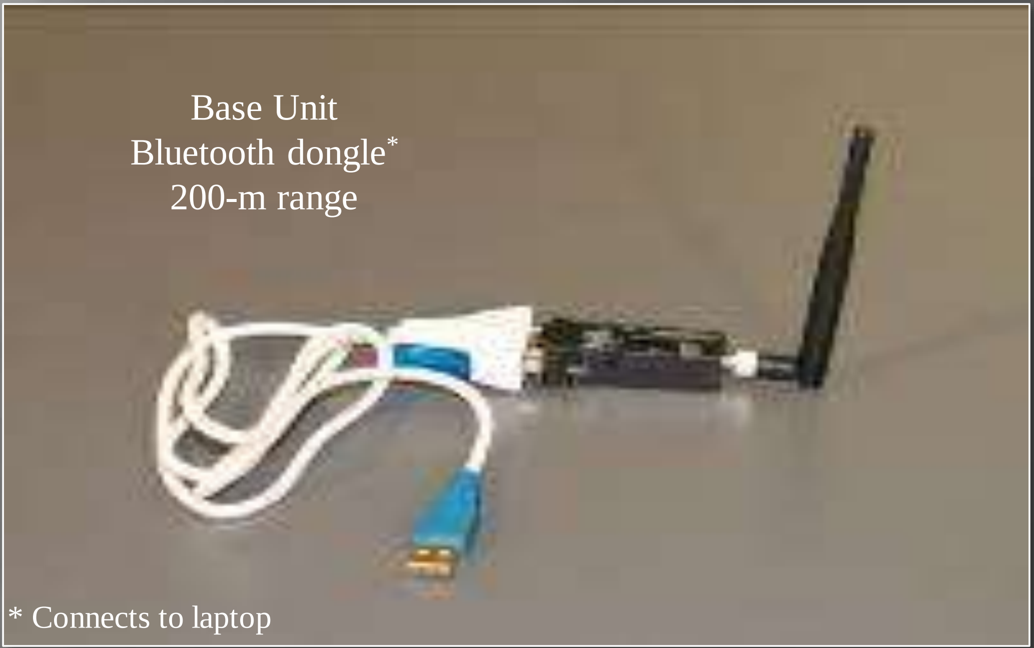
Connector to M9/S5

Power & Communications Module

- Drop-in replaceable/rechargeable 18v battery packs
- Battery charger
- Bluetooth or FreeWave 900-Mhz Communications
- 10-m cable and AC power supply for direct reading and external power



Power and Communication Module (PCM) Telemetry Configurations



- No possibility for data drops – internal ADP calculations and processing

Flow measurement in process

River Surveyor Live Software

Step 1: Site Information

Enter information to better describe the site and measurement conditions:

- Change Site Information

Site Name	SonTek
Station Number	1
Location	Tank
Party	MR
Boat/Motor	HydroBoard
Meas. Number	1
Comments	Test

Step 2: System Configuration

System Type	ADP
Serial Number	5
Firmware Version	0.61

Step 3: System Settings

Modify system settings for...

- Change System Settings

Transducer Depth (m)	0.00
Screening Distance (m)	0.0
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0
Track Reference	Bottom-Track
Depth Reference	Vertical Beam
Coordinate System	ENU

Step 4: Discharge Measurement

Modify measurement settings for...

