DAMODAR VALLEY CORPORATION
HYDRAULIC DATA DIVISION
P.O- MAITHON, DIST-DHANBAD, JHARKHAND
PIN-828207

“Sedimentation Survey Report of Tilaiya Reservoir under NHP”

Precision Survey Consultancy,

“Vichitra” SP -45, (Kolkata West International City)
Salap Junction, Howrah Amta Road &
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Howrah – 711 403, WB

ACKNOWLEDGEMENT

Precision Survey Consultancy expresses its gratitude to Damodar Valley Corporation (D.V.C), for awarding the work of carrying out **"Sedimentation Survey Report of Tilaiya Reservoir under NHP".**

The successful completion of this project required a great amount of guidance and co-ordination between the two organizations.

We would like to use this opportunity to pen down our profound gratitude and appreciations to **the Chief Engineer (C), DVC, Maithon f**or his guidance and extending all the required support from time to time, in all stages of the project.

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1.0 Introduction of Tilaiya Reservoir:-

The Tilaya Dam is located in the upper reaches of Barakar River, about 64.4 kilometers (40.0 mi) downstream of its source. The River at this site passes through a narrow gorge approximately 91.4 metres (300 ft) wide with banks steeply rising about 45.7 metres (150 ft) on either side. The Dam has a catchment area of 984 square kilometers (380 sq mi) comprising mainly forests, pastures, cultivated lands and waste lands. The annual rainfall in the area is 127 centimeters (50 in).

The Tilaiya Dam is a concrete gravity dam with a maximum height of 30.2 metres (99 ft) above the river bed. The spillway has 14 tainter type crest gates of 3.05 m x 9.1 m, with a maximum discharge capacity of 3852 m^3/s. Two modified butterfly type under sluice gates 1m high and 1.7 m wide with a discharge capacity of 14.2 m^3/s are provided in the body of the dam mainly to supply irrigation water during the dry season.

Tilaiya Dam was inaugurated on 21 February 1953. It has a power generation capacity of 2 x 2 MW.

The main (Patna-Ranchi) road from Barhi on Grand Trunk Road passing through hills overlooking the reservoir is picturesque.

It is one of the major Dam and hydro - Electric power station constructed by Damodar Valley Corporation across Barakar River in Koderma district. The Dam is 1200 ft long and 99 ft high situated in an ideal surrounding with a beautiful reservoir in 36 sq km area. Built with the main object of water supply, controlling floods, the hydro -electric station produces 4MW. The beautiful natural surroundings are the attraction to tourists. The main road from Barhi on G.T. Road through reservoir and the hillocks is picturesque.

1.1 Location:-

Tilaiya Reservoir across River Barakar is one of the four main Reservoirs of Damodar Valley Corporation. The Damodar Valley is located in Eastern India within Latitude 22^{0}20' to 24^{0}30' and Longitude 84^{0}45'to 88^{0}30'. River Damodar is the main river of which Barakar is the principal tributary. The location of Tilaiya Reservoir is approximately at **Latitude-24°19'23.21"N** and **Longitude-85°31'14.73"E** in Koderma District of Jharkhand state.

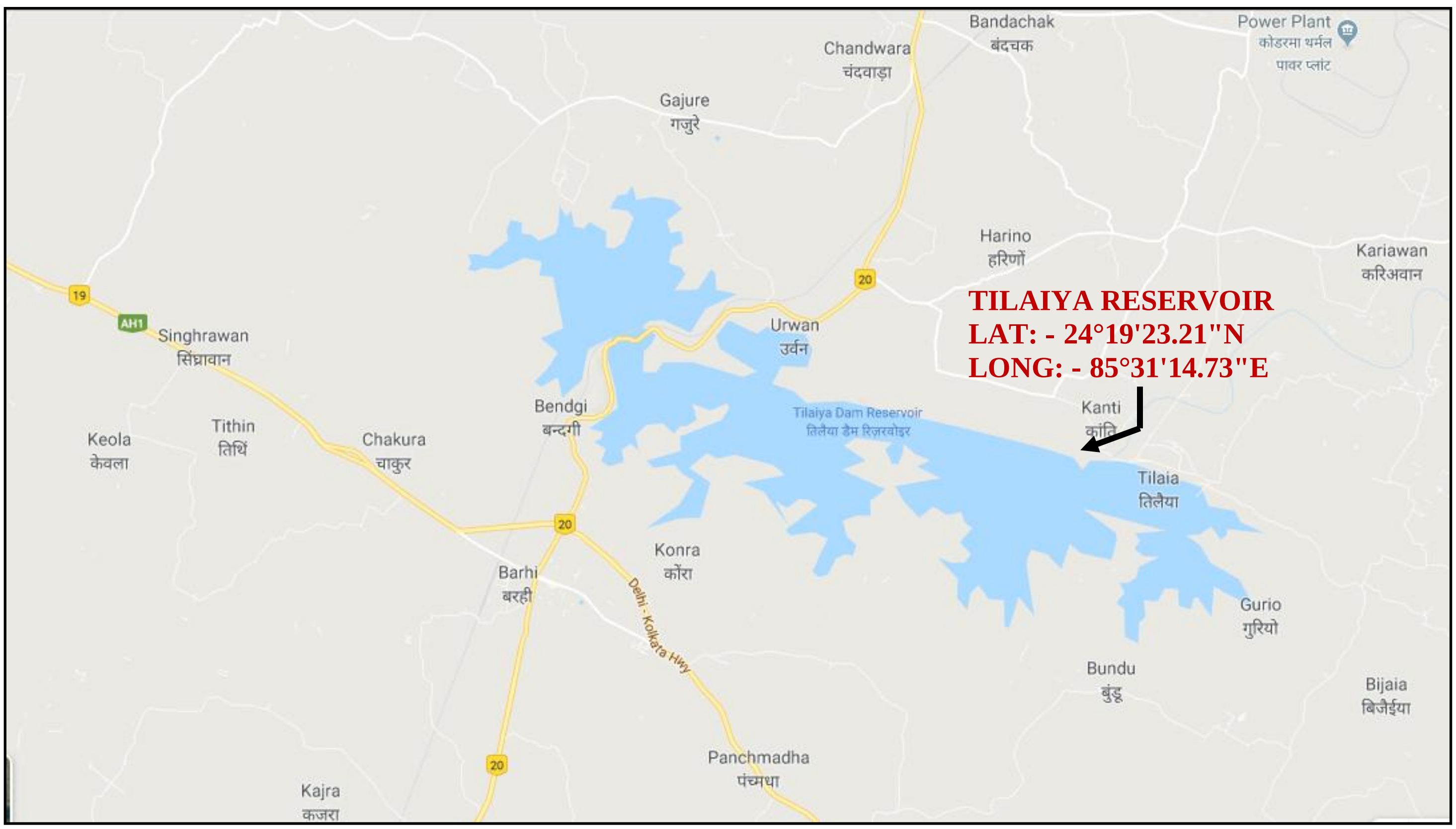


Figure 1-Site Map of Tilaiya Reservoir

1.1.1 Purpose:

The primary purposes of Tilaiya Reservoir are flood control, Irrigation, power generation and water supply are some of other important purposes.

1.2 Reservoir Description:

The Dam is 1200 ft long and 99 ft high situated in beautiful natural sceneries which attract the tourists. The Water spread area of the reservoir is 36 Sq. km, built with the main object of controlling floods, the hydro -electric station produces 4 MW power. The main road from Barhi on G.T.Road through reservoir and the hillocks is picturesque.

1.3 Basin Description:

The Catchment area of the Tilaiya Reservoir is 984 km^2. The Drainage area of Tilaiya reservoir is 380 Sq. miles (984.2 Sq.km). The Elevation of the Stream bed is 1,135 ft (345.95 m). The Average Annual basin precipitation is 44 in (111.76 cm). The Average annual runoff is 3, 50,000 Ac-ft. The Spillway has a discharging capacity of about 1, 35000 Cusec at maximum reservoir level.

1.4 Hydrology:

The Damodar Valley experiences a well defined monsoon which is normally confined to the period from the middle of June to early October. The annual rainfall of the basin averages to above 50 inches (1270 mm). About 90 to 95 percent of the total annual rainfall occurs during the monsoon when all major floods occur. The volume of flow during the monsoon averages to about 90 percent of the total annual flow. During the dry periods, November to through May, there is extended periods of little or no flow in the main stream and its tributaries.

Heavy rainfall in this region is generally caused during the passage of cyclonic depressions which form at the head of the Bay of Bengal during the monsoon period, June through October, and travel in a north-westerly direction. Sometimes, depressions which form overland also cause intense precipitation.

2.0 Description about Sedimentation:-

Reservoir sedimentation is the gradual accumulation of the incoming sediment load from a river. This accumulation is a serious problem in many parts of the world and has severe consequences for water management, flood control, and production of energy. The gradual process of sedimentation proceeds with different speeds that depend on a large number of factors, such as hydrology of the catchments and the characteristics of the river basin. Sediment will eventually fill a reservoir within 50–200 years. Here, the crucial point is the fact that reservoir sedimentation is just a symptom of erosion of the topsoil. The principal causes are anthropogenic activities such as deforestation, and overgrazing. The complexity of the problem increases when the anthropogenic activities interact with natural changes imposed by the dynamic nature of climate and the earth surface.

2.1 Causes of Sedimentation in a Reservoir:-

Trapping sediment behind a Reservoir not only causes sediment to accumulate in the reservoir, but simultaneously results in a decreased sediment supply to the downstream river channel and a hungry water condition, which often results in downstream erosion of the stream bed and banks, and a coarser bed.

All rivers contain sediments a river, in effect, can be considered a body of flowing sediments as much as one of flowing water. When a river is stilled behind a Reservoir, the sediments it contains sink to the bottom of the reservoir.

Trap efficiency can be defined as the ratio between the total sediment deposited in a reservoir and the total sediment flowing in the river for a certain period. Therefore, Trap efficiency is:-

$$\frac{\text{Total Sediment deposited in the Reservoir}}{\text{Total Sediment Flowing in the River}}$$

– Known as its "trap efficiency" – approaches 100 per cent for many projects, especially those with large reservoirs. As the sediments accumulate in the reservoir, so the Reservoir gradually loses its ability to store water for the purposes for which it was built. Every reservoir loses storage to sedimentation although the rate at which this happens varies widely. Despite more than six decades of research, sedimentation is still probably the most serious technical problem faced by the Reservoir industry.

The rate of reservoir sedimentation depends mainly on the size of a reservoir relative to the amount of sediment flowing into it: a small reservoir on an extremely muddy river will rapidly lose capacity; a large reservoir on a very clear river may take centuries to lose an appreciable amount of storage. Apart from rapidly filling their reservoirs, sediment–filled rivers also cause headaches for Reservoir operators due to the abrasion of turbines and other Reservoir components. The efficiency of a turbine is largely dependent upon the hydraulic properties of its blades, just as an Aeroplane depends on the aerodynamic properties of its wings. The erosion and cracking of the tips of turbine blades by water–borne sand and silt considerably reduces their generating efficiency and can require expensive repairs.

2.2 Description about N.H.P:-

NHP will improve and expand hydrology data and information systems, strengthen water resources operation and planning systems, and enhance institutional capacity for water resources management. The project will thus strengthen the information base and institutional capacity for evidence-based decision making in water resources planning and operational management at the basin scale across India using the latest technology and tools. NHP will contribute to the GOI Digital India initiative by integrating water resources information across state and central agencies.

NHP will span both states that benefitted from HP-I and HP-II investments and states that were not included in the earlier projects. In the new states, investments will be needed to move beyond existing basic infrastructure, following the approaches developed in the earlier projects. For HP-I and HP-II states, investment will focus on upgrading and completing networks. For all states, the focus will be on using the information generated for water planning and management.

The expectation is that knowledge, open access and stronger institutional capacity will contribute to a shift towards integrated water resources management at the basin scale. The resulting improved water allocation and use efficiency and the improved management of drought and flood risks are expected to bring substantial socio-economic benefits.

2.3 Survey by Precision Survey Consultancy:-

Precision Survey Consultancy conducted **"Sedimentation Survey Report of Tilaiya Reservoir under NHP" No-M/C&M/NHP/LOA/804 Dated-31.01.2019.**

2.4 Weather:-

The survey was undertaken during the month of 'from November to December, 2019. The Temperatures became average for the Topographic survey and Bathymetry Survey.

3.0 Project Site Location Map of Tilaiya Reservoir:-

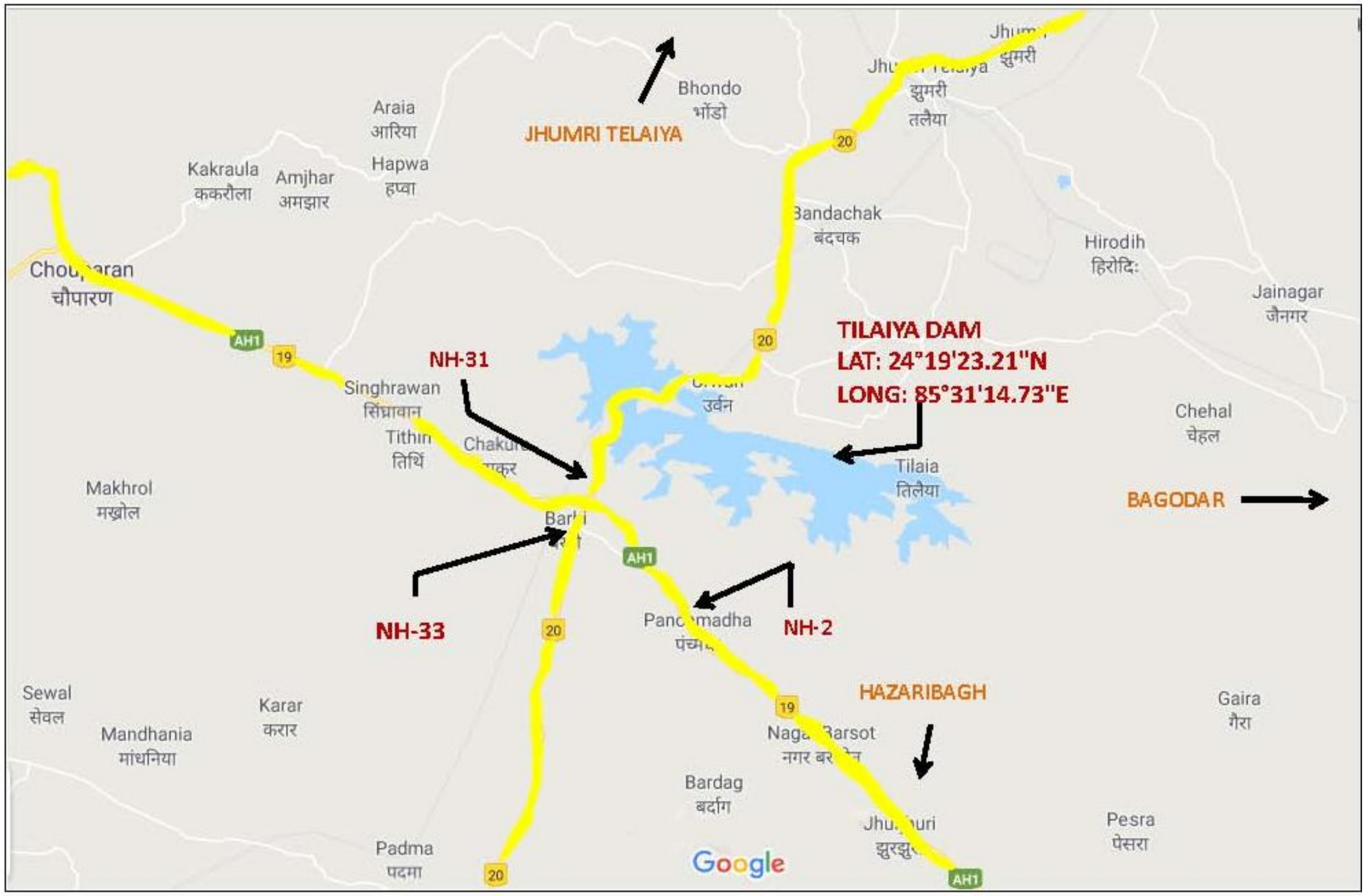


Figure 2-Project site location Map of Tilaiya Reservoir

4.0 Scope of Work:-

The scope of the work includes:-

Brief Description of the work	Intended Completion period
Sedimentation Survey Report of Tilaiya Reservoir under NHP No-M/C&M/NHP/LOA/804 Dated-31.01.2019.	

The Objective of Sedimentation survey is in the following:-

A. Request of Proposal:-

a. Mobilization of Personnel, equipments, instruments, establishment of site camp etc.

b. Lay out of Ground control stations including reconnaissance/Preliminary Surveys, if any.

c. Conduct Hydrographic and Topographic Survey to cover the entire area of the reservoir up to maximum water level (100 m x 100 m grid for hydrographic survey and 100 m x 100 m grid for topographic survey). For small reservoirs (water spread area less than 30 sq.km.), grid of 50 m x 50 m shall be adopted for both hydrographic and topographic survey.

d. Collection and analysis of sediment samples from the reservoir bed with not less than 10 samples covering the entire area of the reservoir. Location of the collection points should be clearly indicated on a map.

e. Collection of information from project authorities/any other agency including data on sediment yield from the upstream free catchment of the reservoir as well as accounting for the effect of upstream reservoirs, if any and incorporating of the same while writing the report.

f. Analysis of data to obtain elevation-area-capacity table/curves, contour plots, balance life of reservoir, cross sections, L-sections, vertical sediment distribution curve/table, estimation of sedimentation in different zones of reservoirs, mathematical modeling studies etc. keeping in line with the objectives laid down for the study.

g. Preparation of Report containing general information about the reservoir, catchment characteristics, details of capacity survey performed including methodology of data collected, analysis of data with standard guidelines/Procedures, finding of results, conclusion and recommendations keeping in view the objective of the study to the satisfaction of DVC.

h. Any difficulties/special problem encountered during the course of the study and how they were overcome may be included in the report.

i. The work shall be completed by the agency in twelve months time with effect from 21 days after the agreement has been signed.

B. Equipments Preferred:-

High-technology equipments like integrated Hydrographic Survey System which should include recording type echo sounder and computer software for interfacing and recording the position and depth data in real time. GPS Survey technology is essential.

C. Capacity Survey:-

a) Hydrographic Survey

Computer based Hydrographic survey shall be carried out within the water spread area so that reservoir area under water is covered at 100 m x 100 m grid. For small reservoirs (water spread area less than 30 Sq.km.), grid of 50 m x 50 m shall be adopted.

b) Topographic Survey

The Area not covered under Hydrographic Survey up to MWL shall be surveyed by taking levels at 100 m. interval along range lines laid at 100 m interval. (100 m x 100 m grid). For small reservoirs (water spread area less than 30 sq.km.), grid of 50 m x 50 m shall be adopted.)

c) Collection of bed materials samples

Not less than 10 samples of the bed material shall be collected as per standard methods prescribed in APHA 1989 (American public health Association) covering the entire area of the reservoir to obtain sediment sizes, density, specific gravity, moisture content etc. Depth and location of sample collection are to be mentioned.

D. Data Analysis/Preparation of Tables/Charts/Drawings:-

After Completion of the capacity survey, the survey data shall be analyzed by the consultant to obtain the following:-

i) Elevation-Area-Capacity Curves as well as table

Elevation–Area-Capacity curve along with table will be prepared from the lowest elevation up to MWL at 1.0 m or less interval.

ii) Assessment of effects of sedimentation on performance of reservoir and balance life of reservoir

Assessment of sediment and its distribution in the reservoir shall be made and likely effects of such sedimentation on the performance of the reservoir shall be assessed. While analyzing the Reservoir data, the validity of Empirical area reduction method using data of silt deposition collected during survey may also be checked out. The Elevation-Area-Capacity curve and L-Section may be produced for another 100 years at 10 years interval by conducting mathematical modeling studies. The Consultant may refer to various standards/references including I.S. 12182-1987 “Guidelines for determination of effects of sedimentation in Planning and Performance of reservoir", C.B.I & P publication on the subject and I.S. 5477 Part-II "Fixing capacities of Reservoirs-Dead storage".

Separate Chapters are to be included in the report for "Sedimentation Analysis", "Life of Reservoir", "Mathematical modeling", "Soil Conservation Measures "and "Conclusions and Recommendations".

A sample calculation is to be shown for each: Estimation of rate of sedimentation, expected life of reservoir, prediction of sediment distribution etc. Future sediment calculations shall be based on every 10 years block.

iii) Estimation of sedimentation in different zones of reservoir:

Loss of storage capacity and rate of sedimentation shall be worked out in each vertical zone separately viz. dead storage, live storage and flood storage, if any. An assessment of the sedimentation behaviors' in different horizontal zones throughout the reservoirs may also be made.

iv) Analysis of Bed material samples

Laboratory analysis of the bed material samples collected from the reservoir bed be carried out to obtain sediment sizes, density, specific gravity, moisture content etc.

Analysis of samples should also be aimed to evaluate geometric standard deviation to know whether the sediment is uniform or non uniform (Melville et al.). Kramer's coefficient shall also be evaluated. Method of calculation of bulk density (Lane's method or miller's method or some other method) is to be mentioned.

v) Cross sections

Cross sections showing the original bed profile, if available and subsequent repeat surveys at every 1 km shall be provided. Raw data of cross sections at every survey line (100 m interval) shall be provided as soft copy in CD to DVC.

Officers of DVC shall be trained on the relevant software at Consultants' office for conversion of raw data into analog form during stage-3 analysis part of the survey.

vi) L-section

L-Section of the reservoirs may be prepared with the lowest bed levels at every survey line.

vii) Vertical sediment Distribution

Vertical sediment distribution curve/table shall be provided. Plot between percent reservoir depth and percent sediment deposited is to be plotted as per IS 5477 PART-II 1994. "Fixing capacities of reservoirs-Dead storage".

viii) Contour map of the reservoir

The Contour map shall be prepared in appropriate size preferably in A0 size with contour at suitable interval from the lowest bed level to MWL (Maximum water level).

ix) Trap Efficiency of Reservoir

The trap efficiency of reservoir is to be calculated according to Brune's trap efficiency curve as per I.S 12182-1987 "Guidelines for determination of Effects of Sedimentation in planning and performance of Reservoirs".

x) Charts/drawings for the Report

All charts/drawings shall be appropriately reduced for inclusion in the report.

xi) The entire data observed during hydrographic survey by the consultant and the subsequent report prepared by him shall be the exclusive property of DVC and the consultant has no right whatsoever to divulge the information/data to others without the specific written permission of DVC.

5.0 Authentic Reference level:-

For the Topographic / Hydrography Survey, the Level has been carried out from the **Gauge level of Tilaiya Reservoir (RL-371.00m) and the level is transferred to the Temporary Bench Mark (TBM) named as BM-1**which is tabulated below :-

Location	BM/CP	Easting (m)	Northing (m)	Latitude (N)	Longitude (E)	Elevation (m)
Tilaiya Reservoir	BM-1	349790.219	2690969.707	24°19'28.729"	85°31'10.357"	370.182

Figure 3-Authentic reference level of Tilaiya reservoir

6.0 Conduct of survey work

6.1 Topographical Survey with RTK:-

The Topographic survey was conducted to ascertain following in the survey area:-

- Spot levels
- High bank Line
- Low Bank Line
- Fixing of bridges / cross structure and marks.
- Collection of local information along the river Banks

The spot levels/Topographical Survey along the reservoir was obtained by using GPS/RTK technique. Local terrain and limitation of line of sight visibility prohibited the use of optical techniques for obtaining spot levels. In the GPS/RTK spot leveling technique being used, the GPS /RTK control was extended using the co-ordinates and height of the recovered geodetic station established to various BM in the respective stretches. These BM were then used as reference stations for deriving the spot levels of the rover locations in the Stop-Go method. The details of all spot levels are provided in the respective sheets being presented along-with this report. Additionally, a soft copy of the same in XYZ format is being handed over as deliverable data.

- **Projection** - **UTM (*Universal Transverse Mercator coordinate system)***
- **Spheroid** - **WGS 84**
- **Vertical Datum** - **M.S.L**
- **Grid** - **UTM North (45 N)**
- **Scale factor** - **As per requirement**

Figure 4- During Topographical Survey with RTK

7.0 Data Processing:-

The Topographic data collected during the field work was processed and analyzed using the proprietary data processing software. The following flow chart explains the sequence and process of digital data processing:-

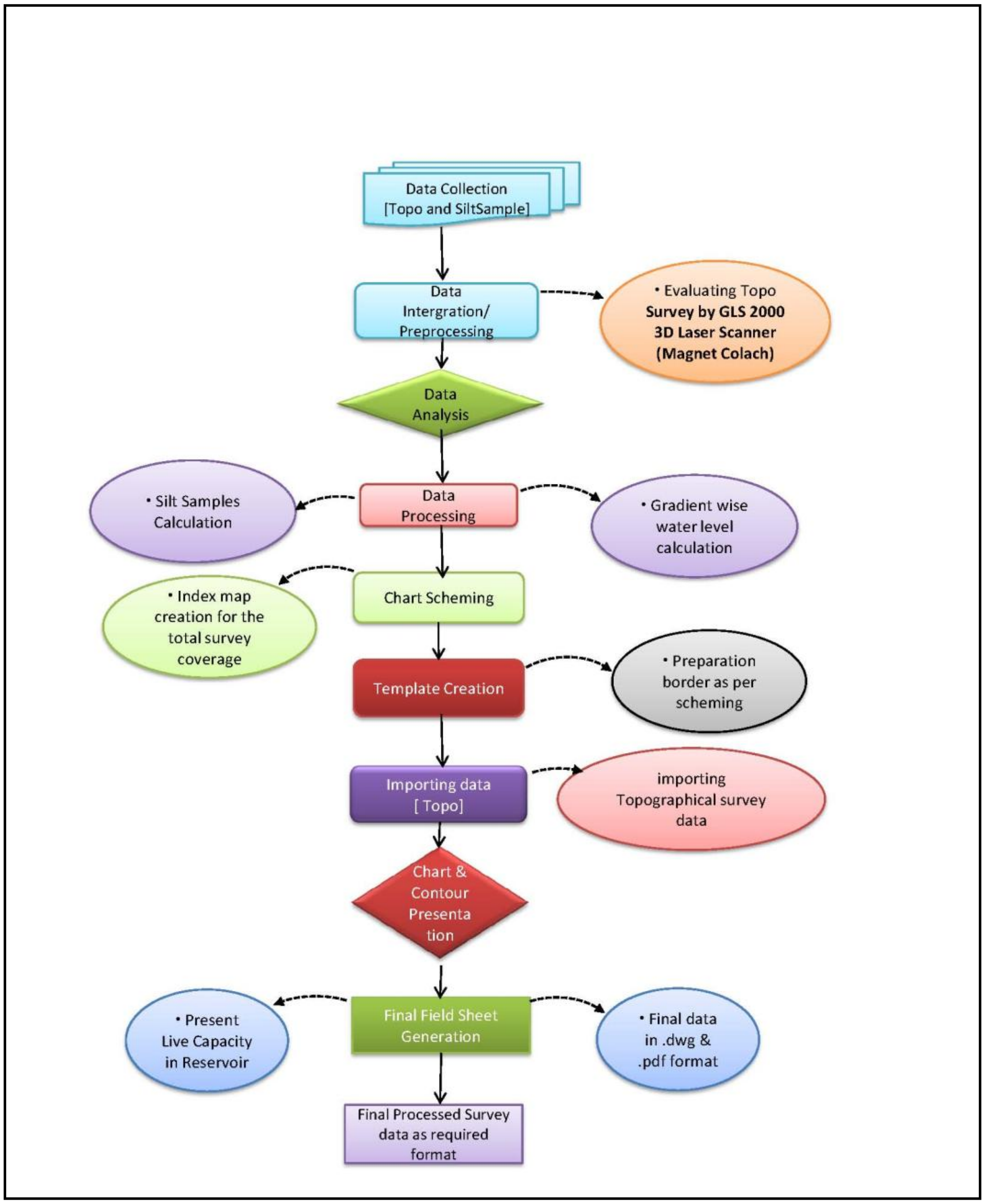


Table 1-Data Processing

8.0 Hydrography Survey:-

Bathy 500 MF was used to obtain soundings onboard the survey boat. A working frequency of 210 KHz was used for sounding operations. The digital output from the echo sounder was automatically fed to the HYPACK data logging software on a real-time basis for the acquisition of survey data. No breakdown of equipment was reported and the performance of the equipment was found to be satisfactory during the entire duration of the survey.
The sound velocity was set to 1499 m/s on single beam echo sounder during acquisition by the Bar check procedure method. The Daily bar checks were done prior to the sounding operation and before the closing of the sounding operation for the day. Being very shallow depths, the echo sounder depths were also cross-checked in between by using demarcated sounding poles during the conduct of the survey. The sounding lines were run using Survey boat to identify the design line of the Tilaiya Reservoir for the possible stretch. The cross lines were run perpendicular to the orientation of Canal flow (i.e. perpendicular to the orientation of depth contours) in respective stretches. The spot sounding was also carried out in the area where the survey boat cannot be operated due to low depth. The hemisphere DGPS and Sounding Pole were used for Spot sounding at shallow locations in the Tilaiya Reservoir. The DGPS position along with water depths was recorded simultaneously and the tidal reduction was applied to the obtained depths.

Bathy- 500MF Echo Sounder: The Bathy-500MF Echo Sounder is an electronic hydrographic survey instrument used for measuring depths with precision chart recordings and digital data output manufactured by SyQuest incorporated, USA. The Bathy-500 echo sounding systems are based on the principle that when a sound signal is sent into the water it will be reflected back when it strikes an object. The Bathy-500 is technologically sophisticated, utilizing modern, micro processor based electronics and a thermal chart recorder mechanism. Digital processing enables the instrument to offer fully automatic digitizing capabilities. When interfaced to a NMEA 0183 compatible position sensor, it provides user with a complete, integrated hydrographic survey environment. The instrument front panel consists of a high contrast, backlit four line LCD displays and a fully sealed input keypad. The front panel encompassing system data, status and setup parameters with RS232/RS422 output format. All operating functions are set via the front panel interface. Setup selections are stored within internal, non-volatile memory for instant availability upon power-up. The instrument decodes and processes the NMEA 0183 formatted sentence GGA or GLL from GPS/DGPS using variable Baud rates for communication.

8.1 Explanation Regarding the Methodology of Survey Work:-

1. Firstly we engaged a boat to survey the project site with equipped machineries.

2. We deployed Real Time Kinematics (RTK) with 20mm vertically & 10mm horizontally capability.

3. RTK had been shown the X & Y value.

4. In addition with this we engaged Echo-Sounder to calculate the depth. **Bathy 500MF** was used to obtain soundings on board the survey launches. A working frequency of 210 KHz was used for sounding operations. The digital output from the echo sounder was fed to the navigation data logging software for acquisition of survey data in real time. The performance of the echo sounder was found to be satisfactory during the entire duration of the survey.

5. We kept Power navigation software to interface RTK & ECHO Sounder.

6. Hypack navigation software helped to show the final date at the surveyed area.

7. Verification of water level in the reservoir have constantly been monitored (manually from outside reservoir) during hydrographic survey which have been used in operating Echo-sounder for measuring depth correctly.

