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Application of a Mathematical Modelling Tool for the Evaluation of Hydrological Parameters using Conventional Survey and Drone Survey

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***Abstract*— The survey work of flood affected area of river basin is significant factor in flood management. The flood management work is done by analysing water discharge and water profiles at different cross-sections of river basin. River bed plays crucial role in distribution of flood water and water velocity profile. Hence topographical detailed survey is very much essential for flood management works.**

Traditionally topographical survey work is carried out manually by using total station to acquire detailed data on the actual spot by the people on the ground. On the other hand, in aerial surveying UAV borne mapping system is developed for survey purpose of river basin in which digital and infrared cameras are used along with GPS. This paper focuses on comparative study between conventional topographical survey and drone or aerial photographic survey by using the HEC-RAS software for achieving results. The comparison is done on the basis of flow rate, water depth and velocity across the flood plain of river. The evaluated parameters in the study provides a guideline for the decision making process for water resource management projects.

***Keywords*— Flood Management, Traditional Surveying Methods, HEC-RAS Modelling, Drone Surveying**

I. Introduction

Flood related disasters contributes over 30% of annual disasters and economical losses. Around half of the victims are flood related. These hazards are likely to become more frequent in near future because of drastic change in environment which has lead to a variation in rainfall pattern. This has increased the events of unpredictable floods in river basins.
The survey work of flood affected area of river basin is significant factor in flood management. The flood management work is done by analysing water discharge and water profiles at different cross-sections of river basin. River bed plays crucial role in distribution of flood water and water velocity profile. Hence topographical detailed survey is very much essential for flood management works.

River survey and investigation are significant in order to get the detailed specific data and information of topography of river basin. It helps in understanding the variation in flow velocity, water depth and roughness of ground. It is essential to analyse water profile and flood water distribution during flood period. From infrastructural point of view accurate survey data of river train and bank is considerable for purpose of designing hydraulic cross drainage structures. Thus, the precise survey work plays major role in coping unpredictable flood situation.

The survey can be done by two methods :
1. Conventional surveying method
2. Drone surveying method

II. Surveying Methods

2.1 Conventional surveying method

The Conventional survey is the oldest method which consists of labor force and traversing tools for survey purpose. The topographical plans are widely used in number of applications and variety of sites. These plans involve several levels of accuracy depending on necessity. For many topographic survey, data is acquired using total station.
Total station is combination of electromagnetic measuring instruments and electronic theodolite. It also contains a microprocessor, electronic data collector and storage devices. Total station can be used for taking measurements in horizontal and vertical direction. The recording of data is done in X-Y-Z coordinate system. It also takes into consideration the atmospheric corrections, geodetic corrections, grid and elevation factors while taking measurement. In total station, data can

be downloaded or uploaded into computer directly. It can also be connected to the satellites through GPS system. The biggest advantage of total station is that it directly gives the topographical map.

Fig 1 : Total station details [1]

Traditionally surveying has used analog methods of recording data. Digital data collection method using electronic total station are far more efficient. Total station have dramatically increased amount of topographic data that can be collected during a day and are well suited for topographic survey in huge flood plain region of river. When proper procedures are performed total station have made trigonometric levelling nearly precise than other levelling techniques.

- *Accuracy of total station*

1. The angular accuracy range from 1” to 20”

2. Distance accuracy depends upon two factors:

a) Instrumental error which ranges from +/- 10mm to +/- 2mm.
b) Error due to the length of measurement. It can be from +/- 10mm to +/- 2mm per kilometre.

3. 1 prism (2.5-2.7 km), 2 prism (5-7 km) and 3 prism (10-12km).

2.1.1 Methodology

Total station uses the electromagnetic rays in order to find out the position of point. The electromagnetic rays are emitted and directed towards the prism located on survey point and the reflected ray is received by the total station and on time and angle made by the ray at reflector gives coordinate of survey point.

Total station works on base coordinate grid system. The coordinates of unknown points are taken relative to the benchmark or the position of the total station which are along the line of sight. Angle and distance can be directly estimates based on X-Y-Z coordinates (easting, northing and elevation) of survey point relative to the position of total station are calculated using principle of trigonometry and triangulation. In order to get exact location and reduced level of survey point, total station requires to be in line of sight of observation and should be set up over known point or with line of sight to 2 or more points, called Resection or Free Stationing. Thus to get the exact coordinates of total station it can be also equipped with Global Navigation Satellite System. However GNSS measurements may require longer occupation period and offer relatively poor accuracy in vertical axis.

Data processing

Total station provide facility of internal electronic data storage is used to record distance, horizontal angle and vertical angle. Along with it and external data collector or computer can directly connected to the total station. The latest version of total station can directly compute result and generate a map of surveyed area with the help of various softwares. The most advance version of total station, map can be directly viewed on touch screen pad of total station.

2.1.2 Advantages of Conventional survey method

- A visual inspection of the area can be done.
- One of the accurate method to measure elevations of geographical features.
- Getting the actual reduced level of the surveying point.
- Error caused by vegetation is minimum in this case.
- Low cost is required for surveying the area from 3-5 km.
- Good statistical significant result can be gathered easily.
- Less initial cost in the surveying equipment as compare to other unconventional method.
- It is preferable when the surveying of closed air areas.

