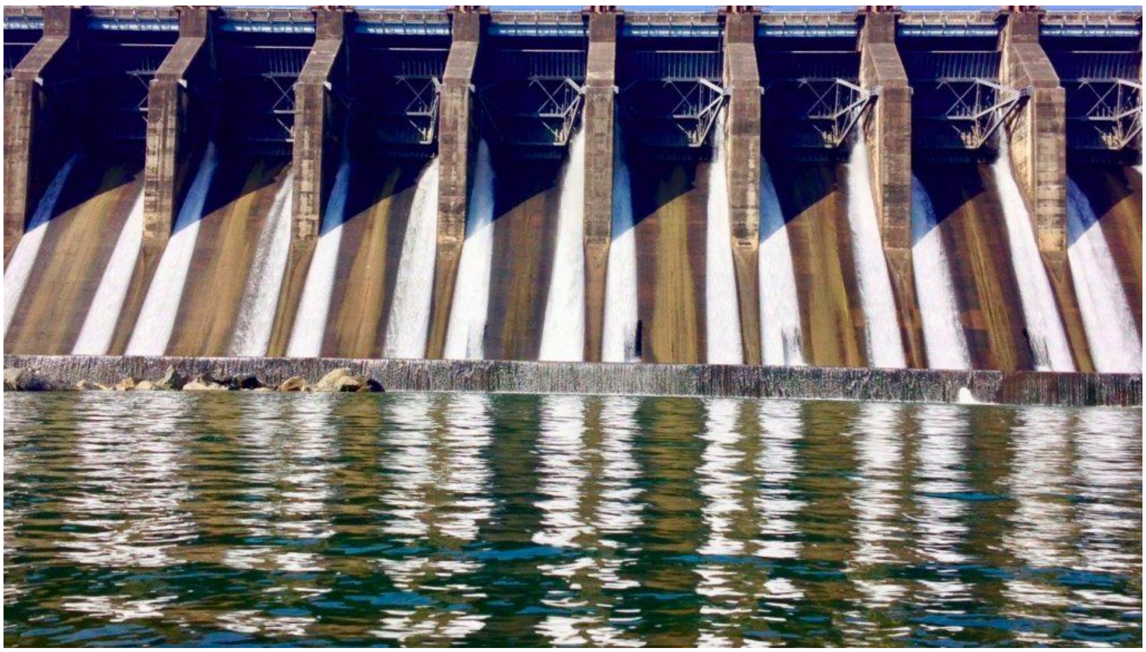
DAMODAR VALLEY CORPORATION
HYDRAULIC DATA DIVISION
P.O-MAITHON DAM, DIST-DHANBAD, JHARKHAND
PIN-828207

"Sedimentation Survey Report of Panchet Reservoir under NHP"



Precision Survey Consultancy,

"Vichitra" SP -45, (Kolkata West International City)
Salap Junction, Howrah Amta Road &
Bombay Road Crossing,NH- 6,
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 Panchet 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.

.

Table of Contents

List of Figure

List of Table

1.0 Introduction of Panchet Reservoir:-

Panchet hill dam on river Damodar is situated in Dhanbad district of Jharkhand, only a couple of miles upstream of the confluence of river Damodar with its major tributary, the Barakar. The Dam is a composite earth cum concrete structure 22,165 ft (6753 m.) in length. The Height over the original lowest bed is 134 ft. (40.8 m).

The Original allocated capacity is stated below in three zones:-

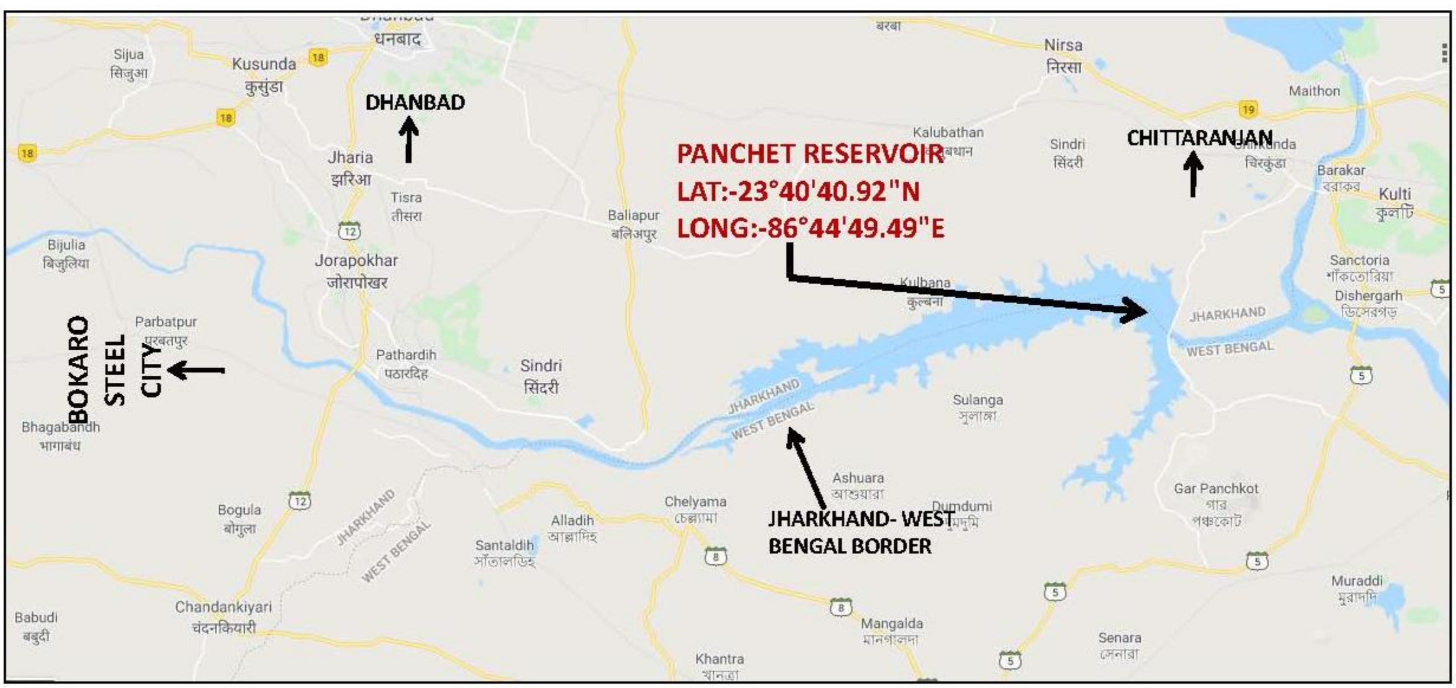
	Elevation		Original Capacity
Dead Storage	(El. 392 FT) (119.5 M)	:	191500 ACRE FEET (236.2 MCM)
Live Storage	(El. 392-410 FT) (119.5-125.0 M)	:	204500 ACRE FEET (252.3 MCM)
Flood Storage	(El. 410-425 FT) (125.0-129.5 M)	:	3, 04,275 ACRE FEET (375.32 MCM)
	(El. 425-435 FT) (129.5-132.6 M)	:	2, 61,425 ACRE FEET (322.46 MCM)
	(El. 435-445 FT) (132.6-135.6 M)	:	3, 20,000 ACRE FEET (394.71 MCM)
	TOTAL	:	**1281700 ACRE FEET (1581.0 MCM)**

The Reservoir has a water spread of 11 Sq. miles (28.48 Sq.km) at the dead storage level and 23 sq. miles (59.56 Sq.km.) at the normal pool level (El. 410 ft) (125.0 m). The Backwater at the normal pool level extends 18 miles (29 km) upstream.

The Total spillway Capacity provided at the dam is around 630,000 Cusecs (17840 cumecs) with the help of 15 nos. radial gates 41 ft. x 40 ft. (12.5 m x 12.2 m) height and 10 nos. under sluices 5 ft. 8 in. x 10 ft. (1.7 m x 3.0 m). The Total installed capacity of Panchet hill power plant is 80 MW at present and the maximum power house discharge is 12000Cusecs (340 Cumecs)

1.1 Location:-

Panchet hill dam is located in Eastern India within Latitude 23040'40.92"N and Longitude 86044'49.49"E. and also it may be stated another way it is situated about a distance of 290 km (approx) in direction from the source of river Damoder and a couple of mile from its confluence with the main tributary, Barakar. Panchet dam is 11 km from Chirkunda on G.T road and 51 km from Dhanbad Railway station. It is 32 km from Asansol via Disergarh and nearer railway station is at kumardubi on grand code line.



1.2 Catctchment characteristics of Damodar both upper and lower catchment and Hydrology:-

The Total catchment area of river Damodar is about 8,500 Sq. miles (22,015 sq. km) out of which Panchet hill commands about 4,200 sq. miles (10,878 sq. km).