8. Thus finally we got the result i.e. water level – depth.

Figure 5-During the Hydrography Survey in Tilaiya Reservoir

8.2 Hydrography Survey Process:-

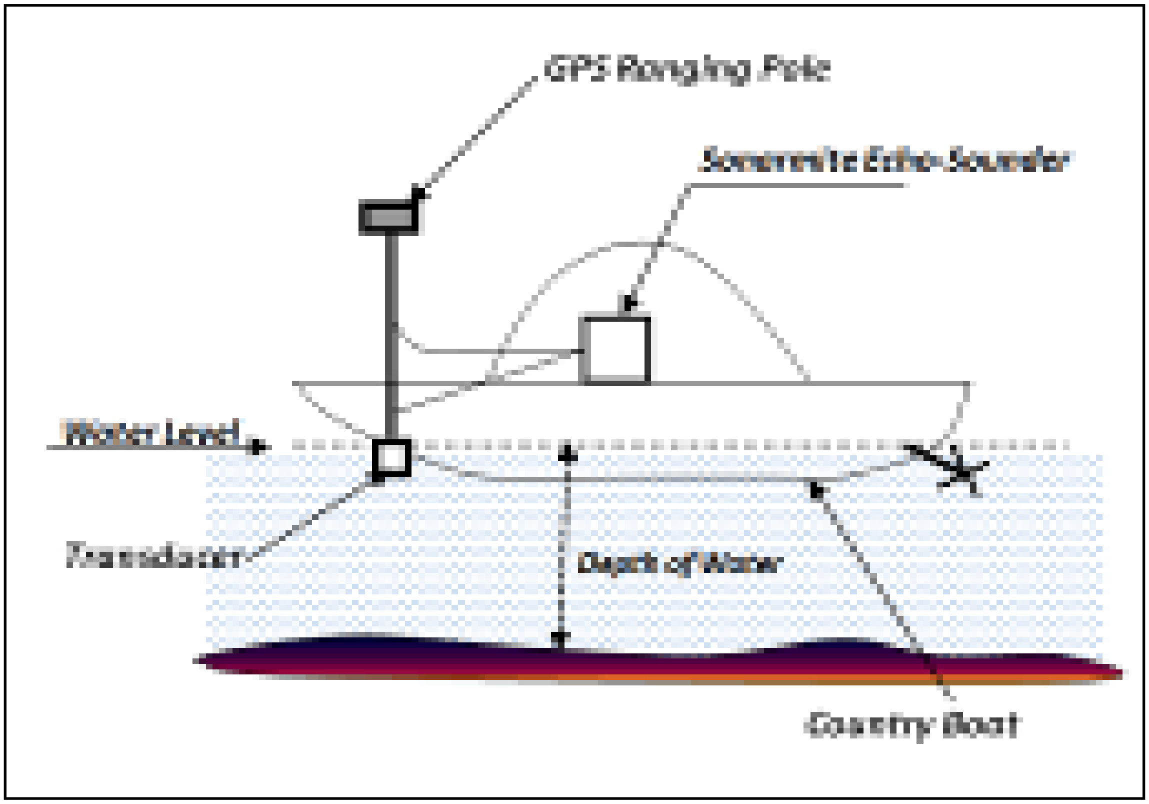


Figure 6-Schematic diagram showing the sequence of operation

8.3 Hypack Data Processing System:-

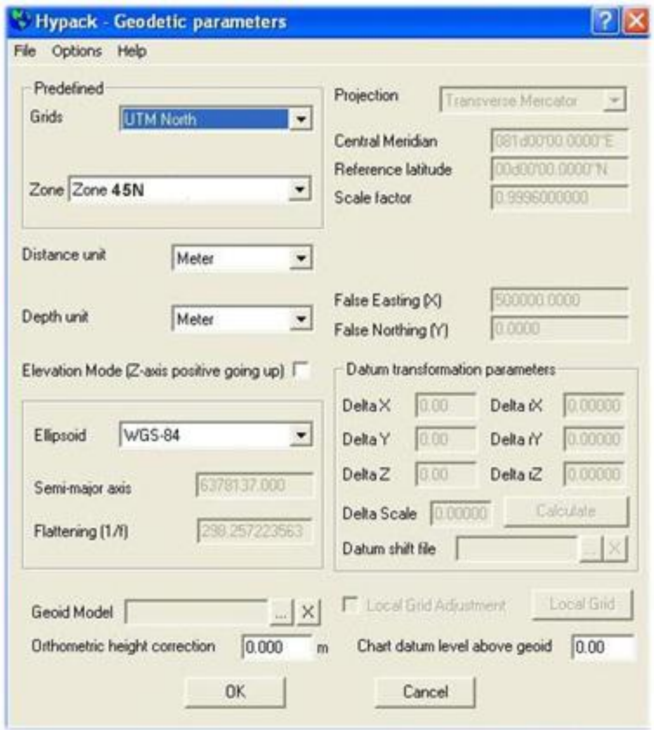


Figure 7-Hypack Data Logging, Geodetic Parameters

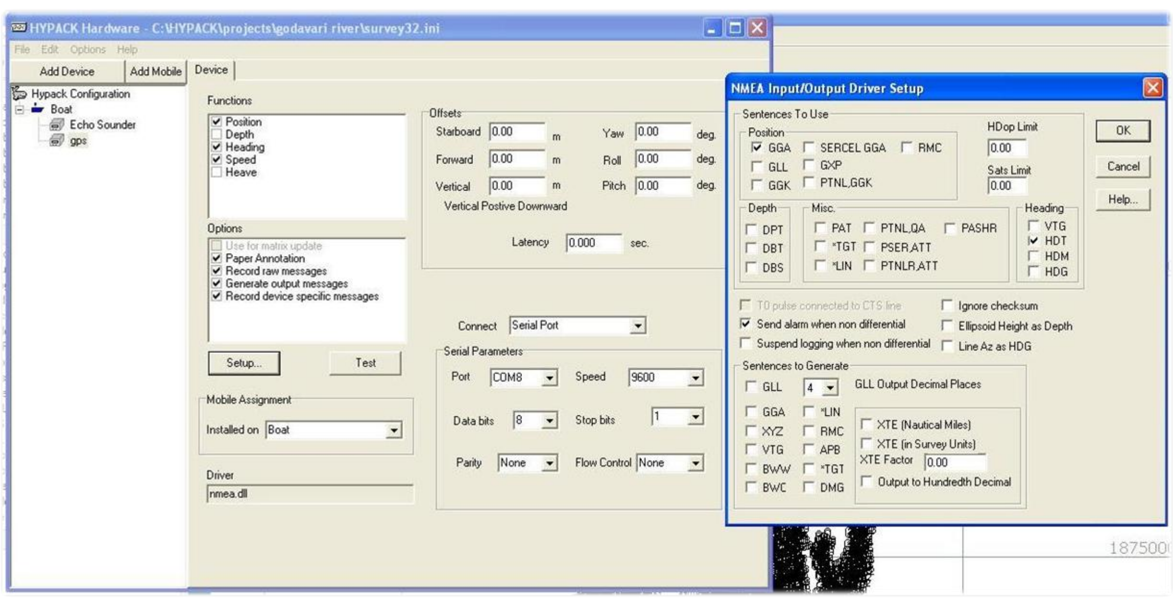


Figure 8-Hypack Data logging, Navigation I/P settings

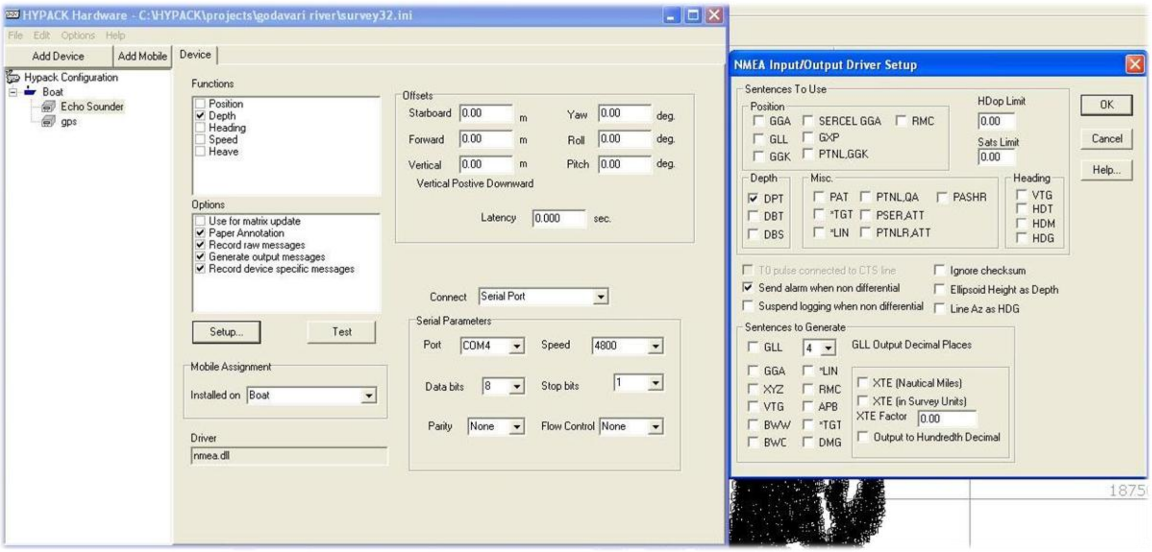


Figure 9-Hypack Data Logging, Echo-sounder I/P settings

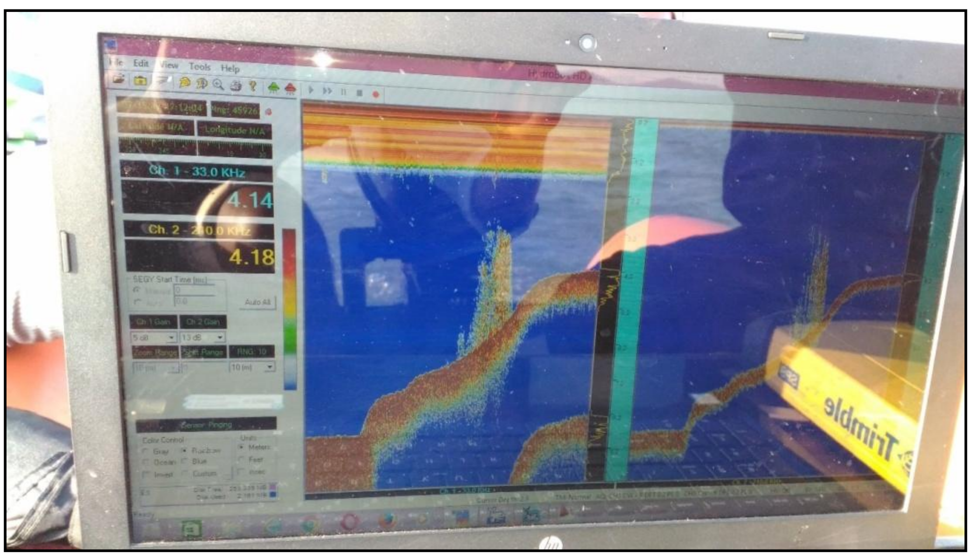


Figure 10-Hypack data processing

9.0 Soil Sample Position:-

The Soil samples (13 no's) are collected from various locations near Tilaiya Reservoir which are tabulated below. The location maps of soil samples are also indicate in the next pages (page no-21) with the same Coordinate. The Distance has been measured from each sample to next sample.

Sample No	Distance (mtr)	Northing (m)	Easting (m)	Latitude (N)	Longitude (E)
1	0.00	2688925.67	351273.9	24°18'22.80"	85°32'3.75"
2	1096.63	2689951.3	350844.33	24°18'55.99"	85°31'48.13"
3	1137.76	2690568.45	349887.53	24°19'15.72"	85°31'13.96"
4	1305.18	2690000.88	348729.24	24°18'56.87"	85°30'33.09"
5	1464.38	2689203.4	347503.23	24°18'30.52"	85°29'49.91"
6	1994.82	2691196.52	347635.27	24°19'35.35"	85°29'53.83"
7	1170.17	2690376.43	346827.44	24°19'8.41"	85°29'25.49"
8	2015.66	2690288.55	344817.72	24°19'4.84"	85°28'14.24"
9	1360.70	2691671.64	344916.09	24°19'49.83"	85°28'17.19"
10	1456.62	2691971.96	343491.85	24°19'59.08"	85°27'26.55"
11	1834.87	2692241.81	341670.12	24°20'7.19"	85°26'21.82"
12	1731.63	2693427.25	341041.6	24°20'45.49"	85°25'59.05"
13	2501.15	2693908.55	340514.87	24°21'0.94"	85°25'40.17"

Table 2-Soil sample positions

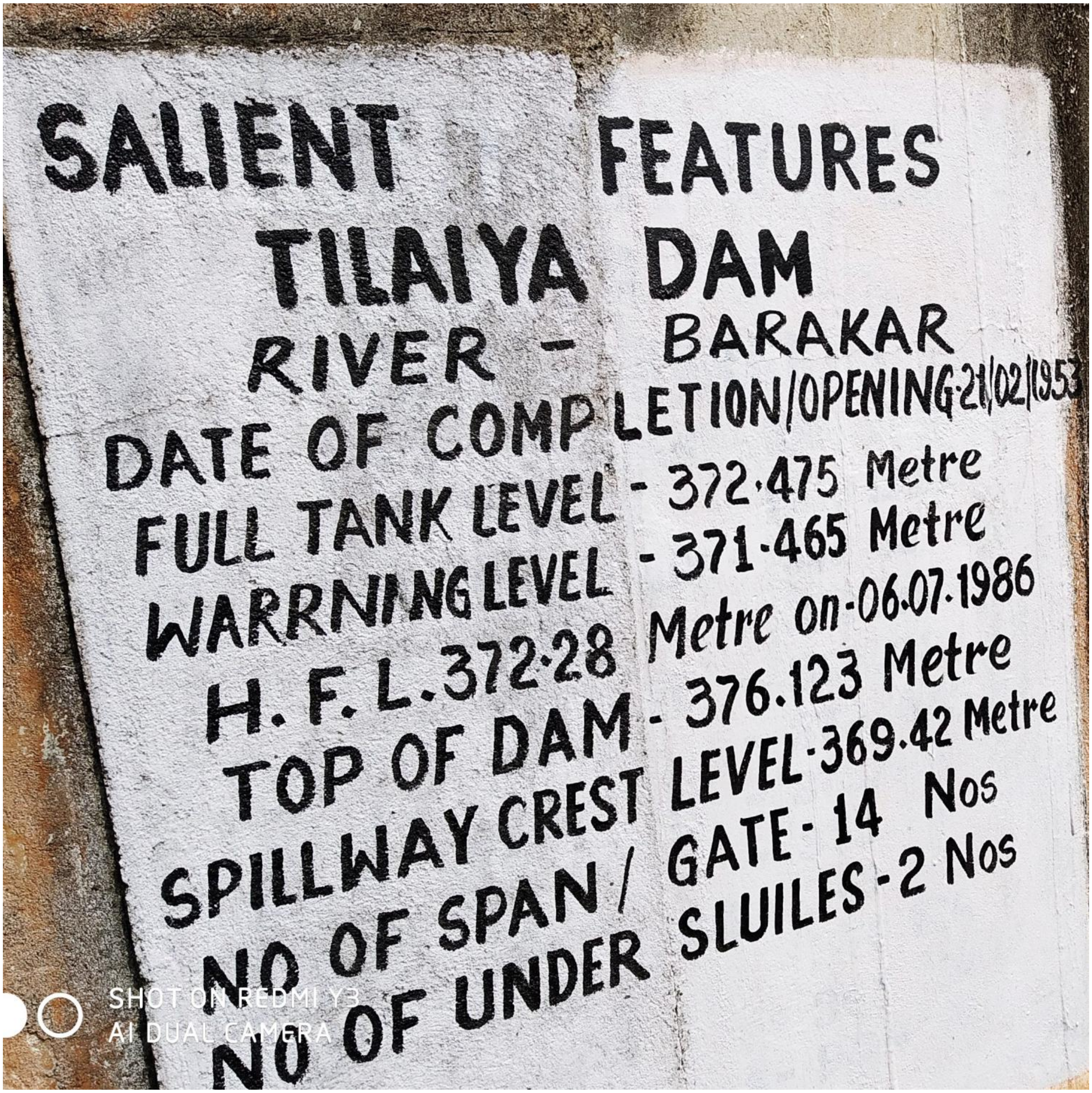
9.1 Google image of Soil Sample locations:-

Figure 11-Soil sample locations

10.0 Salient Features of Tilaiya Reservoir:-

Salient Features of Tilaiya Reservoir, DVC		
General	Inauguration	21.02.1953
	River	Barakar
	District	Koderma
	State	Jharkhand
Hydrological	Catchment Area(km^2)	984
	Avg. Annual Precipitation (cm)	112
	Avg Annual runoff (MCM)	432
Structural	Type	Concrete gravity
	Maximum Height above foundation (m)	30.18
	Type of Spillway	Ogee
	Crest gate type	Tainter
	Crest gate Number	14
	Crest gate size (maxim)	9.14 x 3.05 (Sq. m)
	Under sluice type	Butterfly
	Under sluice Number	2
	Under sluice size (maxim)	1.66 x 1.02 (Sq. m)
Reservoir	Dead storage level (m) above MSL	363.32
	Dead storage (MCM)	140.62
	Conservation level (m) above MSL	368.80
	Conservation Storage (MCM)	194.90
	Max. Utilizable Flood Management level (m) above MSL	372.46
	Flood Management storage (MCM)	214.62
Power	Installed Capacity	4 MW
	Type of Turbine	Vertical Shaft Francis
	Maximum Head	19.51

Table 3- Salient features of Tilaiya Reservoir


SALIENT FEATURES
TILAIYA DAM
RIVER - BARAKAR
DATE OF COMPLETION/OPENING-21/02/1953
FULL TANK LEVEL - 372.475 Metre
WARRNING LEVEL - 371.465 Metre
H. F. L. 372.28 Metre on-06.07.1986
TOP OF DAM - 376.123 Metre
SPILLWAY CREST LEVEL-369.42 Metre
NO OF SPAN / GATE - 14 Nos
NO OF UNDER SLUILES - 2 Nos
SHOT ON REDMI Y3
AI DUAL CAMERA

11.0 Survey Equipments:-

SERIAL NO.	EQUIPMENT NAME	MODEL NO.
1	ECHO SOUNDER	BATHY-500 MF (SYQWEST)
2	BEACON RECEIVER	TRIMBLE SPS-361
3	DGPS	TRIMBLE SPS-986
4	DGPS	SP-80
5	SOIL SAMPLER	VANVEEN GRAB
6	HYPACK NAVIGATION SOFTWARE	VERSION-19
7	AUTOCAD/CIVIL 3D	2015
8	MICROSOFT OFFICE	2015

Table 4- Details of equipment lists

- Positioning System:-

- 1 no Trimble DGPS system (SPS361)

Figure 12- DGPS Survey Instrument

- Navigation & Data Logging System:-

- To provide on-line route guidance, log navigation data, provide QC of navigation data, etc. The system comprises the following equipment:-
- 1 no. DELL Laptop
- 1 no. Hypack version 2019 Navigation & Data Logging Software
- 1 no. Positioning & sensor interfaces
- Sufficient Paper Rolls

- Single Beam Echo Sounder System:-
  - 1 no. Bathy 500MF multi frequency Echo sounder
  - 1 no. transducer 210 kHz + mounting bracket & base plate

Figure 13- Echo Sounder Instrument (Bathy 500 MF)

- 1no DGPS (Trimble SPS-986)

- 1no Soil Sampler (Van veen grab):-

12. Calibration:-

The equipment used for the survey was calibrated by the equipment supplier. The equipment calibration certificates are placed here to:-

12.1 Echo-Sounder Calibration:-

PAN INDIA CONSULTANTS PVT. LTD.

SALES DEPARTMENT

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CALIBRATION CERTIFICATE

CUSTOMER NAME	:	PRECISION SURVEY CONSUTLANCY
ADDRESS	:	P.O. –SALAP, P.S.-Vichitra SP-45,KWIC NH-6, Dist. –Howrah Pin: 711 403 W.B
INSTRUMENT	:	Echo Sounder
SERIES	:	Bathy 500 MF
SERIAL NO.	:	B5MF0560
CALIBRATION DATE	:	17/03/2019
VALIDITY	:	16/03/2020

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENT WAS CHECKED AND CALIBRATED IN ACCORDANCE WITH THE APPLICABLE FACTORY PROCEDURES.

for PAN INDIA CONSULTANTS PVT. LTD.

Pan India Consultants Pvt. Ltd. Gurgaon

AUTHORISED SIGNATORY

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e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 14- Calibration Certificate of Echo-Sounder (Bathy 500MF)

12.2 Trimble SPS-986:-

PAN INDIA CONSULTANTS PVT. LTD.

SALES DEPARTMENT

CORPORATE ADDRESS : 105, PHASE IV, UDYOG VIHAR, GURGAON-122015, HARYANA, INDIA
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e-mail : paie@panindiagroup.com, paie@vsnl.com, www.panindiagroup.com

CALIBRATION CERTIFICATE

CUSTOMER NAME	:	PRECISION SURVEY CONSULTANCY
ADDRESS	:	Vichitra –SP-45, KWIC, NH-6 Crossing, P.O. –Bankra, P.S.-Domjur, Dist. –Howrah Pin: 711 403
INSTRUMENT	:	GNSS Receiver
SERIES	:	SPS-986
SERIAL NUMBER	:	5831F00023
CALIBRATION DATE	:	22/03/2019
VALIDITY	:	21/03/2020

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AUTHORISED SIGNATORY

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e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 15- Calibration Certificate of SPS-986

12.3 G.P.S Beacon Calibration SPS-361:-

PAN INDIA CONSULTANTS PVT. LTD.

SALES DEPARTMENT

CORPORATE ADDRESS : 105, PHASE IV, UDYOG VIHAR, GURGAON-122015, HARYANA, INDIA
PHONES : +91 124 4300950, 4013954. FAX : +91 124 2346646, 2342880, CIN - U74899DL1985PTC021177
e-mail : paie@panindiagroup.com, paie@vsnl.com, www.panindiagroup.com

CALIBRATION CERTIFICATE

CUSTOMER NAME	:	PRECISION SURVEY CONSUTLANCY
ADDRESS	:	Vichitra SP-45, KWIC Bankra, P.S. - Domjur, Dist. –Howrah, Pin: 711 403 (W.B)
INSTRUMENT	:	Beacon Receiver
SERIES	:	SPS-361
SERIAL NUMBER	:	5431R03128
CALIBRATION DATE	:	05/03/2019
VALIDITY	:	04/03/2020

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENT WAS CHECKED AND CALIBRATED IN ACCORDANCE WITH THE APPLICABLE FACTORY PROCEDURES.

For **PAN INDIA CONSULTANTS PVT. LTD.**

AUTHORISED SIGNATORY

REGD. OFFICE : OFFICE NO. 1, D-4, COMMERCIAL AREA, VASANT KUNJ, NEW DELHI-110070, INDIA
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Figure 16-Calibration Certificate of SPS-361

DATA ANALYSIS/PREPARATION OF TABLES/CHARTS/DRAWINGS

ELEVATION AREA CAPACITY CURVE AS WELL AS TABLE

This Section has been analyzed the Elevation area capacity curve along with table which has been prepared from the lowest elevation up to MWL at 0.3 m interval.

13.0 Detail Analysis of Area Capacity Curve:-

13.1 Elevation Area Capacity curves as well as table:-

The Capacity Curve formula and Curve (Capacity Graph) has been shown respectively tabulated below:-

The Elevation area capacity table has been computed by the **Average end area formula**; that is equal to-

$h/2\ (A_1+A_2) = V$ (as per I.S. 5477 part-II-1994**)**

Where

h=the height of the segment (Contour interval)

A_1 and A_2=the contour area at the end of the segment and

V= the volume of the segment (Volume between two consecutive contour)

I.S. 5477 part-II-1994

computed by the average end area formula, that is equal to:

$$\frac{h}{2}(A_1 + A_2) = V \qquad \text{...... (6)}$$

where

h = the height of the segment,

A_1 and A_2 = the areas at the end of the segment, and

V = the volume of the segment.

Tilaiya Reservoir_ Detail Analysis for Elevation and Area Capacity Table 2019						
SL.NO.	Contour EL (m)	Contour Interval	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between two consecutive contour surface (in Cum.)*	Cumulative Vol. *(in M-Cum.)*
1	346.0	0.0	5509.905	0.551	0.000	0.00
2	346.3	0.3	9858.239	0.986	2305.222	0.00
3	346.6	0.3	12206.573	1.221	3309.722	0.01
4	346.9	0.3	19554.908	1.955	4764.222	0.01
5	347.2	0.3	35765.062	3.577	8297.996	0.02
6	347.5	0.3	55906.128	5.591	13750.678	0.03
7	347.8	0.3	65047.193	6.505	18142.998	0.05
8	348.1	0.3	78140.406	7.814	21478.140	0.07
9	348.4	0.3	99137.916	9.914	26591.748	0.10
10	348.7	0.3	106135.427	10.614	30791.001	0.13
11	349.0	0.3	127132.937	12.713	34990.255	0.16
12	349.3	0.3	158791.532	15.879	42888.670	0.21
13	349.6	0.3	210450.128	21.045	55386.249	0.26
14	349.9	0.3	272108.723	27.211	72383.828	0.34
15	350.2	0.3	298936.639	29.894	85656.804	0.42
16	350.5	0.3	358349.216	35.835	98592.878	0.52
17	350.8	0.3	437761.793	43.776	119416.651	0.64
18	351.1	0.3	559186.588	55.919	149542.257	0.79
19	351.4	0.3	714635.820	71.464	191073.361	0.98
20	351.7	0.3	770085.053	77.009	222708.131	1.20
21	352.0	0.3	835534.285	83.553	240842.901	1.44
22	352.3	0.3	889329.577	88.933	258729.579	1.70
23	352.6	0.3	933124.869	93.312	273368.167	1.98
24	352.9	0.3	976920.161	97.692	286506.755	2.26
25	353.2	0.3	1030111.464	103.011	301054.744	2.56

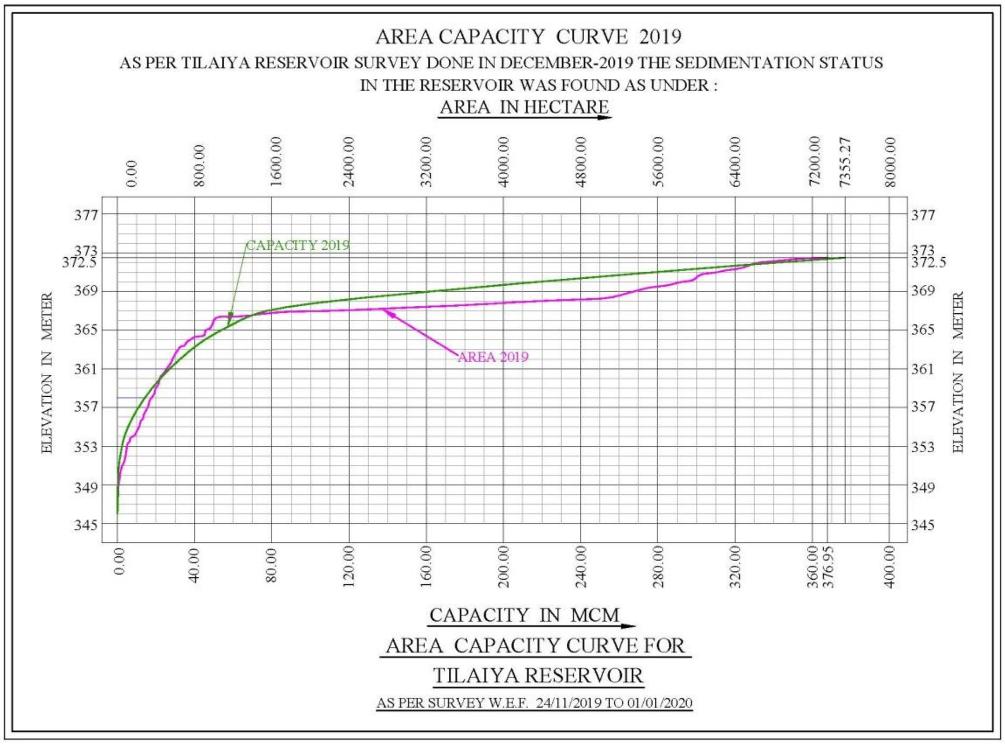
Tilaiya Reservoir_ Detail Analysis for Elevation and Area Capacity Table 2019						
SL.NO.	Contour EL (m)	Contour Interval	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between two consecutive contour surface (in Cum.)*	Cumulative Vol. *(in M-Cum.)*
26	353.5	0.3	1273000.773	127.300	345466.836	2.91
27	353.8	0.3	1315890.081	131.589	388333.628	3.30
28	354.1	0.3	1766009.528	176.601	462284.941	3.76
29	354.4	0.3	1930589.253	193.059	554489.817	4.31
30	354.7	0.3	2095168.979	209.517	603863.735	4.92
31	355.0	0.3	2259748.704	225.975	653237.652	5.57
32	355.3	0.3	2337098.389	233.710	689527.064	6.26
33	355.6	0.3	2414448.073	241.445	712731.969	6.97
34	355.9	0.3	2669147.442	266.915	762539.327	7.74
35	356.2	0.3	2717041.898	271.704	807928.401	8.54
36	356.5	0.3	2866233.266	286.623	837491.275	9.38
37	356.8	0.3	3015424.634	301.542	882248.685	10.26
38	357.1	0.3	3175033.253	317.503	928568.683	11.19
39	357.4	0.3	3255476.374	325.548	964576.444	12.16
40	357.7	0.3	3335919.496	333.592	988709.381	13.14
41	358.0	0.3	3516362.617	351.636	1027842.317	14.17
42	358.3	0.3	3752560.503	375.256	1090338.468	15.26
43	358.6	0.3	3888758.389	388.876	1146197.834	16.41
44	358.9	0.3	3924956.275	392.496	1172057.200	17.58
45	359.2	0.3	4134716.327	413.472	1208950.890	18.79
46	359.5	0.3	4281257.462	428.126	1262396.068	20.05
47	359.8	0.3	4327798.597	432.780	1291358.409	21.34
48	360.1	0.3	4413418.023	441.342	1311182.493	22.65
49	360.4	0.3	4677194.032	467.719	1363591.808	24.02
50	360.7	0.3	4895562.044	489.556	1435913.411	25.45

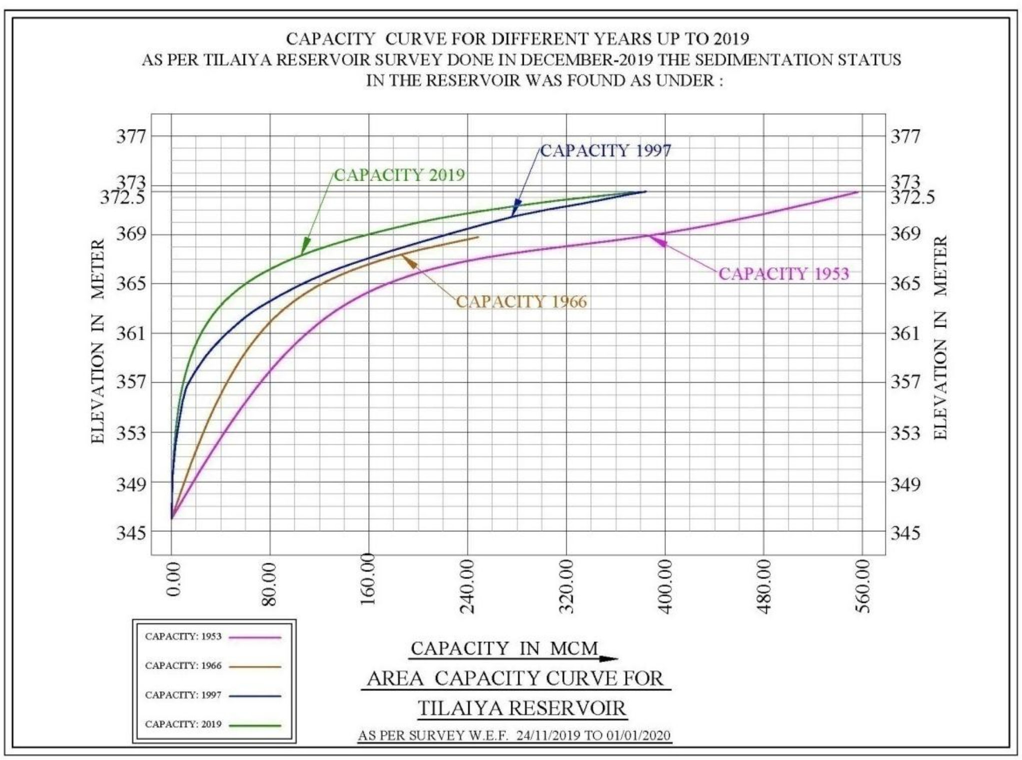
Tilaiya Reservoir_ Detail Analysis for Elevation and Area Capacity Table 2019						
SL.NO.	Contour EL (m)	Contour Interval	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between two consecutive contour surface (in Cum.)*	Cumulative Vol. *(in M-Cum.)*
51	361.0	0.3	5104746.050	510.475	1500046.214	26.95
52	361.3	0.3	5319288.137	531.929	1563605.128	28.52
53	361.6	0.3	5533830.225	553.383	1627967.754	30.15
54	361.9	0.3	5662914.399	566.291	1679511.694	31.83
55	362.2	0.3	5832152.671	583.215	1724260.061	33.55
56	362.5	0.3	5950552.166	595.055	1767405.726	35.32
57	362.8	0.3	6168951.661	616.895	1817925.574	37.14
58	363.1	0.3	6365777.530	636.578	1880209.379	39.02
59	**363.3**	0.2	6534896.607	653.490	1290067.414	40.31
60	363.4	0.1	6932891.049	693.289	673389.383	40.98
61	363.7	0.3	7126874.375	712.687	2108964.814	43.09
62	364.0	0.3	7520857.701	752.086	2197159.811	45.28
63	364.3	0.3	8048996.315	804.900	2335478.102	47.62
64	364.6	0.3	9077134.929	907.713	2568919.687	50.19
65	364.9	0.3	9105273.543	910.527	2727361.271	52.92
66	365.2	0.3	9588984.579	958.898	2804138.718	55.72
67	365.5	0.3	9800481.826	980.048	2908419.961	58.63
68	365.8	0.3	9911979.072	991.198	2956869.135	61.59
69	366.1	0.3	10052392.179	1005.239	2994655.688	64.58
70	366.4	0.3	12350637.008	1235.064	3360454.378	67.94
71	366.7	0.3	15081630.113	1508.163	4114840.068	72.06
72	367.0	0.3	21947126.665	2194.713	5554313.517	77.61
73	367.3	0.3	29120667.130	2912.067	7660169.069	85.27
74	367.6	0.3	36294207.594	3629.421	9812231.209	95.08
75	367.9	0.3	41467748.059	4146.775	11664293.348	106.75

Tilaiya Reservoir_ Detail Analysis for Elevation and Area Capacity Table 2019						
SL.NO.	**Contour EL (m)**	**Contour Interval**	**Area**		**Capacity**	
			in Sqm.	***in Hectare***	***Vol. between two consecutive contour surface (in Cum.)***	**Cumulative Vol. *(in M-Cum.)***
76	368.2	0.3	48577517.310	4857.752	13506789.805	120.25
77	368.5	0.3	51655400.953	5165.540	15034937.739	135.29
78	**368.8**	0.3	52733284.596	5273.328	15658302.832	150.95
79	369.1	0.3	53865087.910	5386.509	15989755.876	166.94
80	369.4	0.3	55073952.927	5507.395	16340856.126	183.28
81	369.7	0.3	57282817.945	5728.282	16853515.631	200.13
82	370.0	0.3	58491682.962	5849.168	17366175.136	217.50
83	370.3	0.3	59834194.556	5983.419	17748881.628	235.25
84	370.6	0.3	60176706.150	6017.671	18001635.106	253.25
85	370.9	0.3	61519217.743	6151.922	18254388.584	271.50
86	371.2	0.3	63145750.563	6314.575	18699745.246	290.20
87	371.5	0.3	64914293.996	6491.429	19209006.684	309.41
88	371.8	0.3	65682837.429	6568.284	19589569.714	329.00
89	372.1	0.3	67580034.860	6758.003	19989430.843	348.99
90	372.4	0.3	70734540.286	7073.454	20747186.272	369.74
91	**372.5**	0.1	73552708.762	7355.271	7214362.452	376.95

Table 5-Capacity area Table of Tilaiya Reservoir 2019

- **Area Capacity Curve 2019 & Different Years Capacity Curve Upto 2019 of Tilaiya Reservoir:-**





Assessment of effects of Sedimentation on performance of Reservoir and balance life of reservoir

This section has been analyzed the **Mathematical Modeling Studies for 100 years at 10 years interval by the reference I.S. 12182-1987 and I.S. 5477 Part-II.**

13.2 Assessment of effects of Sedimentation on performance of Reservoir and Balance life of Reservoir (I.S. 12182-1987):-

This section has been described "I.S. 12182-1987" "Guidelines for determination of effects of sedimentation in planning and performance of Reservoirs". C.B.I & P Publication on the subject and I.S 5477 part-II "Fixing Capacities of Reservoirs – Dead storage" which is described respectively in the report.