- Change Measurement Settings

Start Edge	Left Bank
Rated Discharge (m3/s)	0.0
Measurement Quality	--

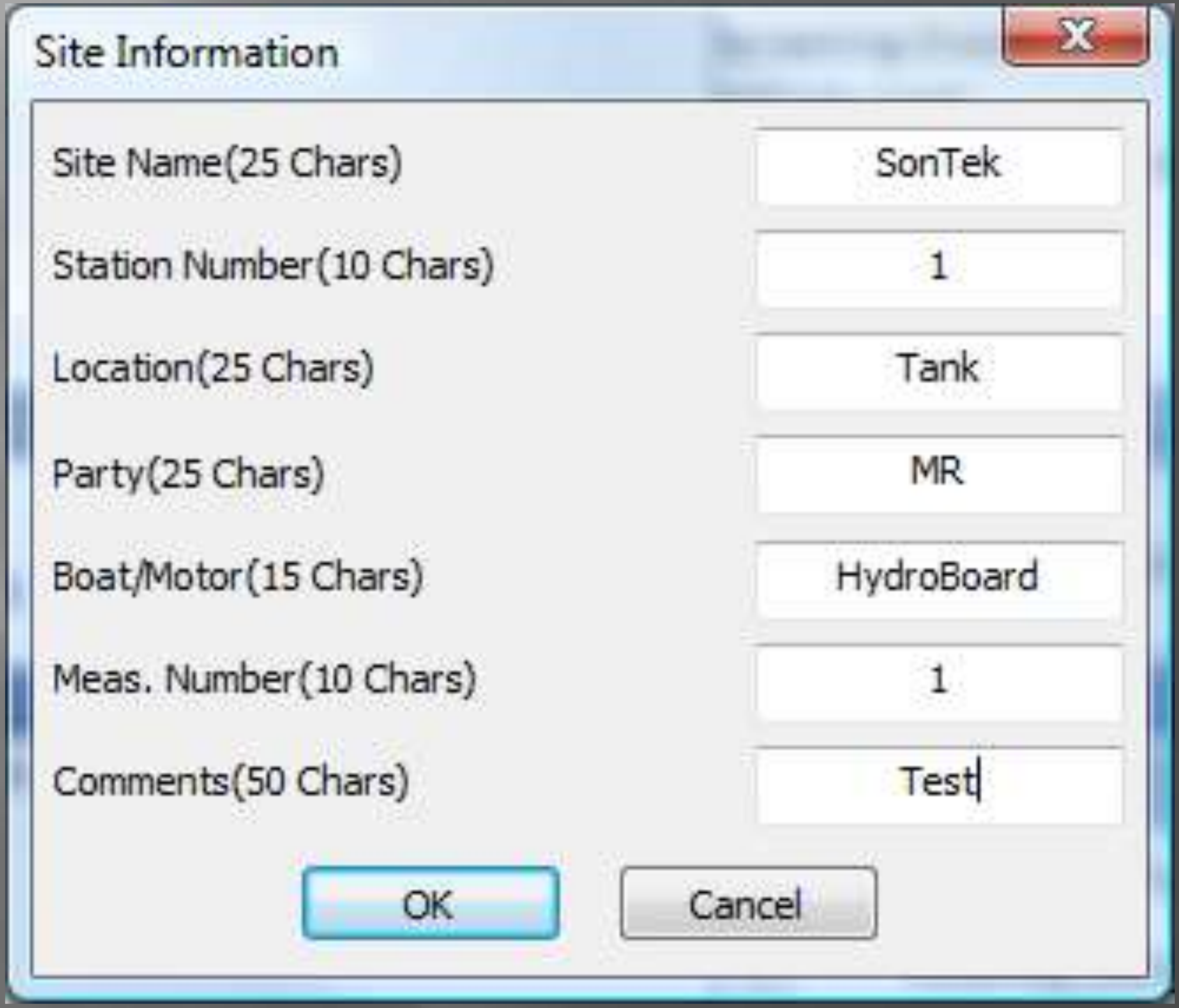
Step 5: Recorder

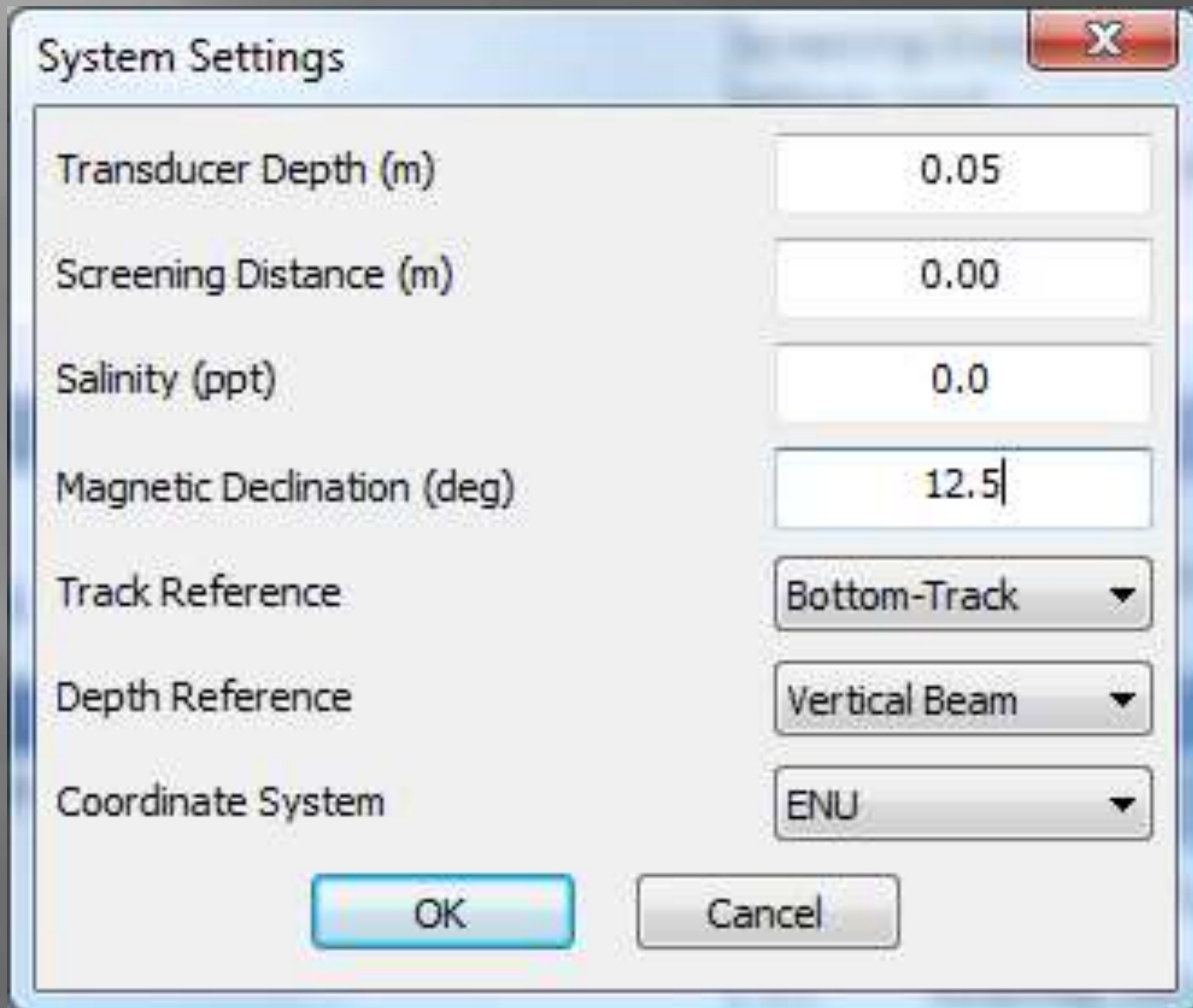
Total Space:7.26 GB Free Space:7.19 GB (98% Free)

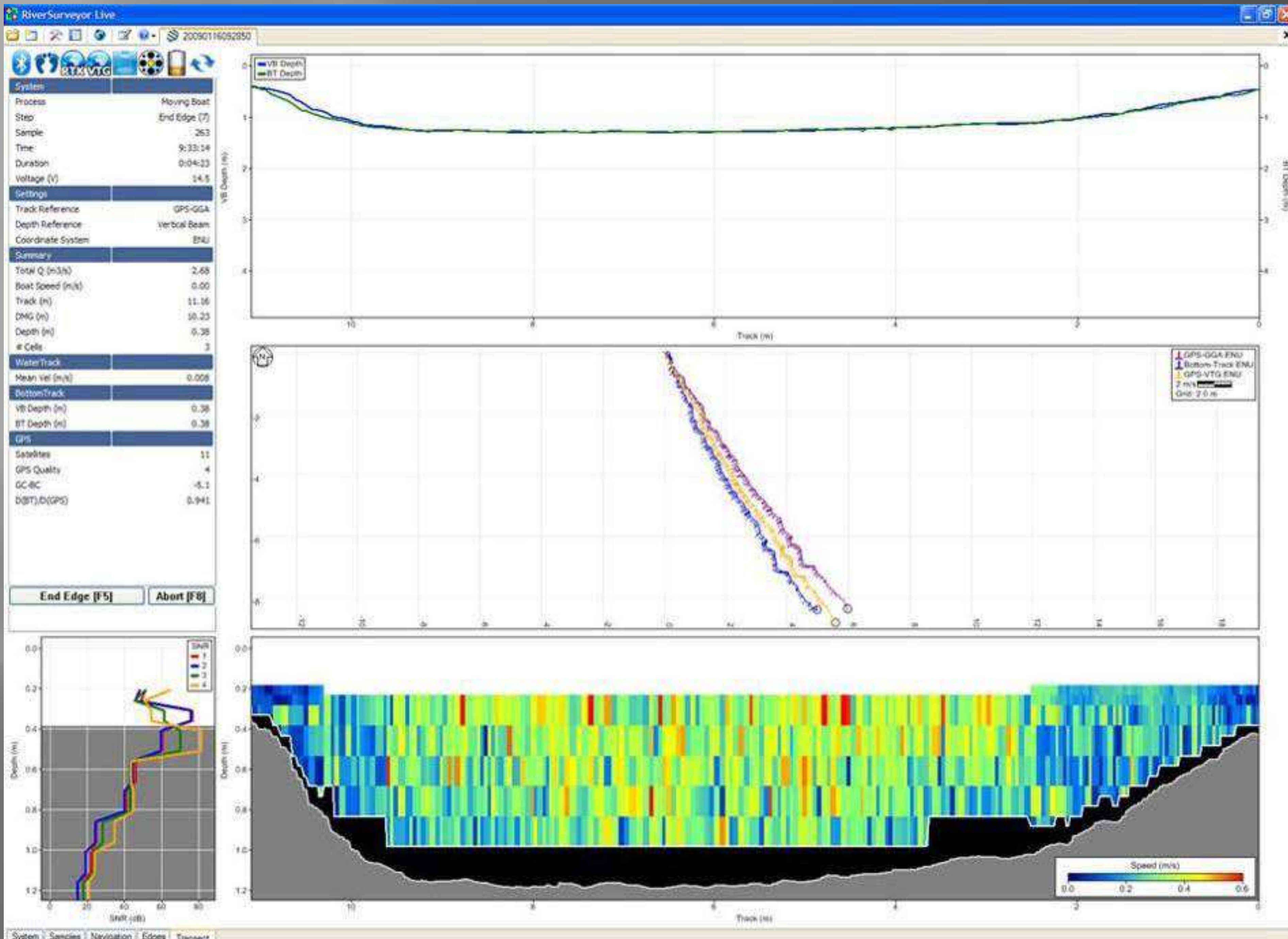
- Download all files
- Download selected files
- Format Recorder