The upper Damodar catchment is fan-shaped and conductive to heavy concentration of floods while the catchment downstream is a very narrow strip. The total catchment may be broadly classified as forest area, cultivated land, waste land and villages, rivers, tanks, town etc. The average rainfall is about 50 inches (1270 mm) annually with a range of about 30-80 inches (760-2030mm). As the catchment is generally denuded of forest cover, soil loss is fast taking place in the form of sheet and gully erosion and the streams carry a large amount of coarse and find grained sediment during the monsoon months which range from June-October. The monsoon is quite well defined in the valley. About 80-95% of the annual rainfall takes place during this period and almost all the major floods appear during these five months. The Peak floods generally occur after the middle of July by which time the ground storage gets more or less saturated. The run-off averages to about 15 inches (380mm) varying upon about 10-30 inches (250-760mm). Heavy rainfall is generally caused during the passage of cyclonic depressions which from at the head of Bay of Bengal during the monsoon months and travel in a north – westerly direction. The worst storm recorded in August 1913 indicated 12 inches (300mm) of rainfall in 5 days with a peak of 6, 50000 cusecs (18408 cumecs) and 9 inches (230mm) run- off. This peak was measured at Rhondia on Damodar where the drainage area is 7690 sq. miles (19917 sq. km).

1.2.1 Upstream Reservoirs:-

In the upper catchment of Panchet hill reservoir an upstream dam on the konar, a tributary to the river Damodar intercepts an area of 325 sq. Miles (842 Sq.km) the net sediment contributing area excluding 46 Sq. Miles (119 Sq.km) of reservoir area at panchet hill was 3830 Sq.Miles (9920 Sq.km). Another upstream dam at Tenughat on river Damodar 75 Miles (121 km) upstream of Panchet hill has since come up intercepting having a catchment area of 1730 sq. Miles (4481 sq.km). Partial impounding in this reservoir was started during the monsoon of 1970 and in 1972 normal operations began.

1.3 Purpose of the Reservoir:-

The Primary purpose of the reservoir is Flood control, irrigation and hydro-electric power generation.

1.4 Tenughat Reservoir and its Catchment:-

Tenughat Dam is located at latitude 23^0 45’ and longitude 45^0 15’ in the district of Bokaro in Jharkhand state on river Damodar 7 miles (11 km) upstream of its confluence with river Konar and 75 miles (111 km) upstream of Panchet hill dam. This is mainly water supply project with ultimate firm water contract of 900 cusecs (25.5 cumecs). The Elevation of the original stream bed at the dam is 730 ft. (222.5 m) above M.S.L. The height of the dam at the end of the 2nd stage of construction is 166 ft. (50.60 m), submerging at the top El. an area of 16,000 acres (6475 Hectere). The allocation of the original capacity is as under:-

Dead Storage (El. 817 ft) (249.0 m)	: 170000 Acre Ft. (209.7 MCM)	The Dam has so far been built upto El. 843.5 ft. only
Live Storage (El. 882ft) (268.8 m)	: 660000 Acre Ft (814.0 MCM)	
Total Storage (El.882 Ft) (268.8 m)	**:** 830000 Acre Ft. (1023.7 MCM)	

The Catchment area of river Damodar above the Dam site is 1730 sq. miles (4481 sq.km). The Catchment is elongated along the river varying in width from 14 to 38 miles (23 to 61 km) with an average of 25 miles (40 km). The River falls from El. 2000 ft. (609.6 m) at its source to El. 730 Ft. (222.5 m) at the dam site in a distance of 94 miles (151 km) with an average slope of 14 ft. /Mile (2.7m/km). This is steeper than the average slope upto Panchet hill dam which is 10 Ft. /Mile (1.9 m/km) in a length of 180 Miles (290 km) from the source.

1.5 Land use pattern in the Panchet hill watershed (Area in Sq. Miles):-

Watershed	Upland	Wooded Forest	Denuded Forest	Gullied land	Paddy land and other land	Total
Tenughat	245 (15%)	455 (28%)	260 (15%)	62 (4%)	626 (38%)	1648 (100%)
Intermediate (Below Tenu. Up to Panchet)	418 (19%)	210 (10%)	150 (7%)	56 (3%)	1316 (61%)	2150 (100%)
Total upto Panchet	669 (18%)	665 (18%)	410 (10%)	118 (3%)	1942 (51%)	3798 (100%)

Since Tenughat catchment has a steeper slope than that of the entire catchment upto panchet hill, it is expected that the rate of erosion from this catchment will be higher than the rate for the overall catchment. The Erosion rates of the two catchment, Tenughat and panchet hill may be compared by the well known Musgrave'S equation:

$$E \quad S^{1.35} \quad L^{0.35} \quad I^{1.75}$$

E = Erosion Rate,

S = Slope of the Catchment,

L = Length of the catchment,

& I = Intensity of the rainfall of a certain duration and frequency.

Since the catchment as a whole is more or less homogeneous from the rainfall point of view, intensity of rainfall for panchet hill and Tenughat may be taken as the same. The Application of the above equation will then indicate the rate of erosion from Tenughat catchment to be 25% higher than that from the overall catchment.

Comparison of the Suspended silt data at Tenughat and Sudamdih which is 21 miles (34 km) upstream of Panchet hill dam and is having a catchment of 3019 Sq. miles (7819 sq.km) also indicates higher erosion rate for Tenughat. For the period 1958-64 the observed suspended silt load at Sudamdih was about 1200 T/Sq.Mile/yr (463T/Sqkm/yr) at an average while at Tenughat it was about 2000 T/Sq.Mile/yr (772 T/Sq.km/yr). It may therefore be concluded that the erosion rate for the Tenughat catchment is 25 % to 70% higher than that for the overall catchment upto panchet hill.

1.6 Schedule of operation nof Panchet hill reservoir:-

The operation schedule is an important factor in governing the mode of sediment deposit as also the extent of deposition to which the deposit would be subjected. Normally during the dry season water is released from panchet hill reservoir through the turbines as per power and irrigation requirements. The released are governed on a joint operation basis along with Maithon reservoir on river Barakar ensuring about 750 cusecs (21 cumecs) to meet the downstream demand. During the monsson the levels start rising above the dead storage elevation of 392 ft (119.5 m) and are allowed to attain the normal pool level of 410 ft (125.0 m). Further rising of water levels is checked by the operation of sluice and spillway gates on the basis of the incoming flood and downstream conditions. The monsoon operation is also in conjunction with that of Maithon reservoir so that the total flow below the two dams does not exceed 200,000 Cusecs (5663 Cumecs).

1.7 Schedule of Capacity Survey:-

The Main objective of Capacity survey is to find out storage loss consequent on the deposition of stream borne sediment in the reservoir upstream of the dam and to revise capacity curves on which proper operation of the reservoir depends. Decrease in storage capacity prevents the reservoir from functioning effectively and estimation of the period of effectiveness is necessary. Systematic capacity surveys are essential from this point of view and they should be carried out on a routine basis in regular intervals of 3 to 5 years depending upon the extend of storage loss, change of the hydraulic condition of the system unusual operations etc.

As the DVC contemplated building a number of Dams, it has its own comprehensive plans for carrying out capacity surveys of the reservoirs. Different types of equipment and accessories such as echo-sounder, motor launch etc. were procured and preliminary ranging work was completed before the start of impounding in the reservoirs. Meanwhile the central board of irrigation and power, New Delhi, took up research work on reservoir sedimentation and offered financial assistance to some selected projectsin India. DVC was included under this programme and a number of capacity surveys of Maithon and panchet hill reservoir and also the study of the density of the deposits in the two lakes have been conducted by DVC on behalf of the CBI & P between 1961 & 1974. As many as 4 capacity surveys were conducted during this period.

The sixth capacity survey of panchet hill reservoir was taken up the year 1995 and completed in January, 1996. This survey was taken up under DVC'S own scheme.

1.8 The Original Survey:-

The pre –dam survey of the DVC reservoirs was conducted by the AIR SURVEY COMPANY of india during 1950, the information on ground control and ground verification being supplied by Survey of India. The compilation work and preparation of maps were done by the AIR SURVEY COMPANY. The original capacity of panchet hill reservoir is based on these latest aerial survey maps with 6 inches to a mile scale (1:10560) and 10 ft (3.0 m) contour interval. These maps have been checked for horizontal and vertical control with reference to the GTS bench marks as well as the datum at the dam. The maps agree well these bench marks a also with some existing prominent features in the reservoir basin.

Just before the start impounding in panchet hill reservoir, cross sections at half miles (0.8km) interval were taken by direct leveling. There are 52 ranges in all in two nearly parallel sets, one along the Damoder river arm and the other along its tributary, the utla nala. The ranges were fixed with monument pillers and they were located on the basic serial survey map with the help of precision triangulation having its base on the straight portion of the dam.

Bench mark pillers were established at every 5 miles (8 km) and the bench marks were connected with the datum at the dam. Later on after impounding of water started, these bench marks were checked with reference to the still pool levels of the reservoir and close agreement was observed. Capacity of different reaches of the reservoir was completed on the basis of area of different contours within the different reaches. This forms the basic original capacity data for the lake.

2.0 The First capacity Survey:-

Impounding in panchet hill reservoir started during monsoon of 1956. The first capacity survey using echo-sounding equipment was carried out during February-June 1962. The depth of water over reservoir bed was measured with an Edo. Model 255 Echo sounder which was checked by ‘Bar check method’ quite frequently. The distance to’ fixes’ on the recorderchat were measured by a plane –table with a telescopic alidade located on shore.