IS : 12182 - 1987

Indian Standard

GUIDELINES FOR DETERMINATION OF EFFECTS OF SEDIMENTATION IN PLANNING AND PERFORMANCE OF RESERVOIRS

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 29 September 1987, after the draft finalized by the Reservoirs Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The storage reservoirs built across rivers or streams lose their capacity on account of deposition of sediment. This deposition of sediment which takes place progressively in time reduces the active capacity of the reservoir which in turn affects the regulating capability of the reservoir to provide the outputs of water through passage of time. Accumulation of sediment at or near the dam may interfere with the future functioning of water intakes and hence affects decisions regarding location and height of various outlets. It may also result in greater inflow of sediment into the canals/water conveyance systems provided at the reservoir. Problems of rise in flood levels in the head reaches and unsightly deposition of sediment from recreation point of view may also crop up in course of time.

0.2.1 Water resources systems operate over a long period of time and are subject to ever increasing demand for water for various purposes. Besides, long term changes in terms of technology and production functions are also encountered. Man-made changes taking place in the river basin and consequent changes in hydrologic regime controlling the water inputs over long term periods are also encountered and have to be provided for (All these factors are to be considered and taken into account while assessing performance of any reservoir project). In this context, sedimentation of reservoirs is to be viewed as an additional factor which has to be considered and its effects studied and evaluated on the reservoir performance.

0.3 In the formulation of this standard, due weightage has been given to the practices prevailing in the field in this country. This has been met by deriving assistance from Chapter II and III of CBI & P Technical Report number 19.

IS : 12182 - 1987

1. SCOPE

1.1 This standard lays down guidelines for determining the various effects of sedimentation on the performance of reservoir projects in order to make suitable allowances in the design of such projects at the time of initial planning.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 4410 (Part 6)-1983* and the following shall apply.

2.1 Dead Storage — Storage of reservoir not susceptible to release by means of the in-built sluices/outlets.

2.2 Economic Life — If at any point of time, the benefits likely to accrue in further operation of the reservoir compare unfavourably under the relevant economic criteria with the future costs involved in operating and maintaining the system, but excluding any element to cover the past costs incurred, the reservoir shall be said to have reached the end of the economic life.

2.3 Feasible Service Time — For a specified purpose, the period or notional period for which the reservoir provided or is/was expected to provide a part of planned benefit in respect of storage in the reservoir being impaired by sedimentation. Customarily, it is estimated as the time after which the new zero elevation of the reservoir would equal the sill of the outlet relevant for the purpose.

2.4 Full Service Time — For a specified purpose, the period or notional period for which the reservoir provided or is/was expected to provide, a part of the full planned benefit inspite of sedimentation.

2.5 New Zero Elevation — The level up to which all the available capacity of the reservoir was or is expected to be lost due to progressive sedimentation of the reservoir up to the specified time.

NOTE — New zero elevation is a time related concept and as sedimentation progresses, the new zero elevation may rise. Thus specified time should be any length of time such as full service time, feasible service time, etc.

3. PROBLEMS ASSOCIATED WITH SEDIMENTATION OF RESERVOIR

3.1 Following are the main effects of sedimentation on the reservoir:

a) The reduction of the active storage capacity which may reduce the capability of the reservoir to deliver the benefits which could have been delivered by the reservoir but for sedimentation. The

*Glossary of terms relating to river valley projects: Part 6 Reservoirs (*first revision*).

progressive reduction of the active storage capacity may reflect on the outputs from the reservoir in following ways:

1) It may reduce the dump or secondary output. However, where demands have not grown as expected, this effect may not be felt. In years of exceptional good run or secondary off, there may be no reduction of dump outputs.

2) It may reduce availability of firm water in marginal years by increase in both the number and quantum of failures. However, in very bad years where no spills would have occurred even otherwise, the number and quantum of failures may remain unaffected by reduction in active storage capacity. Some reduction of benefits from the existing reservoir projects as a result of sedimentation of active storage capacities is inevitable. However, efforts may be made to make the best use of remaining storage capacity as described in **5**.

b) Sedimentation at or near the dam face may tend to block the outlet causing difficulties in operation of the gates. Sedimentation up to intake of the outlet may induce more sediment to be carried through the conservation outlets, thus causing problems of sedimentation of canals, machinery parts, etc. Elevation to which sediment will accumulate at the dam in a given period of time affects the design elevation of outlets for water withdrawals, namely, the sill level of canal's taking off from reservoir and power penstock sills. Location of these outlets is, however, also dependent on other considerations like command areas to be covered and minimum head required for functioning of turbines. In cases where outlet elevations are controlled by above considerations, the effect of sediment accumulation may pose no problem. Sedimentation may cause operational difficulties by tending to jam the intake gates of the outlet when new zero elevation reaches above the gate sill. The problem is more serious for gates which are not frequently operated, and for situations where early floods occur when reservoir is low deposit sediment near the intake. However, in frequently operated gates, a local deep approach channel may develop and allow withdrawal of water. However, in such cases, difficulties caused by passage of sediment in irrigation canals, power houses, etc, may become serious.

c) Sediment accumulation at the dam face may increase the loading on the masonry/concrete dam structure beyond what has been provided for.

d) Sedimentation in upper portion of the reservoir may change the back water profile from what it would have been put for sedimentation. The increase in flood levels upstream of the

IS : 12182 - 1987

reservoir may cause additional submergence, formation of marshy lands, etc.

e) The river regime at the entry to the reservoir may get affected due to sediment deposits. Delta formation and braided river pattern may result and this may be unsightly. Tree growth in the delta lends increase evapotranspiration.

f) The operation constraints for a reservoir may necessitate certain minimum reservoir level and filling generally starts at around same level or range of levels. Over a period of years, large deposits of sediment may be built up in the reservoir. The depth of sediment upstream and downstream of this location is small, resulting in a sort of hump in the reservoir bed. This hump acts as a natural barrier to the flow of sediment closer to the dam. The deleterious effect of this hump formation is the early reduction of live storage capacity.

g) The process of sedimentation in reservoirs may also increase the turbidity of water resulting in the environment problems like deterioration of water quality and reduction of visibility in the reservoir water for fish survival.

4. STUDY OF EFFECTS OF RESERVOIR SEDIMENTATION

4.1 The study normally comprises of the following:

a) Performance assessment with varying rate of sedimentation, and

b) Likely effects of sedimentation at dam face.

In special cases where effects of sedimentation on backwater levels are likely to be significant, backwater studies would be useful. Similarly, special studies to bring out delta formation regime changes may be of interest.

4.2 Performance Assessment (Simulation) Studies with Varying Rate of Sedimentation

4.2.1 The following steps are involved for simulation studies:

a) Selection of annual sediment yields into the reservoir or the average annual sediment yield, and of trap efficiency expected;

b) Distribution of sediment within the reservoir to obtain a sediment elevation and capacity curve at any appropriate time;

c) Simulation studies with varying rate of sedimentation; and

d) Assessment of effect of sedimentation.

4.2.2 *Sediment Yield Assessment*

4.2.2.1 Estimation of sediment yield from the catchment area above the reservoir is usually made using river sediment observation data or more commonly from the experience of sedimentation of existing reservoirs with similar characteristics. On adopting the first procedure, it is usually necessary (though often not complied within practice) to evolve proper sediment water discharge rating curve and combine it with flow duration (or stage duration curve) based on uniformly spaced daily or shorter time units in case of smaller river basins. Where observed stage/flow data is available for only shorter periods, these have to be suitably extended with the help of longer data on rainfall to eliminate, as far as possible, the sampling errors due to shortness of records. The sediment discharge rating curves may also be prepared from hydraulic considerations using sediment load formulae, that is, modified Einstein's procedure but this has not yet become popular. It is also necessary to account for the bed load which may not have been measured. While bed load measurement is preferable; when it is not possible, it is often estimated as a percentage generally ranging from 5 to 20 percent of the suspended load. However, practical means of measuring bed load of sediment needs to be undertaken particularly in cases where high bed loads are anticipated. To assess the volume of sediment that would deposit in the reservoir, it is further necessary to make estimates of average trap efficiency for the reservoir in question and the likely unit weight of sediment deposits, time averaged over the period selected. The trap efficiency would depend mainly on the capacity inflow ratio but would also vary with location of controlling outlets and reservoir operating procedures. Computation of reservoir trap efficiency may be made using the trap efficiency curves such as those developed by Brune and by Churchill. An illustration of these computations and curves is given in Appendix A.

4.2.2.2 The density of deposited sediment would vary with the composition of the deposits, the location of the deposit within the reservoir, the flocculation characteristics of clay and water, and the age of the deposit. For coarse material (0·062 5 mm and above), variation of density with location and age may be unimportant. For silt and clay, this may be significant. Normally, a time and space average density of these fractions, applicable for the period under study is required for finding the overall volume of deposits. For this purpose, the trapped sediment for the period under study would have to be classified in fractions by corrections in inflow estimates of the fractions by trap efficiency. Most of the sediment removed from the reservoir should be from the silt and clay fraction. In some special cases, local estimates of densities at a point in the reservoir may be required instead of average density over the reservoir.

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4.2.2.3 The reservoir surveys give valuable additional information regarding the rate of sediment accumulation. This information may be of guidance in deciding the annual sediment inflow and deposition for the problem of catchment. However, as given in **4.2.2.4**, information obtained through capacity re-survey of reservoirs would have little use unless it is accurate enough. While transferring the rates observed in adjacent reservoir(s), considerations for differences in the sediment production or trapping characteristics of the cases involved have to be kept in view.

4.2.2.4 Estimates of annual sediment yield/sedimentation rate assessed from past data are further required to be suitably interpreted and where necessary, the unit rates which would apply to the future period are computed by analysing data for trends or by making subjective adjustments for the likely future changes. Where the contributing drainage area is likely to be reduced by upstream future storages, only such of the projects as are under construction or which have the same priority of being taken up and completed as the project in question are considered for assessing the total sediment yield. Sediment observation data (*see* IS : 4890-1968*) is necessary if the yield is being assessed from hydrometric data. If observational methods are inadequate, the possibility of large errors should be considered. For drawing conclusions from reservoir re-surveys, it is important that reduction of at least 10 percent or more has been observed in the capacities of the two successive surveys; if this is not done, inaccuracies in the successive surveys will distort the estimation of the capacity reduction between the surveys. If the loss of capacity is small, useful conclusions may not be forthcoming, and in such cases, river sediment measurements with its large observational errors may still provide a better estimate. It is essential to make a proper assessment of sediment yield for reservoir under study taking relevant factors into account. Any adhoc adoption of a sediment yield rate, from experience not fully analysed, may lead to large errors. The range recommended in **3.2.3** of IS : 6518-1972† may at best be used for rough reconnaissance level studies [*see* IS : 5477 (Part 2)-1969†].

4.2.3 *Distribution of Sediment Volume* — Once an assessment of expected volume of total sediment deposition for the required time period has been made, the revised elevation area capacity curves of the reservoir are prepared by using empirical area reduction methods.

4.2.4 *Simulation Studies with Varying Rate of Sediment* — The following are the two ways in which the effect of sedimentation may be considered in the simulation:

a) The first method considers the progressive reduction of capacity every year or for blocks of a few years, and as the simulation

*Methods for measurement of suspended sediment in open channels.
†Code of practice for control of sediment in reservoirs.
‡Methods for fixing the capacities of reservoirs: Part 2 Dead storage.

progresses, uses the newly updated curve. This method would be more appropriate in bringing out the progressive effects on the reservoir; however, it requires that the simulation be carried out for a long period up to which the benefits of the project are required to be monitored through the simulation.

b) The second method lumps the progressive effect of sedimentation up to an appropriate time horizon up to which no reduction in firm target benefits is contemplated (full service time) and considers situation as at the end of that period throughout the simulation. Thus, though the performance as given by this method is the one that considers the effect of sedimentation up to that period (full service time), the progressive reduction of the dump or secondary benefits within that period should not be brought out in this method. The main advantages of this method are:

1) It is relatively simple, and

2) It does not require that the period of simulation should correspond to the full service time.

4.2.5 *Assessment of Effect of Sedimentation on Outputs* — The comparison of the sedimentation studies would bring out the effect of sedimentation, as a vector of the differential performance, as time progresses if method given in **4.2.4**(a) is followed. If the method given in **4.2.4**(b) is followed, it would bring out the change in the range and distribution of the performances over the time period considered. If the studies are for planning purposes, changes in the project features, and necessary progressive adjustment in targetted outputs beyond the full service time would become apparent and the studies may be repeated after modifying the planning decisions.

5. PERFORMANCE ASSESSMENT FOR STORAGE RESERVOIR

5.1 General — The performance of reservoir project under varying hydrologic inputs to meet varying demands is required to be assessed. Although analytical probability based methods are available to some extent, simulation of the reservoir system is the standard method. The method is also known as the working tables, sequential routing, performance assessment studies, etc. In this method, the water balance of the reservoirs and of other specific locations of water use and constraints in the systems are considered. All inflows to and outflows from the reservoirs are worked out to decide the changed storage during the period. In simulation studies, the inflows to be used may be either historical inflow series, adjusted for future upstream water use changes or a synthetically generated series so adjusted. Whichever approach is used, it shall be used uniformly for assessment of alternate scenarios in regard to sedimentation [*see* IS : 5477 (Part 3)-1969*].

NOTE — A synthetic generation of hydrologic series is a technique which involves mathematical modelling of the statistical properties of historical series and the activation of the model to generate alternate equally likely sequences.

5.1.1 A set of practicable and pre-determined operation policies is essential, to such studies; so is the idea of a firm demand which the reservoir shall meet, as long as possible, within the policy and physical limitations. For this purpose, firm irrigation and power and other demands which the reservoir should meet are to be pre-determined. Demands over and above firm demands are considered as secondary or dump demands, meeting of which, although beneficial is not obligatory.

5.1.2 The acceptability of performance as seen in the simulation is decided by checking if the firm demands have been met with the desired reliability: that is, whether these meet the acceptability criteria. In case, these are not met or the performance is better than required, it is customary to change the assumptions and conduct simulation study again in the planning phase of the project. In general for irrigation and hydro power projects, it is customary to adopt the following acceptability criteria:

a) Any year or water year in which the firm demands are not met fully in each time period separately is labelled as a failure year.

b) The ratio of failure years to the total years of simulation is determined. For irrigation and hydro-power, the ratio shall not exceed 0·25 and 0·1 respectively. The evaluation of performance may also be made through economic analysis considering the series of benefits from year to year during the period of simulation.

5.2 Time Units and Period of Simulation

5.2.1 In general, for within the year projects, a monthly simulation is sufficient for assessing conservational benefits. Shorter period simulation is required for assessing benefits of flood control and secondary power. Units longer than one month may be used for carry over projects. The period of simulation has to be long enough to contain different hydrologic situations which are experienced (*see also* **5.1**).

5.3 Inflows and Demands — The water inflows in the desired time units may be based on the historical data as observed, historical as estimated from hydrologic observations of related phenomenon, or synthetic hydrologic data. The last method has the advantage that it does not make any assumption about the actual flows repeating

*Methods for fixing the capacities of reservoirs: Part 3 Live storage.

themselves. In all cases, observed trends in hydrologic data may be projected in the future operational period. Similarly, the effect of the man-made future upstream development may be incorporated, either in the form of time dependent changes, or in the form of scenario studies, with a pseudo stationary approach with different levels of development. Pattern of firm demand is decided on the basis of assessment of future energy requirement. Seasonal requirements may or may not be built in the demands. The growth of demands after construction may also be considered.

6. STANDARD PROCEDURES FOR PLANNING

6.1 Procedures for New Storages — A rough assessment of seriousness of the problem is necessary to classify the reservoir sedimentation problem as insignificant, significant or serious. Assessment of reservoir sedimentation problem, in a particular case, may be made by comparing the expected average annual volume of sediment deposition with the gross capacity of the reservoir. If ratio is more than 0·5 percent per year, the problem is usually said to be serious and special care is required in estimating the sediment yields from the catchment. If it is less than 0·1 percent per year, the problem of siltation may be insignificant and changes in reservoir capacity can be neglected for studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

6.1.1 The following studies are required if the problem is insignificant:

a) No simulation studies with sediment condition is necessary.

b) The feasible service time for the project may be decided. Sediment distribution studies to ensure that the new zero-elevation does not exceed the dead storage level may be made.

6.1.2 The following studies are required if the problem is significant but not serious:

a) Both the full service time and feasible service time for the reservoir may be decided.

b) Simulation studies for conditions expected at the end of full service time may be made by procedure explained in **4.2.4**(a) to ensure that firm outputs with required dependability are obtained. The studies used also assess non-dependable secondary outputs, if relevant, available at the end of this period. Studies without sedimentation, with the same firm outputs should bring out the additional potential secondary outputs which may be available in the beginning, and this information may be used, if required, in the economic analysis, using a linear decrease of these additional benefits over the full service time.

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c) No simulation studies beyond full service time are essential.

d) Studies as described in **6.1.1** for feasible service time are essential.

6.1.3 The following studies are required if sedimentation problem is serious:

a) All studies as described in **6.1.2** would be required.

b) The secondary benefits available in the initial years should be more in such cases. If these are being utilised, for a proper assessment of the charge of these, a simulation at half of full service time should be required.

c) In these cases, the drop of benefits after the full service time may be sharper. To bring out these effects, a simulation of the project at the end of the feasible service time is required to be done.

d) Considering (a), (b), and (c) together, it may be worthwhile to resort to the more realistic method, given in **4.2.4**(a) in simulation for cases where the problem is serious. For this purpose, it should be sufficient to consider sediment trapped in every 10-year block, and to use the expected sedimental elevation area capacity curve at the end of each 10-years block, for simulation of that block.

7. PROCEDURE FOR EXISTING PROJECTS

a) Assess the present elevation area curve either by reservoir re-surveys or by projecting from the earlier survey data, using the estimates of sediment yield and its distribution.

b) Decide the target firm level of the outputs. To start with, this may be based on the earlier planning or on existing situation.

c) Simulate the reservoir by the method described in **4.2.4**(a). It should suffice if 10-yearly block is considered and expected sedimented elevation area capacity curve at the end of each 10-years block is considered for simulation of that block.

d) Screen the performance to see if the frequency of failures, after proper smoothening tends to cross from an acceptable frequency to an unacceptable frequency (*see* **3.1**). If this is happening, estimate the time of switchover from an acceptable frequency of failures to an unacceptable frequency. This represents the end of the full service time, thus giving an estimate of the residual full service time. If the total full service time (lapsed period plus remaining period) is more or less equal to the prescribed full service time in the criteria, this would show that the actual sedimentation has no effect on the project.

e) For period beyond the full service time, it should be necessary to determine the policy changes in operation which may include measures discussed in **7.1** and **7.2**.

7.1 In hydro-electric projects, the slow reduction in the total energy generation as a result of partial loss of active capacity may be adjusted in the system by reducing the load factor without losing the peaking benefits. It is also important to note here that even if the reservoirs for such projects were to be silted up completely, the head available in the reservoir would give a permanent benefit.

7.2 In the case of irrigation projects, the reduction in availability of water may be adjusted to some extent by changing the crop pattern and/or the dependability criteria.

7.3 The simulation shall have to be repeated with these changes. If it is necessary to bring out the overall effect of sedimentation, or the effect of sedimentation due to change in the estimate of sediment load from the earlier planning, it should be necessary to recompute steps given in **7** (a) to (e) for either the no sedimentation case or for the earlier assumption of sediment rate. The time series of the differences in performance should bring out the differential effect.

7.4 If at any time, the new zero elevation is crossing the sill levels of an outlet of a primary purpose, this should signify the end of the feasible service period unless with new engineering measures (*see* **7.2**) or due to natural development of an approach channel this may be extended.

8. LIFE OF RESERVOIR AND DESIGN CRITERIA

8.1 General — The reservoir exists for a long time and the period of its operation should normally check large technological and socio-economic changes. The planning assumptions about the exact socio-economic output are, therefore, likely to be changed during operation, and similarly, the exact implication of socio-economic differences in the output due to sedimentation are difficult to assess. The ever increasing demands due to both increase of population and increases in per capita needs are of a larger magnitude than the reductions in outputs, if any, of existing reservoirs. Thus effects of sedimentation, obsolensence, structural deterioration, etc, of reservoirs may require adjustments in future developmental plans and not simply replacement projects to bring back the lost potential. On a regional or national scale, it is the sufficiency of the total economic outputs, and not outputs of a particular project which is relevant. However, from local considerations, the reduction of outputs of reservoir like irrigation and flood control may cause a much greater degree of distress to the population which has got used to better socio-economic conditions because of the reservoir.

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8.2 Life of Reservoir — Life strictly is a term which may be used for system having two functional states 'ON' and 'OFF'. Systems showing gradual degradation of performance and not showing any sudden non-functional stage have no specific life period. Reservoirs fall in the later category.

8.2.1 The term 'life of reservoir' as loosely used denotes the period during which whole or a specified fraction of its total or active capacity is lost. In calculating this life, the progressive changes in trap efficiency towards the end of the period were commonly not considered. In some of the projects, it was assumed that all sedimentation would occur only in the dead storage pocket and the number of years in which the pocket should be filled under this assumption was also sometimes termed as the life of reservoir. This concept was in fact used to decide the minimum size of the pocket. Under this concept, no effect of sedimentation should be felt in the live storage of the reservoir. It has subsequently been established that the silt occupies the space in the live storage of reservoir as well as the dead storage.

8.2.2 It shall not be possible to express the life of the reservoir as a specific period. The concerned life related terms such as economic life, feasible service time and full service time are defined in **2.2** to **2.4**.

8.2.3 If the operation of the reservoir becomes impossible due to any structural defects, foundation defects, accidental damages, etc, this situation should also signify the end of the feasible service time. Before the expiry of this feasible service time, it may be possible to make large changes in the reservoir (for example, new higher level outlets, structural strengthening, etc) or other measures, if it is economically feasible to do so. If these studies are done, the feasible service time may be extended.

8.2.3.1 *Economic life* — By definition, the economic life cannot be more than the feasible service time. In general, for reservoir projects with gravity irrigation, operation and maintenance costs are so small compared to benefits even from much reduced capacity that economic life should be determined by the feasible sedimentation problem; no check should be required.

9. DESIGN CRITERIA FOR NEW PROJECTS

9.1 General Design Criteria — The design criteria given in **9.1.1** to **9.1.3** are recommended.

9.1.1 *Irrigation Projects* — Full service time shall not be less than 50 years after the start of operation. Feasible service time shall not be less than 100 years after the start of operation. For reservoirs with serious sedimentation problem where extension of feasible service time to over-come social distress is perhaps feasible, the period may be suitably reduced, provided detailed studies as detailed therein are done, and also provided that rigorous economic analysis up to the feasible service time and with changing stream of benefits is made.

9.1.2 For hydro-power projects expected to supply power to a community, in isolation the feasible and full service time shall be the same as for the irrigation projects.

9.1.3 For hydro-power projects supplying power to a grid, full service time shall not be less than 25 years. Feasible service time shall not be less than 70 years. For reservoirs with serious sedimentation problem where extension of feasible service time to overcome social distress is perhaps feasible, the periods may be suitably reduced, provided detailed studies as detailed therein are done, and also provided that rigorous economic analysis up to the feasible service time and with changing stream of benefits is made.

10. CONSIDERATION OF EFFECTS OF SOIL CONSERVATION PROGRAMME

10.1 Soil conservation may lead to reduction of sediment. This programme, apart from benefiting downstream reservoir, could have large beneficial effects on production of the protected area. However, because of the different areas benefitted, socio-economic implication, etc, these programmes normally are not included in the economic analysis of the reservoir project. Therefore, any change in trend of sediment yield, attributable to such programmes, may not be considered in assessment of performance of the reservoir. If economic feasibility of the soil conservation programme is to be established, any properly established reduction of yield, and its effect on the reservoir benefits may be considered in that analysis.

10.2 Normally at the project planning stage, the sediment load calculations used in the sedimentation studies are as per the land use existing then. If adverse human actions come into operation in the catchment, it may result into a higher sediment load than the one assumed in the project planning. This should be reflected in the project.

13.2.1 Assessment of effects of Sedimentation on performance of Reservoir and Balance life of Reservoir (I.S. 5477 PART-II-1994):-

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Reservoirs Sectional Committee had been approved by the River Valley Division Council.

By providing extra storage volume in the reservoir for sediment accumulation, in addition to the live storage, it is ensured that the live storage, although it contains sediment, will function at full efficiency for an assigned number of years. This volume of storage (in the fixation of which the minimum draw down level is also a major criterion in case of power projects) is referred to as the dead storage and is equivalent to the volume of sediment expected to be deposited in the reservoir during the designed life of the structure.

The distribution pattern of sediments in the entire depth of a reservoir depends on many factors, such as slope of the valley, length of reservoir, constriction in the reservoir, particle size of the suspended sediment and capacity inflow ratio; but the reservoir operation has an important control over other factors. However, a knowledge of this pattern is essential. especially, in developing areas, in order to have an idea about the formation of delta and the recreational spots and the consequent increase in back water levels after the reservoir comes into operation.

This standard (Part 2) was first published in 1969. The present revision has been prepared to incorporate the latest knowledge in this field in this revision an additional figure for determining the type of reservoir has been incorporated in addition to modifying Fig. 1 and 2 and some tables.

This standard consists of four parts, Part 1 covers general requirements, Part 3 covers live storage and Part 4 covers flood storage.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Indian Standard

FIXING THE CAPACITIES OF RESERVOIRS — METHODS

PART 2 DEAD STORAGE

(First Revision)

1 SCOPE

This standard (Part 2) covers the methods for computing the sediment yield and for predicting the probable sediment distribution in the reservoir below normal (full) reservoir level (F.R.L.).

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
4410 (Part 6) :1983	Glossary of terms relating to river valley projects : Part 6 Reservoirs (*first revision*)
4890 : 1968	Methods of measurement of suspended sediment in open channels
12182 : 1987	Guidelines for determination of effects of sedimentation in planning and performance of reservoirs

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 4410 (Part 6) : 1983 shall apply.

4 MEASUREMENT OF SEDIMENT YIELDS

4.1 The sediment yield in a reservoir may be estimated by any one of the following two methods:

a) Sedimentation surveys of reservoirs with similar catchment characteristics, or

b) Sediment load measurements of the stream.

4.2 Reservoir Sedimentation Survey

4.2.1 The sediment yield from the catchment is determined by measuring the accumulated sediment in a reservoir for a known period, by means of echo sounders and other electronic devices since the normal sounding operations give erroneous results in large depths. The volume of sediment accumulated in a reservoir is computed as the difference between the present reservoir capacity and the original capacity after the completion of the dam. The unit weight of deposit is determined in the laboratory from the representative undisturbed samples or by field determination using a calibrated density probe developed for this purpose. The total sediment volume is then converted to dry-weight of sediment on the basis of average unit weight of deposits. The total sediment yield for the period of record covered by the survey will then be equal to the total weight of the sediment deposited in the reservoir plus that which has passed out of the reservoir based on the trap efficiency. In this way, reliable records may be readily and economically obtained on long-term basis.

4.2.2 The density of deposited sediment varies with the composition of the deposits, location of the deposit within the reservoir, the flocculation characteristics of clay content and water, the age of deposit, etc. For coarse material (0.0625 mm and above) variation of density with location and age may be unimportant. Normally a time and space average density of deposited materials applicable for the period under study is required for finding the overall volume of deposits. For this purpose the trapped sediment for the period under study would have to be classified in different fractions. Most of the sediment escape from getting deposited into the reservoir should be from the silt and clay fractions. In some special cases local estimates of densities at points in the reservoir may be required instead of average density over the whole reservoir.

4.2.3 The trap efficiency mainly depends upon the capacity-in-flow ratio but may vary with location of outlets and reservoir operating procedure. Computation of reservoir trap efficiency may be made using trap efficiency curves, such as those developed by Brune and by Churchill (*see* IS 12182 : 1987).

4.2.4 The sedimentation rates observed in adjacent reservoirs also serve as guide while designing dead storage capacity for a new reservoir, the rate of sedimentation observed in similar reservoirs and/or adjacent basin should be suitably modified keeping in view the density of deposited material, trap efficiency and sediment yield from the catchment.

4.3 Sediment Load Measurements

Periodic samples from the stream should be taken at various discharges along with the stream gauging observations and the suspended sediment concentration should be measured as detailed in IS 4890 : 1968. A sediment rating curve which is a plot of sediment concentration against the discharge is then prepared and is used in conjunction with stage duration curve (or flow duration) based on uniformly spaced daily or shorter time units data in case of smaller river basins to assess sediment load. For convenience, the correlation between sediment concentration against discharge may be altered to the relation of sediment load against run-off for calculating sediment yield. Where observed stage/flow data is available for only shorter periods, these have to be suitably extended with the help of longer data on rainfall. The sediment discharge rating curves may also be prepared from hydraulic considerations using sediment load formula, that is, modified Einstein's procedure.

4.3.1 The bed load measurement is preferable. However, where it is not possible, it may be estimated using analytical methods based on sampled data or as a percentage of suspended load (generally ranging from 10 to 20 percent). This should be added to the suspended load to get the total sediment load.

5 PREDICTING SEDIMENT DISTRIBUTION

5.1 The sediment entering into a storage reservoir gets deposited progressively with the passage of time and thereby reduces the dead as well as live storage capacity of the reservoir. This causes the bed level near the dam to rise and the raised bed level is termed as new zero elevation. It is, therefore, necessary to assess the revised areas and capacities at various reservoir elevations that would be available in future and could be used in simulation studies to test the reservoir performance and also the new zero-elevation.

The following procedure may be adopted for fixing the dead storage level and sill levels of the outlets:

a) The distribution of the estimated sediment load for the feasible service time of the reservoir should be carried out and new zero-elevations should be determined, and

b) The minimum drawdown level is fixed a little above the new zero-elevation computed in (a) above. When other considerations like command area elevation, providing extra head for power generation, etc, prevail, this elevation is fixed higher than one of these.

5.2 Several methods are in use for predicting sediment distribution in reservoirs for design purposes. Either the empirical area reduction method or the area increment method may be used.

5.2.1 *Empirical Area Reduction Method*

This method is based on the analysis of data of sediment distribution. In this method, reservoirs are classified into four types, namely, (a) gorge, (b) hill, (c) flood plain-foot hill, and (d) lake, based on the ratio of the reservoir capacity to the reservoir depth plotted on a log-log scale (*see* Fig. 1). Figures 2 and 3 give the sediment distribution-area design curves for each type of these reservoirs. The equation for the design curve used is:

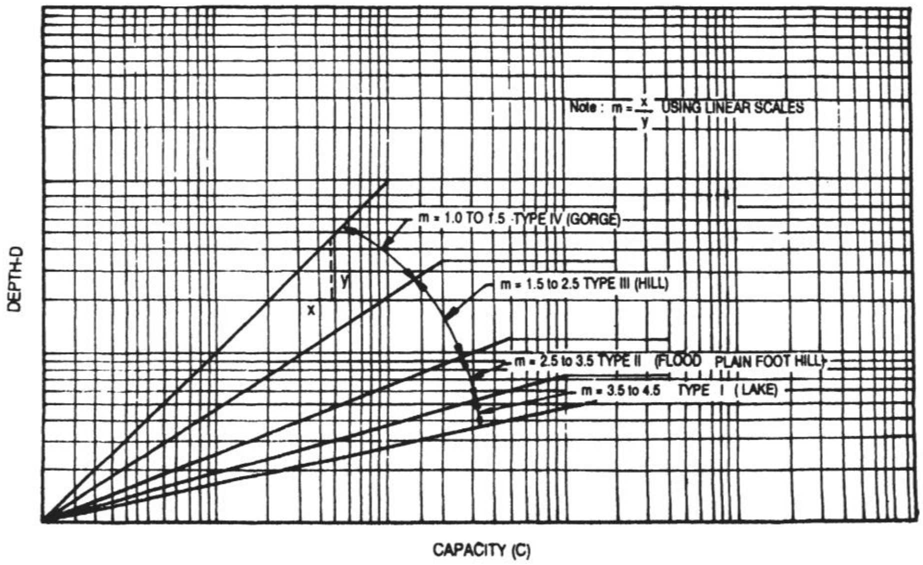
$$A_p = Cp^m (l - p)^n \qquad ......(1)$$

where

A_p = a non-dimensional relative area at relative distance 'p' above the stream bed, and

C, m and n = non-dimensional constants which have been fixed depending on the type of reservoir.

5.2.1.1 These curves are used to work out the probable sediment deposition in the reservoir at different depths. This method is more reliable than the area increment method. An example of the usage of this method is given in Annex A.