2.1.3 Disadvantages of Conventional survey method

- It requires longer time as compare to other unconventional method.
- Limited area can be covered.
- Surveyors are exposed to large numbers of natural risks.
- Conventional method is not preferable in rough terrain or area having large number of inaccessible points.
- The accuracy of survey differ from the skill level of operators.
- It requires large skilled labor force.

2.2 Unconventional surveying method (Drone Survey).

River survey and investigation are significant in order to get the detailed specific data and information of topography of river basin. Thus most accurate RL of basin is required. From the last dace there has been a huge advancement in technology of UAVs for obtaining the surface spatial information. So there is huge platform available for the UAVs in the survey.

UAV is able to produce high quality elevation model along with high spatial resolution. UAVs can detect morphological changes, river vegetation dynamics, canopy heights, post flood river morphology, plan form changes, meandering neck cutoffs with high accuracy. Due to this features drones are preferable tool for the survey of river basin.

Drones are equipped with Digital cameras, IR cameras, GPS systems, digital imaging processor, LIDAR.

2.2.1 Work flow of Drone

The working of the drone for data acquisition of river basin is dine in five steps

1. Reconnaissance of mapped site — identification of potential problems and danger in flight mission, take off and landing point.

2. Pre-flight field work — the placement and targeting of ground control point for precise geo-referencing.

3. Flight mission — aerial imaging of study area.

4. Quality check and precessing of aerial data — data accuracy assessment and software data processing, and

5. Operations above processed lanes and landform mapping — comprising visualisation, landform identification and morphometric analysis.

2.2.2 Advantages of Unconventional survey method (Drone Survey).

- Risk reduction — Drone survey does not involve workers requirement at the survey point which reduces health risk factor in rough terrain.

- No need to shut down plant — In the drone survey, there is no involvement of ground work which interferes in project task. Hence there is no loss in production

- Better overview — Flying at low lights gives very sharp images and also gives clear overview of the basin.

- Survey of inaccessible locations — In river survey there are large number of points which are inaccessible or it is difficult to measure its RL. So this can easily done with the help of drone.

- Improved data density — Advancement in technology of the cameras and LIDAR as lead to the measurement of the RL with high accuracy. Comparing to manual survey, drone can get much closer to survey goal, resulting in improve data density and quality of survey.