Dry portions of the lake were covered up by the direct leveling and the shallow water portions were surveyed with the help of a country boat. The fifty two cross sections taken before impounding, were repeated and their sectional areas compared to arrive at the volume of deposit and the revised capacity. This method of survey is known as the range method. The computation of the volume of deposit was carried on by “constant factor method”. This method of survey and computation have been extensively usedin the lakes of the Tennessee valley authority in the USA with consistently accurate results. They have been checked by us as well with reference to contour surveys and the results have been quite consistant even in case of small amounts of bends and embankments in the reservoir reach under investigation. While other methods need personal judgement, ‘Constant Factor’ method gives uniformly accurate results. The accuracy is consistently greater than that obtained by other conventional method with the exception of contour method which is both expensive and time consuming. The “CONSTANT FACTOR” formula is given by the simple equation,

$$V = \left(\frac{V_0}{A_0} \right) \text{as}$$

Where, for vertical strip between two horizontal planes,

V_S = Volume of deposit in the reach,

V_O = Original capacity of the reach,

A_O = Original sum of end areas in the reach,

And A_S = Sum of sediment areas in the reach.

The results are expected to be more and more accurate with closure spacing of ranges and thinner vertical strips reach. For panchet hill reservoir the ranges are half mile (0.8 km) apart and vertical strips are of 10 ft. (3.0 m) thickness. Cross section survey in panchet hill reservoir was conducted up to El. 430 ft. (131.0 m). Between El. 430 ft. (131.0 m) and 445 ft. (135.6 m) it was assumed that no change in area had taken place. The first capacity survey of panchet hill reservoir indicated an annual deposition rate of about 2.80 AF/Sq. mile/yr. (1330 cu.m./sq.km/yr.) of the catchment. The total volume of deposit during the first 6 years of impounding was 64.2 KAF (80.2 MCM) with an average of 10.7 KAF/Yr. (13.4 MCM/Yr).

3.0 The Second Survey:-

The Second capacity survey of panchet hill reservoir was carried out during February –June, 1964 after an interval of 2 years after first survey and 8 years after first impounding. The object of this repeat survey at a close interval of 2 years was to verify the results obtained in the first survey. The procedure adopted in the survey and computation was identical with that of first survey. This survey indicated an annual deposition rate of about 2.60 AF/Sq. mile/yr. (1240 Cu.m./Sqkm/yr.) of the catchment which closely follows the result obtained previously. The total volume of deposit in the first 8 years of impounding was 78.3 KAF (96.6 MCM).

4.0 The Third Survey:-

The Third Capacity survey of panchet hill reservoir was carried out during the summer of 1966 when it was drawn to El. 343 ft. (104.5 m) in order to carry out some paining and repair works to the trash rack and penstock gates etc. The entire stretches of the reservoir basin starting from the dam upto the delta region near sindri, some 11 miles (18 km) upstream, was inspected. As the reservoir bottom was exposed more or less fully, a re-survey with direct leveling across the silt ranges was conducted. The main objective of this re-survey was to have a check over the previous surveys carried out with echo-sounding equipment. There had been a feeling in certain quarters in those days that hydrographic surveys conducted with electronic equipment might not be accurate. The doubt had, perhaps, crept in on account of the trend of siltation observed in the country which was more than double the estimated load adopted at the time of project planning. The direct survey has confirmed the hydrographic surveys dispelling the prevalent doubt.

The third survey showed a total sediment deposit of 85.8 KAF (105.8 MCM) in ten years giving an average annual deposition rate of about 2.20 AF/Sq.mile/Yr. (1050 cu.m/sq.km/yr) of the catchment.

It may be noted that during the period 1964 to 1965 the runoff into the reservoir was low. During 1964 the runoff was normal while in 1965 it was 30% below normal. During these to years, the volume of deposit was only 7.5 KAF (9.3 MCM) with an average annual rate of about 1.00 Af/Sq.mile/yr. (476 cu.m/sq.km/yr.) of the catchment. The low runoff was one of the reasons for the low deposition rate.

Another reason was the exposure of the deposited sediment and the consequent shrinkage. In this connection it may be noted that a major portion of panchet hill reservoir was exposed during summer of 1965 and it was completely exposed during the summer of 1966. Yet another reason for the drop in the deposition rate was the increasing sand stowing activities from year to year from the head reaches of the reservoir. During January to December, 1963 the amount of sand extracted by different collieries from the head reaches was 2.38 million tones. During the same period in 1964 and 1965 the extraction went to 2.55 and 2.61 million tones respectively. The average annual rate upto 1966 was about 2.5 million tones.

5.0 The Fourth Survey:-

The Fourth survey which should have been conducted in 1970 when Tenughat Reservoir started impounding could not be taken up in time on account of breakdown of certain facilities. The survey was conducted during March-May, 1974 and this will from the base for measurement of sediment load into panchet hill reservoir from the reduced sediment producing area. Since there was no actual measurement in Tenughat Reservoir, the quantity of deposit in that reservoir during the period 1970 to 1973 was estimated. This volume along with the volume of sediment deposited in panchet hill reservoir upto 1973 will indicate the total volume of sediment that would have been deposited in panchet hill reservoir had Tenughat dam not been built.MS 26 F Echo-Sounder with an outboard oscillator was used in this survey.Adequate 'Bar Check' was conducted before and after each day'S work. On account of motor launch troubles a reduced number of ranges were surveyed this time. As a result, the range spacing in the reach between 3 and 8 miles (4.8 and 12.9 km) from the dam waskept at one mile. (1.6 km). This was considered adequate as the volume of deposit in this reach is only about 20% of the total deposit.

The total volume of deposit in panchet hill reservoir upto the beginning of monsoon , 1974 was 117.7 KAF (145.2 MCM). The estimated volume of deposit in Tenughat Reservoir upto this date is 24.9 KAF (30.7 MCM).Adding this together we get 142.6 KAF (175.9 MCM)of sediment which would have been deposited in panchet hill reservoir had Tenughat dam not been built. This gives an average annual deposition rate of about 2.10 AF/Sq. Mile/Yr. (1000 Cu.m/Sq.km/Yr) of the catchment including both panchet hill and Tenughat. The other reasons of decrease in deposition rate are ex[osure of the deposit and its shrinkness due to desiccation almost every year. Increasing rates of sand extraction by collieries since 1966 and to some extent, the land treatment measures taken up in some areas of the upper catchment.

6.0 The Fifth Survey:-

Fifth capacity survey of Panchet hill reservoir was due in 1979 but could not be taken up on account of major break down of the motor launch. The launch was thoroughly repaired in 1984 and capacity survey was under taken. The Survey was completed in May, 1985. Kelvin Hughes MS 26 F Echo sounder was used for depth recording and adequate bar check was conducted. Computation of capacity was done by constant factor method.

As per this survey, total volume of deposit in panchet hill reservoir upto May 1985 is 150.3 KAF (185.4 MCM). The total volume of deposit upto 1974 was 117.7 KAF (145.2 MCM) which means that 32.6 KAF (40.2 MCM) of sediment have been deposited during the period 1974-1985. The average annual rate of deposition is about 1.40 AF/Sq. Mile/Yr. (670 cu.m./Sq.km/yr) of catchment.

7.0 The Sixth Survey:-

Sixth capacity survey of panchet hill reservoir was due in 1990 but could not be taken up on account of major break down of motor launch. The Launch was hired in 1995 and capacity survey was under taken. The Survey was completed in January 1996. Kelvin Hughes MS 26 F Echo sounder was used for depth velocity and adequate bar check was conducted. Computation of capacity was done by constant factor method.

As per this survey, the total volume of deposit in panchet hill reservoir up to January 1996 is 180.700 KAF (222.91 MCM). The total volume of deposit upto 1974 was 117.7 KAF (145.2 MCM) which means that 63.00 KAF (77.71 MCM) of sediment have been deposited during the period 1974 –January 1996. Average annual rate of deposition is about 1.36 AF/Sq.Mile/Yr (648 Cu.m/Sq. km/Yr) of the catchment excluding Tenughat, Konar and Reservoir area at Panchet hill. An appreciable amount of decrease has been indicated on account of nterception of sediment at Tenughat Dam.

8.0 The Seventh Survey:-

The Seventh Capacity survey of Panchet hill reservoir was carried out during the month of January to March, 2020. The Capacity Survey was completed perfectly. The Motor launch, Bathy 500 Echo – Sounder was used for depth recording and adequate bar check was conducted. Computation of Capacity was done by '**Contouring Method'.**

As per this survey, the total volume of sediment deposit in Panchet Hill Reservoir up to March, 2020 is 247263 AF (304.99 MCM). The total volume of sediment deposited upto year 1974 was 1, 17,700 Acre Feet. (145.2 MCM). Hence, the sediment have been deposited during the period of year 1974 to 2020 is (247263-117700) Acre Feet =1, 29,563 Acre Feet (159.81 MCM). Average annual rate of deposition in 46 years is (1, 29,563 ACF/2100 Sq Mile/46 Yr) = 1.34 ACF/Sq. Mile/Yr.