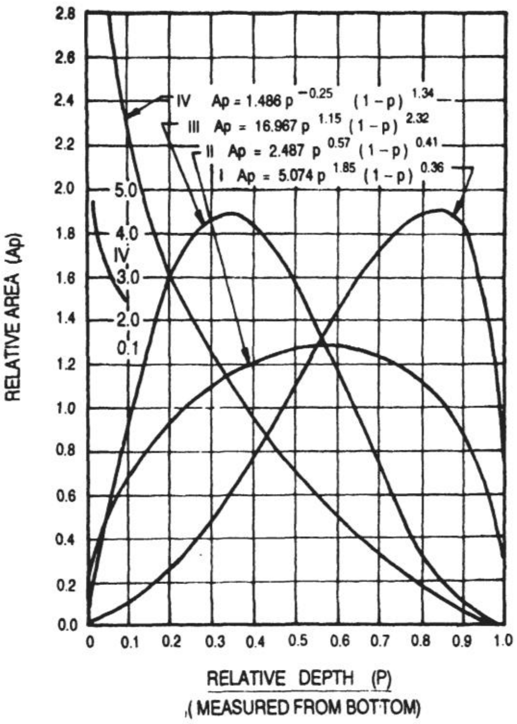


FIG. 2 SEDIMENT DISTRIBUTION – AREA DESIGN CURVES (BASED ON RESERVOIR STORAGE CURVES)

5.2.2 *Area Increment Method*

The basic assumption in this method is that the sediment deposition in the reservoir may be approximated by reducing the reservoir area at each reservoir elevation by a fixed amount. Successive approximations are made. Average end area (or prismoidal formula) is used to compute the reservoir capacities on the basis of reduced surface areas until the total reservoir capacity below the full reservoir level is the same as the predetermined capacity obtained by subtracting the sediment accumulation with time from the original capacity.

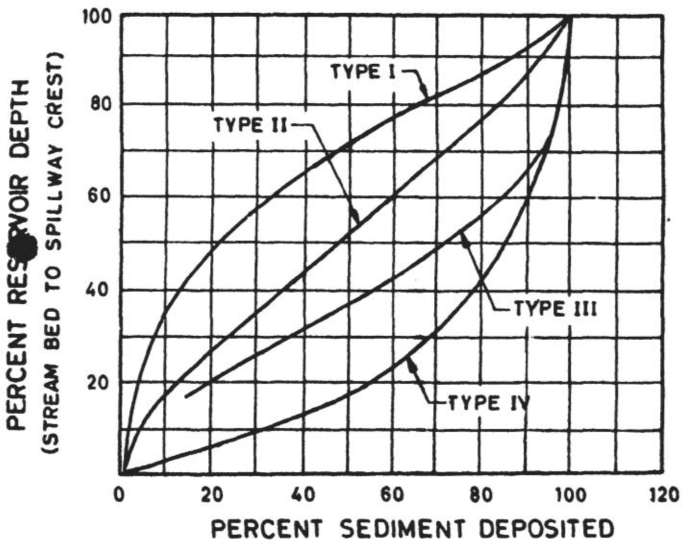
The basic equation in this method is:

$$V_s = A_o (H - h_o) + V_o \qquad \text{........(2)}$$

where

- V_s = the sediment volume to be distributed in the reservoir in hectare metres,
- A_o = the area correction factor in hectares which is original reservoir area at the new zero elevation of the reservoir,
- H = the reservoir depth below full reservoir level (F.R.L.) in metres,
- h_o = the depth in metres to which the reservoir is completely filled with sediment, and
- V_o = the sediment volume below new zero elevation in hectare metres.

5.2.2.1 In other words, the equation mathematically expresses that the total sediment volume V_s consists of two parts, namely, (a) the protion which is uniformly distributed vertically over the height $H - h_o$ with an



IS 5477 (Part 2) : 1994

area equal to A_o and (b) the portion V_o below the new zero elevation of the reservoir.

5.2.2.2 An example of the usage of this method is given in Annex B.

NOTE – The applicability of this method decreases with the increase in the ratio of $\frac{\text{sediment deposit}}{\text{reservoir capacity}}$. If the hundred years sediment, accumulation exceeds 15 percent of the original capacity, a more exact method should be applied.

5.2.3 *Moody's Method to Find New Zero Elevation*

This method is used to determine the new zero elevation 0, directly without trial and error process. Two parameters $f(p)$ and $f'(p)$ as explained below are made use of:

$$f(p) = \frac{1 - V(p)}{a(p)} \quad \text{....(3)}$$

$$f'(p) = \frac{S - V(pH)}{H\,A(pH)} \quad \text{....(4)}$$

where

$f(p)$ = a function of the relative depth of reservoir for one of the four types of theoretical design curves,

$V(p)$ = relative volume at a given elevation,

$a(p)$ = relative area at a given elevation,

$f'(p)$ = a function of the relative depth of reservoir for a particular reservoir and its anticipated sediment storage,

S = total sediment in the reservoir in hectare metres,

$V(pH)$ = reservoir capacity at a given elevation in hectare metres,

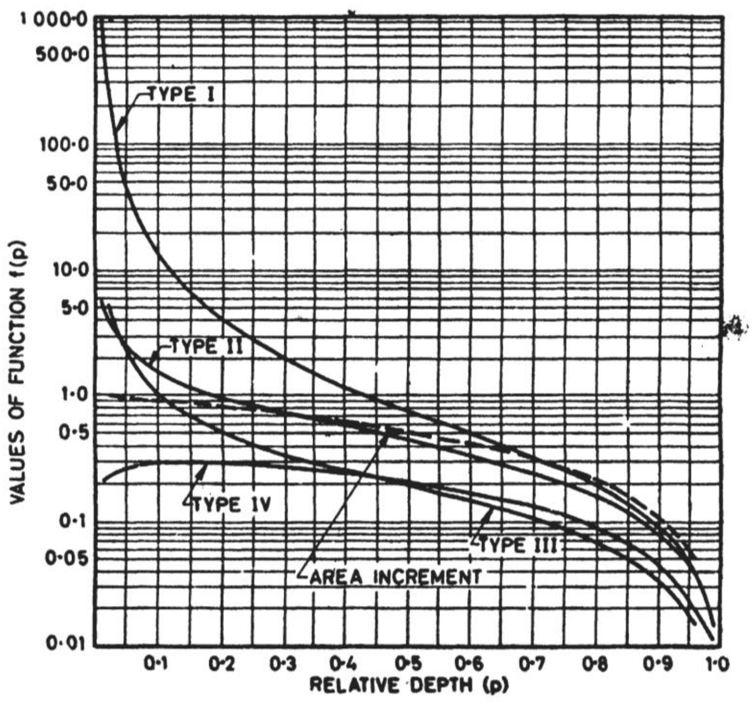
H = the total depth of reservoir for normal water surface in metres, and

$A(pH)$ = reservoir area at a given elevation in hectares.

5.2.3.1 Table 1 gives the values of the function $f(p)$ for the four types of reservoirs (*see* **5.2.1**) and Fig. 4 shows the plotting of $f(p)$ against relative reservoir depth, p, for the four types of reservoirs of the empirical area method (*see* **5.2.1**) and also for the area increment method (*see* **5.2.2**).

5.2.3.2 To determine the new zero elevation, $f(p)$ should equal $f'(p)$. This is done graphically by plotting the values of $f'(p)$ and superposing this over the relevant $f(p)$ curve. The intersection gives the relative depth of (P_o) reservoir at new zero elevation after sedimentation. New zero-elevation may be computed by adding the product P_o. H to the original stream bed elevation. After arriving at the new zero elevation, either empirical area method (*see* **5.2.1**) or the area increment method (*see* **5.2.2**) is used.

5.2.3.3 An example to find out the new zero elevation is given in Annex C.



MATHEMATICAL MODELLING STUDIES

The Mathematical modeling studies has been described for 100 years at 10 years interval including I.S. 12182-1987 and I.S. 5477 part-II. The Mathematical Modeling Studies has been tabulated from the next pages.

SOFTWARE NAME - IBM SPSS STATISTICS (STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES)

CURRENT VERSION - 2015

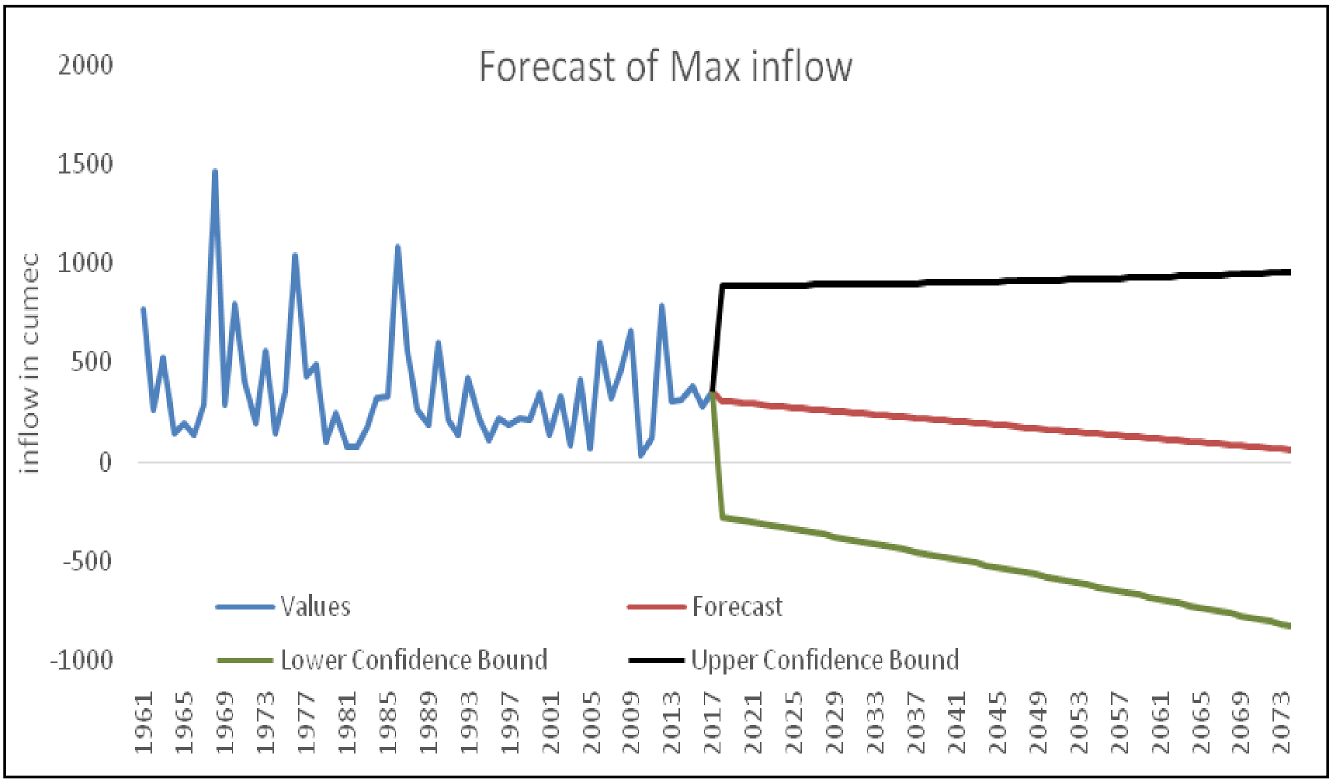
The Mathematical modeling study has been prepared by the above software and this study is completely prepared by Shri Arun Roy.

- **Mathematical Modeling Studies for 100 Years at 10 years interval (I.S.12182-1987 and I.S. 5477 Part-II):-**

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
1961.00	772.00			
1962.00	262.00			
1963.00	529.00			
1964.00	145.00			
1965.00	192.00			
1966.00	134.00			
1967.00	289.00			
1968.00	1464.00			
1969.00	291.00			
1970.00	795.00			
1971.00	403.00			
1972.00	199.00			
1973.00	558.00			
1974.00	143.00			
1975.00	359.00			
1976.00	1043.00			
1977.00	433.00			
1978.00	491.00			
1979.00	104.00			
1980.00	247.00			
1981.00	73.00			
1982.00	80.00			
1983.00	166.00			
1984.00	324.00			
1985.00	328.00			
1986.00	1080.00			
1987.00	561.00			
1988.00	259.00			
1989.00	189.00			
1990.00	600.00			
1991.00	212.00			
1992.00	133.00			
1993.00	427.00			
1994.00	221.00			
1995.00	111.00			
1996.00	217.00			
1997.00	188.00			

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
1998.00	219.00			
1999.00	212.00			
2000.00	344.00			
2001.00	138.00			
2002.00	327.00			
2003.00	81.00			
2004.00	414.00			
2005.00	70.00			
2006.00	600.00			
2007.00	323.00			
2008.00	463.00			
2009.00	661.00			
2010.00	34.00			
2011.00	119.00			
2012.00	789.00			
2013.00	308.00			
2014.00	310.00			
2015.00	385.00			
2016.00	279.00			
2017.00	354.00	354.00	354.00	354.00
2018.00		304.67	-274.73	884.06
2019.00		300.35	-283.70	884.40
2020.00		296.02	-292.72	884.76
2021.00		291.70	-301.76	885.17
2022.00		287.38	-310.85	885.61
2023.00		283.06	-319.96	886.08
2024.00		278.74	-329.11	886.59
2025.00		274.42	-338.30	887.13
2026.00		270.09	-347.52	887.71
2027.00		265.77	-356.78	888.32
2028.00		261.45	-366.07	888.97
2029.00		257.13	-375.39	889.65
2030.00		252.81	-384.74	890.36
2031.00		248.49	-394.13	891.11
2032.00		244.17	-403.55	891.88
2033.00		239.84	-413.00	892.69
2034.00		235.52	-422.49	893.54
2035.00		231.20	-432.01	894.41
2036.00		226.88	-441.56	895.32
2037.00		222.56	-451.14	896.25
2038.00		218.24	-460.75	897.22

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
2039.00		213.92	-470.39	898.22
2040.00		209.59	-480.06	899.25
2041.00		205.27	-489.77	900.31
2042.00		200.95	-499.50	901.40
2043.00		196.63	-509.27	902.52
2044.00		192.31	-519.06	903.68
2045.00		187.99	-528.88	904.86
2046.00		183.67	-538.74	906.07
2047.00		179.34	-548.62	907.31
2048.00		175.02	-558.53	908.57
2049.00		170.70	-568.47	909.87
2050.00		166.38	-578.44	911.20
2051.00		162.06	-588.44	912.55
2052.00		157.74	-598.46	913.93
2053.00		153.42	-608.51	915.34
2054.00		149.09	-618.59	916.78
2055.00		144.77	-628.70	918.25
2056.00		140.45	-638.84	919.74
2057.00		136.13	-649.00	921.26
2058.00		131.81	-659.19	922.81
2059.00		127.49	-669.41	924.38
2060.00		123.16	-679.66	925.99
2061.00		118.84	-689.93	927.61
2062.00		114.52	-700.22	929.27
2063.00		110.20	-710.55	930.95
2064.00		105.88	-720.90	932.65
2065.00		101.56	-731.27	934.39
2066.00		97.24	-741.67	936.15
2067.00		92.91	-752.10	937.93
2068.00		88.59	-762.55	939.74
2069.00		84.27	-773.03	941.57
2070.00		79.95	-783.53	943.43
2071.00		75.63	-794.06	945.32
2072.00		71.31	-804.61	947.23
2073.00		66.99	-815.19	949.16
2074.00		62.66	-825.79	951.12

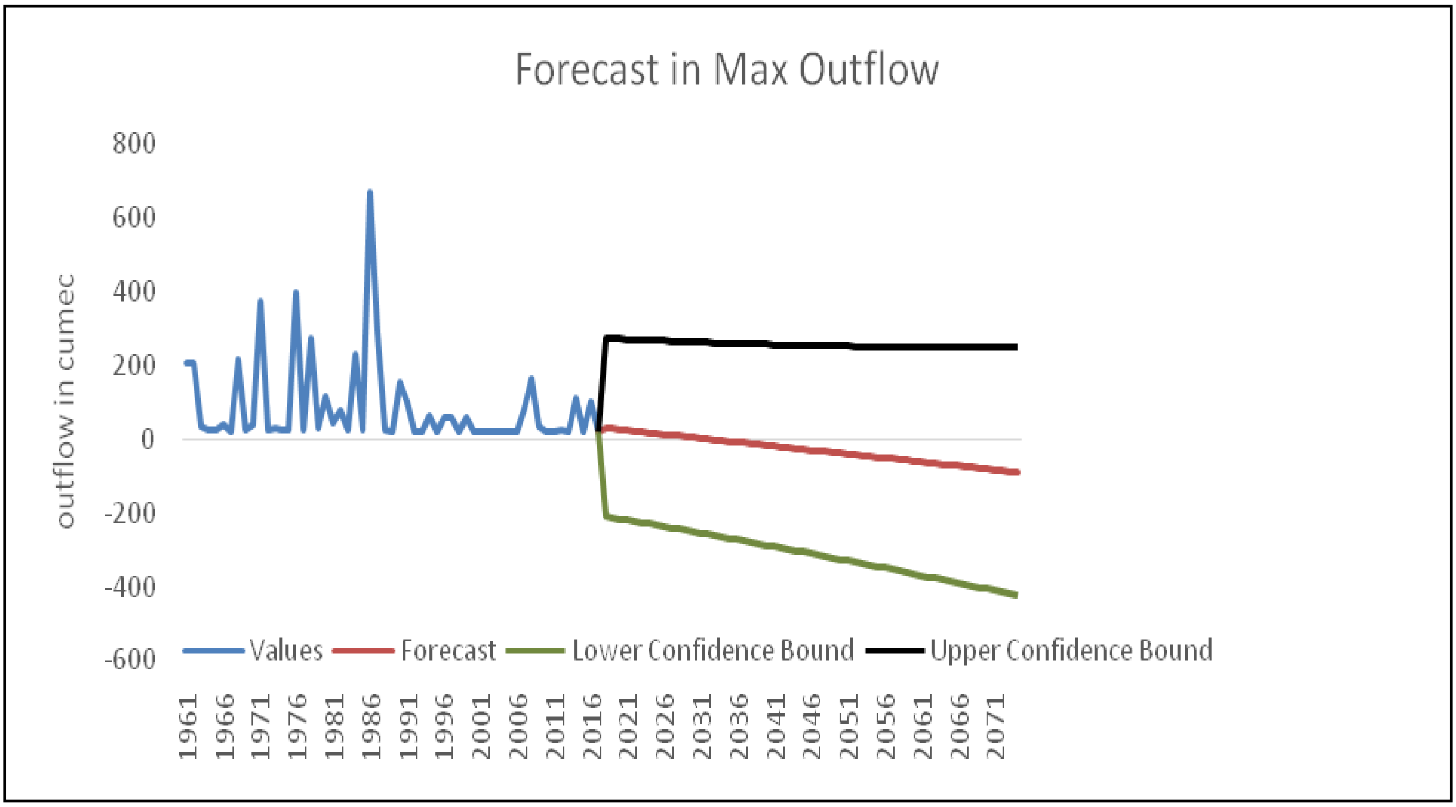


Forecast of Max inflow
inflow in cumec
2000
1500
1000
500
0
-500
-1000
Values
Forecast
Lower Confidence Bound
Upper Confidence Bound
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017
2021
2025
2029
2033
2037
2041
2045
2049
2053
2057
2061
2065
2069
2073

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
1961.00	205.00			
1962.00	206.00			
1963.00	34.00			
1964.00	25.00			
1965.00	26.00			
1966.00	40.00			
1967.00	22.00			
1968.00	214.00			
1969.00	24.00			
1970.00	37.00			
1971.00	372.00			
1972.00	25.00			
1973.00	28.00			
1974.00	26.00			
1975.00	25.00			
1976.00	399.00			
1977.00	26.00			
1978.00	272.00			
1979.00	31.00			
1980.00	116.00			
1981.00	44.00			
1982.00	75.00			
1983.00	26.00			
1984.00	228.00			
1985.00	25.00			
1986.00	669.00			
1987.00	288.00			
1988.00	27.00			
1989.00	20.00			
1990.00	152.00			
1991.00	100.00			
1992.00	22.00			
1993.00	22.00			
1994.00	61.00			
1995.00	20.00			
1996.00	58.00			
1997.00	56.00			
1998.00	22.00			
1999.00	56.00			
2000.00	21.00			
2001.00	21.00			
2002.00	22.00			
2003.00	22.00			
2004.00	21.00			

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
2005.00	21.00			
2006.00	20.00			
2007.00	82.00			
2008.00	162.00			
2009.00	34.00			
2010.00	22.00			
2011.00	21.00			
2012.00	25.00			
2013.00	21.00			
2014.00	110.00			
2015.00	21.00			
2016.00	102.00			
2017.00	21.00	21.00	21.00	21.00
2018.00		30.76	-210.35	271.86
2019.00		28.61	-213.73	270.94
2020.00		26.46	-217.12	270.04
2021.00		24.32	-220.52	269.16
2022.00		22.17	-223.95	268.30
2023.00		20.03	-227.39	267.45
2024.00		17.88	-230.86	266.62
2025.00		15.74	-234.34	265.81
2026.00		13.59	-237.84	265.01
2027.00		11.44	-241.35	264.24
2028.00		9.30	-244.88	263.48
2029.00		7.15	-248.43	262.74
2030.00		5.01	-252.00	262.02
2031.00		2.86	-255.59	261.31
2032.00		0.72	-259.19	260.62
2033.00		-1.43	-262.81	259.95
2034.00		-3.58	-266.45	259.30
2035.00		-5.72	-270.11	258.66
2036.00		-7.87	-273.78	258.04
2037.00		-10.01	-277.47	257.44
2038.00		-12.16	-281.17	256.85
2039.00		-14.30	-284.90	256.29
2040.00		-16.45	-288.64	255.73
2041.00		-18.60	-292.39	255.20
2042.00		-20.74	-296.17	254.68
2043.00		-22.89	-299.96	254.18
2044.00		-25.03	-303.76	253.69
2045.00		-27.18	-307.58	253.23
2046.00		-29.33	-311.42	252.77
2047.00		-31.47	-315.28	252.34
2048.00		-33.62	-319.15	251.92
2049.00		-35.76	-323.04	251.51
2050.00		-37.91	-326.94	251.12

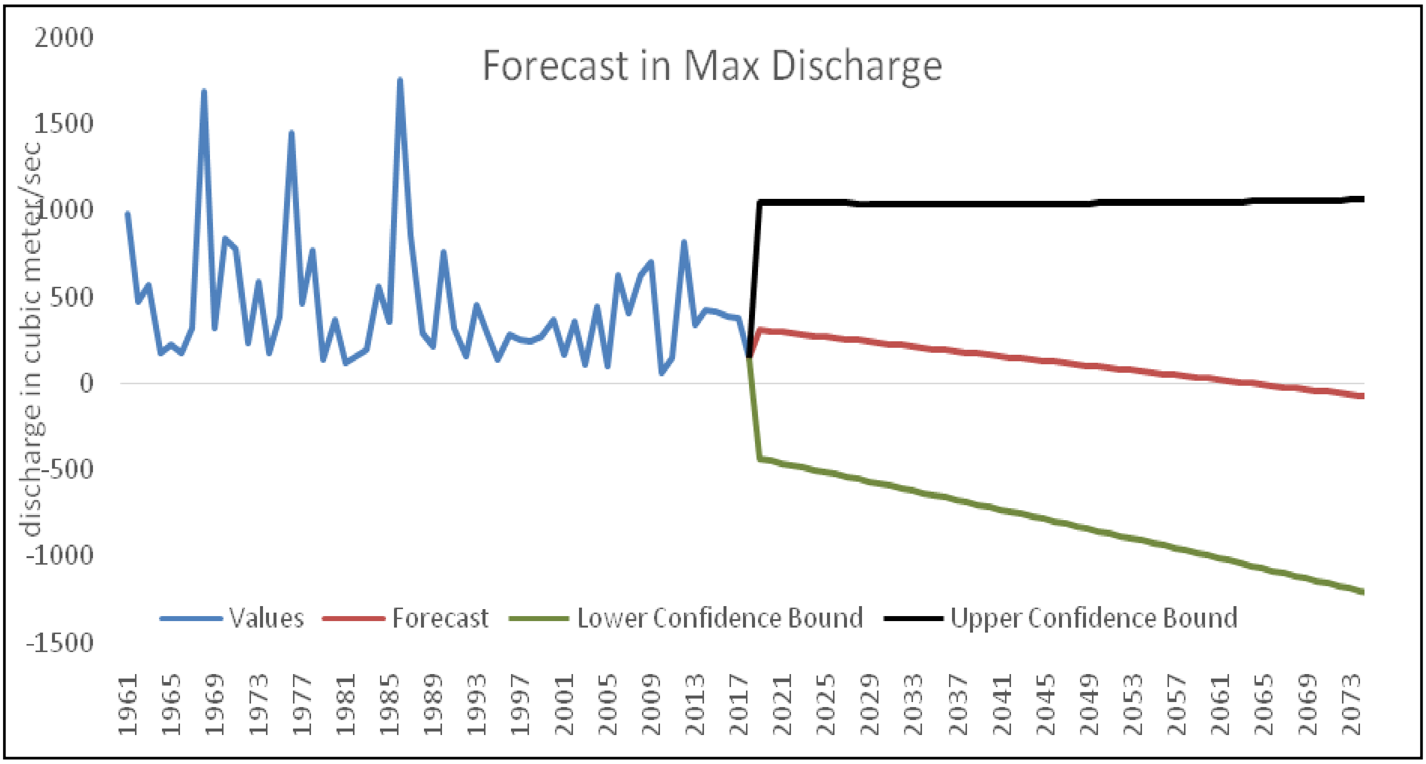
Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
2051.00		-40.05	-330.86	250.75
2052.00		-42.20	-334.79	250.40
2053.00		-44.35	-338.75	250.05
2054.00		-46.49	-342.71	249.73
2055.00		-48.64	-346.69	249.42
2056.00		-50.78	-350.69	249.13
2057.00		-52.93	-354.70	248.85
2058.00		-55.07	-358.73	248.58
2059.00		-57.22	-362.77	248.33
2060.00		-59.37	-366.83	248.10
2061.00		-61.51	-370.90	247.88
2062.00		-63.66	-374.99	247.68
2063.00		-65.80	-379.09	247.49
2064.00		-67.95	-383.21	247.32
2065.00		-70.09	-387.34	247.16
2066.00		-72.24	-391.49	247.01
2067.00		-74.39	-395.65	246.88
2068.00		-76.53	-399.83	246.76
2069.00		-78.68	-404.01	246.66
2070.00		-80.82	-408.22	246.57
2071.00		-82.97	-412.44	246.50
2072.00		-85.11	-416.67	246.44
2073.00		-87.26	-420.91	246.39
2074.00		-89.41	-425.17	246.36


Forecast in Max Outflow
800
600
400
200
0
-200
-400
-600
outflow in cumec
Values
Forecast
Lower Confidence Bound
Upper Confidence Bound
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
2056
2061
2066
2071

Timeline	Values (Cubic meter/Sec)	Forecast (Cubic meter/Sec)	Lower Confidence Bound (Cubic meter/Sec)	Upper Confidence Bound (Cubic meter/Sec)
1961.00	977.00			
1962.00	468.00			
1963.00	563.00			
1964.00	170.00			
1965.00	218.00			
1966.00	174.00			
1967.00	311.00			
1968.00	1678.00			
1969.00	315.00			
1970.00	832.00			
1971.00	775.00			
1972.00	224.00			
1973.00	586.00			
1974.00	169.00			
1975.00	384.00			
1976.00	1442.00			
1977.00	459.00			
1978.00	763.00			
1979.00	135.00			
1980.00	363.00			
1981.00	117.00			
1982.00	155.00			
1983.00	192.00			
1984.00	552.00			
1985.00	353.00			
1986.00	1749.00			
1987.00	849.00			
1988.00	286.00			
1989.00	209.00			
1990.00	752.00			
1991.00	312.00			
1992.00	155.00			
1993.00	449.00			
1994.00	282.00			
1995.00	131.00			
1996.00	275.00			
1997.00	244.00			
1998.00	241.00			

Timeline	Values (Cubic meter/Sec)	Forecast (Cubic meter/Sec)	Lower Confidence Bound (Cubic meter/Sec)	Upper Confidence Bound (Cubic meter/Sec)
1999.00	268.00			
2000.00	365.00			
2001.00	159.00			
2002.00	349.00			
2003.00	103.00			
2004.00	435.00			
2005.00	91.00			
2006.00	620.00			
2007.00	405.00			
2008.00	625.00			
2009.00	695.00			
2010.00	56.00			
2011.00	140.00			
2012.00	814.00			
2013.00	329.00			
2014.00	420.00			
2015.00	406.00			
2016.00	381.00			
2017.00	375.00			
2018.00	143.29	143.29	143.29	143.29
2019.00		305.49	-437.98	1048.95
2020.00		298.72	-450.72	1048.16
2021.00		291.95	-463.50	1047.41
2022.00		285.19	-476.33	1046.71
2023.00		278.42	-489.21	1046.05
2024.00		271.65	-502.13	1045.43
2025.00		264.89	-515.09	1044.87
2026.00		258.12	-528.10	1044.34
2027.00		251.35	-541.16	1043.86
2028.00		244.59	-554.25	1043.43
2029.00		237.82	-567.39	1043.03
2030.00		231.05	-580.58	1042.68
2031.00		224.29	-593.80	1042.37
2032.00		217.52	-607.07	1042.11
2033.00		210.75	-620.38	1041.89
2034.00		203.99	-633.73	1041.70
2035.00		197.22	-647.12	1041.56
2036.00		190.45	-660.56	1041.46
2037.00		183.69	-674.03	1041.40
2038.00		176.92	-687.55	1041.39

Timeline	Values (Cubic meter/Sec)	Forecast (Cubic meter/Sec)	Lower Confidence Bound (Cubic meter/Sec)	Upper Confidence Bound (Cubic meter/Sec)
2039.00		170.15	-701.10	1041.41
2040.00		163.39	-714.70	1041.47
2041.00		156.62	-728.33	1041.57
2042.00		149.85	-742.00	1041.71
2043.00		143.09	-755.71	1041.89
2044.00		136.32	-769.47	1042.10
2045.00		129.55	-783.25	1042.36
2046.00		122.79	-797.08	1042.65
2047.00		116.02	-810.95	1042.98
2048.00		109.25	-824.85	1043.35
2049.00		102.49	-838.79	1043.76
2050.00		95.72	-852.76	1044.20
2051.00		88.95	-866.78	1044.68
2052.00		82.19	-880.83	1045.20
2053.00		75.42	-894.91	1045.75
2054.00		68.65	-909.03	1046.34
2055.00		61.89	-923.19	1046.96
2056.00		55.12	-937.38	1047.62
2057.00		48.35	-951.61	1048.32
2058.00		41.59	-965.87	1049.05
2059.00		34.82	-980.17	1049.81
2060.00		28.05	-994.51	1050.61
2061.00		21.29	-1008.87	1051.44
2062.00		14.52	-1023.27	1052.31
2063.00		7.75	-1037.71	1053.21
2064.00		0.99	-1052.18	1054.15
2065.00		-5.78	-1066.68	1055.12
2066.00		-12.55	-1081.21	1056.12
2067.00		-19.31	-1095.78	1057.15
2068.00		-26.08	-1110.38	1058.22
2069.00		-32.85	-1125.01	1059.32
2070.00		-39.61	-1139.68	1060.45
2071.00		-46.38	-1154.38	1061.62
2072.00		-53.15	-1169.11	1062.81
2073.00		-59.91	-1183.87	1064.04
2074.00		-66.68	-1198.66	1065.30
2075.00		-73.45	-1213.49	1066.59
2076.00		-80.21	-1228.35	1067.92


Forecast in Max Discharge
discharge in cubic meter/sec
2000
1500
1000
500
0
-500
-1000
-1500
Values
Forecast
Lower Confidence Bound
Upper Confidence Bound
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017
2021
2025
2029
2033
2037
2041
2045
2049
2053
2057
2061
2065
2069
2073

- **Original Allotted Capacity in the Year of 1953:-**

Original Capacity Survey:-

During 1950, DVC arranged for the aerial survey map of the valley for sediment studies. Although the original capacity has been computed from the air survey maps of six inches to a mile with 10 feet contour interval.

As per the sedimentation survey 1966 -1967, original storage capacity provided up to the elevation 1220 feet was 4, 23,500 acre feet and also original allocated capacity computed of 4, 46000 acre feet up to elevation 1222 ft by interpolation method. Hence the total original allocated capacity was established in the year 1953 as 4, 46000 acre feet.