	Name	Date	Size
☐	RiverAdp_193.ydff	2009/02/05 07:53:44	13.58 MB
☐	RiverAdp_189.ydff	2009/02/04 10:34:02	26.96 KB
☐	RiverAdp_177.ydff	2009/01/14 11:06:44	28.32 KB

River Surveyor Live Software




System Settings
Transducer Depth (m)
0.05
Screening Distance (m)
0.00
Salinity (ppt)
0.0
Magnetic Declination (deg)
12.5
Track Reference
Bottom-Track
Depth Reference
Vertical Beam
Coordinate System
ENU
OK
Cancel

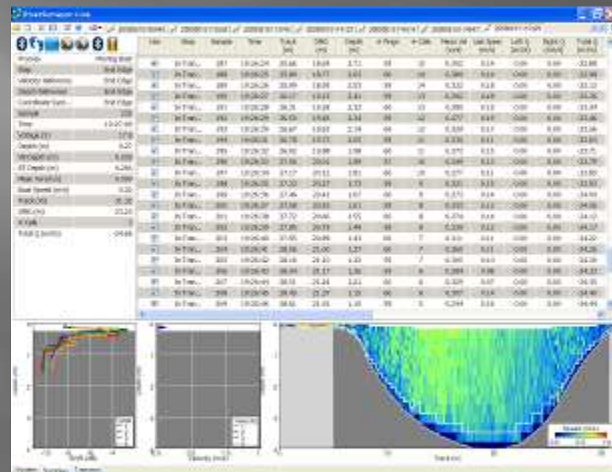


RiverSurveyor Live
20090116092850
System
Process Moving Boat
Step End Edge (7)
Sample 263
Time 9:33:14
Duration 0:04:23
Voltage (V) 14.5
Settings
Track Reference GPS-GGA
Depth Reference Vertical Beam
Coordinate System ENU
Summary
Total Q (m3/s) 2.68
Boat Speed (m/s) 0.00
Track (m) 11.16
DMG (m) 10.23
Depth (m) 0.38
Cells 3
WaterTrack
Mean Vel (m/s) 0.008
BottomTrack
VB Depth (m) 0.38
BT Depth (m) 0.38
GPS
Satellites 11
GPS Quality 4
GC-BC -5.1
D(BT)/D(GPS) 0.941
End Edge [F5]
Abort [F8]
VB Depth
BT Depth
Track (m)
GPS-GGA ENU
Bottom-Track ENU
GPS-VTG ENU
SNR
SNR (dB)
Depth (m)
Speed (m/s)
System
Samples
Navigation
Edges
Transect

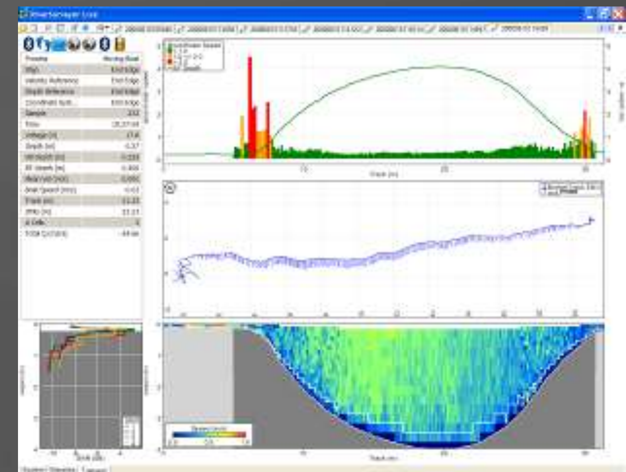
RiverSurveyor Live! Software

- 5 Primary Software Function Tabs:

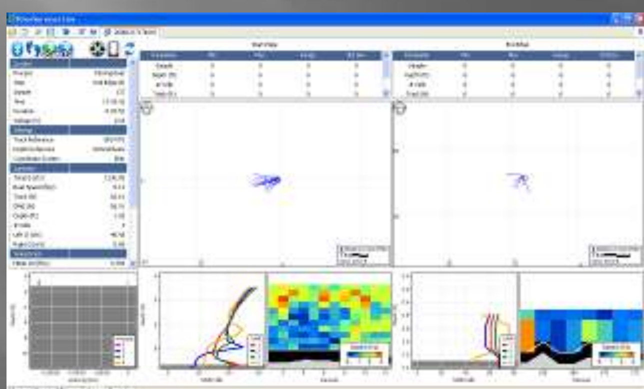
System Setup Tab



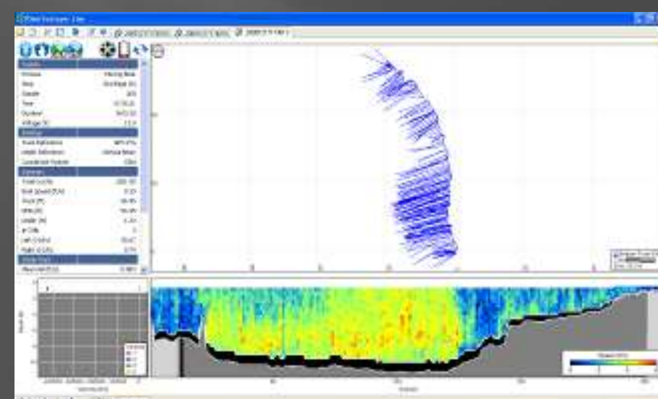
Samples Tab



Transect Tab



Edge Section Tab



Navigation Tab

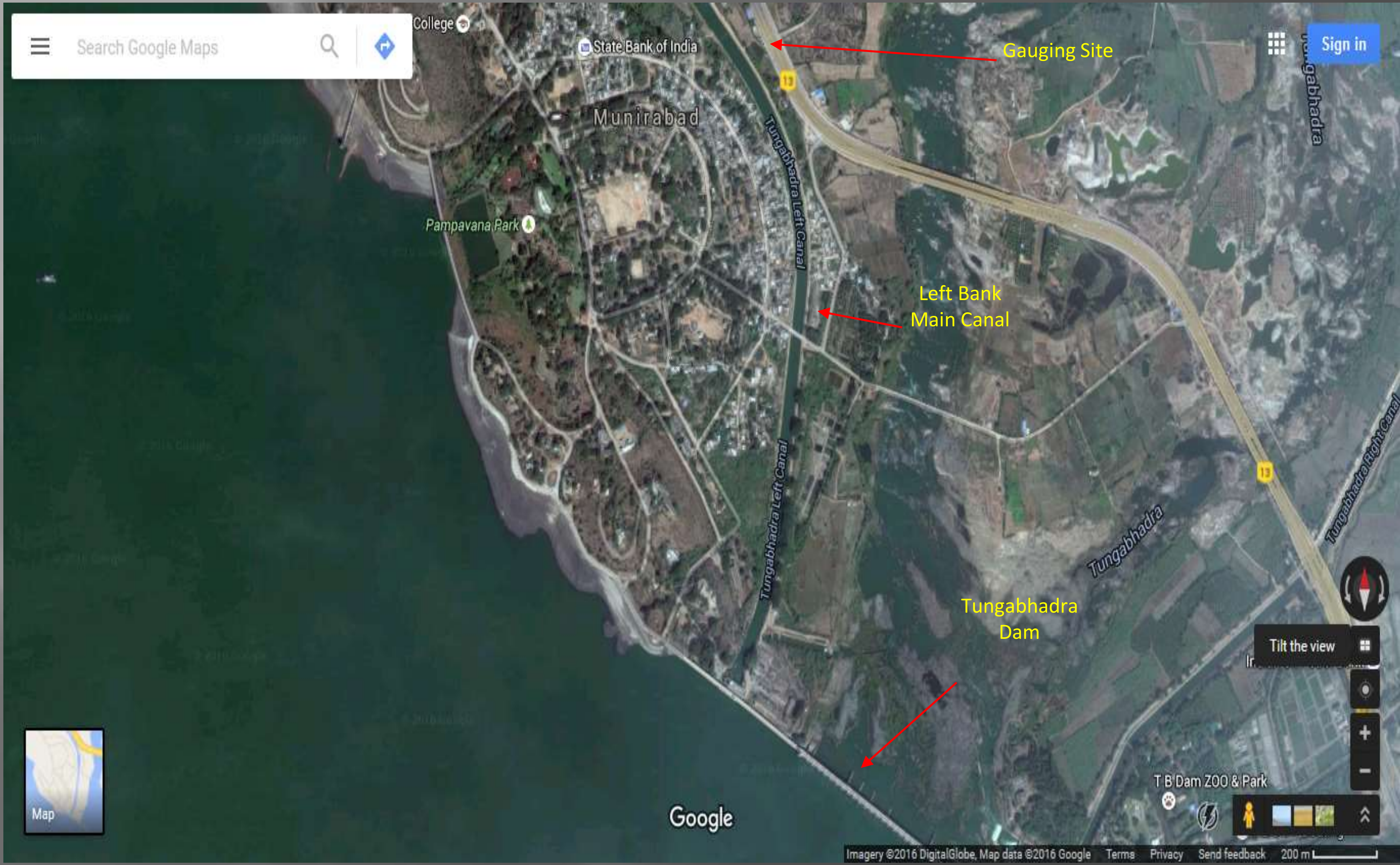
Tungabhdara Dam

- A multipurpose dam has been constructed across Tungabhadra river at Munirabad district Koppal, Karnataka and is an inter state project between Karnataka and Andhra Pradesh, Water from the dam is released in to the Left Bank Canal (LBC) and is utilized for power generation and irrigation in the Karnataka state

Rating of Left bank canal of Tungabhadra dam

- The river Tungabhadra is a major tributary of Krishna river and is so named after the confluence of the two rivers Tunga and Bhadra, which rise in Western Ghats at an elevation of El 1198.00 m. The Tungabhadra river flows for about 531 km in the North Eastern direction through Karnataka state and Andhra Pradesh beyond Kurnool, before it joins, Krishna River at an elevation of El 294.10 m.

Location Map of Tungabhadra Dam



Estimation of Transmission Losses in Canals

- The transmission losses which include leakage losses, seepage losses, Evaporation losses, operational losses and losses due to any other mean through a canal network depend on a number of physical, operational, and climatic factors. Some of these factors can be quantified but most of them are not easy to be incorporated into precise calculations. Due to climatic and other uncertainties, prediction of the reliable amount of losses in irrigation projects cannot be done confidently.

- Tungabhadra Dam project, requested Central Water & Power Research Station (CWPRS), Pune, to take up field studies for rating of canal sites at ch. 28, mile 1.
- Accordingly, studies were conducted at gauging site i.e. ch. 28, mile 1 for higher range discharges in the month of August 2014 & August 2015 and for lower discharges studies were conducted in the month of March 2015. Results of these studies are given in the present report.

Gauging site at ch.28 in mile 1.

- The canal in this section is mostly lined and is designed for 116 cumec (4100 cusec) at the head.
- A permanent gauging site on the canal is located at ch.28 in mile 1
- A permanent foot bridge constructed at one km downstream of the site, at ch. 28.
- A gauge well is constructed on the right bank of the canal at the site.