9.0 Revised Capacity:-

The Revised capacity of Panchet hill Reservoir as per the survey of 2020 is as tabulated below:

REVISED CAPACITY OF PANCHET HILL RESERVOIR

JANUARY-MARCH, 2020

Elevation		Capacity	
Feet	Meter	Acre Feet	MCM
320	97.5	0	0
330	100.5	0	0
340	103.6	121.6	0.15
350	106.6	2075.4	2.56
360	109.7	10060.9	12.41
370	112.7	24386.2	30.08
380	115.8	46972.72	57.94
390	118.8	77058.28	95.05
400	121.9	127857.57	157.71
410	125.0	225548.51	278.21
420	128.0	376430.34	464.32
430	131.0	575030.75	709.29
435	132.6	705335.1	870.02
445	135.6	1034437.60	1275.96

10.0 Location of Sediment Deposit:-

It has been observed that capacity has been lost not only in the dead storage space but in the live storage and Flood storage also. The total original capacity of the reservoir to top of gates was 1281700 Acre Feet (1581.0 MCM). It has now been reduced to 1034437.60 AF (1275.96 MCM) as per the present survey. The total loss of capacity in this reservoir upto January-March, 2020 is 247263 Acre Feet (304.99 MCM).

Storage capacity and progressive loss of storage capacity in different allocated storage spaces and capacities at the end of different surveys have been shown in table no VI, VIIA and the table no IIIA, III shows the average annual volume of deposit and the rate of sediment deposition in panchet hill reservoir.

11.0 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.

11.1 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.

11.2 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.

11.3 Survey by Precision Survey Consultancy:-

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

11.4 Weather:-

The survey was undertaken during the month of 'from 31st January to 11th March, 2020. The Temperatures became average for the Topographic survey and Bathymetry Survey.

12.0 Project Site Location Map of Panchet Reservoir:-

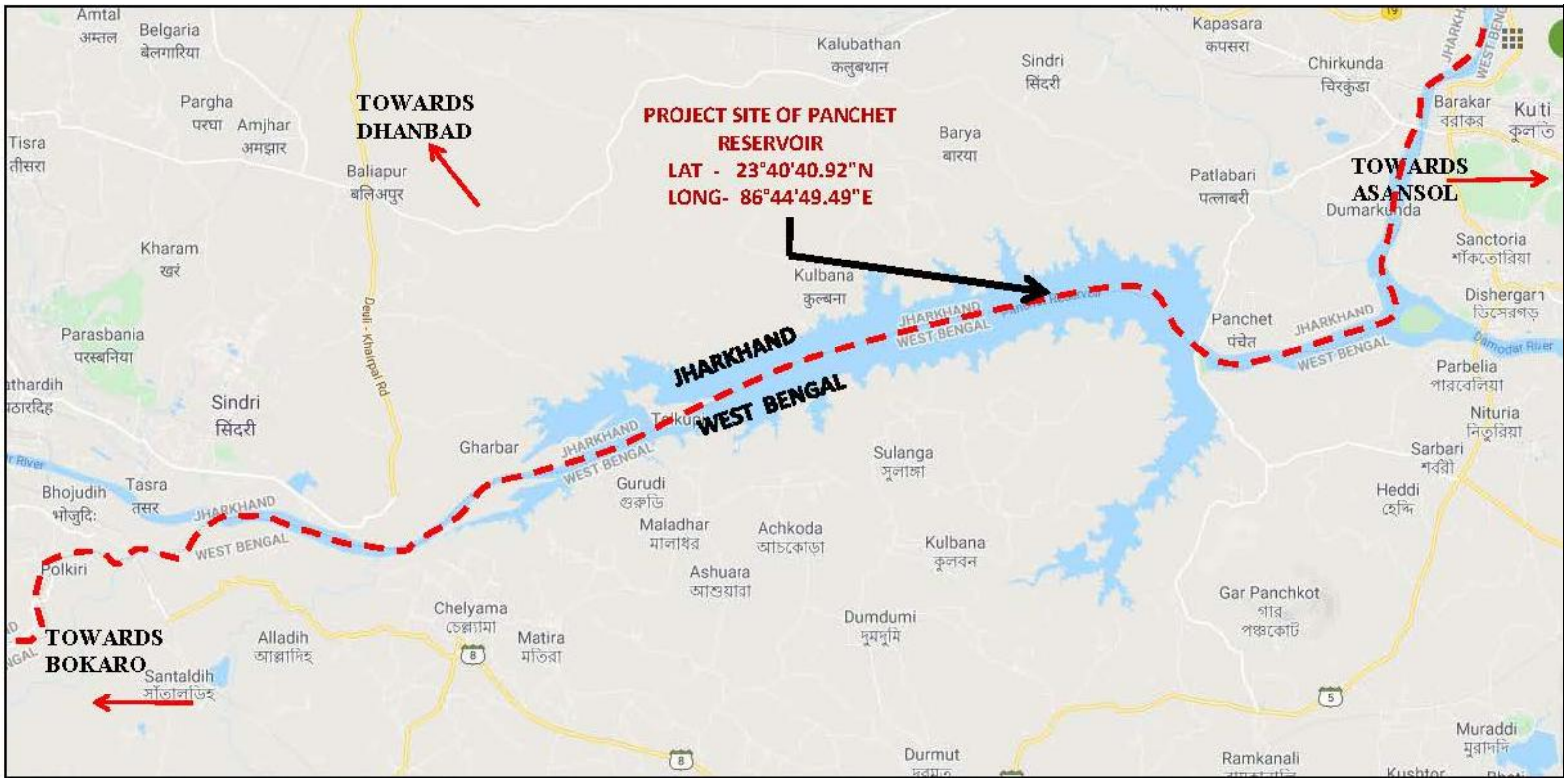


Figure 1-Project site location Map of Panchet Reservoir

13.0 Scope of Work:-

The scope of the work includes:-

Brief Description of the work	Intended Completion period
Sedimentation Survey of Panchet 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 then 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) <u>Estimation of sedimentation in different zones of reservoir:</u>
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) <u>Analysis of Bed material samples</u>
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) <u>Cross sections</u>
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.
<u>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.</u>

vi) <u>L-section</u>
L-Section of the reservoirs may be prepared with the lowest bed levels at every survey line.

vii) <u>Vertical sediment Distribution</u>
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) <u>Contour map of the reservoir</u>
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) <u>Trap Efficiency of Reservoir</u>
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) <u>Charts/drawings for the Report</u>
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.

14.0 Authentic Reference level for the Survey:-

For the Topographic/Bathymetry Survey, The Level has been carried out from the gauge level and the level is transferred to control point named as PD-1. The details are tabulated below:-

Location	Easting (m)	Northing (m)	Latitude (N)	Longitude (E)	Elevation (m)
Panchet Reservoir	475033.885	2620861.332	23°41'54.37"	86°45'18.384"	139.357 w.r.t M.S.L

Figure 2 - Authentic reference level for the Survey

15.0 Conduct of survey work

15.1 Topographical Survey

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 reservoir Banks

The spot levels/Topographical Survey along the Panchet 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** - **MSL**
- **Grid** - **UTM North (45N)**
- **Scale factor** - **As per requirement**

16.0 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:-

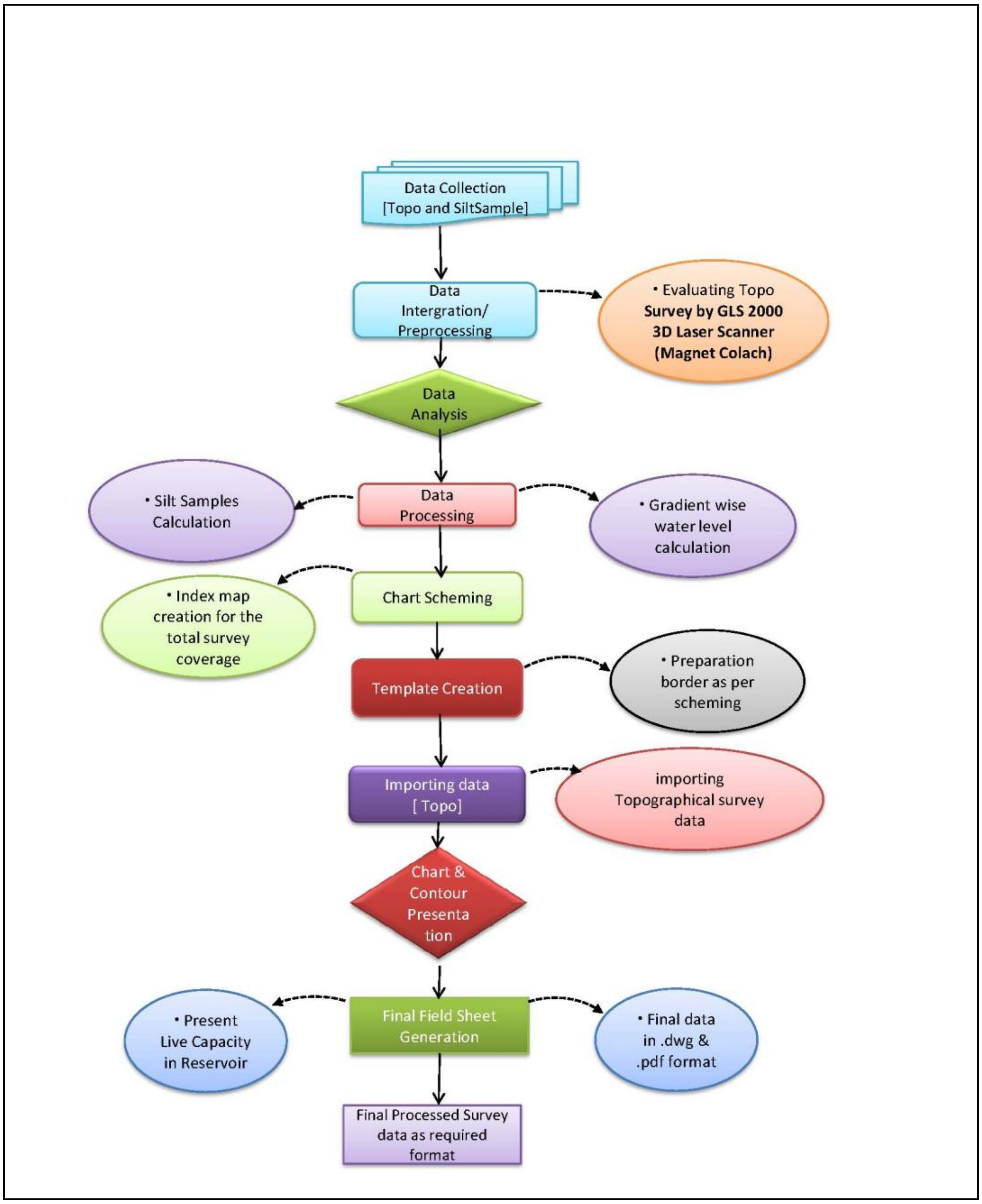


Table 1-Data Processing

17.0 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 1500 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 Konar 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 Konar 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.