Storage level	El-From-To	Original Allocated Capacity (MCM)	Original Allocated Capacity (ACRE FT)
Dead Storage	(Upto El.1192 ft (363.32 m)	140.62	114000
Live Storage	(El.1192-1210 ft (363.32-368.80 m)	194.90	158000
Flood Control	(El.1210-1222 ft (368.80-372.46 m)	214.62	174000
	Total =	550.13	446000

- **CAPACITY OF TILAIYA RESERVOIR IN DIFFERENT SURVEY IN DIFFERENT ZONES:-**

Storage level	El-From-TO	Year- 1953		Year- 1966		Year- 1997		Year- 2019	
		Capacity (MCM)	Capacity (ACRE FT)	Capacity (MCM)	Capacity (ACRE FT)	Capacity (MCM)	Capacity (ACRE FT)	Capacity (MCM)	Capacity (ACRE FT)
Dead Storage	(Upto El.1192 ft (363.32 m)	140.62	114000	95.37	77322	74.67	60535.95	40.31	32679.85
Live Storage	(El.1192-1210 ft (363.32-368.80 m)	194.90	158000	153.09	124118	141.37	114610.52	110.64	89697.30
Flood Control	(El.1210-1222 ft (368.80-372.46 m)	214.62	174000	Not Available	Not Available	165.48	134156.82	226.00	183221.18
TOTAL		550.13	446000	248.46	201440	381.52	309303.29	376.95	305598.33

Table-I

- **Peak Flood and Annual monsoon flow at Tilaiya Dam:-**

YEAR	Annual peak stream flow (Cumecs/M3/S)
1961	977
1962	468
1963	563
1964	170
1965	218
1966	174
1967	311
1968	1678
1969	315
1970	832
1971	775
1972	224
1973	586
1974	169
1975	384
1976	1442
1977	459
1978	763
1979	135
1980	363
1981	117
1982	155
1983	192
1984	552
1985	353
1986	1749
1987	849
1988	286
1989	209
1990	752
1991	312
1992	155
1993	449
1994	282
1995	131
1996	275
1997	244
1998	241

YEAR	Annual peak stream flow (Cumecs/M3/S)
1999	268
2000	365
2001	159
2002	349
2003	103
2004	435
2005	91
2006	620
2007	405
2008	625
2009	695
2010	56
2011	140
2012	814
2013	329
2014	420
2015	406
2016	381
2017	375
2018	143.29
2019	11.92

Table 6-Peak Flow of Tilaiya Dam in different year

- **<u>Gumbel Distribution Method Showing Prediction Stream flow of Tilaiya Reservoir (E.J.Gumbel-1935-54):</u>**

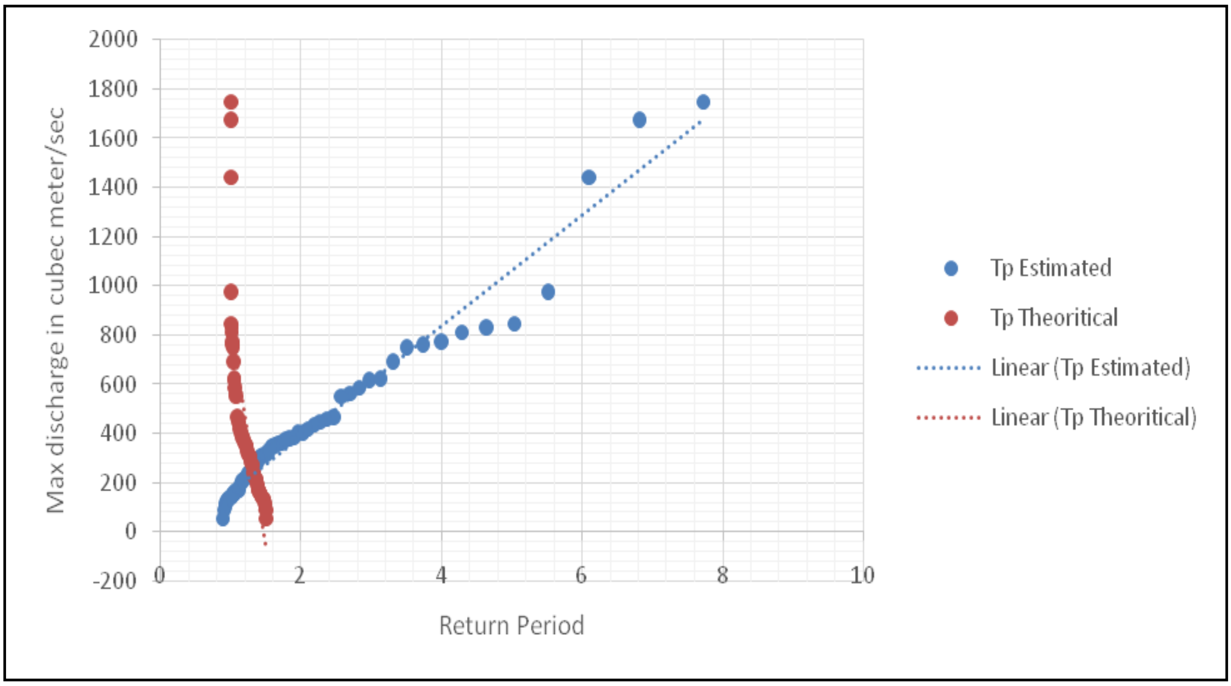


Table 7- Prediction of Stream flow by Gumbel distribution method

Table-II

- **Range of Operation of Tilaiya Reservoir in different year:-**

Year	Reservoir level (meter)		Reservoir level (FEET)	
	Maximum (m)	Minimum (m)	Maximum (FT)	Minimum (FT)
1961	371.37	363.14	1218.40	1191.40
1962	369.31	363.69	1211.64	1193.20
1963	370.53	355.09	1215.65	1164.99
1964	369.59	363.21	1212.255	1191.329
1965	368.81	362.53	1209.697	1189.098
1966	366.51	359.04	1202.153	1177.651
1967	368.83	357.76	1209.762	1173.453
1968	370.28	362.78	1214.518	1189.918
1969	369.06	362.17	1210.517	1187.918
1970	369.77	362.71	1212.846	1189.689
1971	372.35	363.06	1221.308	1190.837
1972	368.25	362.68	1207.86	1189.59
1973	370.76	362.75	1216.093	1189.82
1974	369.16	363.02	1210.845	1190.71
1975	369.84	362.50	1213.075	1189.00

Year	Reservoir level (meter)		Reservoir level (FEET)	
	Maximum (m)	Minimum (m)	Maximum (FT)	Minimum (FT)
1976	371.72	362.49	1219.55	1189.27
1977	369.83	362.82	1213.35	1190.35
1978	370.79	362.39	1216.50	1188.94
1979	367.07	362.75	1204.29	1190.12
1980	367.94	364.45	1207.15	1195.70
1981	366.63	363.28	1202.85	1191.86
1982	367.47	363.40	1205.61	1192.26
1983	368.51	361.84	1209.02	1187.14
1984	370.79	364.14	1216.50	1194.69
1985	370.61	362.89	1215.91	1190.58
1986	372.12	363.41	1220.87	1192.29
1987	371.70	363.18	1219.49	1191.54
1988	367.86	363.34	1206.89	1192.06
1989	368.56	362.97	1209.19	1190.85
1990	371.50	363.53	1218.83	1192.68
1991	370.54	363.41	1215.68	1192.29
1992	366.66	363.20	1202.95	1191.60
1993	369.42	363.72	1212.01	1193.31
1994	370.44	365.32	1215.35	1198.56
1995	369.26	365.44	1211.48	1198.95

Year	Reservoir level (meter)		Reservoir level (FEET)	
	Maximum (m)	Minimum (m)	Maximum (FT)	Minimum (FT)
1996	370.18	363.57	1214.50	1192.81
1997	371.24	363.14	1217.98	1191.40
1998	367.96	363.37	1207.22	1192.16
1999	371.42	363.10	1218.57	1191.27
2000	369.00	363.20	1210.63	1191.60
2001	367.11	363.41	1204.43	1192.29
2002	369.53	363.43	1212.37	1192.36
2003	366.91	363.95	1203.77	1194.06
2004	369.68	363.35	1212.86	1192.09
2005	366.54	363.51	1202.56	1192.62
2006	370.99	363.76	1217.16	1193.44
2007	371.64	365.56	1219.29	1199.34
2008	371.80	364.27	1219.82	1195.11
2009	370.10	364.01	1214.24	1194.26
2010	368.19	364.07	1207.97	1194.46
2011	369.57	364.31	1212.50	1195.24
2012	368.66	365.40	1209.51	1198.82
2013	368.52	365.29	1209.06	1198.46
2014	371.39	366.19	1218.47	1201.41
2015	369.44	365.99	1212.07	1200.75
2016	371.67	364.49	1219.39	1195.83
2017	369.16	365.27	1211.15	1198.39
2018	368.52	364.03	1209.06	1194.32
2019	368.55	363.61	1209.15	1192.95

Table 8-Range of Operation of Tilaiya Reservoir

Table-III

Drainage area of Tilaiya Reservoir =380 Sq, Miles (984 Sq. Km)

Sediment Deposition Rate in Tilaiya Reservoir

Between Years	No. of years	Volume of Deposit		Sediment Deposition Rate	
		Acre feet	MM^3	Aft./Sq.mile/year	M3/Sq km/year
1953-66	13	70560	8.70	14.28	6803
1953-97	44	136697	16.8	8.2	3892
1953-2019	66	140402	17.3	5.6	2665

Table-III A

Average Annual volume of Deposit

VOLUME IN ACRE FEET (M.C.M)			
	1966	1997	2019
1953	5427 (6.7)	3107 (3.83)	2127 (2.62)
1966	-	848.17 (1.046)	1491.75 (1.84)
1997	-	-	168 (-0.207)

Table-IV

CAPACITY OF TILAIYA RESERVOIR FOR DIFFERENT YEAR:-

Capacity of Tilaiya Reservoir (Acre ft) was computed up to E.l. 1222 ft. (372.5m). The Below table shows reservoir capacity at 10 feet (3m) (in different year) depth interval as here under:-

YEAR		1953		1966		1997		2019	
Elevation in Feet	Elevation in Meter	Capacity in Acre Feet	Capacity in MCM	Capacity in Acre Feet	Capacity in MCM	Capacity in Acre Feet	Capacity in MCM	Capacity in Acre Feet	Capacity in MCM
1140	347.5	-	-	-	-	-	-	24.32	0.03
1150	350.5	2700	3.33	910	1.12	-	-	421.57	0.52
1160	353.6	10130	12.5	3630	4.47	89.17	0.11	2675.35	3.30
1170	356.6	25180	31.06	15920	19.63	9760.98	12.04	8317.91	10.26
1180	359.7	52350	64.57	35510	43.80	26161.71	32.27	17300.62	21.34
1190	362.7	96170	118.62	66920	82.54	52696.35	65.00	30109.88	37.14
1200	365.8	165760	204.46	118930	146.69	98153.04	121.07	49931.82	61.59
1210	368.8	272000	335.52	201440	248.47	175146.47	216.04	122377.15	150.95
1220	371.9	416998	514.36	Not available	Not available	285598.04	352.28	266724.64	329.00
1222	372.5	446000	550.13	Not available	Not available	309303.29	381.52	305598.33	376.95

Table 9- Capacity of Tilaiya Dam at 10 feet (3 mtr)

Table-V

Capacity Table –Tilaiya Reservoir, 2019 (Pre-Monsoon):-

The Elevation with capacity table of Tilaiya Reservoir 2019 has been computed by the **Average end area formula**; that is equal to -

$h/2\ (A_1+A_2) = V$ (as per I.S. 5477 part-II-1994**)**

Where

h=the height of the segment (Contour interval)

A_1 and A_2=the contour area at the end of the segment and

V= the volume of the segment (Volume between two consecutive contour)

The Capacity have been shown at 01 feet (0.3 m) depth interval by interpolation as tabulated here under :-

Elevation ft above M.S.L	Capacity in Acre Ft.	Capacity in M.C.M	Elevation ft above M.S.L	Capacity in Acre Ft.	Capacity in M.C.M
1135	0.00	0.00	1181	18366.62	22.65
1136	1.87	0.00	1182	19472.10	24.02
1137	4.55	0.01	1183	20636.22	25.45
1138	8.41	0.01	1184	21852.32	26.95
1139	15.14	0.02	1185	23119.96	28.52
1140	26.29	0.03	1186	24439.77	30.15
1141	41.00	0.05	1187	25801.38	31.83
1142	58.41	0.07	1188	27199.26	33.55
1143	79.97	0.10	1189	28632.12	35.32
1144	104.93	0.13	1190	30105.93	37.14
1145	133.30	0.16	1191	31630.24	39.02
1146	168.07	0.21	1192	32676.12	40.31
1147	212.97	0.26	1192	33222.04	40.98
1148	271.65	0.34	1193	34931.81	43.09
1149	341.10	0.42	1194	36713.08	45.28
1150	421.03	0.52	1195	38606.48	47.62
1151	517.84	0.64	1196	40689.14	50.19
1152	639.08	0.79	1197	42900.24	52.92
1153	793.98	0.98	1198	45173.60	55.72
1154	974.53	1.20	1199	47531.49	58.63
1155	1169.79	1.44	1200	49928.66	61.59
1156	1379.54	1.70	1201	52356.47	64.58
1157	1601.17	1.98	1202	55080.83	67.94
1158	1833.44	2.26	1203	58416.79	72.06
1158	2077.51	2.56	1204	62919.74	77.61
1159	2357.59	2.91	1205	69129.94	85.27
1160	2672.41	3.30	1206	77084.85	95.08
1161	3047.19	3.76	1207	86541.25	106.75
1162	3496.73	4.31	1208	97491.38	120.25
1163	3986.29	4.92	1209	109680.40	135.29
1164	4515.87	5.57	1210	122374.79	150.95
1165	5074.88	6.26	1211	135337.90	166.94
1166	5652.70	6.97	1212	148585.65	183.28
1167	6270.91	7.74	1213	162249.01	200.13
1168	6925.90	8.54	1214	176328.00	217.50
1169	7604.87	9.38	1215	190717.25	235.25
1170	8320.12	10.26	1216	205311.42	253.25
1171	9072.92	11.19	1217	220110.49	271.50
1172	9854.92	12.16	1218	235270.62	290.20
1173	10656.48	13.14	1219	250843.61	309.41
1174	11489.76	14.17	1220	266725.14	329.00
1175	12373.71	15.26	1221	282930.83	348.99
1176	13302.95	16.41	1222	305599.63	376.95
1177	14253.15	17.58	-	-	-
1178	15233.27	18.79	-	-	-
1179	16256.71	20.05	-	-	-
1180	17303.63	21.34	-	-	-

Table 10-Capacity of Tilaiya dam at 01 feet depth interval

Table-VI

- **Capacity of Tilaiya Reservoir in different Zones for different year:-**

The Below table shows the Capacity of Tilaiya Reservoir in different zones for different year i.e. Dead zone, Live zone and Flood zone of the Reservoir.

Capacity in Acre Feet /MCM				
ZONE YEAR	1953	1966	1997	2019
DEAD STORAGE UPTO EL. 363.32 M	114000 (140.62)	77322 (95.37)	60535.95 (74.67)	32679.85 (40.31)
LIVE STORAGE EL. 363.32-368.80 M	158000 (194.90)	124118 (153.09)	114610.52 (141.37)	89697.30 (110.64)
FLOOD ZONE EL. 368.80-372.46 M	174000 (214.62)	N.A	134156.82 (165.48)	183221.18 (226.00)
OVERALL UPTO EL. 372.46 M	446000 (550.13)	201440 (248.46)	309303.29 (381.52)	305598.33 (376.95)

Table-VII

Loss of Storage Capacity in Tilaiya Reservoir

Period	No. of years	Total volume of Loss of Capacity		Average Annual loss of Capacity	
		Acre Feet	10^6 m^3	Acre Feet	10^6 m^3
1953-66	13	70,560	87.03	5427	6.7
1953-97	44	136,697	168.6	3107	3.8
1953-2019	66	140,402	173.1	2127	2.6

Table-VIII

Percent loss of Capacity in Tilaiya Reservoir

Zone/Period	Total loss percent			Average Annual loss percent		
	53-66	53-97	53-2019	53-66	53-97	53-2019
Dead Storage (upto El. 363.32m)	32.17	46.9	71.33	2.47	1.07	1.08
Live Storage (363.32 m-368.80m)	21.44	27.4	43.22	1.65	0.62	0.65
Flood Zone (368.80M-372.46M)	N.A	22.8	Negligible	N.A	0.35	Negligible
Overall	25.94	30.64	31.48	1.99	0.69	0.48

Table-IX

•Distribution of Sediment Deposit in Different Reaches of Tilaiya Reservoir:-

	PERCENT OF TOTAL VOLUME DEPOSIT			
	REACHES OF TILAIYA RESERVOIR			
REACH MILES U/S	1966	1997	2019	REACH KM (U/S)
0-2	1.7	2.2	2.7	(0-3.2)
2-4	7.3	7.7	8.5	(3.2-6.4)
4-6	15.7	16.9	18.8	(6.4-9.6)
6-8	22.1	21.0	22.1	(9.6-12.8)
8-10	32.1	30.0	29.6	(12.8-16.0)
10-12	21.1	22.3	18.3	(16-19.2)
Total Volume Acre Ft./MCM of Deposit	70830 (87.36)	136697 (168.62)	140402 (173.18)	

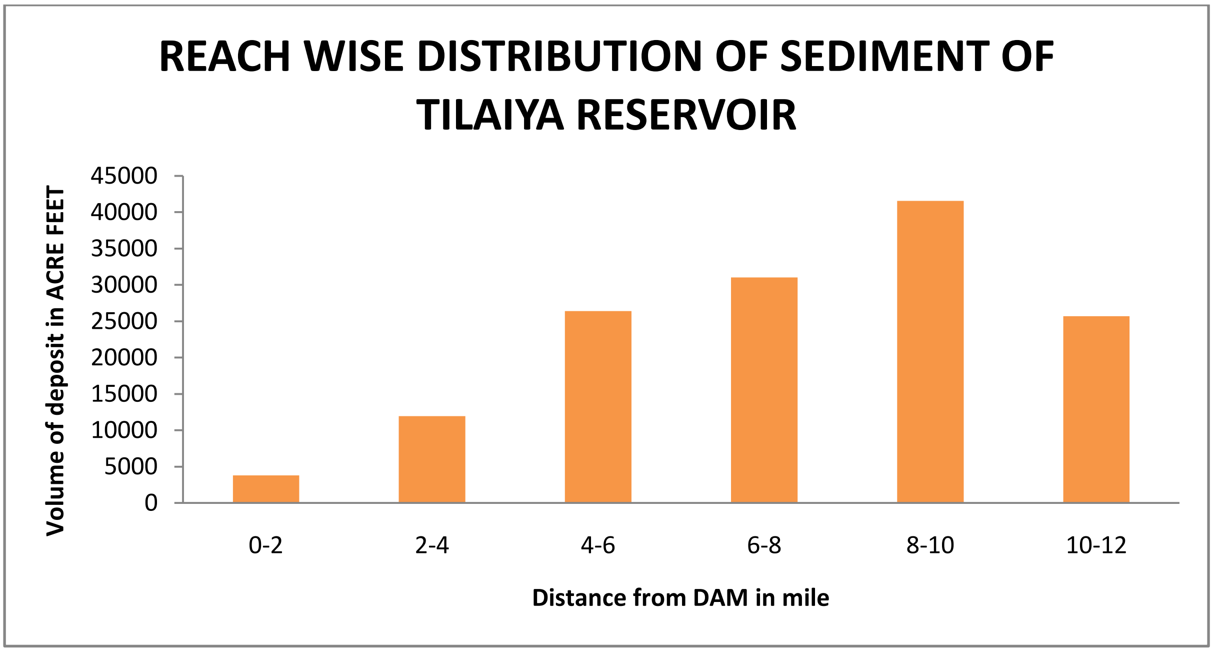
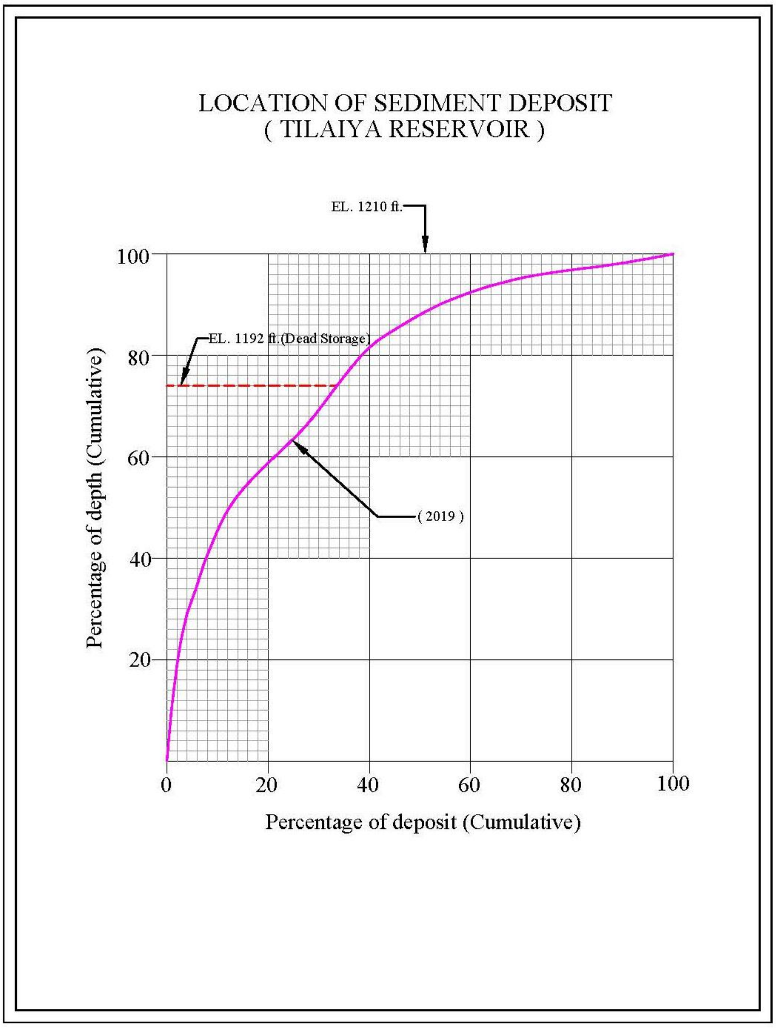


Table-X

Depth Wise location of Deposit in Percentage of Tilaiya Reservoir

DEPTH -WISE LOCATION OF DEPOSIT IN TILAIYA RESERVOIR								
BET ELE IN FT/M	1140-1150 (347.472-350.52)	1150-1160 (350.52-353.56)	1160-1170 (353.56-356.61)	1170-1180 (356.61-359.66)	1180-1190 (359.66-362.71)	1190-1200 (362.71-365.76)	1200-1210 (365.76-368.80)	1210-1222 (368.80-372.46)
DEPTH IN FT/M	0-10 (0-3.05)	10-20 (3.05-6.1)	20-30 (6.1-9.14)	30-40 (9.14-12.2)	40-50 (12.2-15.24)	50-60 (115.24-18.3)	60-70 (18.3-21.3)	70-82 (21.3-25.00)
2019	0.67	3.08	4.05	14.05	12.07	26.52	27.4	12.16



ANALYSIS OF BED MATERIAL SAMPLES

This section has been analyzed bed material samples to obtain sediment sizes, density, specific gravity, moisture content etc.

13.4 Analysis of bed Material Samples:-

1.0 Grain size analysis (As per IS: 2720 (Part-4)-1985)

The grain size distributions of all representative samples were determined from sieve analysis and hydrometer analysis upon the average grain diameter of the soil samples. The higher grained samples like sand, gravel were analyzed through sieve hydrometer analysis depending upon the average grain diameter of the soil samples. The higher grained samples like sand were analyzed through sieve and the lower grain samples like fine silt and clay were analyzed through hydrometer. The results have been presented in the tables and graphs.

2.0 Natural Moisture Content (NMC) (As per IS: 2720 (Part-1)-1983)

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

3.0Specific Gravity (As per IS: 2720 (Part-3/ sec-1)-1980)

This test has been carried out to determine the specific gravity of fine-grained soil by density bottle method as per IS: 2720 (Part III/Sec 1) –1980. Specific gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of equal volume of distilled water at the same stated temperature.

13.4.1 Soil Sample Positions:-

Figure 17-Locations of Soil Samples

13.4.2 Sediment Size, Density, Specific Gravity and Moisture Content:-

SITE: TILAIYA RESERVOIR													
TEST RESULTS													
Sl. No.	Sample No.	Northing (m)	Easting (m)	Latitude (N)	Longitude (E)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Specific Gravity	Uniformity of soil
1	1	2688925.67	351273.9	24°18'22.80"	85º32'3.75"	Greyish sandy clayey silt	0.00	39.76	39.70	20.54	65.27	2.63	Non-Uniform
2	2	2689951.3	350844.33	24°18'55.99"	85°31'48.13"	Greyish sandy clayey silt	0.00	56.52	21.34	22.14	57.86	2.64	Non-Uniform
3	3	2690568.45	349887.53	24°19'15.72"	85°31'13.96"	Brwonish grey sandy clayey silt with gravels	12.60	34.85	25.61	26.94	62.70	2.65	Uniform
4	4	2690000.88	348729.24	24°18'56.87"	85°30'33.09"	Greyish sandy clayey silt	0.00	44.90	31.36	23.74	59.85	2.64	Non-Uniform
5	5	2689203.4	347503.23	24°18'30.52"	85°29'49.91"	Brwonish grey sandy clayey silt with gravels	7.89	38.98	24.59	28.54	54.95	2.65	Non-Uniform
6	6	2691196.52	347635.27	24°19'35.35"	85°29'53.83"	Light brownish grey sandy clayey silt with gravels	18.20	43.10	21.36	17.34	61.95	2.67	Uniform
7	7	2690376.43	346827.44	24°19'8.41"	85°29'25.49"	Light brownish grey sandy clayey silt with gravels	15.90	45.85	19.31	18.94	57.15	2.67	Uniform
8	8	2690288.55	344817.72	24°19'4.84"	85º28'14.24"	Light brownish grey sandy clayey silt with gravels	20.70	39.80	15.76	23.74	60.70	2.67	Uniform
9	9	2691671.64	344916.09	24°19'49.83"	85°28'17.19"	Brwonish grey sandy clayey silt with gravels	9.60	42.50	19.36	28.54	58.48	2.65	Non-Uniform
10	10	2691971.96	343491.85	24°19'59.08"	85°27'26.55"	Brwonish grey sandy clayey silt with gravels	10.75	35.70	26.61	26.94	59.78	2.66	Uniform
11	11	2692241.81	341670.12	24°'20'7.19"	85°26'21.82"	Light brownish grey sandy clayey silt with gravels	14.90	43.90	12.66	28.54	61.35	2.65	Uniform
12	12	2693427.25	341041.6	24° 20'45.49"	85°25'59.05"	Light brownish grey sandy clayey silt with gravels	26.70	28.12	23.04	22.14	60.10	2.69	Uniform
13	13	2693908.55	340514.87	24°21'0.94"	85°25'40.17"	Light brownish grey sandy clayey silt with gravels	21.50	32.10	19.46	26.94	57.86	2.67	Uniform

13.4.3 Bulk Density of the samples:-

Sample - 1

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	39.76					
Silt (%)	39.70					
Clay (%)	20.54	Cont. Submerged	256	91	0	0.89
		Periodic drwadown	135	29	0	0.39
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	987.33	987.48	987.58	987.65	987.72	987.77	987.59	987.75	987.86	987.95	988.02
Periodic drwadown	1025.05	1025.12	1025.16	1025.19	1025.2	1025.25	1025.17	1025.24	1025.29	1025.32	1025.35
Resvr. normally empty	1045.45	1045.45	1045.45	1045.45	1045.5	1045.45	1045.45	1045.45	1045.45	1045.45	1045.45

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 2

Sand (%)	56.52	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	21.34					
Clay (%)	22.14	Cont. Submerged	256	91	0	0.76
		Periodic drwadown	135	29	0	0.36
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	981.09	981.22	981.30	981.37	981.42	981.47	981.32	981.45	981.55	981.62	981.68
Periodic drwadown	1017.46	1017.52	1017.56	1017.59	1017.6	1017.64	1017.57	1017.63	1017.68	1017.71	1017.74
Resvr. normally empty	1037.31	1037.31	1037.31	1037.31	1037.3	1037.31	1037.31	1037.31	1037.31	1037.31	1037.31

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 3

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	47.45					
Silt (%)	25.61					
Clay (%)	26.94	Cont. Submerged	256	91	0	0.92
		Periodic drwadown	135	29	0	0.44
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	944.58	944.73	944.84	944.92	944.98	945.04	944.86	945.02	945.13	945.22	945.30
Periodic drwadown	988.76	988.84	988.89	988.92	989.0	988.98	988.89	988.97	989.03	989.07	989.10
Resvr. normally empty	1012.88	1012.88	1012.88	1012.88	1012.9	1012.88	1012.88	1012.88	1012.88	1012.88	1012.88

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 4

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	44.90		Reservoir condition:				
Silt (%)	31.36						
Clay (%)	23.74		Cont. Submerged	256	91	0	0.89
			Periodic drwadown	135	29	0	0.41
Total (%)	100.00		Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	966.34	966.49	966.59	966.67	966.73	966.79	966.61	966.77	966.88	966.96	967.04
Periodic drwadown	1007.04	1007.10	1007.15	1007.19	1007.2	1007.24	1007.16	1007.23	1007.28	1007.32	1007.36
Resvr. normally empty	1029.16	1029.16	1029.16	1029.16	1029.2	1029.16	1029.16	1029.16	1029.16	1029.16	1029.16

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 5

Sand (%)	46.87	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	24.59					
Clay (%)	28.54	Cont. Submerged	256	91	0	0.95
		Periodic drwadown	135	29	0	0.46
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	933.14	933.30	933.41	933.49	933.56	933.62	933.43	933.59	933.71	933.81	933.88
Periodic drwadown	979.44	979.52	979.57	979.61	979.6	979.67	979.58	979.66	979.72	979.76	979.80
Resvr. normally empty	1004.73	1004.73	1004.73	1004.73	1004.7	1004.73	1004.73	1004.73	1004.73	1004.73	1004.73

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 6

Sand (%)	61.30	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	21.36					
Clay (%)	17.34	Cont. Submerged	256	91	0	0.64
		Periodic drwadown	135	29	0	0.30
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	1016.32	1016.42	1016.50	1016.55	1016.6	1016.64	1016.51	1016.62	1016.70	1016.76	1016.81
Periodic drwadown	1045.73	1045.78	1045.81	1045.84	1045.9	1045.88	1045.82	1045.87	1045.91	1045.94	1045.96
Resvr. normally empty	1061.74	1061.74	1061.74	1061.74	1061.7	1061.74	1061.74	1061.74	1061.74	1061.74	1061.74

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 7

Sand (%)	61.75	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	19.31					
Clay (%)	18.94	Cont. Submerged	256	91	0	0.66
		Periodic drwadown	135	29	0	0.31
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	1005.19	1005.30	1005.37	1005.43	1005.5	1005.52	1005.39	1005.50	1005.59	1005.65	1005.70
Periodic drwadown	1036.51	1036.56	1036.60	1036.63	1036.6	1036.67	1036.61	1036.66	1036.70	1036.73	1036.75
Resvr. normally empty	1053.60	1053.60	1053.60	1053.60	1053.6	1053.60	1053.60	1053.60	1053.60	1053.60	1053.60

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 8

Sand (%)	60.50	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	15.76					
Clay (%)	23.74	Cont. Submerged	256	91	0	0.75
		Periodic drwadown	135	29	0	0.37
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	971.02	971.15	971.23	971.30	971.4	971.40	971.25	971.38	971.47	971.55	971.60
Periodic drwadown	1008.60	1008.66	1008.70	1008.73	1008.8	1008.78	1008.71	1008.77	1008.82	1008.85	1008.88
Resvr. normally empty	1029.16	1029.16	1029.16	1029.16	1029.2	1029.16	1029.16	1029.16	1029.16	1029.16	1029.16

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 9

Sand (%)	52.10	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	19.36					
Clay (%)	28.54	Cont. Submerged	256	91	0	0.91
		Periodic drwadown	135	29	0	0.44
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	934.71	934.86	934.96	935.04	935.1	935.16	934.98	935.14	935.25	935.34	935.41
Periodic drwadown	979.96	980.04	980.09	980.13	980.2	980.18	980.10	980.17	980.23	980.27	980.31
Resvr. normally empty	1004.73	1004.73	1004.73	1004.73	1004.7	1004.73	1004.73	1004.73	1004.73	1004.73	1004.73

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 10

Sand (%)	46.45	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	26.61					
Clay (%)	26.94	Cont. Submerged	256	91	0	0.93
		Periodic drwadown	135	29	0	0.44
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	944.28	944.43	944.54	944.62	944.7	944.74	944.56	944.72	944.84	944.93	945.00
Periodic drwadown	988.66	988.74	988.79	988.82	988.9	988.88	988.80	988.87	988.93	988.97	989.01
Resvr. normally empty	1012.88	1012.88	1012.88	1012.88	1012.9	1012.88	1012.88	1012.88	1012.88	1012.88	1012.88

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 11

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	58.80	Reservoir condition:					
Silt (%)	12.66						
Clay (%)	28.54	Cont. Submerged		256	91	0	0.85
		Periodic drwadown		135	29	0	0.42
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	936.72	936.86	936.96	937.03	937.1	937.14	936.97	937.12	937.23	937.31	937.38
Periodic drwadown	980.63	980.70	980.75	980.79	980.8	980.84	980.76	980.83	980.89	980.93	980.96
Resvr. normally empty	1004.73	1004.73	1004.73	1004.73	1004.7	1004.73	1004.73	1004.73	1004.73	1004.73	1004.73

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 12

Sand (%)	54.82	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	23.04					
Clay (%)	22.14	Cont. Submerged	256	91	0	0.78
		Periodic drwadown	135	29	0	0.37
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	980.58	980.71	980.80	980.87	980.9	980.97	980.81	980.95	981.05	981.12	981.18
Periodic drwadown	1017.29	1017.35	1017.39	1017.43	1017.5	1017.47	1017.40	1017.47	1017.51	1017.55	1017.58
Resvr. normally empty	1037.31	1037.31	1037.31	1037.31	1037.3	1037.31	1037.31	1037.31	1037.31	1037.31	1037.31