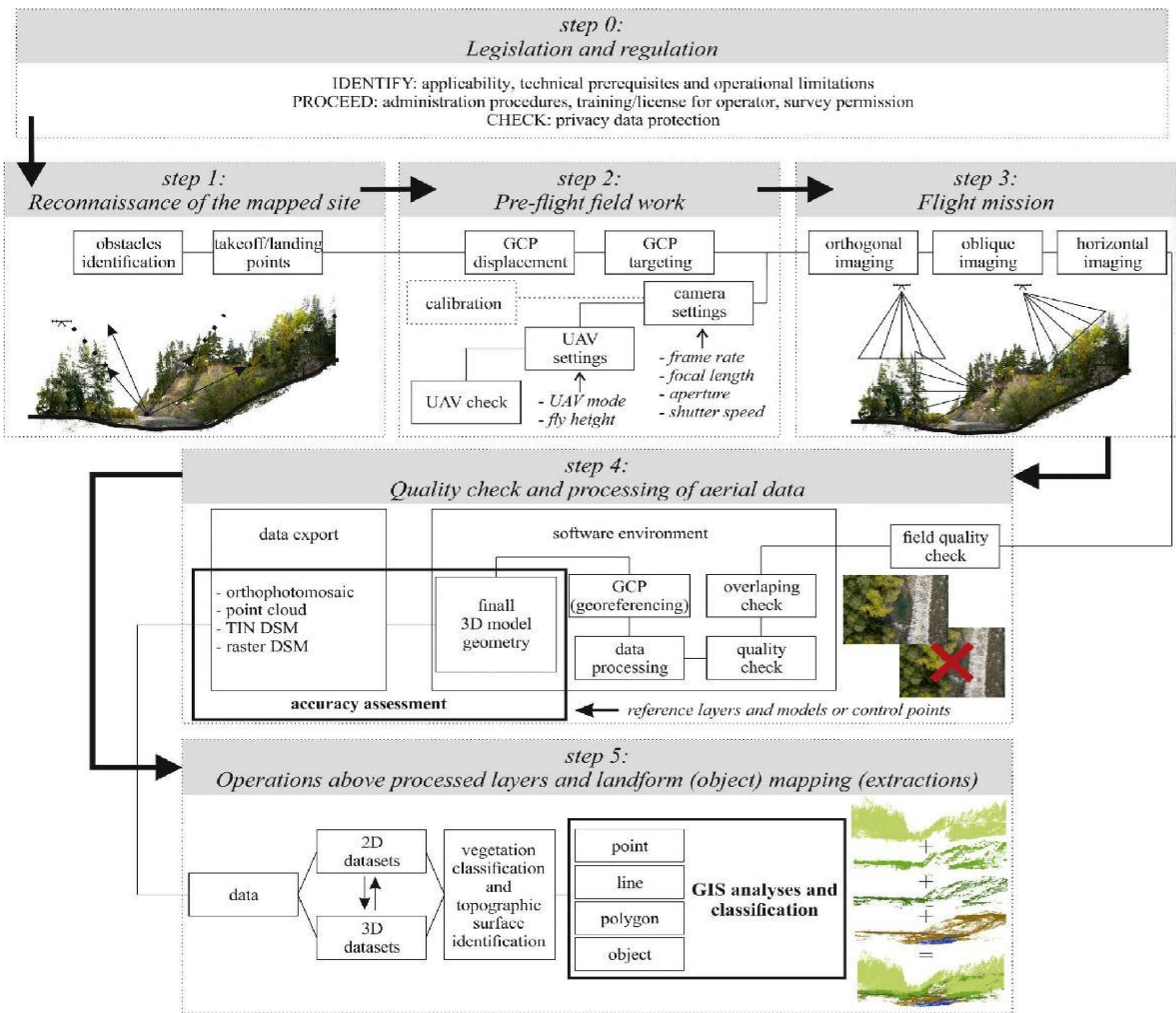


Fig 2 : Work Flow of Drone [5]

- Faster data acquisition — As compare to manual survey, since less people and equipments are involves, the time requires for drone survey is much lesser than manual survey method.

- Lower cost — Drone survey are much cheaper because it does not require to shut down the plant, no requirement of extra cost for inaccessible points, falser data acquisition and less involvement of workforce and equipments.

2.2.3 Disadvantages of Unconventional survey method (Drone Survey).

- High initial cost — Along with the advancement in the drone, the cost of the drone also increases at very high rate.

- Requirement of high skilled labour — These drone have higher complexity. Hence flying of multi rotor drone is difficult task.

- Limited flying time — The most of the drones energy is spent on fighting gravity and stabilising in air. Thus, Drone have limited flying time about 15-30 min.

- Underground and covered area survey — The drone is not preferable for the survey if there are large number of covered area.

- Maintenance and repairing of drone — Maintenance and repairing work of drone is very complex and technical supervision is needed. Parts of drones are expensive.

For the flood mitigation and reducing vulnerability of floods, flood modelling is done. Flood modelling replaces the trial and error methods of flood control and management. Efficient flood mitigation strategies can be implemented using mathematical model as a tool.

1-D mathematical modelling is adopted to analyse flow characteristics of flood water. A mathematical model is description of a system using mathematical concept and language. In 1-D analysis, Hydrologic Engineering Centre's River Analysis System (HEC-RAS) is a common hydraulic model used to study flow depths and total energy loss along a study reach of a river system. HEC-RAS is a 1-D model that performs calculations for steady and unsteady flow in gradually varied or rapidly varied flow analysis. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels.

Fig 3 : Drone survey[1]

III. Case Study : Banas River Basin And Narmada Main Canal Crossing

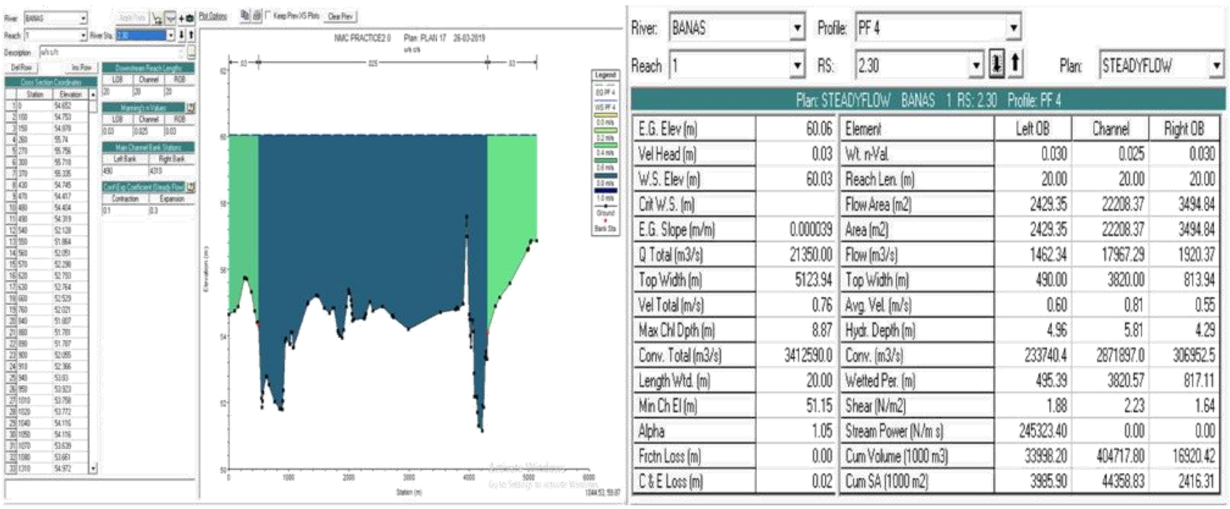
In the province of Totana village in Gujarat state, NMC crosses River Banas and its tributary Khariya. At the intersection point there were two hydraulic structures present i.e. Syphon at Banas and NMC crossing and super passage at Khariya and NMC crossing. These hydraulic structures allow river water to pass by NMC without getting intermixed. Heavy unprecedented rainfall occurred in the catchment area of the Banas basin during July 2017. Due to severe flood condition, huge damage is inspected to hydraulic structures and canal due to excess unexpected flood water.