GAUGE DISCHARGE DATA OF TUNGABHADRA LEFT BANK CANAL AT CH 28 IN MILE 1

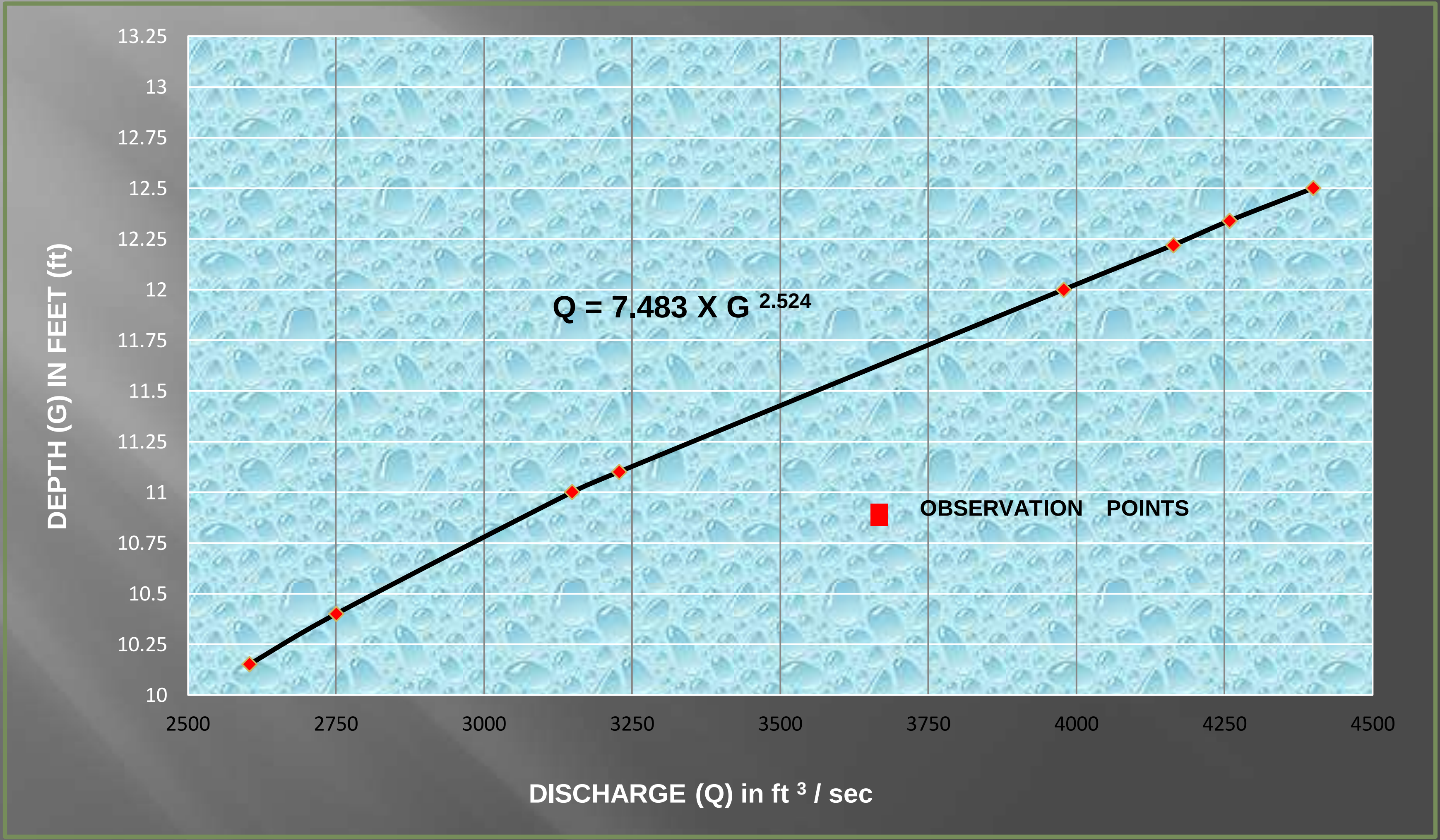
S.No	Date	Time of Gauging in Hrs.		Gauge reading in Feet	Discharge	
		From	To		ft^3/s	m^3/s
1	03.08.2014	11.30	12.50	10.01	2564	72.62
2	03.08.2014	14.45	15.40	10.4	2761	78.18
3	04.08.2014	16.30	17.15	11.0	3181	90.07
4	04.08.2014	18.00	19.00	11.1	3254	92.15
5	17.03.2015	09.45	10.30	12.0	3962	112.20
6	17.03.2015	11.30	12.10	12.2	4131	116.98
7	06.08.2015	13.40	14.20	12.3	4217	119.41
8	07.08.2015	15.00	16.00	12.5	4392	124.37

The following gauge-discharge correlation were established

- **Ch. 28 in mile 1**
- **$Q = 7.483 \times G^{2.54}$**
- Where
- Q is discharge in cusec and
- G is gauge in ft

- It may be mentioned that these results/losses are applicable for the range of observed discharges. Any extrapolation of these results/losses may cause additional error. It may also be pointed out that the results/losses will be valid as long as the site conditions, existing at the time of field measurements are not changed i.e. no silting or no erosion of the canal bed, canal lining not disturbed or removed, no weed growth in the canal, locations of gauge and zero of gauge not changed.

Gauge – Discharge Curve of Tungabhadra LBC at CH. 28 mile 1



RATING CHART OF TUNGABHADRA LEFT BANK CANAL AT CH 28 IN MILE 1

Gauge(G) in ft	Discharge(Q) in ft^3/s	Discharge (Q) in m^3/s
10.1	2564	72.62
10.2	2629	74.44
10.3	2694	76.30
10.4	2761	78.18
10.5	2829	80.09
10.6	2897	82.03
10.7	2966	84.00
10.8	3037	86.00
10.9	3108	88.02
11.0	3181	90.07
11.1	3254	92.15
11.2	3329	94.26

Gauge(G) in ft	Discharge(Q) in ft^3/s	Discharge (Q) in m^3/s
11.3	3404	96.40
11.4	3481	98.57
11.5	3559	100.77
11.6	3637	102.99
11.7	3717	105.25
11.8	3798	107.54
11.9	3879	109.85
12.0	3962	112.20
12.1	4046	114.57
12.2	4131	116.98
12.3	4217	119.41
12.4	4304	121.88
12.5	4392	124.37

Indian Standards

Measurement / Estimation, Analysis and Recording	
IS:1191	Glossary of terms and symbols
IS:1192	Velocity area methods
IS:1193	Notches, weirs and flumes
IS:1194	Forms for recording measurement
IS:2912	Slope area method
IS:2913	Flow in tidal channels
IS:2914	Stage discharge relation
IS:2915	Instructions for collection of data for analysis of errors
IS:3918	Use of current meter
IS:6059	Weirs of finite crest width
IS:6062	Standing wave flume-falls
IS:6063	Standing wave flume
IS:6330	End depth method for rectangular channels

Instruments	
IS:3910	Current meters
IS:3911	Surface floats
IS:3912	Sounding rods
IS:4073	Sounding weights
IS:4080	Velocity rods
IS:4858	Velocity rods
IS:6064	Sounding and suspension equipment

Conclusion

- Rating curves / Tables
- The results/losses are applicable for the range of observed discharges.
- Any extrapolation of these results/losses may cause additional error.
- The results/losses will be valid as long as the site conditions, existing at the time of field measurements are not changed i.e. no silting or no erosion of the canal bed, canal lining not disturbed or removed, no weed growth in the canal, locations of gauge and zero of gauge not changed.