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 13

Sand (%)	53.60	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	19.46					
Clay (%)	26.94	Cont. Submerged	256	91	0	0.87
		Periodic drwadown	135	29	0	0.42
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	946.42	946.57	946.67	946.74	946.8	946.86	946.68	946.84	946.94	947.03	947.10
Periodic drwadown	989.38	989.45	989.50	989.53	989.6	989.59	989.50	989.58	989.63	989.67	989.70
Resvr. normally empty	1012.88	1012.88	1012.88	1012.88	1012.9	1012.88	1012.88	1012.88	1012.88	1012.88	1012.88

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

13.4.4 Kramer's Coefficient:-

Kramer's coefficient

% Finer	Dia (mm)	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6	Sample-7	Sample-8	Sample-9	Sample-10	Sample-11	Sample-12	Sample-13
0	D0													
10	D10													
20	D20						0.0038	0.0038	-	-	-			
30	D30	0.007	0.009	0.005	0.007	0.005	0.0578	0.0408	0.0083	0.0023	0.0053	0.0037	0.0092	0.0075
40	D40	0.025	0.028	0.070	0.025	0.066	0.087	0.086	0.079	0.012	0.0569	0.074	0.031	0.07
50	D50	0.068	0.100	0.074	0.070	0.072	0.17	0.18	0.160	0.1	0.072	0.14	0.1	0.094
60	D60	0.075	0.137	0.170	0.100	0.150	0.27	0.27	0.230	0.2	0.17	0.22	0.2	0.17
70	D70	0.130	0.2	0.265	0.170	0.240	0.54	0.5	0.400	0.3	0.23	0.35	0.096	0.425
80	D80	0.220	0.28	0.6	0.270	0.470	2.36	1.6	-	0.42	0.42	1.2	-	-
90	D90	0.425	0.58	-	0.520	3.000	-	-	-	4.75	-	-	-	-
100	D100	4.75	4.75	-	4.75	-	-	-	-	-	-	-	-	-
84	D84	0.235	0.32	2.30	0.30	0.52	-	4.60	-	1	0.6	3.4	-	-
16	D16	-	-	-	-	-	-	-	-	-	-	-	-	-

For Sample-1

Dia (mm)	For Sample-1	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.007	30				
D40	0.025	40	10	0.014	0.137	-0.865
D50	0.068	50	10	0.041	0.412	-0.385
D60	0.075	60	10	0.071	0.714	-0.146
D70	0.130	70	10	0.099	0.987	-0.005
D80	0.220	80	10	0.169	1.691	0.228
D90	0.425	90	10	0.306	3.058	0.485
D100	4.750	100	10	1.421	14.208	1.153
D84	0.235	84				
D16		16				

da	0.303	mm
dg	1.011	mm
σg	-	
M	0.027	

Remarks: Sediment is non-uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-2

Dia (mm)	For Sample-2	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.009	30				
D40	0.028	40	10	0.016	0.160	-0.796
D50	0.100	50	10	0.053	0.533	-0.273
D60	0.137	60	10	0.117	1.170	0.068
D70	0.200	70	10	0.166	1.655	0.219
D80	0.280	80	10	0.237	2.366	0.374
D90	0.580	90	10	0.403	4.030	0.605
D100	4.75	100	10	1.660	16.598	1.220
D84	0.320	84				
D16		16				

da	0.379	mm
dg	1.033	mm
σg	-	
M	0.027	

Remarks: Sediment is non-uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-3

Dia (mm)	For Sample-3	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.005	30				
D40	0.070	40	10	0.019	0.192	-0.716
D50	0.074	50	10	0.072	0.720	-0.143
D60	0.170	60	10	0.112	1.122	0.050
D70	0.265	70	10	0.212	2.122	0.327
D80	0.600	80	10	0.399	3.987	0.601
D90		90	10			
D100		100	10			
D84	2.300	84				
D16		16				

da	0.163	mm
dg	1.003	mm
σg	-	
M	0.126	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-4

Dia (mm)	For Sample-4	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.007	30				
D40	0.025	40	10	0.013	0.127	-0.895
D50	0.070	50	10	0.042	0.418	-0.378
D60	0.100	60	10	0.084	0.837	-0.077
D70	0.170	70	10	0.130	1.304	0.115
D80	0.270	80	10	0.214	2.142	0.331
D90	0.520	90	10	0.375	3.747	0.574
D100	4.750	100	10	1.572	15.716	1.196
D84	0.300	84				
D16		16				

da 0.347 mm

dg 1.020 mm

σg

M 0.023

Remarks: Sediment is non-uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-5

Dia (mm)	For Sample-5	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.005	30				
D40	0.066	40	10	0.017	0.174	-0.760
D50	0.072	50	10	0.069	0.687	-0.163
D60	0.150	60	10	0.104	1.039	0.017
D70	0.240	70	10	0.190	1.897	0.278
D80	0.470	80	10	0.336	3.359	0.526
D90	3.000	90	10	1.187	11.874	1.075
D100		100	10			
D84	0.520	84				
D16		16				

da 0.317 mm

dg 1.023 mm

σg

M 0.047

Remarks: Sediment is non - uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-6

Dia (mm)	For Sample-6	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	0.004	20				
D30	0.058	30	10	0.015	0.148	-0.829
D40	0.087	40	10	0.071	0.709	-0.149
D50	0.170	50	10	0.122	1.216	0.085
D60	0.270	60	10	0.214	2.142	0.331
D70	0.540	70	10	0.382	3.818	0.582
D80	2.360	80	10	1.129	11.289	1.053
D90		90				
D100		100				
D84		84				
D16		16				

da	0.322	mm
dg	1.025	mm
σg		
M	0.120	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-7

Dia (mm)	For Sample-7	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	0.004	20				
D30	0.041	30	10	0.012	0.124	-0.905
D40	0.086	40	10	0.059	0.593	-0.227
D50	0.180	50	10	0.124	1.244	0.095
D60	0.270	60	10	0.220	2.205	0.343
D70	0.500	70	10	0.367	3.674	0.565
D80	1.600	80	10	0.894	8.944	0.952
D90	-	90				
D100	-	100				
D84	4.600	84				
D16		16				

da 0.280 mm

dg 1.019 mm

σg

M 0.132

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-8

Dia (mm)	For Sample-8	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.008	30				
D40	0.079	40	10	0.026	0.256	-0.592
D50	0.160	50	10	0.112	1.124	0.051
D60	0.230	60	10	0.192	1.918	0.283
D70	0.400	70	10	0.303	3.033	0.482
D80	-	80				
D90	-	90				
D100	-	100				
D84	-	84				
D16		16				

da 0.158 mm

dg 1.005 mm

σg

M 0.279

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-9

Dia (mm)	For Sample-9	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.0023	30				
D40	0.012	40	10	0.005	0.053	-1.280
D50	0.100	50	10	0.035	0.346	-0.460
D60	0.200	60	10	0.141	1.414	0.151
D70	0.300	70	10	0.245	2.449	0.389
D80	0.420	80	10	0.355	3.550	0.550
D90	4.750	90	10	1.412	14.124	1.150
D100	-	100				
D84	1.000	84				
D16		16				

da 0.366 mm

dg 1.012 mm

σg

M 0.019

Remarks: Sediment is non- uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-10

Dia (mm)	For Sample-10	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.0053	30				
D40	0.0569	40	10	0.017	0.173	-0.762
D50	0.0720	50	10	0.064	0.640	-0.194
D60	0.1700	60	10	0.111	1.106	0.044
D70	0.2300	70	10	0.198	1.977	0.296
D80	0.4200	80	10	0.311	3.108	0.492
D90	-	90				
D100	-	100				
D84	0.6000	84				
D16		16				

da 0.140 mm

dg 0.997 mm

σg

M 0.131

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-11

Dia (mm)	For Sample-11	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.0037	30				
D40	0.0740	40	10	0.017	0.166	-0.779
D50	0.1400	50	10	0.102	1.018	0.008
D60	0.2200	60	10	0.175	1.755	0.244
D70	0.3500	70	10	0.277	2.775	0.443
D80	1.2000	80	10	0.648	6.481	0.812
D90	-	90				
D100	-	100				
D84	3.4000	84				
D16	-	16				

da 0.244 mm

dg 1.017 mm

σg

M 0.108

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-12

Dia (mm)	For Sample-12	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.0092	30				
D40	0.0310	40	10	0.017	0.169	-0.772
D50	0.1000	50	10	0.056	0.557	-0.254
D60	0.2000	60	10	0.141	1.414	0.151
D70	0.0960	70	10	0.139	1.386	0.142
D80	-	80				
D90	-	90				
D100	-	100				
D84	-	84				
D16	-	16				

da	0.088	mm
dg	0.983	mm
σg		
M	0.259	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-13

Dia (mm)	For Sample-13	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30	0.0075	30				
D40	0.0700	40	10	0.023	0.228	-0.641
D50	0.0940	50	10	0.081	0.811	-0.091
D60	0.1700	60	10	0.126	1.264	0.102
D70	0.4250	70	10	0.269	2.688	0.429
D80	-	80				
D90	-	90				
D100	-	100				
D84	-	84				
D16	-	16				

da	0.125	mm
dg	0.995	mm
σg		
M	0.263	

Remarks: Sediment is uniform

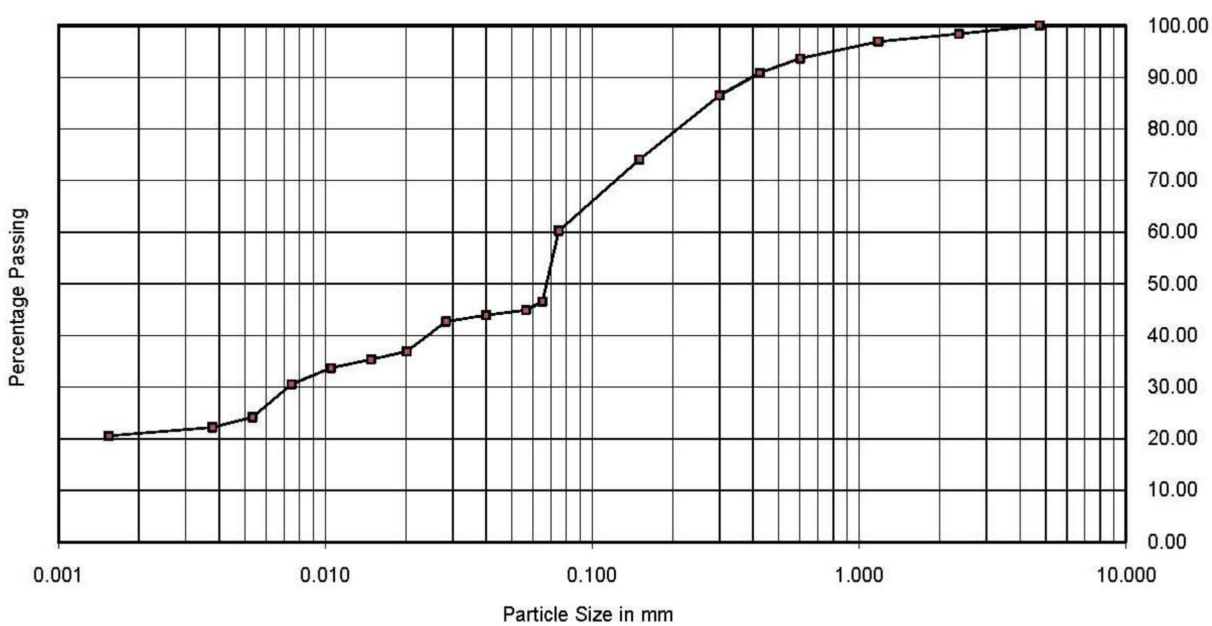
Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

13.4.5 Grain Size Distribution curves:-

GRAIN SIZE DISTRIBUTION CURVES

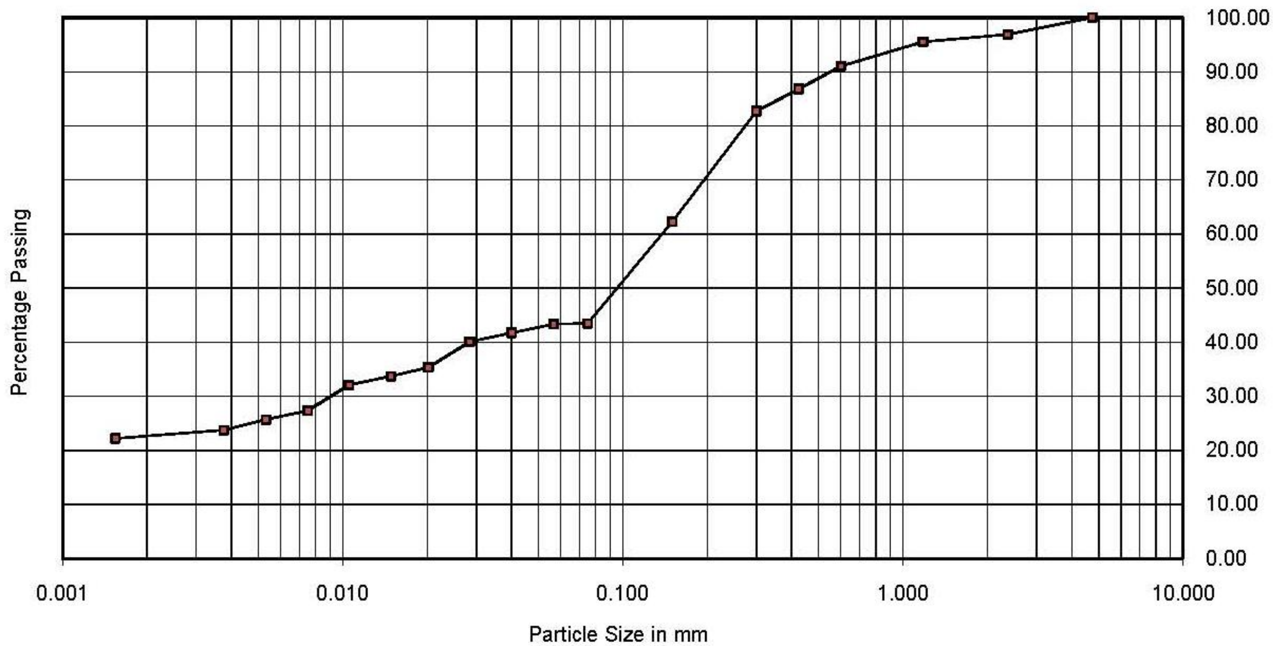
Site:	Tilaiya Reservoir,D.V.C
Sample No.	1



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
1	20.54	39.70	39.76	0.00

GRAIN SIZE DISTRIBUTION CURVES

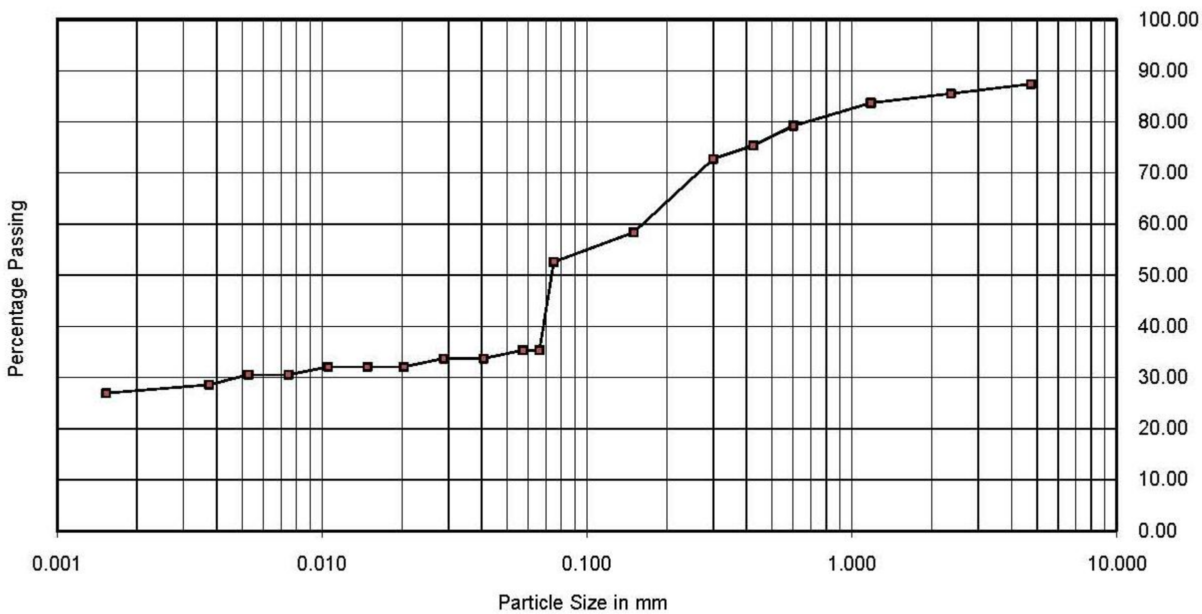
Site:	Tilaiya Reservoir,D.V.C
Sample No.	2



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
2	22.14	21.34	56.52	0.00

GRAIN SIZE DISTRIBUTION CURVES

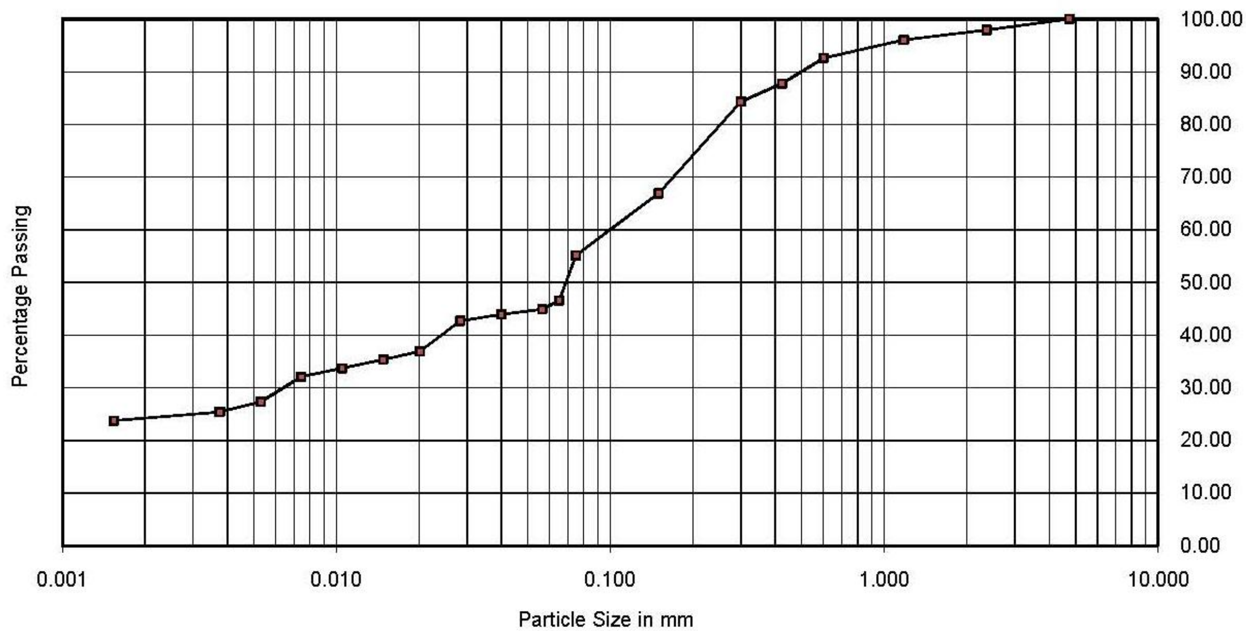
Site:	Tilaiya Reservoir,D.V.C
Sample No.	3



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
3	26.94	25.61	34.85	12.60

GRAIN SIZE DISTRIBUTION CURVES

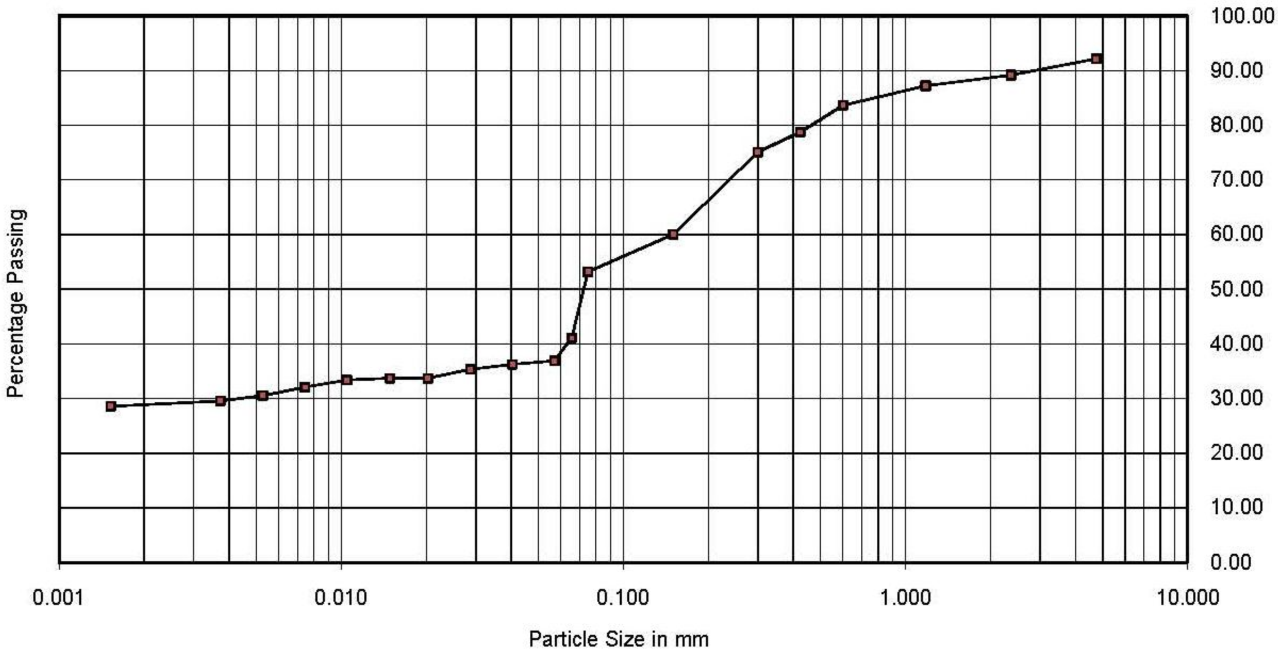
Site:	Tilaiya Reservoir,D.V.C
Sample No.	4



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
4	23.74	31.36	44.90	0.00

GRAIN SIZE DISTRIBUTION CURVES

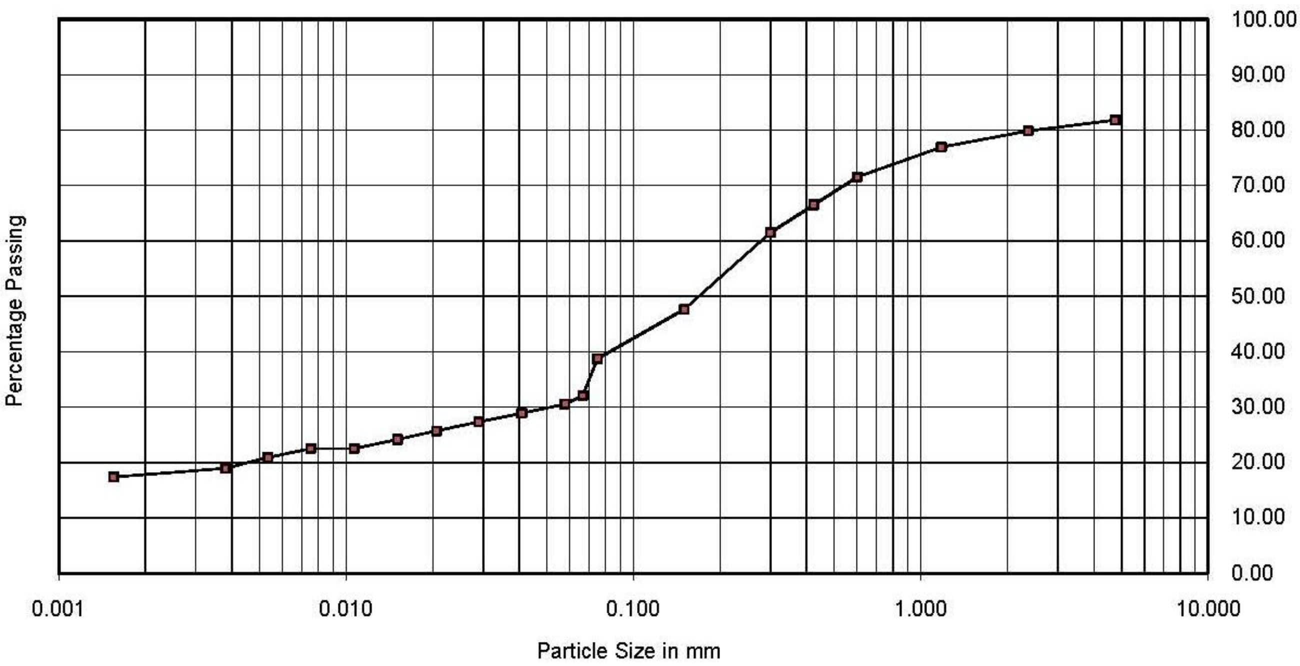
Site:	Tilaiya Reservoir,D.V.C
Sample No.	5



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
5	28.54	24.59	38.98	7.89

GRAIN SIZE DISTRIBUTION CURVES

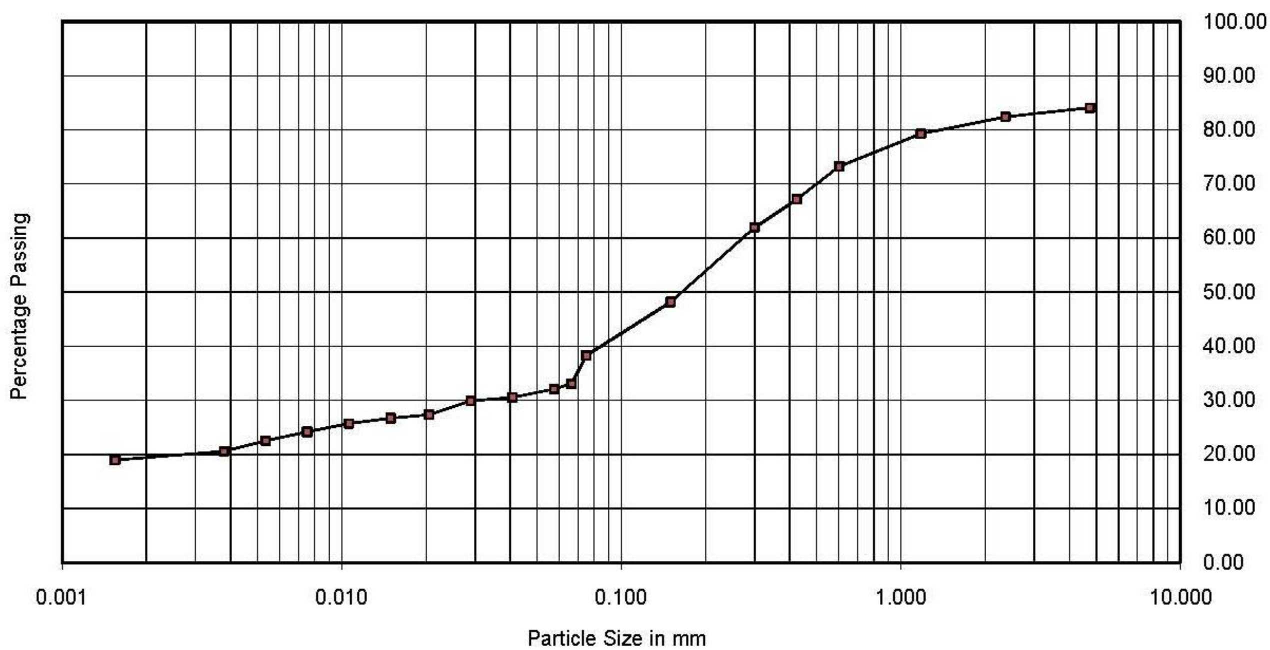
Site:	Tilaiya Reservoir,D.V.C
Sample No.	6



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
6	17.34	21.36	43.10	18.20

GRAIN SIZE DISTRIBUTION CURVES

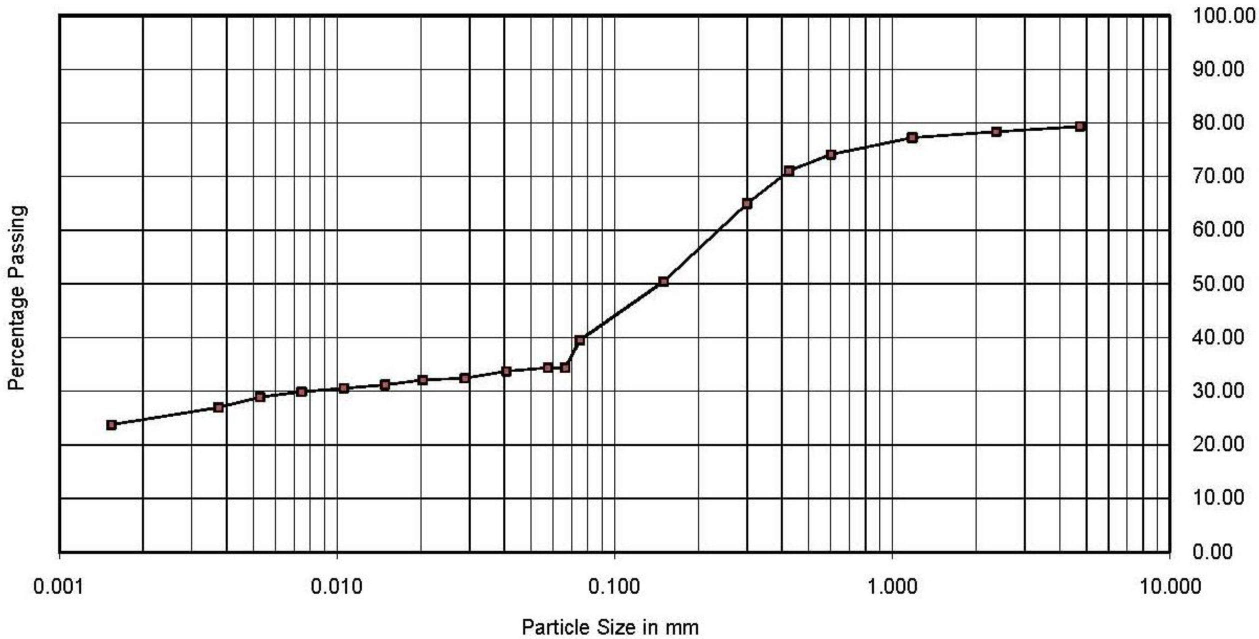
Site:	Tilaiya Reservoir,D.V.C
Sample No.	7



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
7	18.94	19.31	45.85	15.90

GRAIN SIZE DISTRIBUTION CURVES

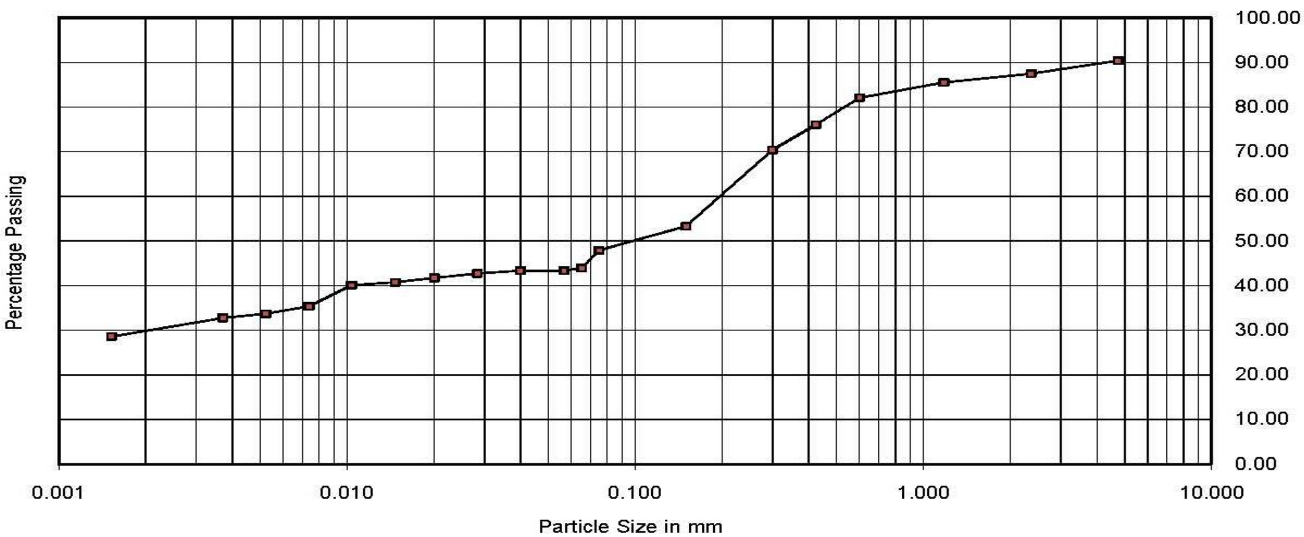
Site:	Tilaiya Reservoir,D.V.C
Sample No.	8