This paper represents the comparative study between results obtained by conventional survey method and drone survey method simulated in HEC-RAS software and run in steady flow and unsteady flow condition.

3.1 Case 1 :-Steady flow comparison

HEC-RAS is used to analyse 1-D model that performs calculations for steady flow. The comparison consists of cross section of banas basin obtained from conventional survey method (for 6 km) and Drone survey method (for 12 km). The following images shows 2 cross sections of respective survey methods and compare flow properties across the sections.

The figures below represent the cross sections at two points of the banas river collected using conventional and drone survey respectively. The images are taken from 1-D mathematical model which is analyse using HEC-RAS software. Parameters in Steady flow conditions, such as topography, discharge , flow velocity have been compared.



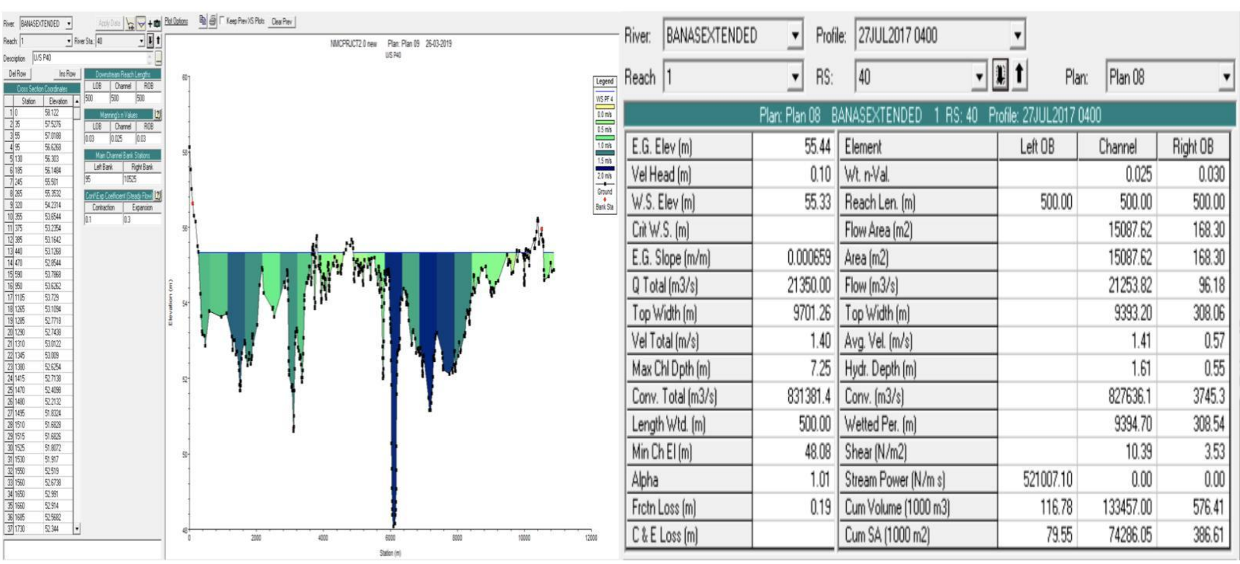
River: BANAS Profile: PF 4
Reach: 1 RS: 2.30 Plan: STEADYFLOW

Plan: STEADYFLOW BANAS 1 RS: 2.30 Profile: PF 4

E.G. Elev (m)	60.06	Element	Left OB	Channel	Right OB
Vel Head (m)	0.03	Wt. n-Val.	0.030	0.025	0.030
W.S. Elev (m)	60.03	Reach Len. (m)	20.00	20.00	20.00
Crit W.S. (m)		Flow Area (m2)	2429.35	22208.37	3494.84
E.G. Slope (m/m)	0.000039	Area (m2)	2429.35	22208.37	3494.84
Q Total (m3/s)	21350.00	Flow (m3/s)	1462.34	17967.29	1920.37
Top Width (m)	5123.94	Top Width (m)	490.00	3820.00	813.94
Vel Total (m/s)	0.76	Avg. Vel. (m/s)	0.60	0.81	0.55
Max Chl Dpth (m)	8.87	Hydr. Depth (m)	4.96	5.81	4.29
Conv. Total (m3/s)	3412590.0	Conv. (m3/s)	233740.4	2871897.0	306952.5
Length Wtd. (m)	20.00	Wetted Per. (m)	495.39	3820.57	817.11
Min Ch El (m)	51.15	Shear (N/m2)	1.88	2.23	1.64
Alpha	1.05	Stream Power (N/m s)	245323.40	0.00	0.00
Frctn Loss (m)	0.00	Cum Volume (1000 m3)	33998.20	404717.80	16920.42
C & E Loss (m)	0.02	Cum SA (1000 m2)	3985.90	44358.83	2416.31

Fig 4 : Cross sectional data of Steady flow by Conventional Survey Method

(Cross section 1)