17.1 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 3-During the Hydrography Survey in Panchet Reservoir

17.2 Hydrography Survey Process:-

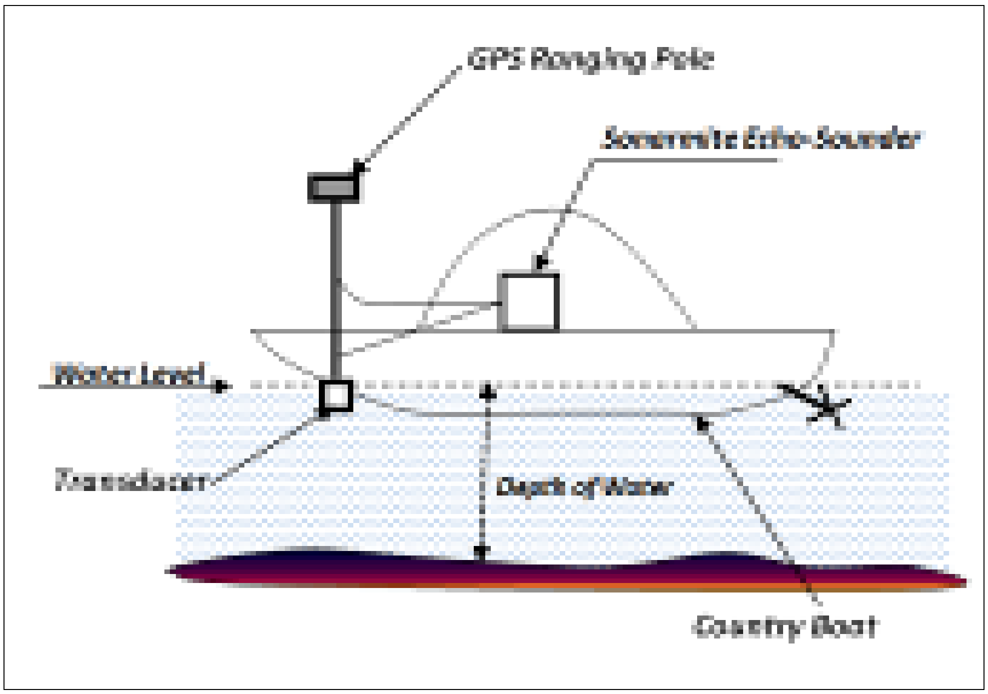


Figure 4-Schematic diagram showing the sequence of operation

17.3 Hypack Data Processing System:-

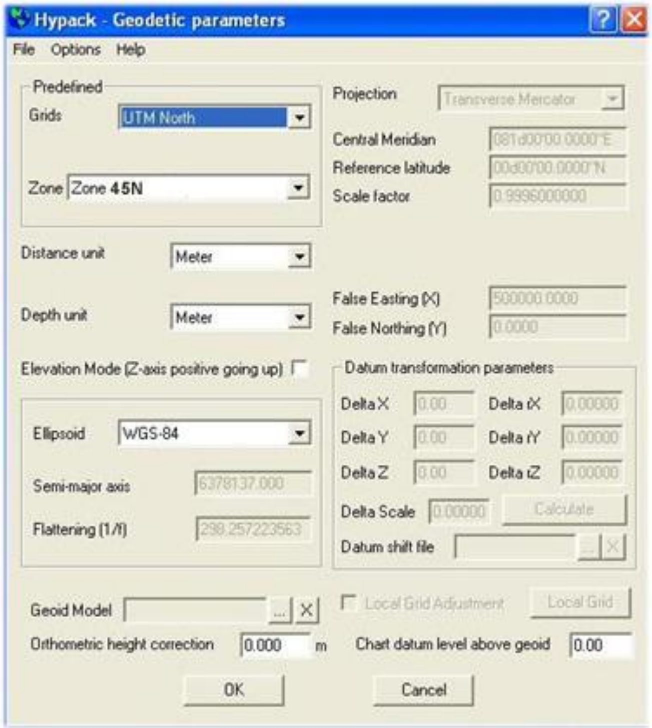


Figure 5-Hypack Data Logging, Geodetic Parameters

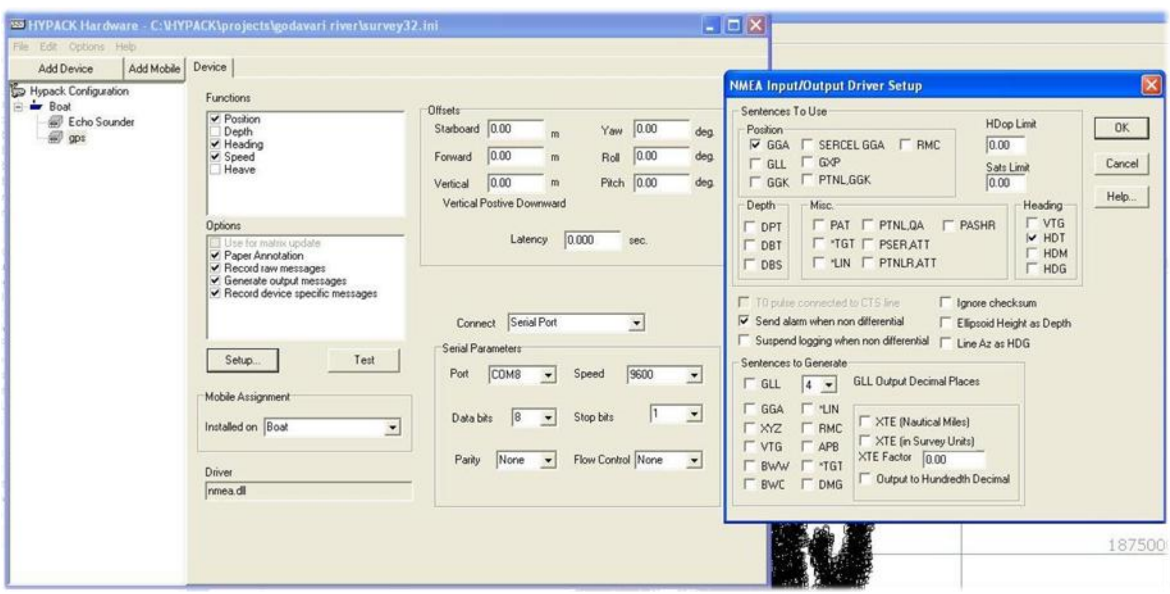


Figure 6-Hypack Data logging, Navigation I/P settings

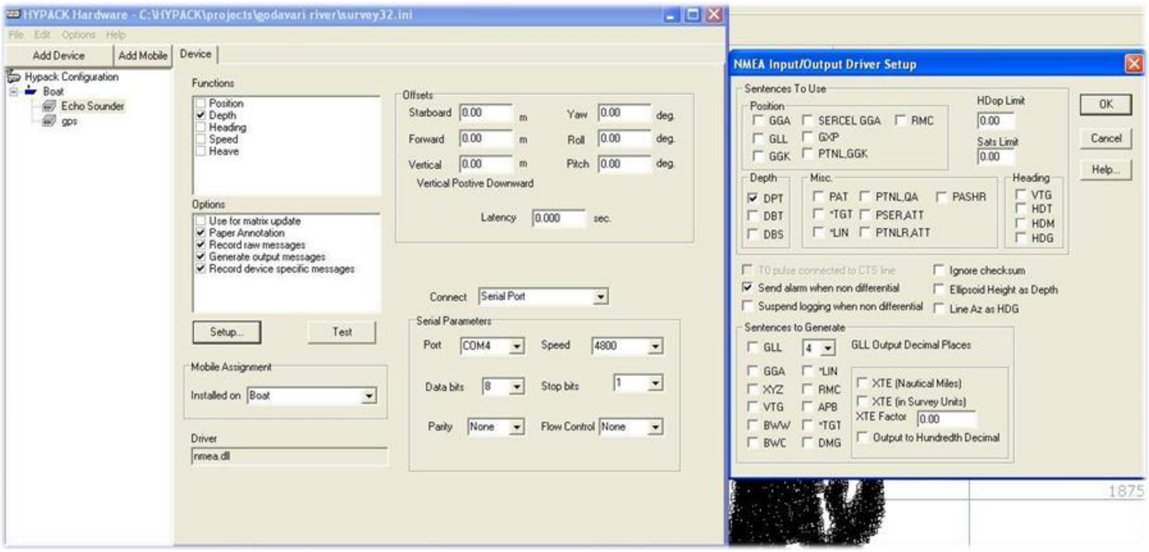


Figure 7-Hypack Data Logging, Echo-sounder I/P settings

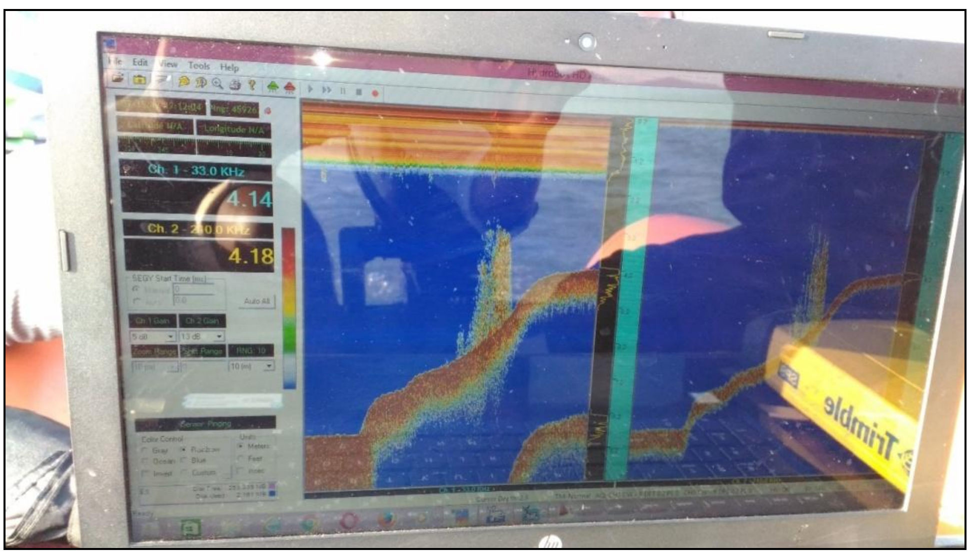


Figure 8-Hypack data processing

18.0 Soil Sample Position:-

The Soil samples are collected 15 nos of various locations from Panchet Reservoir which are tabulated below. The location maps of soil samples are also indicate at page no-21 with the same Coordinate.

SAMPLE NO	DISTANCE (m)	EASTING (m)	NORTHING (m)	LATITUDE (N)	LONGITUDE (E)
1	0.00	470916.00	2613129.00	23°37'42.687"	86°42'53.518"
2	1353.40	472168.00	2613643.00	23°37'59.481"	86°43'37.671"
3	2500.08	472674.00	2614672.00	23°38'32.972"	86°43'55.462"
4	4364.00	474042.00	2615938.00	23°39'14.221"	86°44'43.668"
5	6114.44	473971.00	2617687.00	23°40'11.089"	86°44'41.052"
6	7800.71	474181.00	2619049.00	23°40'55.39"	86°44'48.38"
7	9282.14	473856.00	2620835.00	23°41'53.447"	86°44'36.792"
8	11247.21	471924.00	2621194.00	23°42'05.003"	86°43'28.544"
9	12926.07	471005.00	2619789.00	23°41'19.258"	86°42'56.191"
10	15280.03	468715.00	2620334.00	23°41'36.826"	86°41'35.291"
11	16820.50	468001.00	2618969.00	23°40'52.389"	86°41'10.185"
12	19189.93	465820.00	2619895.00	23°41'22.339"	86°39'53.103"
13	20793.32	464741.00	2618709.00	23°40'43.69"	86°39'15.105"
14	22393.14	463144.00	2618804.00	23°40'46.65"	86°38'18.712"
15	23720.00	462185.00	2617887.00	23°40'16.752"	86°37'44.937"

Table 2-Soil Sample location

18.1 Google image of Soil Sample locations:-

Figure 9-Soil sample locations in google images

19.0 Salient Features of Panchet Reservoir:-

Salient Features of Panchet Reservoir, DVC		
General	Inauguration	06.12.1959
	River	Damodar
	District	Dhanbad
	State	Jharkhand
Hydrological	Catchment Area(km^2)	10,878
	Avg. Annual Precipitation (cm)	114
	Avg Annual runoff (MCM)	4540
Structural	Type	Composite 1
	Maximum Height above foundation (m)	47.85
	Type of Spillway	ogee
	Crest gate type	Tainter
	Crest gate Number	15
	Crest gate size (mxm)	12.19x12.5
	Undersluice type	vertical lift
	Undersluice Number	10
	Undersluice size (mxm)	1.73x3.05
Reservoir	Dead storage level (m) above MSL	119.48
	Flood management level (m) above MSL	124.97
	Deaad Storage (MCM)	169
	Max. Utilizable Flood Management level (m) above MSL	132.58
	Flood Management storage (MCM)	434