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
8	23.74	15.76	39.80	20.70

GRAIN SIZE DISTRIBUTION CURVES

Site:	Tilaiya Reservoir,D.V.C
Sample No.	9

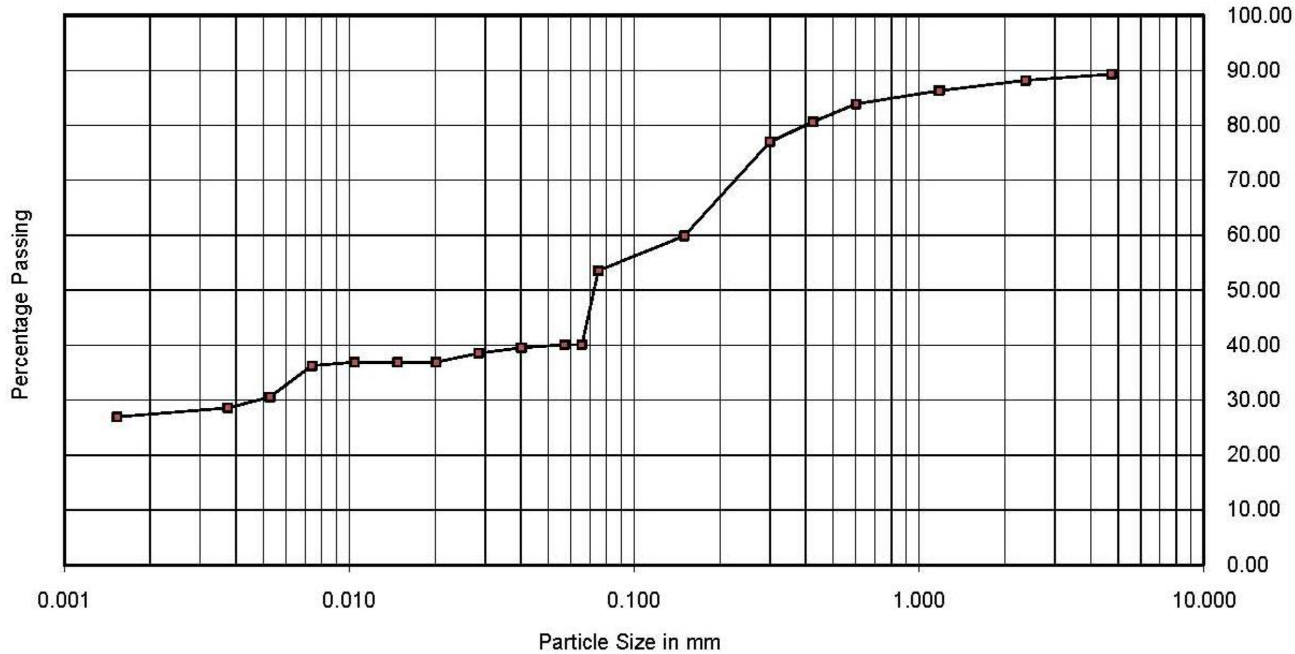


Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
9	28.54	19.36	42.50	9.60

GRAIN SIZE DISTRIBUTION CURVES

Site: Tilaiya Reservoir,D.V.C

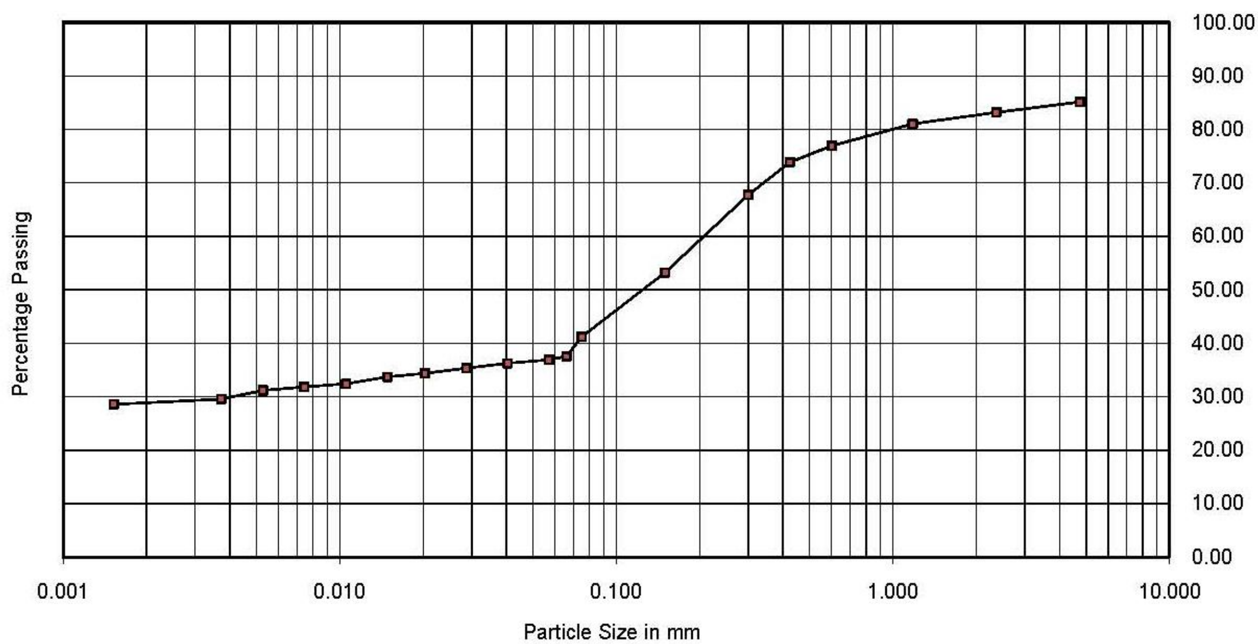
Sample No. 10



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
10	26.94	26.61	35.70	10.75

GRAIN SIZE DISTRIBUTION CURVES

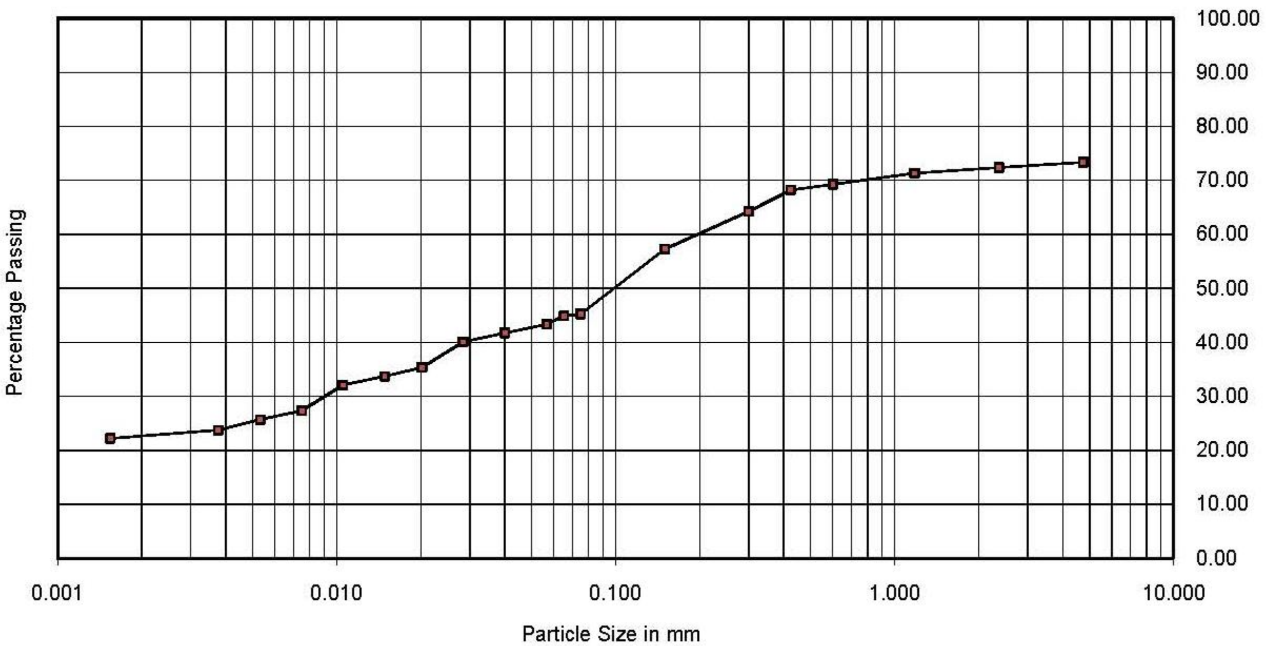
Site:	Tilaiya Reservoir,D.V.C
Sample No.	11



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
11	28.54	12.66	43.90	14.90

GRAIN SIZE DISTRIBUTION CURVES

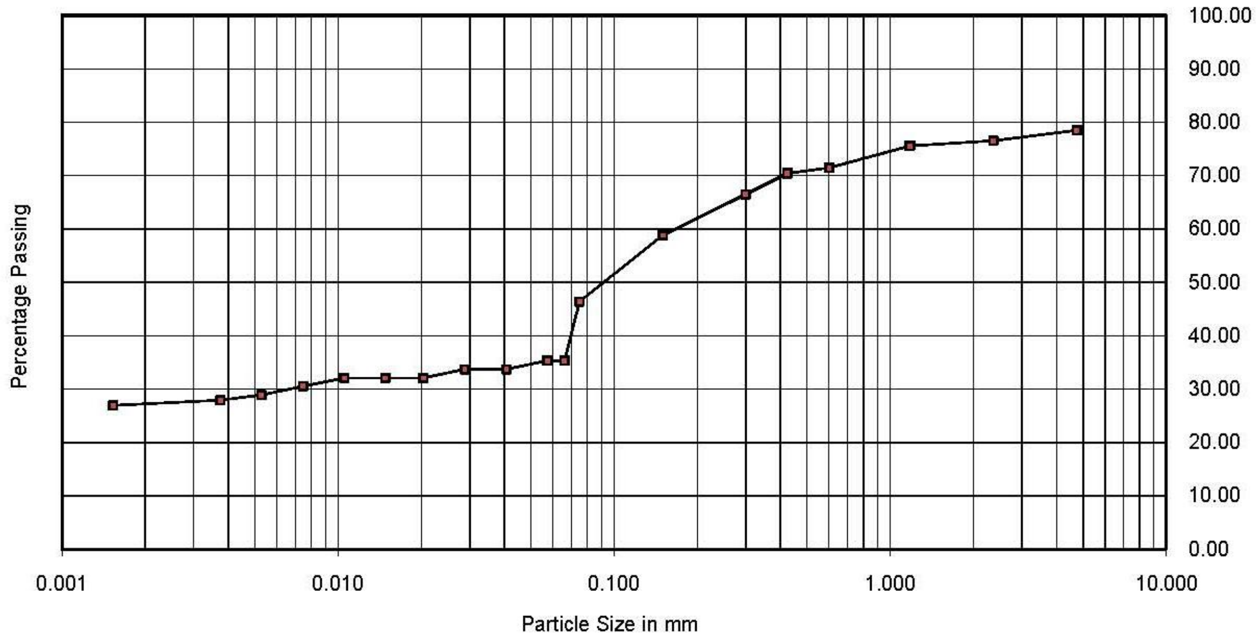
Site:	Tilaiya Reservoir,D.V.C
Sample No.	12



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
12	22.14	23.04	28.12	26.70

GRAIN SIZE DISTRIBUTION CURVES

Site:	Tilaiya Reservoir,D.V.C
Sample No.	13



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
13	26.94	19.46	32.10	21.50

13.5 Contour Elevation & Area of Tilaiya Reservoir (Sq. m. and Sq. km):-

Contour EL (M)	Area	Area
	in Sq m.	***in Sq km.***
346.0	5509.905	0.006
346.3	9858.239	0.010
346.6	12206.573	0.012
346.9	19554.908	0.020
347.2	35765.062	0.036
347.5	55906.128	0.056
347.8	65047.193	0.065
348.1	78140.406	0.078
348.4	99137.916	0.099
348.7	106135.427	0.106
349.0	127132.937	0.127
349.3	158791.532	0.159
349.6	210450.128	0.210
349.9	272108.723	0.272
350.2	298936.639	0.299
350.5	358349.216	0.358
350.8	437761.793	0.438
351.1	559186.588	0.559
351.4	714635.820	0.715
351.7	770085.053	0.770
352.0	835534.285	0.836
352.3	889329.577	0.889
352.6	933124.869	0.933
352.9	976920.161	0.977
353.2	1030111.464	1.030
353.5	1273000.773	1.273
353.8	1315890.081	1.316
354.1	1766009.528	1.766
354.4	1930589.253	1.931
354.7	2095168.979	2.095
355.0	2259748.704	2.260
355.3	2337098.389	2.337
355.6	2414448.073	2.414
355.9	2669147.442	2.669
356.2	2717041.898	2.717
356.5	2866233.266	2.866
356.8	3015424.634	3.015

Contour EL (M)	Area	Area
	in Sq m.	*in Sq km.*
357.1	3175033.253	3.175
357.4	3255476.374	3.255
357.7	3335919.496	3.336
358.0	3516362.617	3.516
358.3	3752560.503	3.753
358.6	3888758.389	3.889
358.9	3924956.275	3.925
359.2	4134716.327	4.135
359.5	4281257.462	4.281
359.8	4327798.597	4.328
360.1	4413418.023	4.413
360.4	4677194.032	4.677
360.7	4895562.044	4.896
361.0	5104746.050	5.105
361.3	5319288.137	5.319
361.6	5533830.225	5.534
361.9	5662914.399	5.663
362.2	5832152.671	5.832
362.5	5950552.166	5.951
362.8	6168951.661	6.169
363.1	6365777.530	6.366
363.3	6534896.607	6.535
363.4	6932891.049	6.933
363.7	7126874.375	7.127
364.0	7520857.701	7.521
364.3	8048996.315	8.049
364.6	9077134.929	9.077
364.9	9105273.543	9.105
365.2	9588984.579	9.589
365.5	9800481.826	9.800
365.8	9911979.072	9.912
366.1	10052392.179	10.052
366.4	12350637.008	12.351
366.7	15081630.113	15.082
367.0	21947126.665	21.947
367.3	29120667.130	29.121
367.6	36294207.594	36.294
367.9	41467748.059	41.468
368.2	48577517.310	48.578
368.5	51655400.953	51.655
368.8	52733284.596	52.733
369.1	53865087.910	53.865

Contour EL (M)	Area	Area
	in Sq m.	*in Sq km.*
369.4	55073952.927	55.074
369.7	57282817.945	57.283
370.0	58491682.962	58.492
370.3	59834194.556	59.834
370.6	60176706.150	60.177
370.9	61519217.743	61.519
371.2	63145750.563	63.146
371.5	64914293.996	64.914
371.8	65682837.429	65.683
372.1	67580034.860	67.580
372.4	70734540.286	70.735
372.5	73552708.762	73.552

Table 11-Contour Elevation Data (in Sq.km and Sq. m.)

TRAP EFFICIENCY

This section has been analyzed the trap efficiency of Tilaiya Reservoir according to Brune'S curve as per I.S. 12182-1987

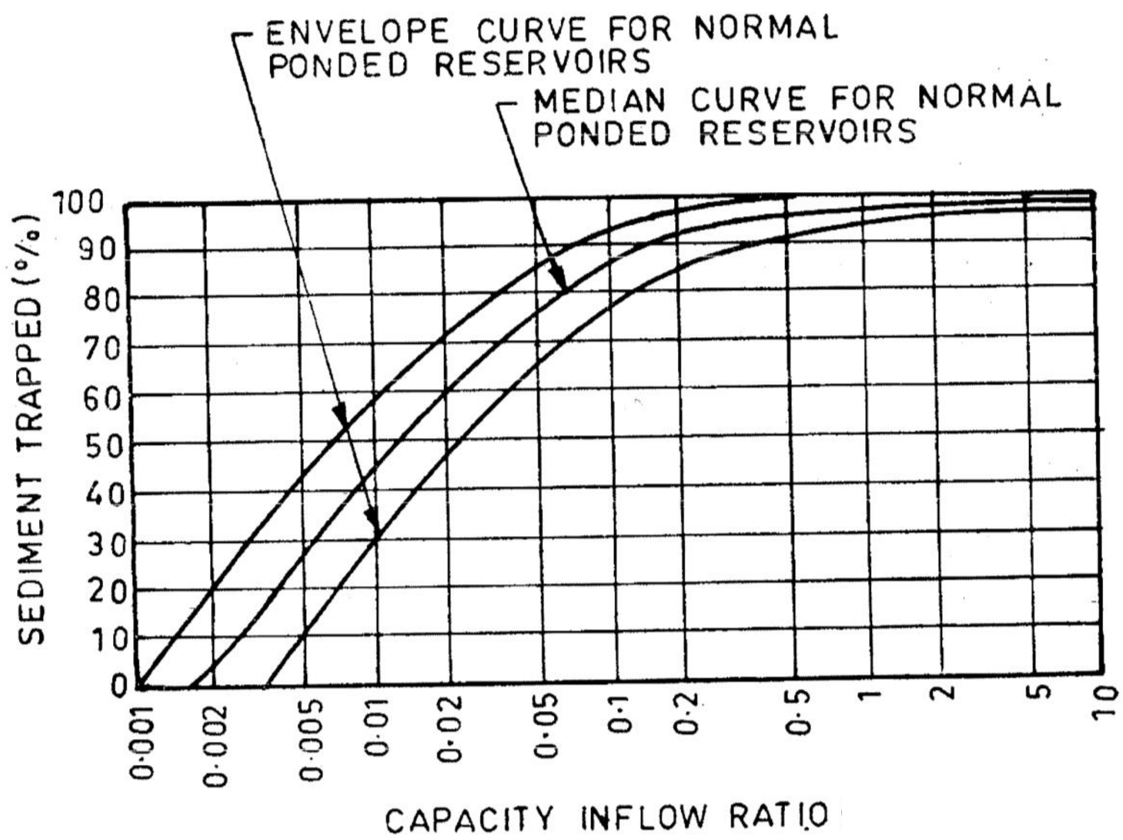
13.6 Trap Efficiency of reservoir (IS 12182-1987):-

The Trap efficiency of Tilaiya reservoir has been calculated according to Brune'S trap efficiency curve as per I.S 12182-1987 "Guidelines for determination of effects of sedimentation of Effects of sedimentation in planning and performance of Reservoirs".

Trap efficiency can be defined as the ratio between the total sediment deposited in a reservoir and the total sediment flowing in the river for a certain period. Therefore, Trap efficiency is:-

$$\frac{\text{Total Sediment deposited in the Reservoir}}{\text{Total Sediment Flowing in the River}}$$

Trap efficiency of a reservoir, over a period is the ratio of the total deposited sediment inflow. Gunnar Brune analyzed data from the Reservoirs with catchment areas varying from small to very large and presented a median curve together with lower and upper envelope curves which is shown below -



BRUNE'S CURVE

- **Reservoir Data :-**

a) Full Reservoir level (FRL) = 372.46 m.
b) Mean operating Pool elevation = 368.80 m.
c) Capacity at FRL, C1= 376.95 MCM
d) Capacity at mean Operating Pool elevation, C2 = 150.95 M.C.M
e) Average inflow, I, over the study period of 10 years, in volume-tric units = 3076.21 MCM
f) Length of Reservoir, L, at the mean operating level = 23.300 km

- **Brune'S Method:-**

Capacity Inflow Ratio

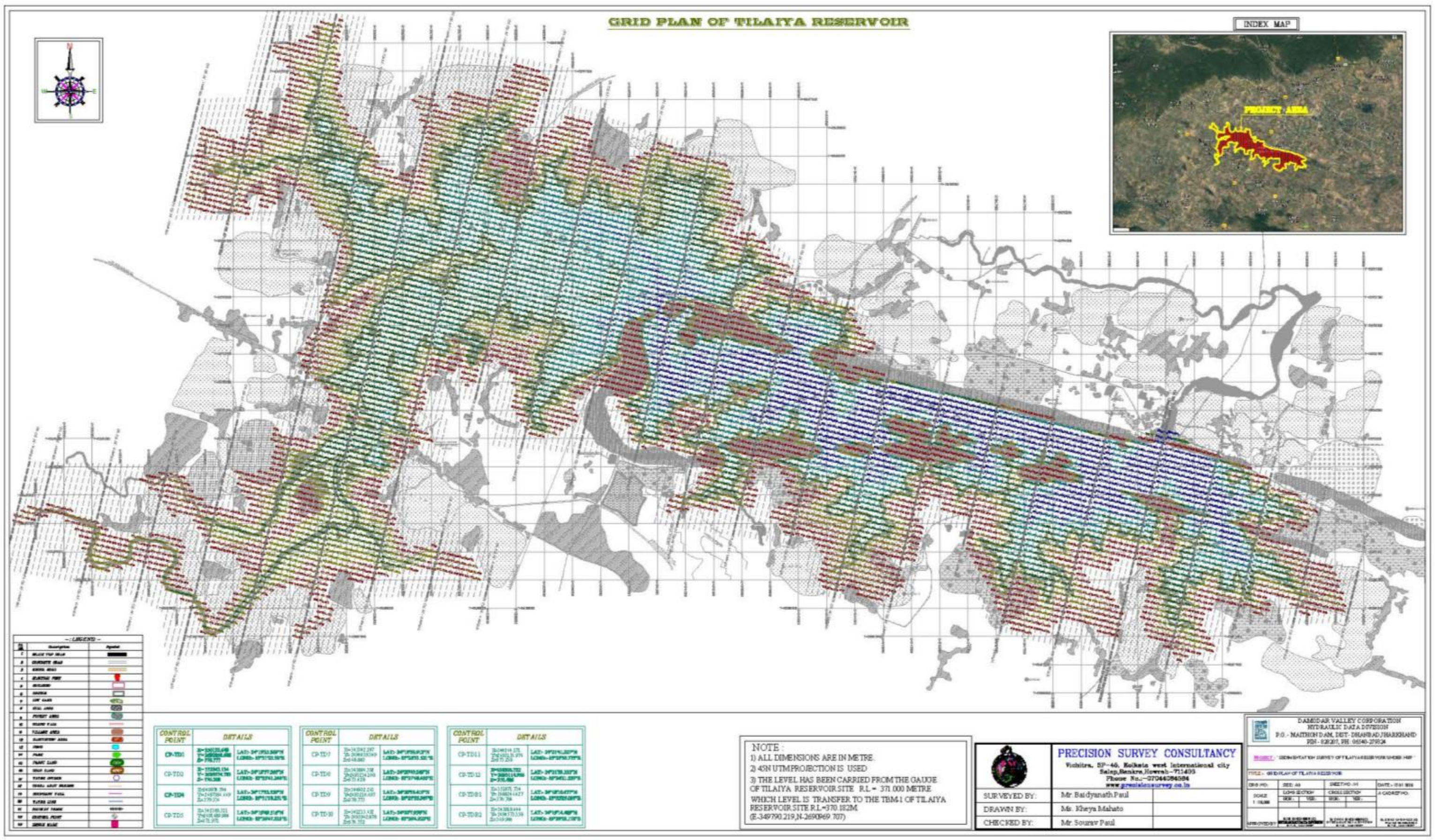
C1/I= 376.95/3076.21= 0.123

Trap efficiency corresponding to above ratio C/I as read from median curve for normally ponded reservoir = 88 percent

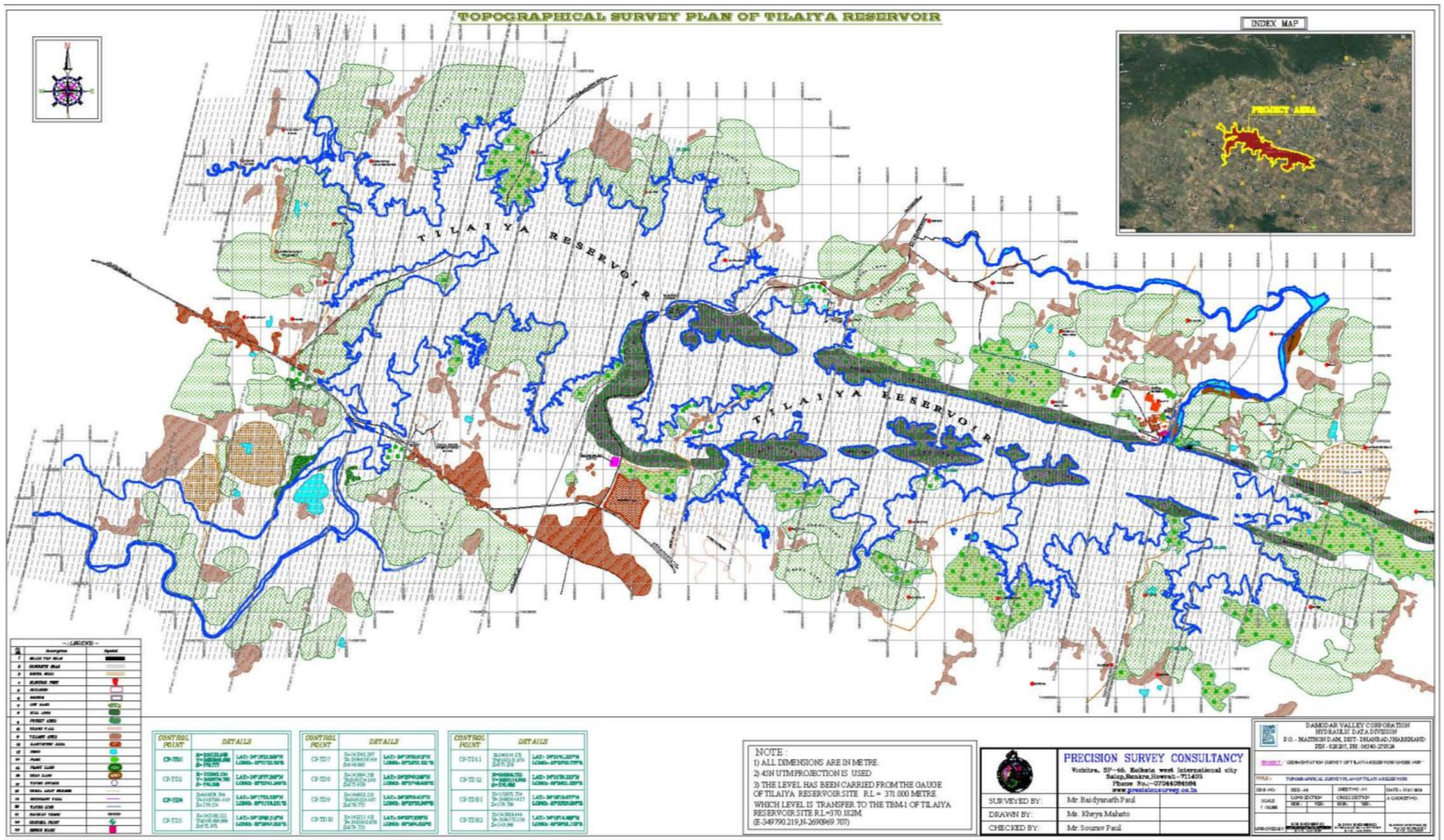
CHARTS/DRAWINGS

13.7 Charts/Drawing:-

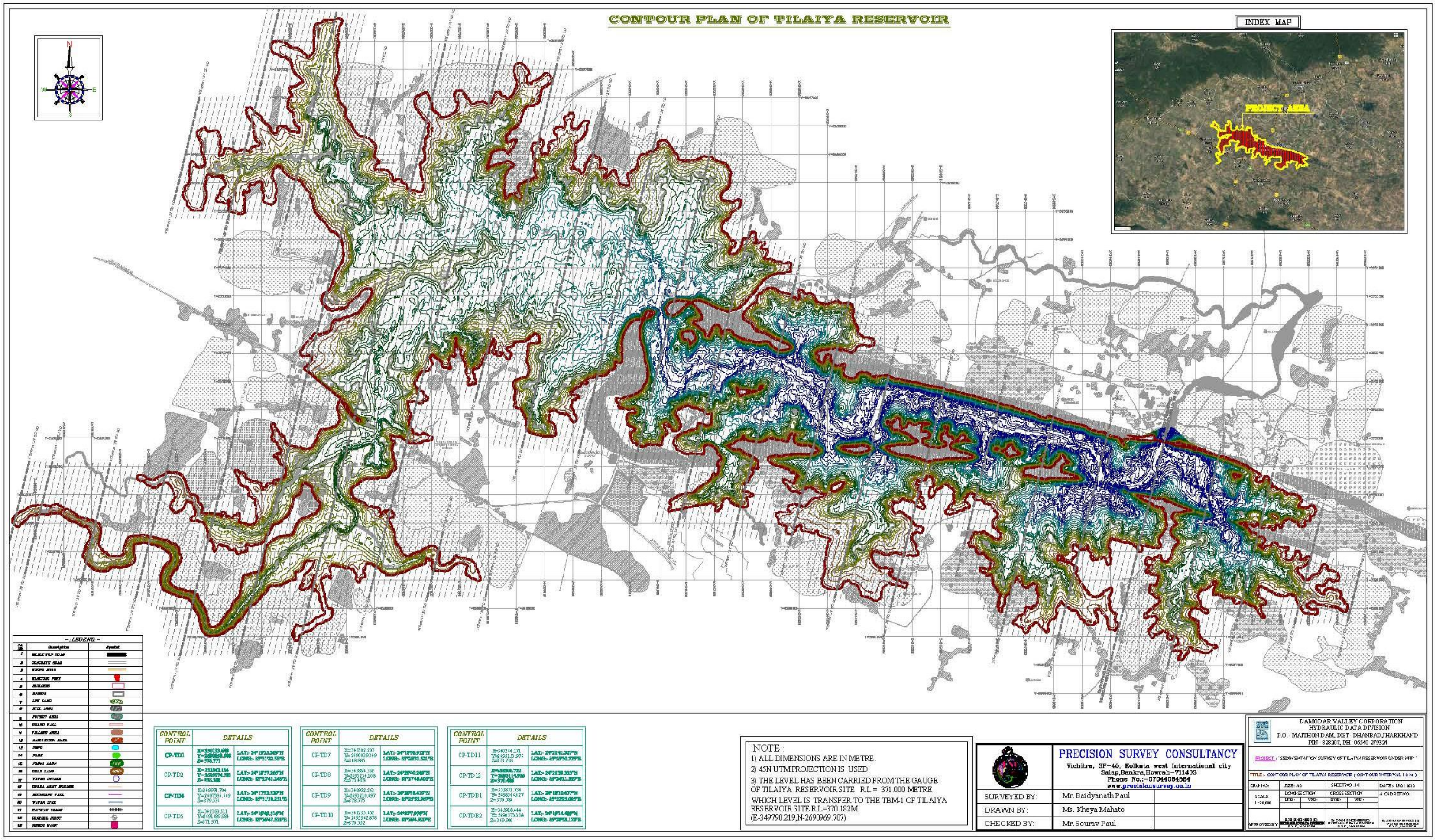
13.7.1 Grid Plan of Tilaiya Reservoir:-



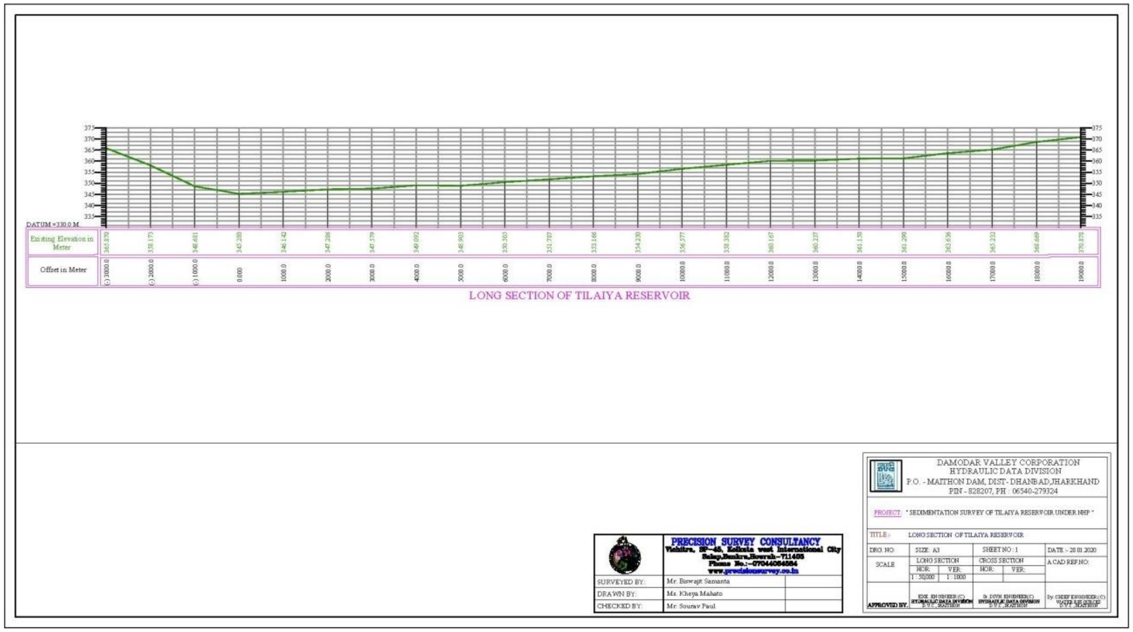
13.7.2 Topographical Plan of Tilaiya Reservoir:-