River: BANASEXTENDED Profile: 27JUL2017 0400
Reach: 1 RS: 40 Plan: Plan 08

Plan: Plan 08 BANASEXTENDED 1 RS: 40 Profile: 27JUL2017 0400

E.G. Elev (m)	55.44	Element	Left OB	Channel	Right OB
Vel Head (m)	0.10	Wt. n-Val.		0.025	0.030
W.S. Elev (m)	55.33	Reach Len. (m)	500.00	500.00	500.00
Crit W.S. (m)		Flow Area (m2)		15087.62	168.30
E.G. Slope (m/m)	0.000659	Area (m2)		15087.62	168.30
Q Total (m3/s)	21350.00	Flow (m3/s)		21253.82	96.18
Top Width (m)	9701.26	Top Width (m)		9393.20	308.06
Vel Total (m/s)	1.40	Avg. Vel. (m/s)		1.41	0.57
Max Chl Dpth (m)	7.25	Hydr. Depth (m)		1.61	0.55
Conv. Total (m3/s)	831381.4	Conv. (m3/s)		827636.1	3745.3
Length Wtd. (m)	500.00	Wetted Per. (m)		9394.70	308.54
Min Ch El (m)	48.08	Shear (N/m2)		10.39	3.53
Alpha	1.01	Stream Power (N/m s)	521007.10	0.00	0.00
Frctn Loss (m)	0.19	Cum Volume (1000 m3)	116.78	133457.00	576.41
C & E Loss (m)		Cum SA (1000 m2)	79.55	74286.05	386.61

Fig 5 : Cross sectional data of Steady flow by Drone Survey Method

(Cross section 1)

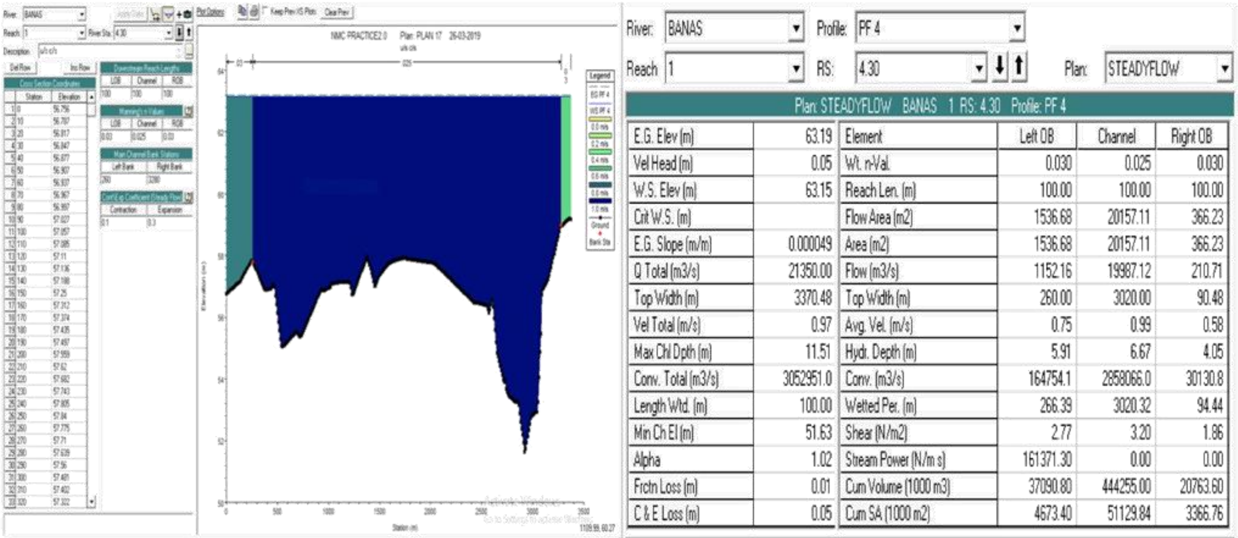


Fig 6 : Cross sectional data of Steady flow by Conventional Survey Method

(Cross section 2)