Power	Installed Capacity	80MW
	Type of Turbine	Vertical Shaft Kaplan
	Maximum Head	31.39 meter

Table 3- Salient features of Panchet Reservoir

20.0 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 10- 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 11- Echo Sounder Instrument

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

21. Calibration

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

21.1 Echo-Sounder Calibration:-

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	:	ADVANCE LAND & HYDROGRAPHY SURVEY INDIA PVT LTD.
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	:	17/04/2019
VALIDITY	:	16/04/2020

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

REGD. OFFICE : OFFICE NO. 1, D-4, COMMERCIAL AREA, VASANT KUNJ, NEW DELHI-110070, INDIA
PHONES : +91 11 26137657, 26137659, 26899952, 26899962, 26132214 FAX : +91 11 26138633
e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 12-Sonarmite Echo-Sounder Calibration Certificate

21.2 RTK –Spectra Precision SP-80:-

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	:	ADVANCE LAND & HYDROGRAPHY SURVEY INDIA PVT. LTD
ADDRESS	:	Vichitra –SP-45, KWIC, NH-6 Crossing, P.O. –Bankra, P.S.-Domjur, Dist. –Howrah Pin: 711 403
INSTRUMENT	:	GNSS Receiver
SERIES	:	SP-80 - Spectra Precision
SERIAL NUMBER	:	5508550620, 5509550021
CALIBRATION DATE	:	22/04/2019
VALIDITY	:	22/03/2020

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.**

M Srivastava

AUTHORISED SIGNATORY

REGD. OFFICE : OFFICE NO. 1, D-4, COMMERCIAL AREA, VASANT KUNJ, NEW DELHI-110070, INDIA
PHONES : +91 11 26137657, 26137659, 26899952, 26899962, 26132214 FAX : +91 11 26138633
e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 13-Spectra Precision SP-80Calibration Certificate

21.3 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	:	ADVANCE LAND & HYDROGRAPHY SURVEY INDIA PVT LTD.
ADDRESS	:	Vichitra SP-45, KWIC Bankra, P.S.- Domjur, Dist. –Howrah, Pin: 711 403 (W.B)
INSTRUMENT	:	Beacon Receiver
SERIES	:	SP361
SERIAL NUMBER	:	5431R03128
CALIBRATION DATE	:	05/06/2019
VALIDITY	:	04/06/2020

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.**

M Srivastava

AUTHORISED SIGNATORY

REGD. OFFICE : OFFICE NO. 1, D-4, COMMERCIAL AREA, VASANT KUNJ, NEW DELHI-110070, INDIA
PHONES : +91 11 26137657, 26137659, 26899952, 26899962, 26132214 FAX : +91 11 26138633
e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 14-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.

22.0 Detail Analysis of Area Capacity Curve:-

22.1 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

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

V= the volume of the segment

<u>I.S. 5477 part-II-1994</u>

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.