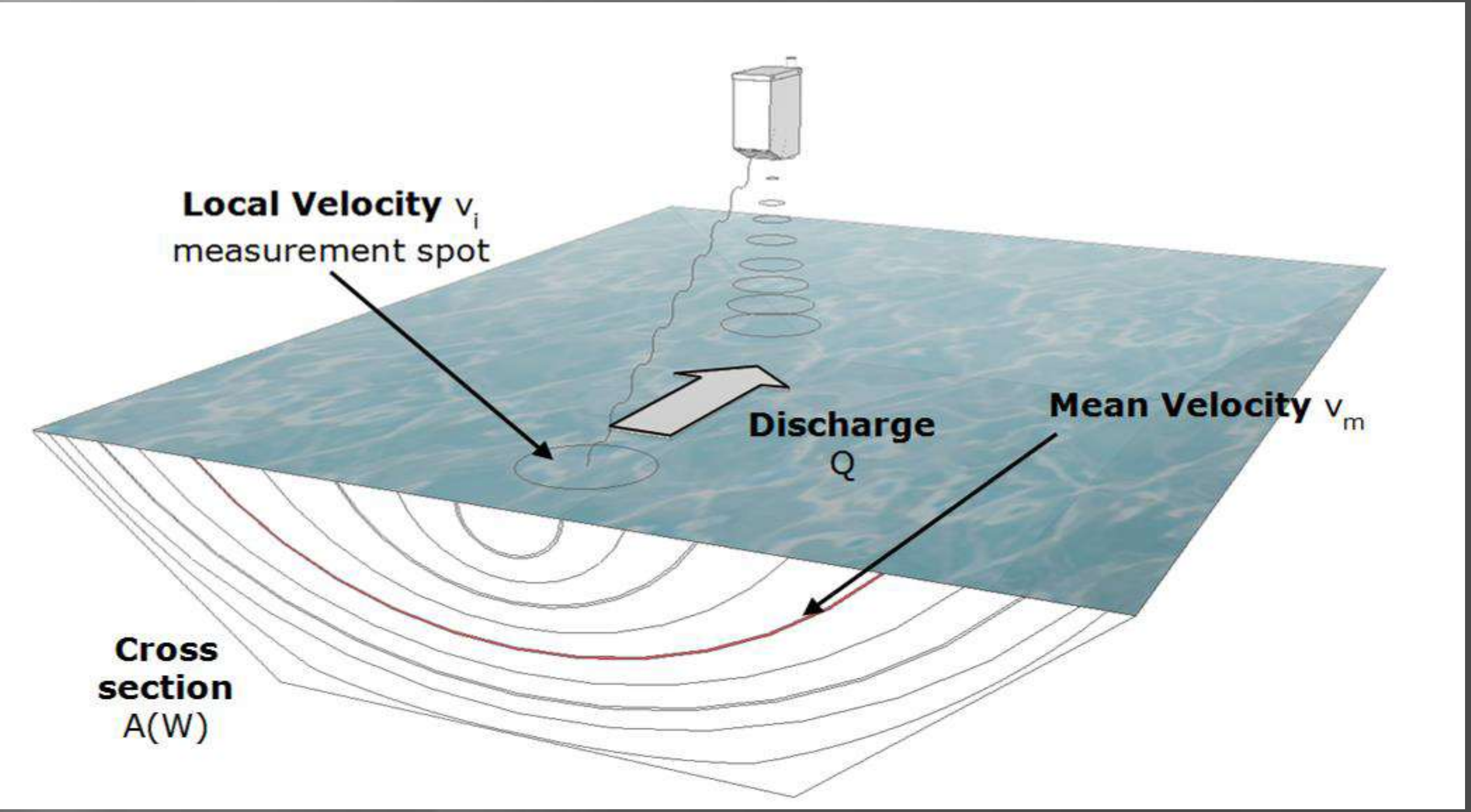
Validation of Open Channel Non Contact radar type discharge measurement sensors in Carrier Lined Channel and Delhi Sub-Branch, Delhi Jal Board, Delhi

- Delhi Jal Board (DJB) is responsible for supply of water in Delhi and its distribution in the area under the control of Municipal Corporation of Delhi. The Board also caters water supply in large quantities to N.D.M.C. and Delhi Cantonment areas.
- There are numerous techniques for measuring flow rates in open channels and closed conduits.
- The exact and real-time measurement of the discharge is an important task in the fields of hydrology, water storage management, irrigation and prevention of natural hazards.

FLOW MEASUREMENT ARRANGEMENT AT SITE

- Delhi Jal Board(DJB) had acquired contact-free radar type discharge sensors from Sommer Messtechnik, GmbH, Austria to measure the continuous river flow velocity which are of sophisticated and advanced technology.
- The RQ-30 contact free radar sensor measures the flow velocity and water level at the water surface.