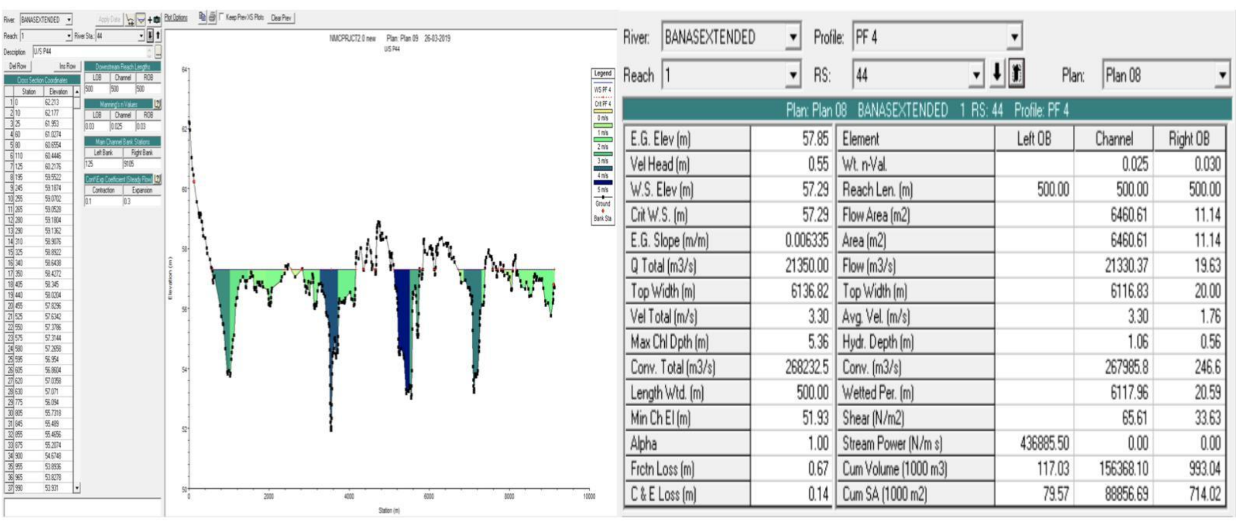


Fig 7 : Cross sectional data of Steady flow by Drone Survey Method

(Cross section 2)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(m)	(m)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m)
BANAS	1	4.30	PF 4	63.19	63.15	0.05	0.01	0.05	1152.16	19987.12	210.71	3370.48
BANAS	1	2.30	PF 4	60.06	60.03	0.03	0.00	0.02	1462.34	17967.29	1920.37	5123.94

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(m)	(m)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m)
BANASEXTENDED	1	44	PF 4	57.85	57.29	0.55	0.67	0.14		21330.37	19.63	6136.82
BANASEXTENDED	1	40	PF 4	55.42	55.32	0.10	0.19	0.02		21256.64	93.35	9659.33

Fig 8 : Result Tables of Cross sections for Steady flow

3.2 Case 2 :-Unsteady flow comparison

HEC-RAS is used to analyse 1-D model that performs calculations for unsteady flow. The comparison consists of cross section of banas basin obtained from conventional survey method (for 6 km) and Drone survey method (for 12 km). The following images shows 2 cross sections of respective survey methods and compare flow properties across the sections.

The figures below represent the cross sections at two points of the banas river collected using conventional and drone survey respectively. The images are taken from 1-D mathematical model which is analyse using HEC-RAS software. Parameters in Unsteady flow conditions, such as topography, discharge , flow velocity have been compared.

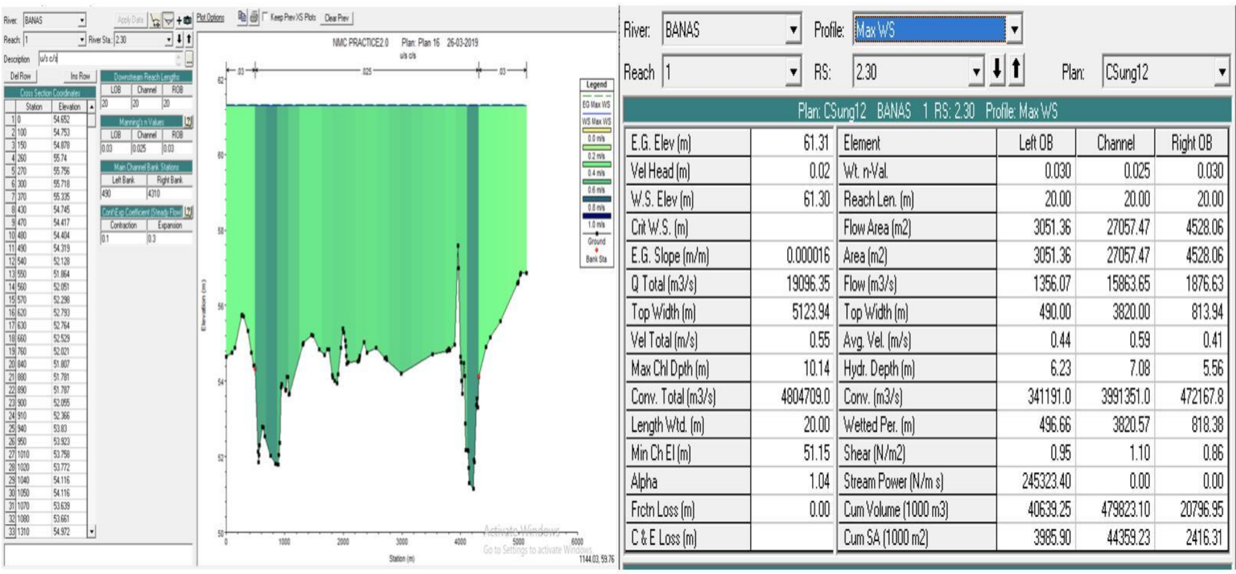


Fig 9 : Cross sectional data of Unsteady flow by Conventional Survey Method

(Cross section 1)