Panchet Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2020						
SL.NO.	Contour EL (meter)	Contour Interval (meter)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between* two consecutive contour surface *(in Cum.)*	Cumulative Vol. *(in M-Cum.)*
1	102.0	0.0	19890.081	1.989	0.000	0.00
2	102.3	0.3	45789.829	4.579	9851.986	0.01
3	102.6	0.3	71689.576	7.169	17621.911	0.03
4	102.9	0.3	97589.324	9.759	25391.835	0.05
5	103.2	0.3	131115.446	13.112	34305.716	0.09
6	103.5	0.3	168454.757	16.845	44935.530	0.13
7	103.8	0.3	205794.067	20.579	56137.323	0.19
8	104.1	0.3	273334.360	27.333	71869.264	0.26
9	104.4	0.3	401276.622	40.128	101191.647	0.36
10	104.7	0.3	529218.883	52.922	139574.326	0.50
11	105.0	0.3	657161.144	65.716	177957.004	0.68
12	105.3	0.3	825346.689	82.535	222376.175	0.90
13	105.6	0.3	993532.234	99.353	272831.838	1.17
14	105.9	0.3	1161717.779	116.172	323287.502	1.50
15	106.2	0.3	1434364.109	143.436	389412.283	1.89
16	106.5	0.3	1759240.833	175.924	479040.741	2.37
17	106.8	0.3	2084117.556	208.412	576503.758	2.94
18	107.1	0.3	2383012.190	238.301	670069.462	3.61
19	107.4	0.3	2629942.646	262.994	751943.225	4.36
20	107.7	0.3	2876873.101	287.687	826022.362	5.19
21	108.0	0.3	3123803.557	312.380	900101.499	6.09
22	108.3	0.3	3442639.363	344.264	984966.438	7.08
23	108.6	0.3	3761475.170	376.148	1080617.180	8.16

Panchet Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2020						
SL.NO.	Contour EL (meter)	Contour Interval (meter)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between* two consecutive contour surface *(in Cum.)*	Cumulative Vol. *(in M-Cum.)*
24	108.9	0.3	4080310.976	408.031	1176267.922	9.33
25	109.2	0.3	4345697.327	434.570	1263901.245	10.60
26	109.5	0.3	4584358.950	458.436	1339508.441	11.94
27	109.8	0.3	4823020.572	482.302	1411106.928	13.35
28	110.1	0.3	5062456.478	506.246	1482821.558	14.83
29	110.4	0.3	5303440.948	530.344	1554884.614	16.38
30	110.7	0.3	5544425.419	554.443	1627179.955	18.01
31	111.0	0.3	5785409.889	578.541	1699475.296	19.71
32	111.3	0.3	6043659.614	604.366	1774360.425	21.49
33	111.6	0.3	6301909.339	630.191	1851835.343	23.34
34	111.9	0.3	6560159.063	656.016	1929310.260	25.27
35	112.2	0.3	6820750.490	682.075	2007136.433	27.27
36	112.5	0.3	7082512.767	708.251	2085489.488	29.36
37	112.8	0.3	7344275.043	734.428	2164018.171	31.52
38	113.1	0.3	7612973.787	761.297	2243587.325	33.77
39	113.4	0.3	7895545.463	789.555	2326277.887	36.09
40	113.7	0.3	8178117.139	817.812	2411049.390	38.50
41	114.0	0.3	8460688.815	846.069	2495820.893	41.00
42	114.3	0.3	8771297.521	877.130	2584797.950	43.58
43	114.6	0.3	9081906.226	908.191	2677980.562	46.26
44	114.9	0.3	9392514.932	939.251	2771163.174	49.03
45	115.2	0.3	9726216.498	972.622	2867809.715	51.90
46	115.5	0.3	10071464.496	1007.146	2969652.149	54.87
47	115.8	0.3	10416712.493	1041.671	3073226.548	57.94
48	116.1	0.3	10775955.224	1077.596	3178900.157	61.12

Panchet Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2020						
SL.NO.	Contour EL (meter)	Contour Interval (meter)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between* two consecutive contour surface *(in Cum.)*	Cumulative Vol. *(in M-Cum.)*
49	116.4	0.3	11163187.424	1116.319	3290871.397	64.41
50	116.7	0.3	11550419.623	1155.042	3407041.057	67.82
51	117.0	0.3	11937651.823	1193.765	3523210.717	71.34
52	117.3	0.3	12412724.652	1241.272	3652556.471	75.00
53	117.6	0.3	12887797.480	1288.780	3795078.320	78.79
54	117.9	0.3	13362870.309	1336.287	3937600.168	82.73
55	118.2	0.3	13901172.802	1390.117	4089606.467	86.82
56	118.5	0.3	14471090.129	1447.109	4255839.440	91.08
57	118.8	0.3	15041007.456	1504.101	4426814.638	95.50
58	119.1	0.3	15656267.355	1565.627	4604591.222	100.11
59	119.4	0.3	16362212.399	1636.221	4802771.963	104.91
60	**119.5**	0.1	16597527.414	1659.753	1647986.991	106.56
61	119.7	0.2	17190208.651	1719.021	3378773.607	109.94
62	120.0	0.3	18079230.507	1807.923	5290415.874	115.23
63	120.3	0.3	19279477.104	1927.948	5603806.142	120.83
64	120.6	0.3	20479723.701	2047.972	5963880.121	126.79
65	120.9	0.3	21679970.298	2167.997	6323954.100	133.12
66	121.2	0.3	23286584.213	2328.658	6744983.177	139.86
67	121.5	0.3	25096381.786	2509.638	7257444.900	147.12
68	121.8	0.3	26906179.359	2690.618	7800384.172	154.92
69	122.1	0.3	28795001.138	2879.500	8355177.075	163.28
70	122.4	0.3	30841871.326	3084.187	8945530.870	172.22
71	122.7	0.3	32888741.514	3288.874	9559591.926	181.78
72	123.0	0.3	34935611.702	3493.561	10173652.982	191.96
73	123.3	0.3	37269545.833	3726.955	10830773.630	202.79

Panchet Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2020						
SL.NO.	Contour EL (meter)	Contour Interval (meter)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between* two consecutive contour surface *(in Cum.)*	Cumulative Vol. *(in M-Cum.)*
74	123.6	0.3	39603479.963	3960.348	11530953.869	214.32
75	123.9	0.3	41937414.094	4193.741	12231134.108	226.55
76	124.2	0.3	44595969.194	4459.597	12980007.493	239.53
77	124.5	0.3	47416834.779	4741.683	13801920.596	253.33
78	124.8	0.3	50237700.364	5023.770	14648180.271	267.98
79	**125.0**	0.2	52118277.421	5211.828	10235597.779	278.21
80	125.1	0.1	52812644.627	5281.264	5246546.102	283.46
81	125.4	0.3	54895746.244	5489.575	16156258.631	299.62
82	125.7	0.3	56978847.861	5697.885	16781189.116	316.40
83	126.0	0.3	59061949.478	5906.195	17406119.601	333.80
84	126.3	0.3	60844483.878	6084.448	17985965.003	351.79
85	126.6	0.3	62627018.278	6262.702	18520725.323	370.31
86	126.9	0.3	64409552.678	6440.955	19055485.643	389.37
87	127.2	0.3	66369420.922	6636.942	19616846.040	408.98
88	127.5	0.3	68417956.088	6841.796	20218106.551	429.20
89	127.8	0.3	70466491.254	7046.649	20832667.101	450.03
90	128.1	0.3	72443240.094	7244.324	21436459.702	471.47
91	128.4	0.3	74276416.281	7427.642	22007948.456	493.48
92	128.7	0.3	76109592.468	7610.959	22557901.312	516.04
93	129.0	0.3	77942768.655	7794.277	23107854.168	539.14
94	129.3	0.3	79997777.782	7999.778	23691081.966	562.83
95	**129.54**	0.24	81641785.083	8164.179	19396747.544	582.23
96	129.6	0.06	82052786.909	8205.279	4910837.160	587.14
97	129.9	0.3	84107796.036	8410.780	24924087.442	612.07
98	130.2	0.3	86105450.092	8610.545	25531986.919	637.60

Panchet Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2020						
SL.NO.	Contour EL (meter)	Contour Interval (meter)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between* two consecutive contour surface *(in Cum.)*	Cumulative Vol. *(in M-Cum.)*
99	130.5	0.3	88652187.511	8865.219	26213645.640	663.81
100	130.8	0.3	91198924.929	9119.892	26977666.866	690.79
101	131.1	0.3	93810483.278	9381.048	27751411.231	718.54
102	131.4	0.3	96551683.489	9655.168	28554325.015	747.10
103	131.7	0.3	99292883.699	9929.288	29376685.078	776.47
104	132.0	0.3	102034083.909	10203.408	30199045.141	806.67
105	132.3	0.3	105577852.652	10557.785	31141790.484	837.81
106	**132.6**	0.3	109121621.394	10912.162	32204921.107	870.02
107	132.9	0.3	112665390.137	11266.539	33268051.730	903.29
108	133.2	0.3	119074627.227	11907.463	34761002.605	938.05
109	133.5	0.3	126916598.492	12691.660	36898683.858	974.95
110	133.8	0.3	134758569.757	13475.857	39251275.237	1014.20
111	134.1	0.3	140859315.670	14085.932	41342682.814	1055.54
112	134.4	0.3	143477610.878	14347.761	42650538.982	1098.19
113	134.7	0.3	146095906.087	14609.591	43436027.545	1141.63
114	135.0	0.3	148714201.295	14871.420	44221516.107	1185.85
115	135.3	0.3	150190894.830	15019.089	44835764.419	1230.68
116	**135.6**	0.3	151667588.364	15166.759	45278772.479	1275.96