Principle of measurement of the RQ-30 radar sensor



Specification of radar sensor for Velocity measurement

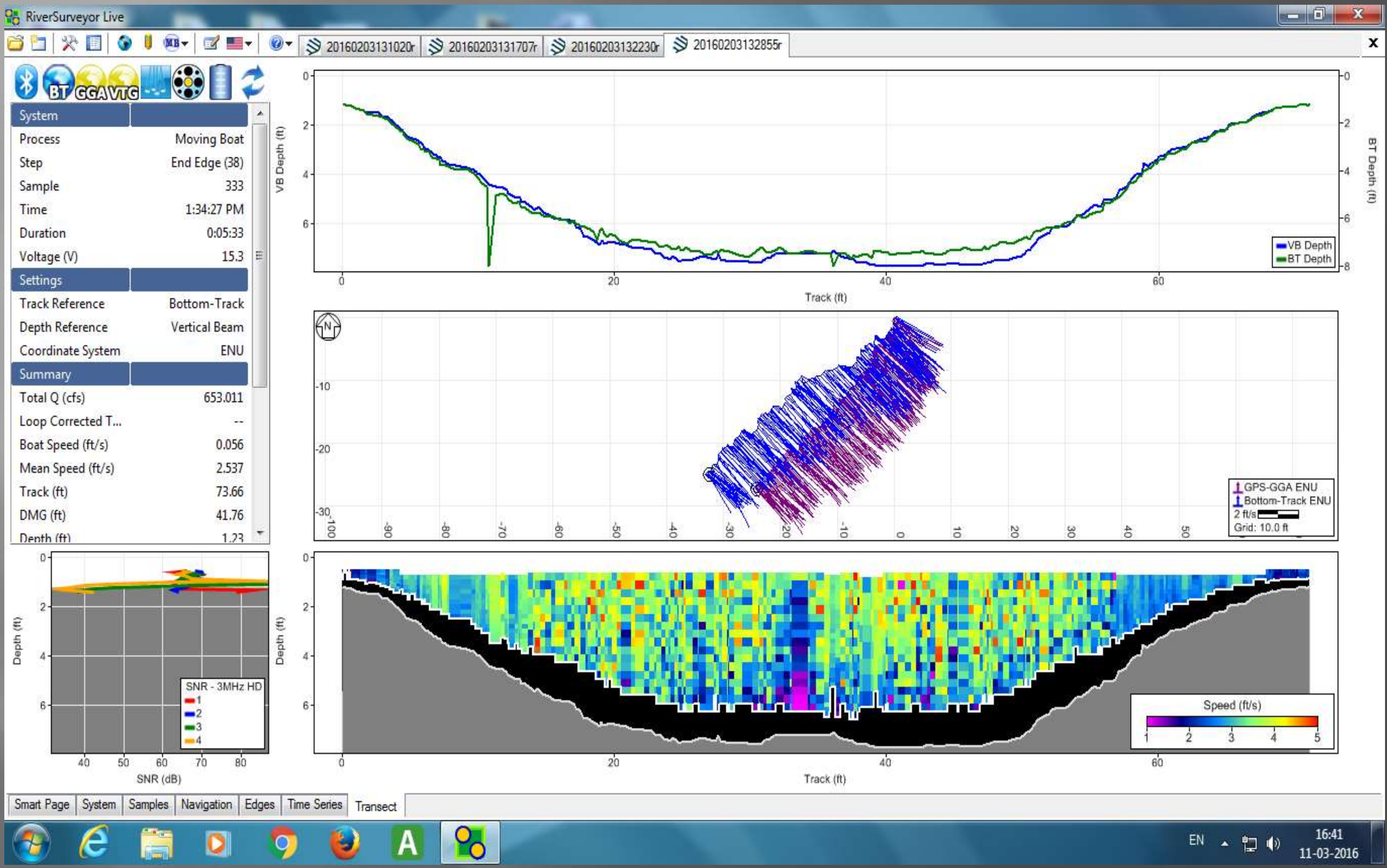
Detectable measurement range	0.10 to 5 m/s (depending on the flow conditions)
Accuracy	± 0.02 m/s
Resolution	1 mm/s
Direction recognition	+/-
Measurement duration	5 to 40 s
Measurement interval	8 s to 5 h
Measurement frequency	24 GHz (K-Band)
Radar opening angle	12 °
Distance to water surface	0.50 to 35 m
Vertical inclination	measured internally

Specification of radar sensor for Water level measurement

Measurement range (from radar transmitter to water surface)	0 to 15 m (0 to 49.21 ft.) - standard version 0 to 35 m (0 to 114.83 ft.) - extended measurement range (optional)
Resolution	1 mm
Accuracy	± 2 mm; ± 0.025 % FS (15 m)
Radar frequency	26 GHz (K-Band)
Radar opening angle	10 °

Non Contact radar sensor at the site of CLC

Typical Insight of the pixel data of ADCP



Delhi Sub Branch (DSB)								
S.NO	Date	Time	Discharge measured by Non contact radar at site		Discharge measured by CWPRS		Error	Percentage Error
			m^3/s	ft^3/s	m^3/s	ft^3/s		
1	30.03.2019	17.20-18.00	8.414	297.138	8.764	309.498	-0.4	-3.99%
2	31.03.2019	10.40-11.00	9.16	323.520	8.56	302.294	0.6	7.01%
3	01.04.2019	10.50-11.20	9.776	345.236	10.071	355.654	-0.3	-2.93%
4	02.04.2019	09.00-10.00	11.276	398.208	11.115	392.523	0.2	1.45%
5	03.04.2019	11.40-12.20	9.409	332.276	8.911	314.689	0.5	5.59%

	Carrier Lined Channel (CLC)							
S.NO	Date	Time	Discharge measured by Non contact radar at site		Discharge measured by CWPRS		Error	Percentage Error
			m^3/s	ft^3/s	m^3/s	ft^3/s		
1	30.03.2019	16.00-16.30	19.101	674.545	18.043	637.183	1.06	5.86%
2	31.03.2019	09.00-10.00	18.731	661.479	18.043	637.183	0.69	3.81%
3	01.04.2019	09.30-10.30	17.111	604.269	16.643	587.742	0.47	2.81%
4	02.04.2019	10.30-11.30	15.891	561.185	16.348	577.324	-0.46	-2.80%
5	03.04.2019	10.50-11.30	17.296	610.802	17.433	615.641	-0.14	-0.79%