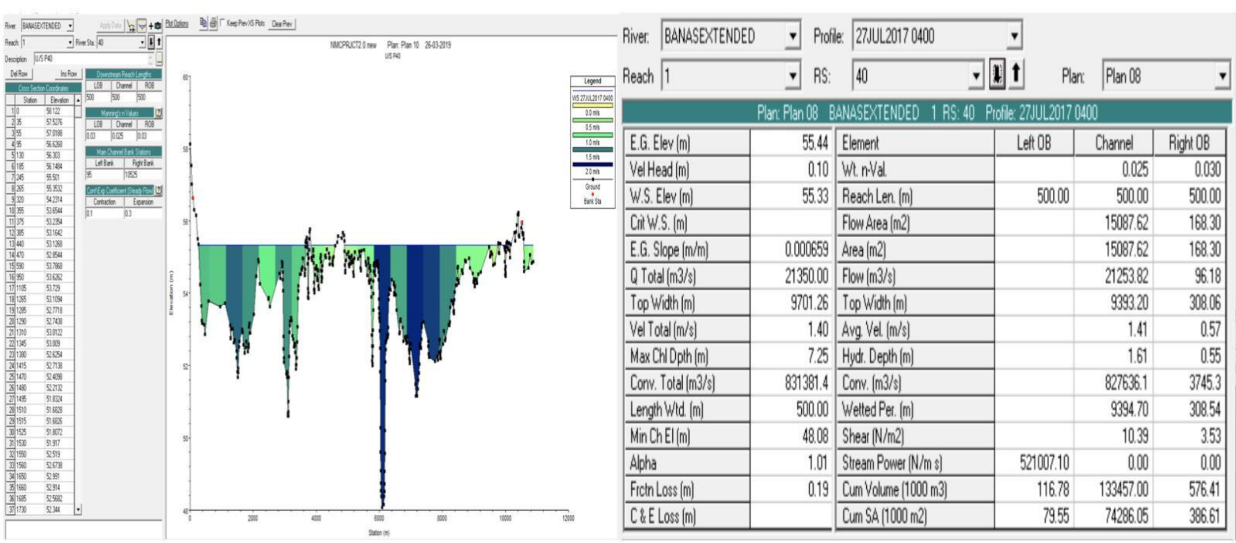


Fig 10 : Cross sectional data of Unsteady flow by Drone Survey Method

(Cross section 1)

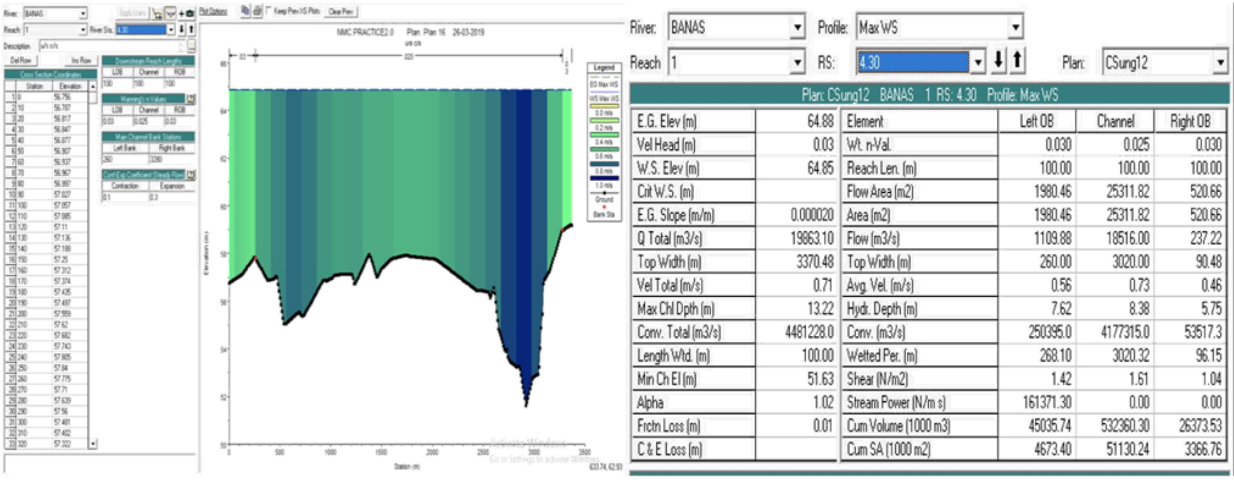


Fig 11 : Cross sectional data of Unsteady flow by Conventional Survey Method

(Cross section 2)