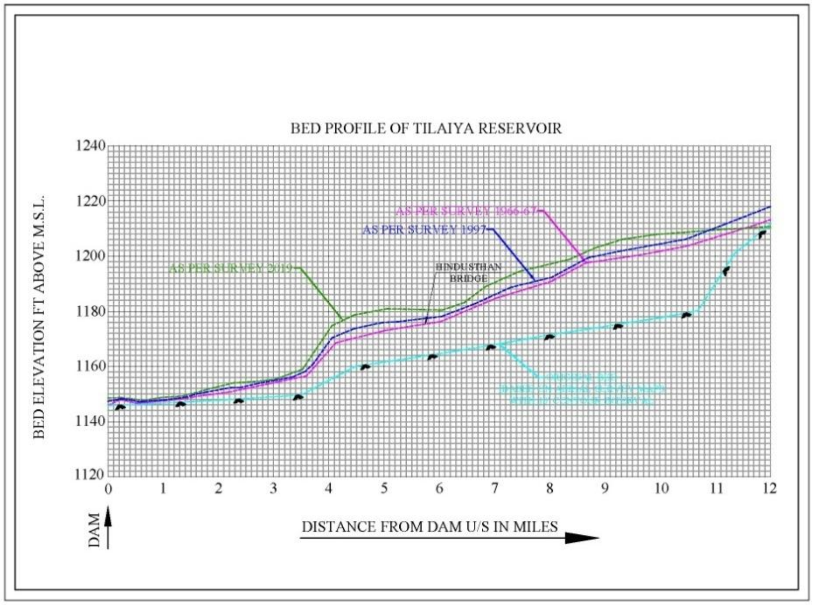


13.7.3 Contour Plan of Tilaiya Reservoir:-

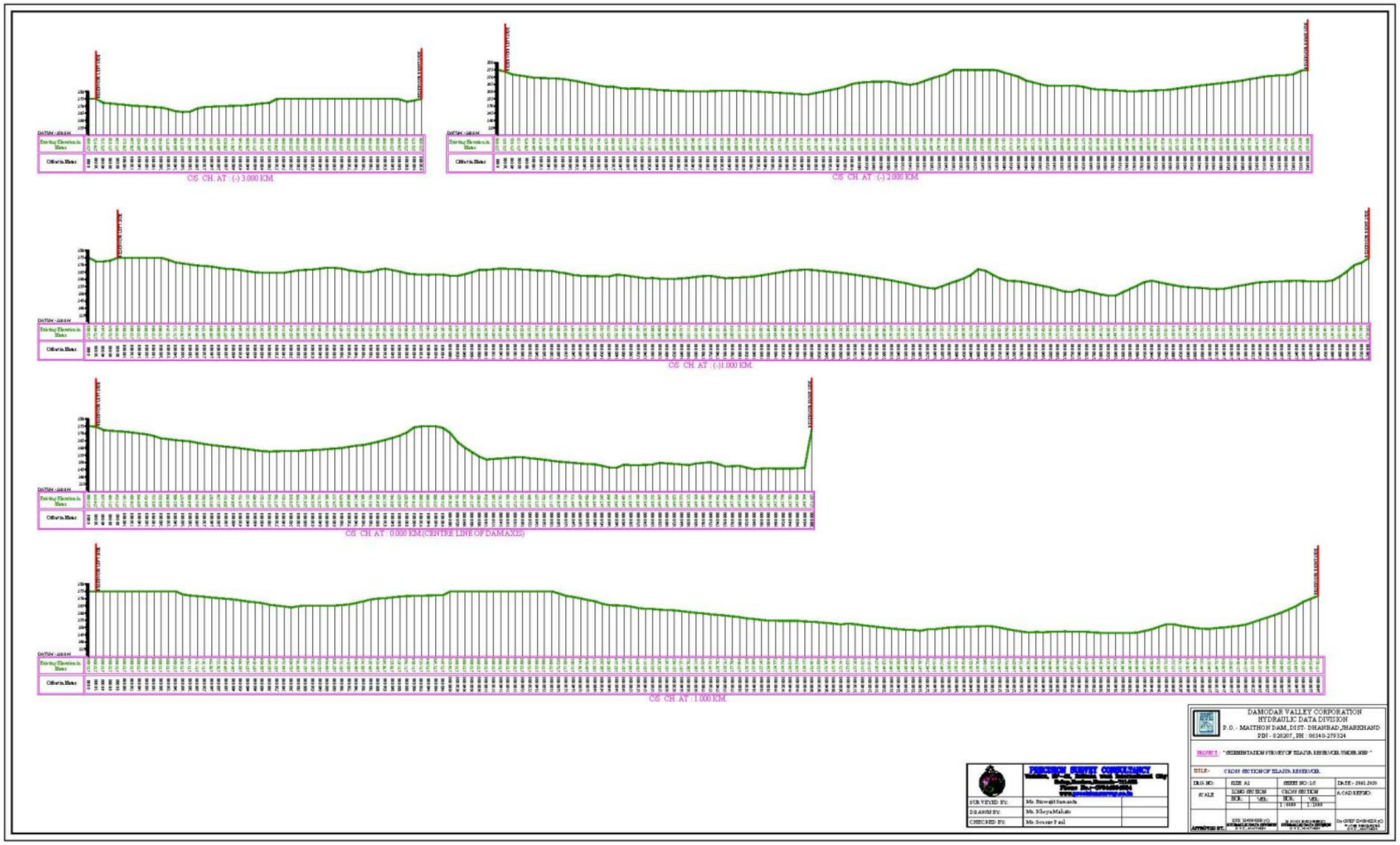


13.7.4 Long Section of Tilaiya Reservoir & Bed Profile of Tilaiya Reservoir:-

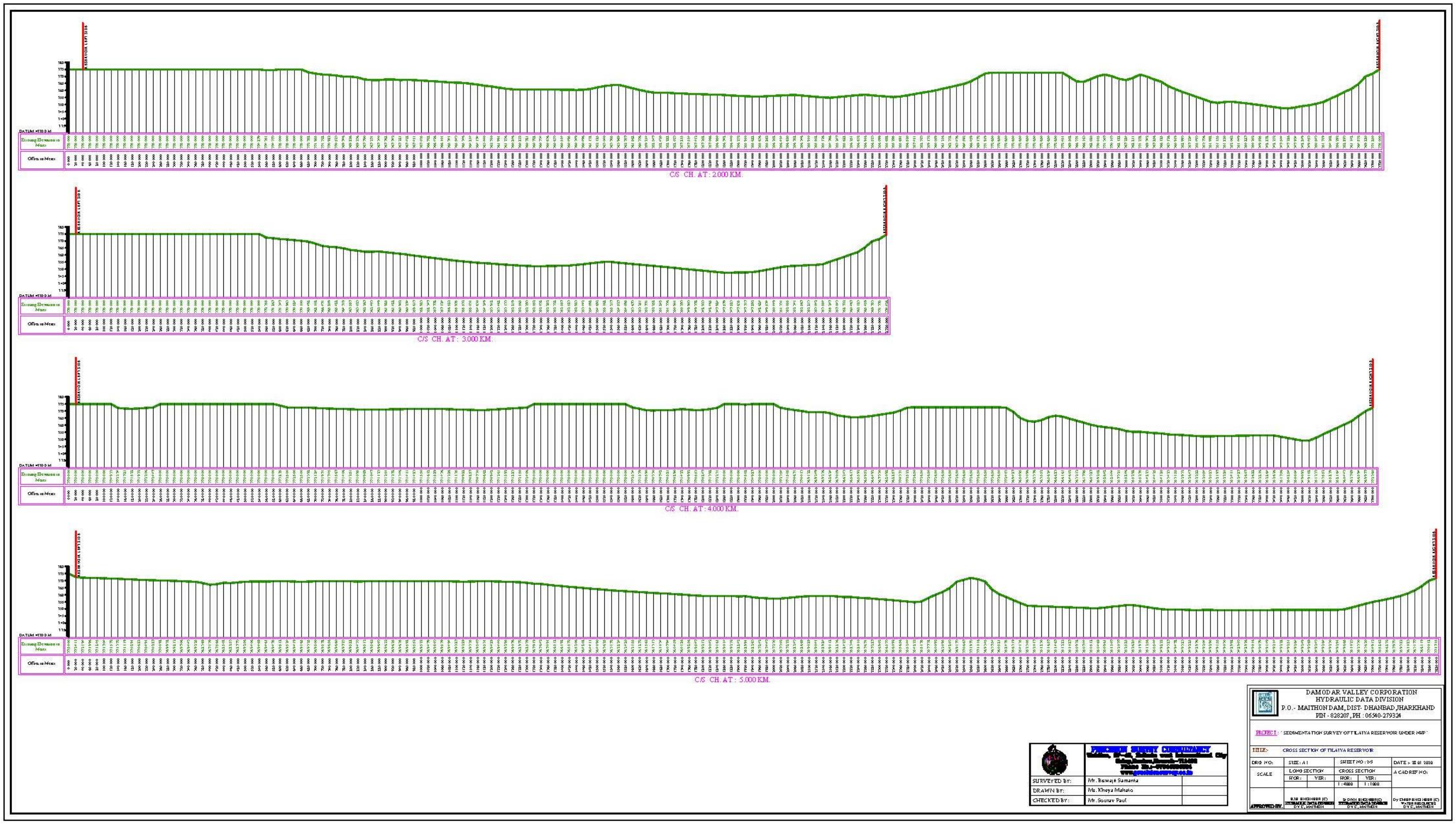




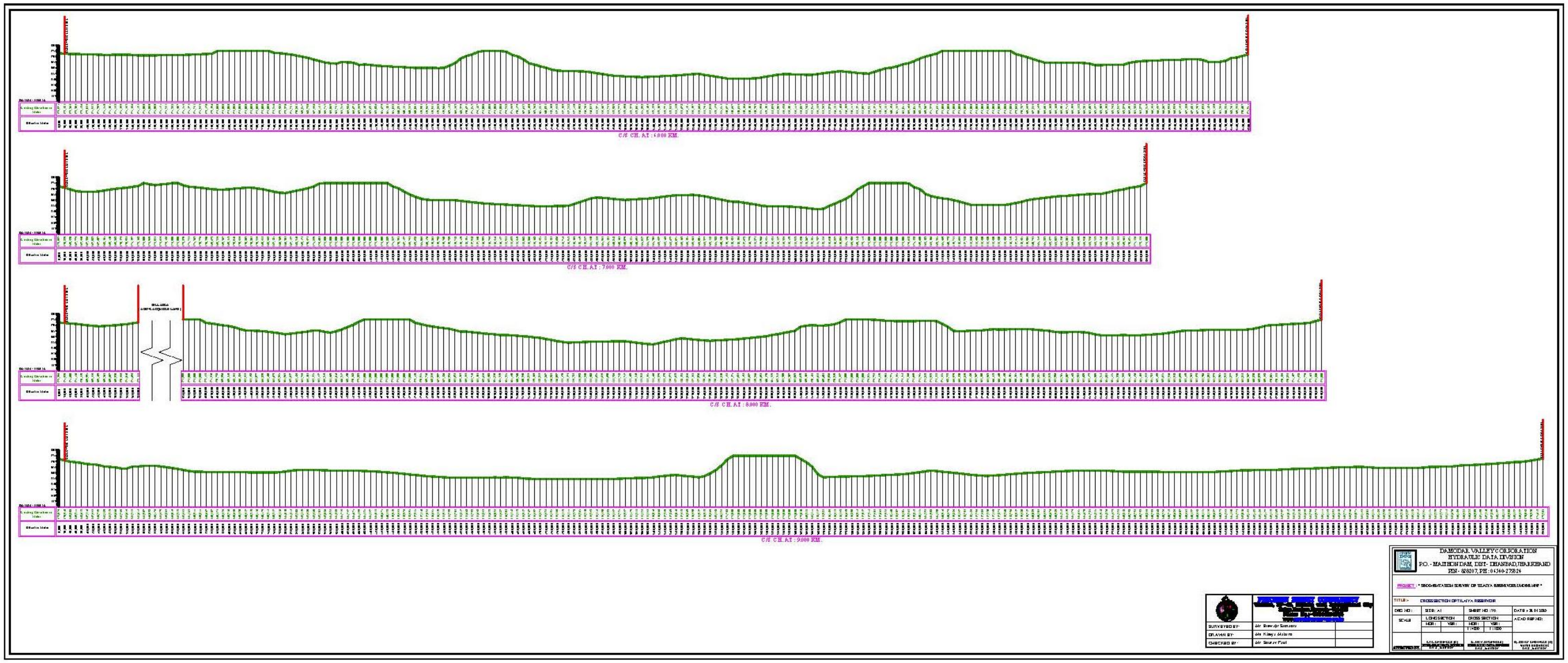
13.7.5 Cross Section of Tilaiya Reservoir near Chainage (-3.000 km to 1.000 km):-



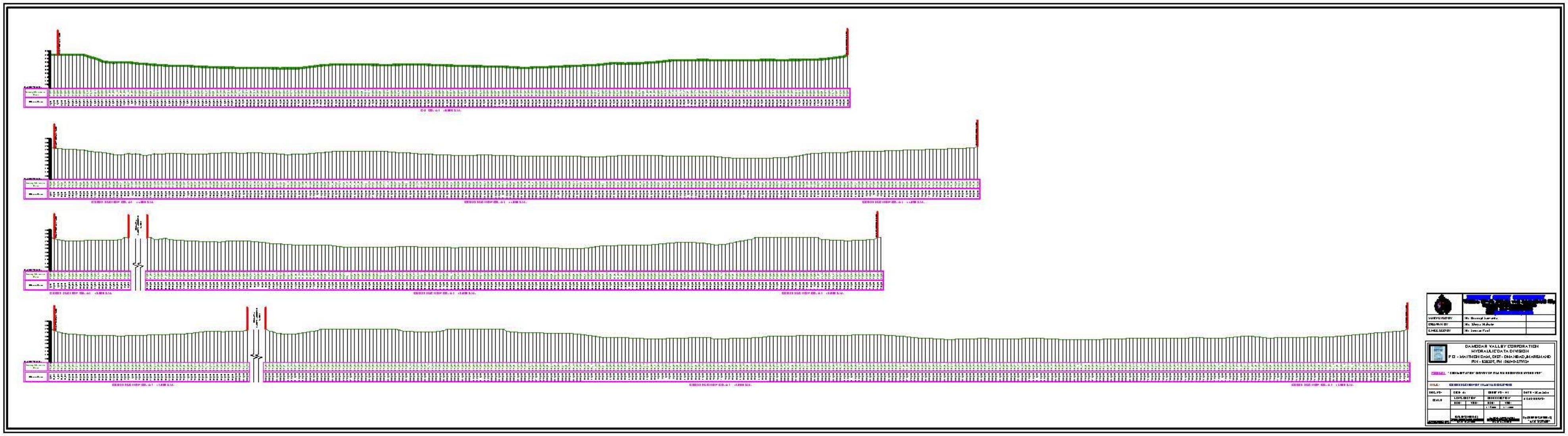
13.7.6 Cross Section of Tilaiya Reservoir near Chainage (2.000 km to 5.000 km):-



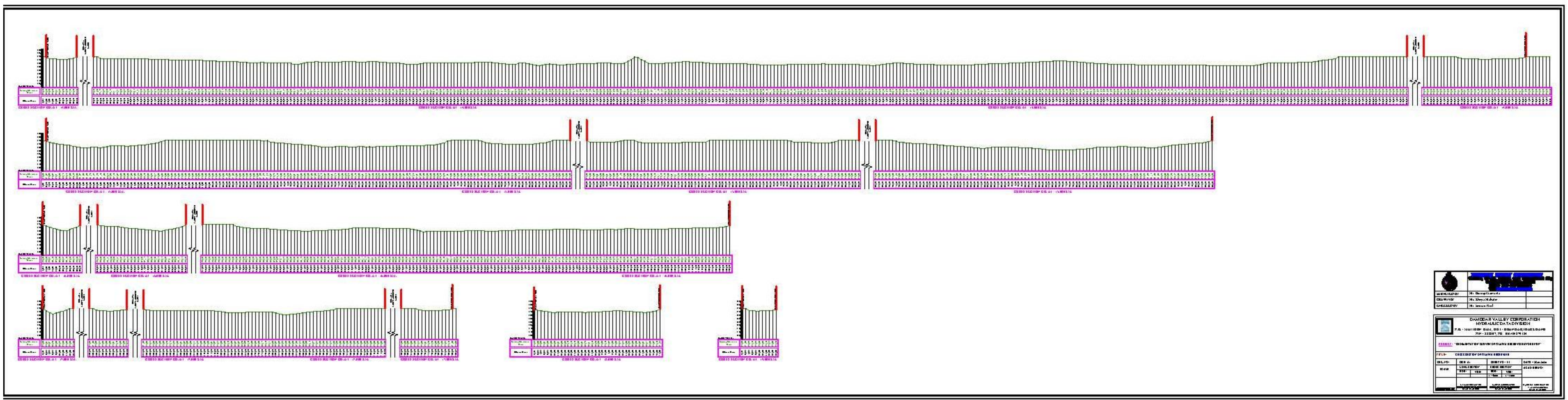
13.7.7 Cross Section of Tilaiya Reservoir near Chainage (6.000 km to 9.000 km):-



13.7.8 Cross Section of Tilaiya Reservoir near Chainage (10.000 km to 13.000 km):-



13.7.9 Cross Section of Tilaiya Reservoir near Chainage (14.000 km to 19.000 km):-



CONCLUSIONS/RECOMMENDATIONS

14.0 Conclusion:-

It can be seen that on the basis of 1/500th of the volume of monsoon flow along, the deposition rate cannot be adequately worked out, as it will further require information on volume of water flow, bed load, trap efficiency and unit weight of deposited sediment. It appears, however, that 1/500th of the volume of monsoon flow was considered as the overall deposition rate which amount to 458.67 acre feet of annual deposit on the basis of 229333.01 acre feet of monsoon flow (1961 to 2019). Taking 380 square miles (984 square km) as the net sediment producing area, the average annual deposition rate works out to 1.21 acre feet per square miles per year (576.37 M3/Sq. Km) of the catchment area.

14.1 Recommendations:-

Remembering the emerging problems of riverine flood, we have mentioned that the current factors of flood risk of lower Damodar River are as follows: (1) bottle-neck and physically handicapped location of lower Damodar Basin in the Gangetic West Bengal (huge volume of channel flow collected from funnel-shaped rocky upper catchment passing through narrow and shallow reach of lower Damodar) including the tidal effect of lower reach, (2) three to four days continuous heavy rainfall due to SW-NE directional monsoonal depressions, (3) uncontrolled runoff of upper catchment, (4) increasing siltation of dams, barrages, canals, and river beds, (5) only four large dams (i.e., Tilaiya, Konar, Maithon and Panchet), Tenughat Reservoir and Durgapur Barrage serving the purpose of all proposed eight large dams and combined flood moderation capacity of Maithon and Panchet dams reducing up to only 32 per cent, (6) the dams compelling to release excess water in the month of late September because of already storing water in the previous months of monsoon, (7) annual peak discharge of short duration occurring in between late September and October at the time of over-saturation of alluvial soils, ground water and existing streams, and (8) drainage congestion and encroachment of active river bed and flood plain.

From the perspective of flood climate, the recurrent floods of Damodar River is directly influenced by rainstorms of 3- to 4-day duration, path of cyclone, extreme rainfall event of 3 to 6 hours, runoff yield, and discharging of excess water from the upstream dams and Durgapur barrage. From the standpoint of flood hydrology, the stream flow during high magnitude floods in our study area is primarily confined within bank full level, with occasional overtopping of the levees. The floodplain flow, whenever it took place, is intermittent in nature. To manage floods, we should focus on the travel time of flood waves from Durgapur barrage to the downstream end and on the up-to-date accurate estimation of critical bank full discharge at the ungauged sites of lower Damodar River.

From the above analysis, it is understood that observing the drawbacks of large scale Damodar Valley Planning, we can only predict or manage the flood discharge to a certain level, not stopping it completely. So scrutinizing the exiting framework of basin planning, it is the exact time to rethink the increasing flood risk of lower Damodar River and renovation of Damodar Valley Planning in West Bengal in the frame of global warming and climate change. It is also found that the large scale deposition will affect the area in near future. So, flood will become devastating in nature.

From the above analysis, it is understood that observing the drawbacks of large scale Damodar Valley Planning, we can only predict or manage the flood discharge to a certain level, not stopping it completely. So scrutinizing the exiting framework of basin planning, it is the exact time to rethink the increasing flood risk of lower Damodar River and renovation of Damodar Valley Planning in West Bengal in the frame of global warming and climate change. It is also found that the large scale deposition will affect the area in near future. So, flood will become devastating in nature. The Recommendation is also described in the following:-

i) **The study also reflects that in future the flood zone and live storage will increase up to 42% and 61% respectively**.

ii) **The volume of sediment deposit will increase up to 27% in 100 years due to lack of flow in summer time.**

Control of sediment deposition:-

The deposition of sediment in a reservoir may be controlled to a certain extent by designing and operating gates or other outlets in the dam in such a manner as to permit selective withdrawals of water having a higher than average sediment content. The suspended sediment content of the water in reservoirs is higher during and just after flood flow. Thus, more the water wasted at such times, the smaller will be the percentage of the total sediment load to settle into permanent deposits. There are generally two methods: (a) density currents, and (b) waste-water release, for controlling the deposition and both will necessarily result in loss of water.

1. Density Current :-

Water at various levels of a reservoir often contains radically different concentrations of suspended sediment particularly during and after flood flows and if all waste-water could be withdrawn at those levels where the concentration is highest, a significant amount of sediment might be removed from the reservoir. Because a submerged outlet draws water towards it from all directions, the vertical dimension of the opening should be small with respect to the thickness of the layer and the rate of withdrawal also should be low. With a view to passing the density current by sluices that might be existed, it is necessary to trace the movement of density currents and observation stations (consisting of permanently anchored rafts from which measurements could be made of temperature and conductivity gradient from the surface of the lake to the bottom, besides collecting water samples at various depths) at least one just above the dam and two or more additional stations in the upstream (one in the inlet and one in the middle) should be located.

2. Waste-Water Release :-

Controlling the sedimentation by controlling waste-water release is obviously possible only when water can be or should be wasted. This method is applicable only when a reservoir is of such size that a small part of large flood flows will fill it.

In the design of the dam, sediment may be passed through or over it as an effective method of silt control by placing a series of outlets at various elevations. The percentage of total sediment load that might be ejected from the reservoir through proper gate control will differ greatly with different locations. It is probable that as much as 20 percent of the sediment inflow could be passed through many reservoirs by venting through outlets designed and con- trolled.

3. Scouring Sluicing :-

This method is somewhat similar to both the control of waste-water release and the draining and flushing methods. The distinction amongst them cares the following:

1) The waste-water release method ejects sediment laden flood flows through deep spillway gates or large under sluices at the rate of discharge that prevents sedimentation.

2) Drainage and flushing method involves the slow release of stored water from the reservoir through small gates or valves making use of normal or low flow to entrain and carry the sediment and

3) Scouring sluicing depends for its efficiency on either the scouring action exerted by the sudden rush of impounded water under a high head through under sluices or on the scouring action of high flood discharge coming into the reservoir.

Scouring sluicing method can be used in the following:

a) Small power dams that depend to a great extent on pondage but not on storage;

b) Small irrigation reservoirs, where only a small fraction of the total annual flow can be stored;

c) Any reservoir in narrow channels, gorges, etc, where water wastage can be afforded; and

d) When the particular reservoir under treatment is a unit in an interconnected system so that the other Reservoirs can supply the water needed.

4. Draining and Flushing :-

The method involves relatively slow release of all stored water in a reservoir through gates or valves located near bottom of the dam and the maintenance thereafter of open outlets for a shorter or longer period during which normal stream flow cuts into or directed against the sediment deposits. Therefore, this method may be adopted in flood control reservoirs.

5. Sluicing with Controlled Water :-

This method differs from the flood sluicing in that the controlled water supply permits choosing the time of sluicing more advantageously and that the water may be directed more effectively against the sediment deposits. While the flood sluicing depends either on the occurrence of flood or on being able to release rapidly all of a full or nearly full supply of water in the main reservoir is empty. The advantage of this method is that generally more sediment can be removed per unit of water used than in flood scouring or draining and flushing.

6. Sluicing with Hydraulics and Mechanical Agitation :-

Methods that stir up break up or move deposits of sediment into a stream current moving through a drained reservoir basin or into a full reservoir will tend to make the removal of sediment from the reservoir more complete. Wherever draining, flushing or sluicing appear to be warranted, the additional use of hydraulic means for stirring up the sediment deposits, or sloughing them off, into a stream flowing through the reservoir basin should be considered. It has, however, limited application.

15.0 Personnel:-

The Following Personnel were associated with the Sedimentation Survey of Tilaiya Reservoir:-

- **Survey:-**
  1. Shri Baidyanath Pal, Surveyor
  2. Shri Biswajit Samanta, Surveyor
  3. Shri Debjit Bakshi, Surveyor

- **Checked by the Following Personnel:-**
  1. Shri Nasim Ansari, Sr. Divisional Engineer (C), Hydraulic Data Division, DVC, Maithon
  2. Shri Atul Kumar Singh, Executive Engineer, (Civil), Hydraulic Data Division, DVC, Maithon
  3. Shri Basudev Das , Surveyor, Grade-I, PG-II, Hydraulic Data Division, DVC, Maithon

- **Approved By:-**
  1. Shri S.K.Maji, DCE (Civil), W/R, DVC, Maithon

All the Report have been furnished as per given guide lines mentioned in TOR.

15.1 Guidance/Recommendation and consultation of the Report:-

Name- Arun Kumar Roy
Designation- Chief Consultant Research & Hydro Solutions
[Retired Chief Engineer, Inland waterways Authority of India (I.W.A.I)]

Name-Bimalendu Ghosh

Designation- Senior Survey Consultant

The Institution of Surveyors (Delhi)

15.2 Certificate of Arun Roy:-

भारतीय अन्तर्देशीय जलमार्ग प्राधिकरण
(पोत परिवहन मंत्रालय, भारत सरकार)
मुख्यालय : ए–13, सैक्टर–1, नौएडा–201 301, (उ० प्र०)

INLAND WATERWAYS AUTHORITY OF INDIA
(Ministry of Shipping, Govt. of India)
Head Office : A-13, Sector-1, Noida-201 301 (U.P.)
Website : www.iwai.gov.in | www.iwai.nic.in

Tel. : +91-120-2544036, 2543972, 2527667, 2448101 Fax : +91-120-2544009, 2544041, 2543973, 2521764

No.11/IWAI/Estt./10/2016 Part

Dated:-28.05.2018

OFFICE MEMORANDUM

Consequent upon acceptance of recommendation of 7th CPC and instruction as contained in DoPT OM No. 38/37/2016-P&PW(A) dat 12.05.2017, No.38/37/2016-P&PW(A) dated 06.07.2017 and OM No.IWT-11011/15/2017-IWT dated 19.12.2017, Competent Authority h approved revision of pension/family pension w.e.f 01.01.2016 to the officials superannuated/expired prior to 2016 as per details mentioned under

Annuity No:	Original PPO No:	Last Corrigendum PPO No:
01IM1223142101	-	12/IWAI/Estt./03/2014 Dated: 31.07.2014

BASIC PARTICULARS

Name of Pensioner	Type of Pension	Date of Death of Employee/Pensioner (in case of family pension)
SH. ARUN ROY	SUPERANNUATION	-

Name of Deceased Employee (in case of Family Pension)	Relation of Pensioner with deceased employee (in case of Family Pension)	Post last held with scale of pay
-	-	CHIEF ENGINEER (Rs 37400-67000+GP8700/-)

Office Address	Pensioner's/Family Pensioner's Address
IWAI, Guwahati	Sh. Arun Roy Flat No.4D, Capricorn Castle, 188/93 A, Prince Anwar Shah Road, Kolkata-700045 (WB)

Date of Appointment in Service	Basic Pay and Scale of Pay at the time of Retirement/Death	Date of Retirement
19.08.1987	Rs. 37400-67000 + G.P. 8700/-	30.11.2014

Last Pay Drawn(Pay in Pay Band and Grade Pay to be separately shown in case of 6th CPC)	Notional Pay as on 01.01.2016(in the corresponding Pay Scale under 7th CPC as per Concordance Table-with Table No.)
Rs. 46380+8700 = 55080/-	Rs. 1,42,700/- (as per Table no. 44)

PENSIONARY ENTITLEMENT

Sl.No.	Particular	Pensioner	Spouse/Family (only in Service Pension PPO)
1.	Name	Sh. Arun Roy	Smt. Disha Roy (Wife)
2.	Date of Birth	20.11.1954	09.07.1968
3.	PAN Number	ADLPR1433J	
4.	Aadhaar Number	8090 5548 6311	
5.	Telephone/Mobile Number		
6.	E-mail ID	arunroy1@yahoo.com	
7.	Pre-Revised Basic Pension/Family Pension (As per circular No. C-153) before 01.01.2016	Rs. 27,540/- (Pension) Rs. 16,524/- (Family Pension)	
8.	Revised Rate of Pension / Family Pension wef 01.01.2016 (multiplying pre revised pension by 2.57	Rs. 70,778/- (Pension) Rs. 42,467/- (Family Pension)	
9.	Revised Pension wef 01.01.2016 as per Concordance Table-with Table No. 44	Rs. 71,350/-	
10.	Revised Family Pension wef 01.01.2016 as per Concordance Table-with Table No. 44	Rs. 42,810/-	
11.	Revised Pension payable wef 01.01.2016 (higher of serial no. 8 & 9)	Rs. 71,350/-	
12.	Revised Family Pension (at normal rate) payable wef 01.01.2016 (higher of sl. no. 8&10)	Rs. 42,810/- (wef. 20.11.2021)	
13.	Revised Family Pension at Enhanced Rate	Rs. 71,350/- (upto 19.11.2021)	
14.	Amount of Pension Commuted and Date of Commutation/Date of Payment of Commuted Value	Rs. 11,016/-	
15.	Revised Residual Pension wef 01.01.2016 (sl. no. 11-14)	Rs. 60,334/-	
16.	Medical Allowance	Separate order will be issued	

(Arun Roy), FIE, B.Tech IIT Kharagpur
Chief Consultant, river research & Hydro solutions
(Retired Chief Engineer, Inland waterways Authority of India)

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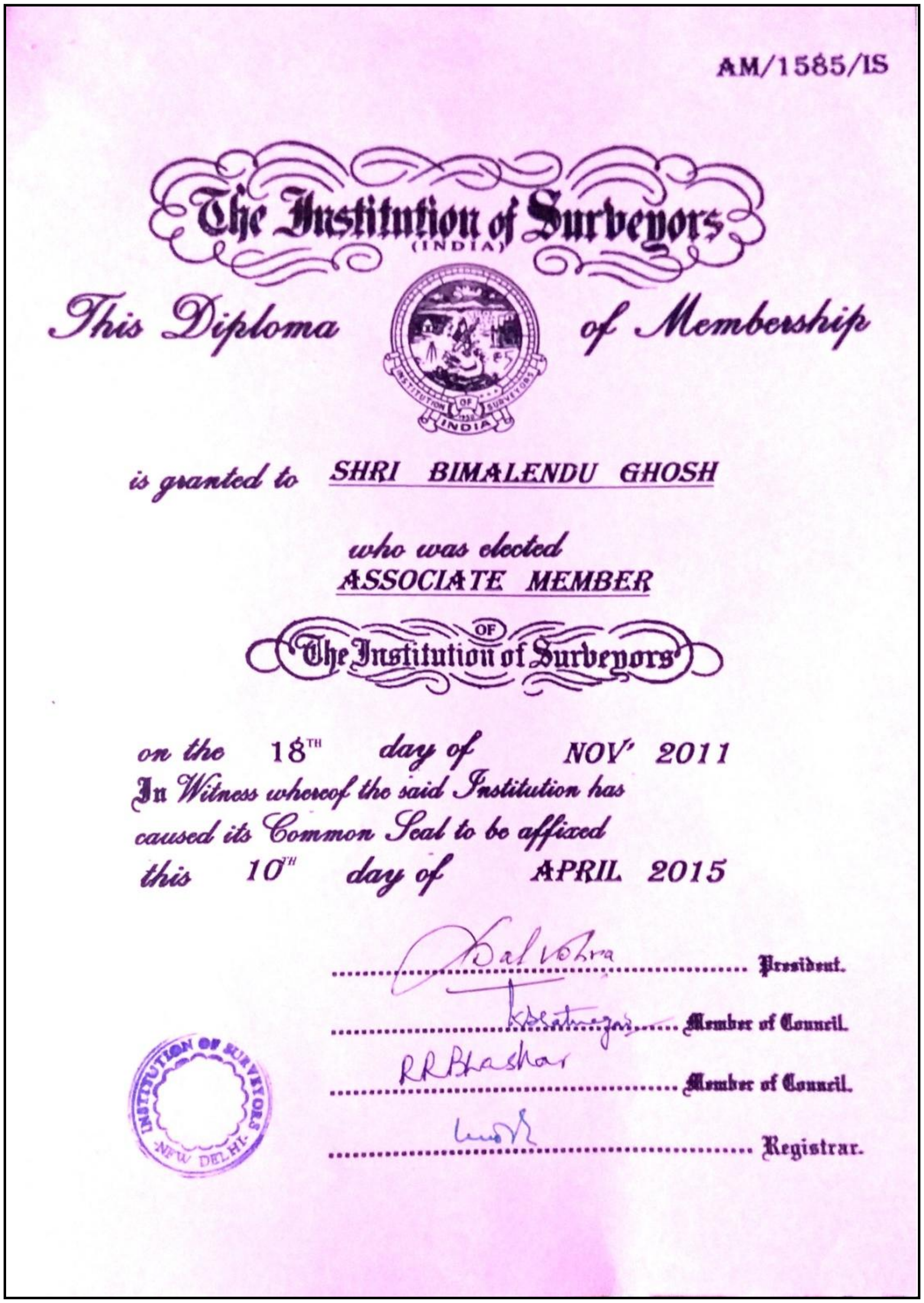
15.3 Certificate of Bimalendu Ghosh:-



AM/1585/IS

The Institution of Surveyors (INDIA)

This Diploma of Membership

is granted to SHRI BIMALENDU GHOSH

who was elected ASSOCIATE MEMBER

OF The Institution of Surveyors

on the 18TH *day of* NOV' 2011

In Witness whereof the said Institution has caused its Common Seal to be affixed this 10TH *day of* APRIL 2015

.... President.

.... Member of Council.

.... Member of Council.

.... Registrar.

INSTITUTION OF SURVEYORS NEW DELHI

SITE IMAGES

16.0 Site Images:-

Figure 18-During the Topographical Survey

Figure 19-Char land

Figure 20- Preparing the Vessel for Hydrography Survey