Acquiring ADCP Data & Ecosounder Data

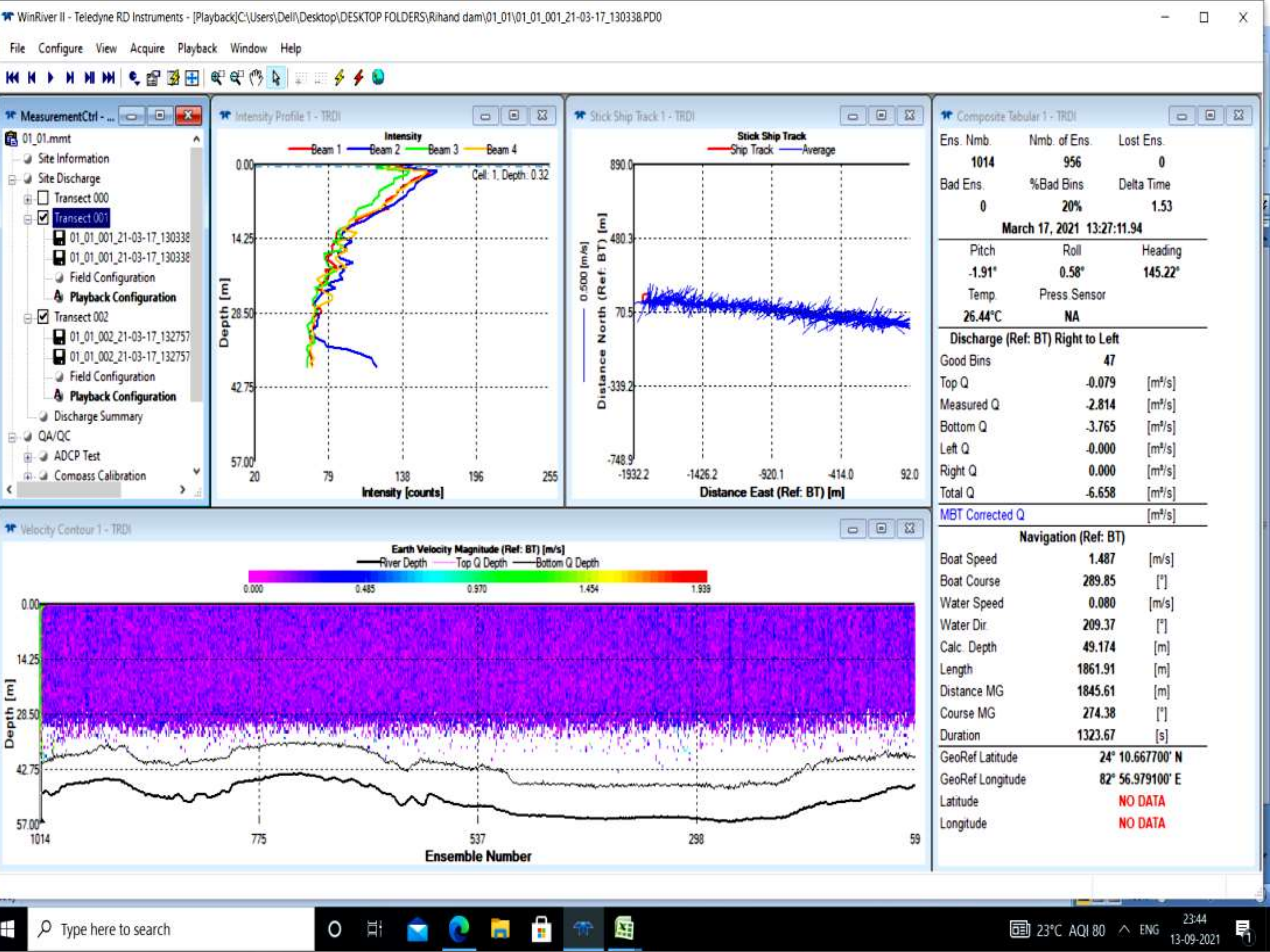
On site verification of ADCP Data & Ecosounder Data

Pre-calibration of ADCP

Depth measurement of Rihand Reservoir by ADCP

Results

Rihand Reservoir								
Sl. No.	Date	Time	Depth measured by Bathymetry System in Metres		Depth measured by ADCP in Metres		Error	Percentage Error
			Min	Max	min	Max		
1	19.03.2021	10.20 – 12.30	34.72	49.10	34.77	48.37	-0.05	-0.14%


WinRiver II - Teledyne RD Instruments - [Playback]C:\Users\Dell\Desktop\DESKTOP FOLDERS\Rihand dam\01_01\01_01_001_21-03-17_130338.PD0
File Configure View Acquire Playback Window Help
MeasurementCtrl - ...
01_01.mmt
Site Information
Site Discharge
Transect 000
Transect 001
01_01_001_21-03-17_130338
01_01_001_21-03-17_130338
Field Configuration
Playback Configuration
Transect 002
01_01_002_21-03-17_132757
01_01_002_21-03-17_132757
Field Configuration
Playback Configuration
Discharge Summary
QA/QC
ADCP Test
Compass Calibration
Intensity Profile 1 - TRDI
Intensity
Beam 1 Beam 2 Beam 3 Beam 4
Cell: 1, Depth: 0.32
Depth [m]
0.00
14.25
28.50
42.75
57.00
20 79 138 196 255
Intensity [counts]
Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track Average
0.500 [m/s]
Distance North (Ref: BT) [m]
890.0
480.3
70.5
-339.2
-748.9
-1932.2 -1426.2 -920.1 -414.0 92.0
Distance East (Ref: BT) [m]
Composite Tabular 1 - TRDI
Ens. Nmb. 1014
Nmb. of Ens. 956
Lost Ens. 0
Bad Ens. 0
%Bad Bins 20%
Delta Time 1.53
March 17, 2021 13:27:11.94
Pitch -1.91°
Roll 0.58°
Heading 145.22°
Temp. 26.44°C
Press Sensor NA
Discharge (Ref: BT) Right to Left
Good Bins 47
Top Q -0.079 [m³/s]
Measured Q -2.814 [m³/s]
Bottom Q -3.765 [m³/s]
Left Q -0.000 [m³/s]
Right Q 0.000 [m³/s]
Total Q -6.658 [m³/s]
MBT Corrected Q [m³/s]
Navigation (Ref: BT)
Boat Speed 1.487 [m/s]
Boat Course 289.85 [°]
Water Speed 0.080 [m/s]
Water Dir 209.37 [°]
Calc. Depth 49.174 [m]
Length 1861.91 [m]
Distance MG 1845.61 [m]
Course MG 274.38 [°]
Duration 1323.67 [s]
GeoRef Latitude 24° 10.667700' N
GeoRef Longitude 82° 56.979100' E
Latitude NO DATA
Longitude NO DATA
Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [m/s]
River Depth Top Q Depth Bottom Q Depth
0.000 0.485 0.970 1.454 1.939
Depth [m]
0.00
14.25
28.50
42.75
57.00
1014 775 537 298 59
Ensemble Number
Type here to search
23°C AQI 80 ENG
23:44
13-09-2021

The discharge values as observed at the Rihand reservoir are given in Table 1 taken during 19.03.2021 and the entire transect values observed on 19.03.2021 are enclosed as annexure 1.

It is observed from the table that the percentage error of Depth measured by Bathymetry System and that of Depth measured by ADCP is observed to be -0.14% .

Therefore an attempt to verify the results of the Bathymetry system and that of the ADCP are satisfied and the results of the depth measurements taken from Bathymetry system and are finalized.

The above values are of only a part of the reservoir and an attempt to verify the results of the Bathymetry system was conducted successfully


AMARON
SEALED MAINTENANCE FREE
QUANTA
UNINTERRUPTED LIFE


THANK YOU
sreekanth.s@cwprs.gov.in