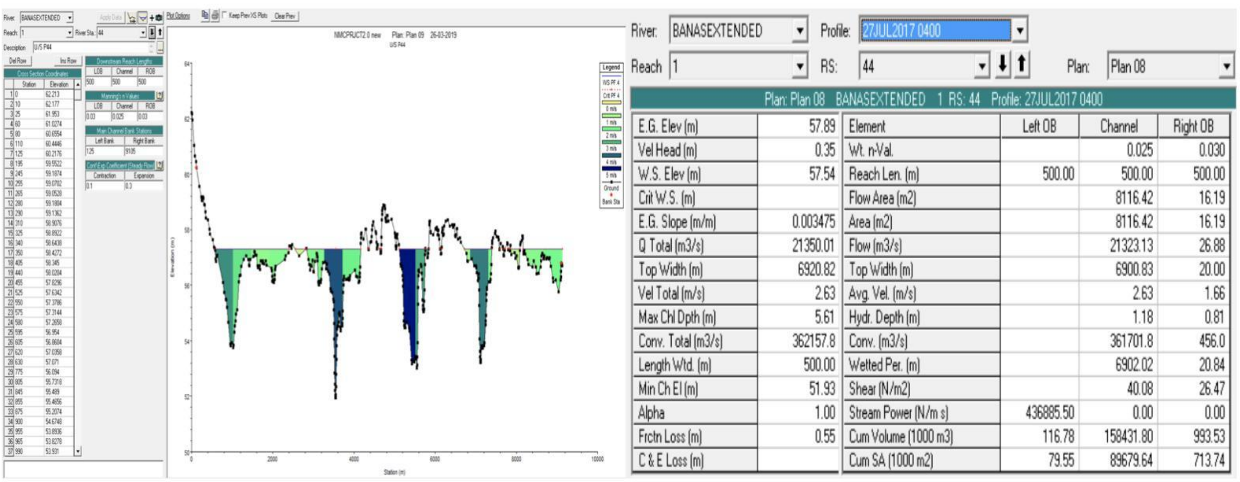


Fig 12 : Cross sectional data of Unsteady flow by Drone Survey Method

(Cross section 2)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(m)	(m)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m)
BANAS	1	4.30	Max WS	64.88	64.85	0.03	0.01		1109.88	18516.00	237.22	3370.48
BANAS	1	2.30	Max WS	61.31	61.30	0.02	0.00		1356.07	15863.65	1876.63	5123.94

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(m)	(m)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m)
BANASEXTENDED	1	44	27JUL2017 0400	57.89	57.54	0.35	0.55			21323.13	26.88	6920.82
BANASEXTENDED	1	40	27JUL2017 0400	55.44	55.33	0.10	0.19			21253.82	96.18	9701.26

Fig 13 : Result Tables of Cross sections for Unsteady flow

IV. Result and Discussion

4.1 Steady flow data

As shown in above fig 4 and fig. 5 , we can see that there is difference in the topography obtain for the same cross section by the two survey methods i.e conventional survey method and drone survey method. Similarly, fig 6 and fig 7 also shows the difference in topography of cross section 2 of same river reach. The comparative data obtained from analysing and comparing respective figures. The comparative result shown in fig 8 which is obtained by analysing 1-D mathematician modelling of banas basing using HEC-RAS tool, for the discharge of 21350 cumec.

In this study, parameters such as energy gradient elevation, water surface elevation and velocity head are compare as in fig

8. The difference in the Energy gradient elevation is 4.64 m and 5.34 m for cross section 1 and 2 respectively. The difference in the Water surface elevation is 4.61 m and 5.86 m for cross section 1 and 2 respectively. The difference in the Velocity head is 0.07 m and 0.5 m for cross section 1 and 2 respectively.

4.2 Unsteady flow data

As shown in above fig 9 and fig. 10, we can see that there is difference in the topography obtained for the cross section 1 by the two survey methods i.e. conventional survey method and drone survey method. Similarly, fig 11 and fig 12 also shows the difference in topography of cross section 2 of same river reach. The comparative data obtained from analysing and comparing respective figures. The comparative result shown in fig 13 is obtained by analysing 1-D mathematical modelling of banas basin using HEC-RAS tool, for the unsteady flow discharge.

In this study, parameters such as Energy Grade Elevation, Water Surface Elevation and Velocity Head are compare as in fig

13. The difference in the Energy Grade Elevation is 5.87 m and 6.99 m for cross section 1 and 2 respectively. The difference in the Water surface elevation is 5.97 m and 7.31 m for cross section 1 and 2 respectively. The difference in the Velocity head is 0.08 m and 0.32 m for cross section 1 and 2 respectively.

As per the results obtained it can be seen that the cross sections topography plays an important role in flow properties of water across respective cross section

V. Conclusion

This paper highlights the variable aspects and out come conventional survey and drone survey. The inferences drawn from the detailed survey conducted predict the dynamic parameters of the flow pattern of the river basin. The outcomes of steady and unsteady flow, can assist inn evaluating on field flow parameters. This analysis streamlines the decision making process and can predict the behavioural patterns for the reach. It also shows that when the topographical data of cross section changes, it makes a huge difference in flow parameters. Which further affects the prediction of flow distribution during the flood period and this finally affects the functioning of cross drainage structures.

In this study, the width of cross section is 6 km in conventional survey method and 12 km for same cross section from the drone survey. This indicates that drone survey is more comparable and can be an explicit tool is more preferable for massive survey over conventional survey. Drone survey take less time as compared to conventional survey. Hence survey data can be obtained very fast before topography of basin changes due to different parameters like man-made changes, sand minings and vegetation in the river basin.

Since drone survey exposes us to a large area it gives more accurate and realistic distribution which lack behind in conventional survey method. The flow parameter such as Energy Grade-line Elevation, Water Surface Elevation and Velocity Head can be evaluated precisely for drone surveyed topography as compared to conventionally surveyed topography. It suggests that since large area is covered in drone survey which helps to distribute flood water effectively. According to this study drone survey has an advantage in flood management and river basin topography analysis over the conventional survey.

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