Table 5-Capacity area Table of Panchet Reservoir 2020

22.1.1 Area Capacity Curve 2020 in Panchet Reservoir:-

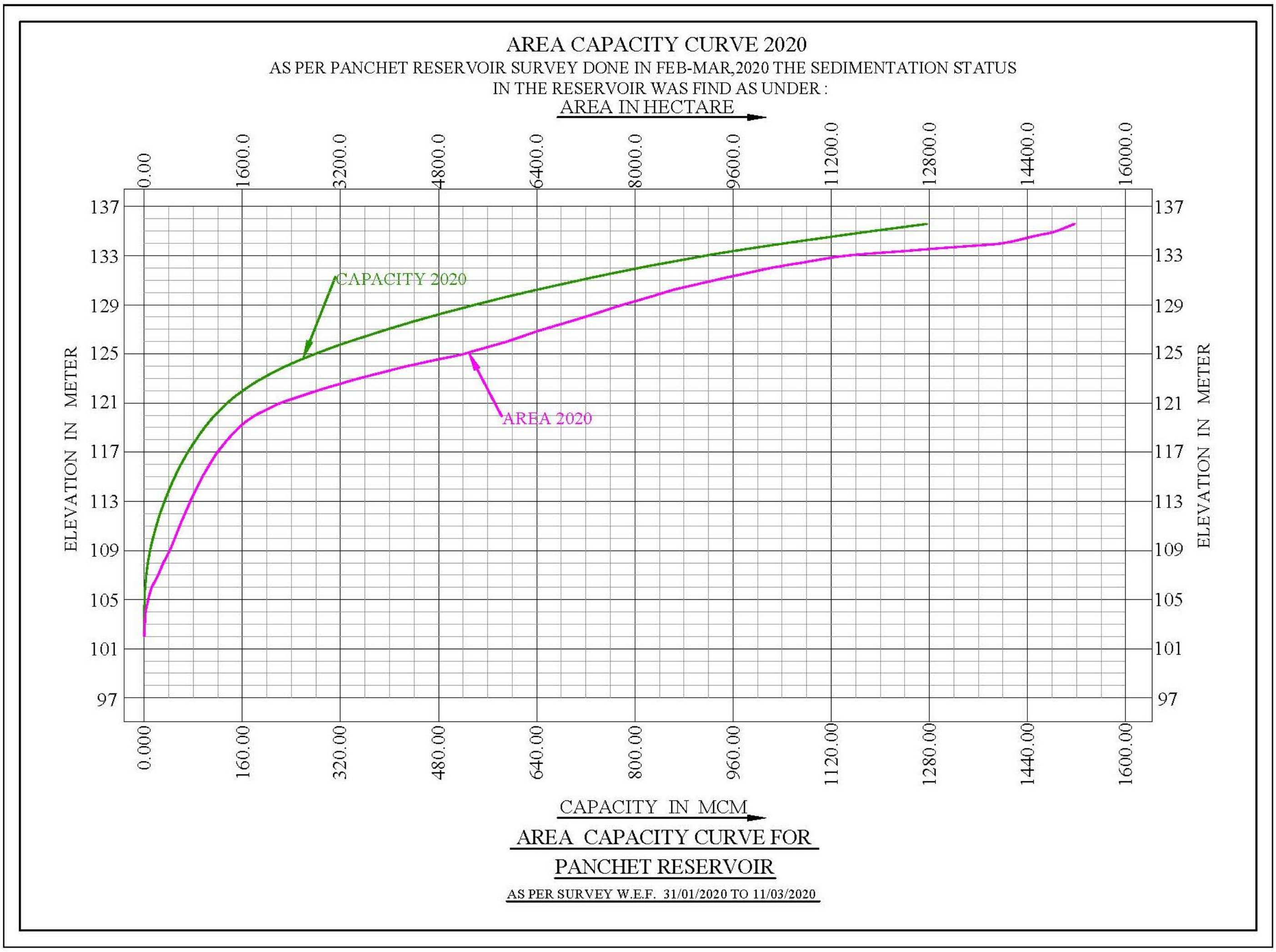


Table 6-Area Capacity Curve of Panchet Reservoir in 2020

22.1.2 Capacity Curve for Different Year (1956-2020) in Panchet Reservoir:-

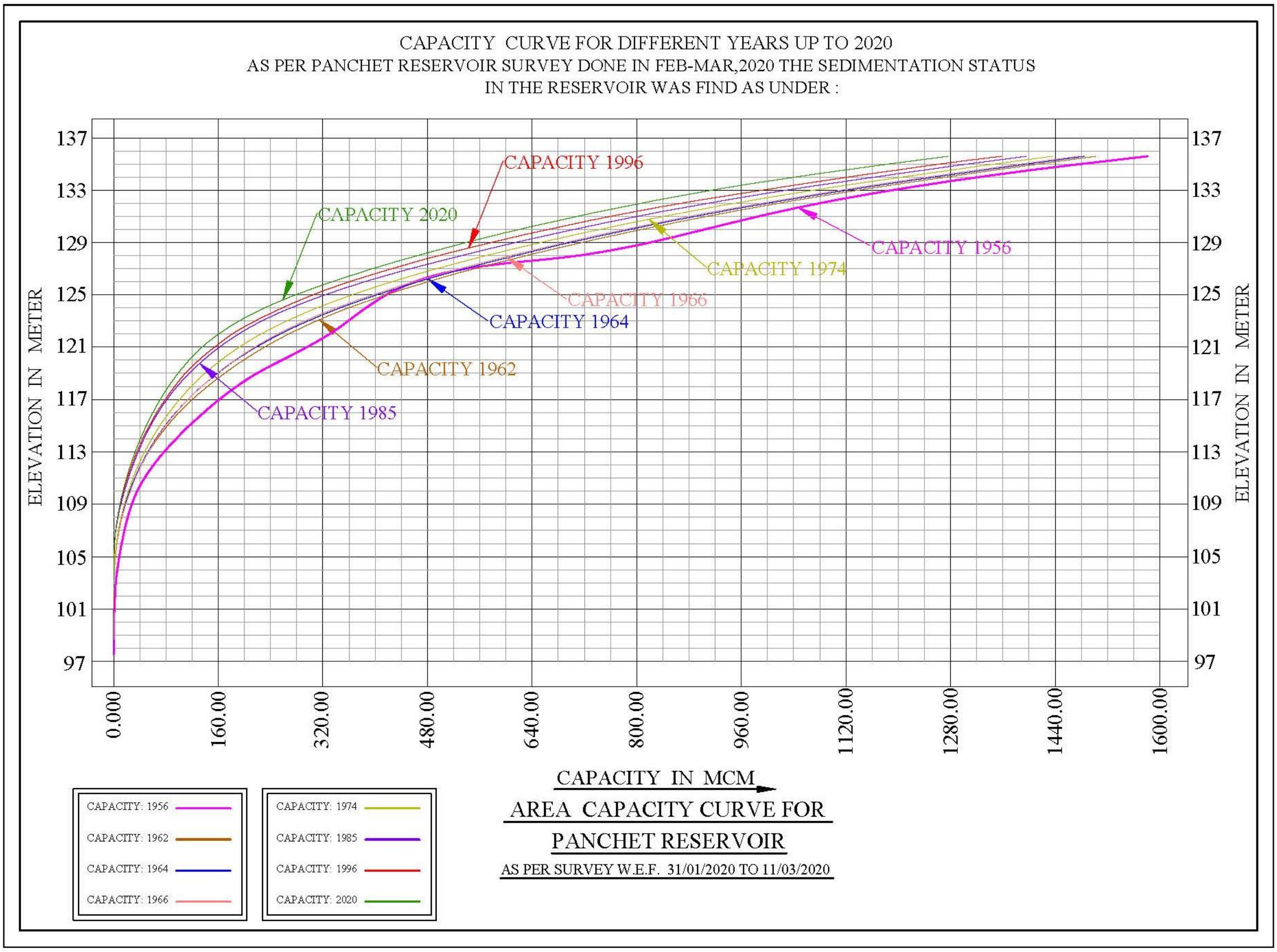


Table 7- Capacity Curve for Different year (1956-2020) in panchet Reservoir

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.**

22.2 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 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.

IS : 12182 - 1987

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.

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.

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 overcome 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.

22.2.1 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.

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:

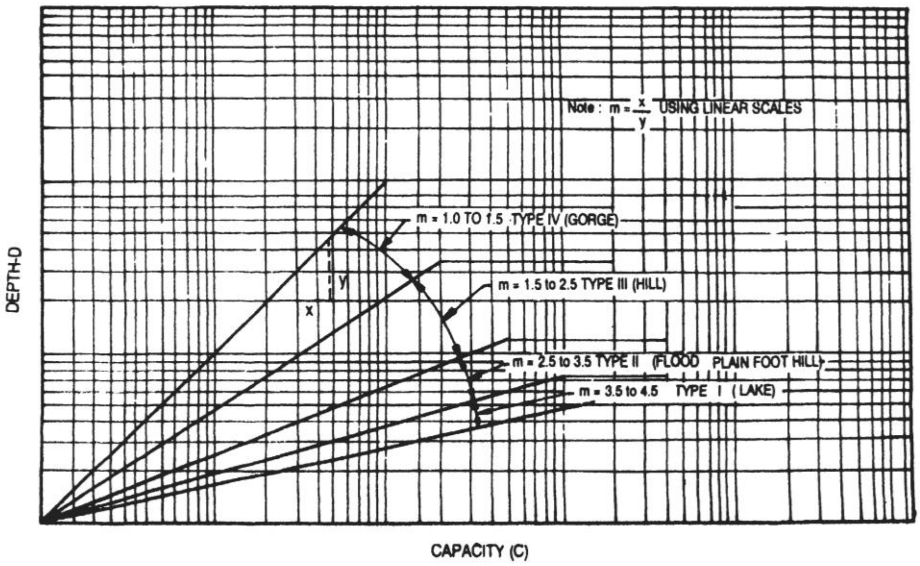
$$A_p = Cp^m (l - p)^n \qquad ......(1)$$

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.



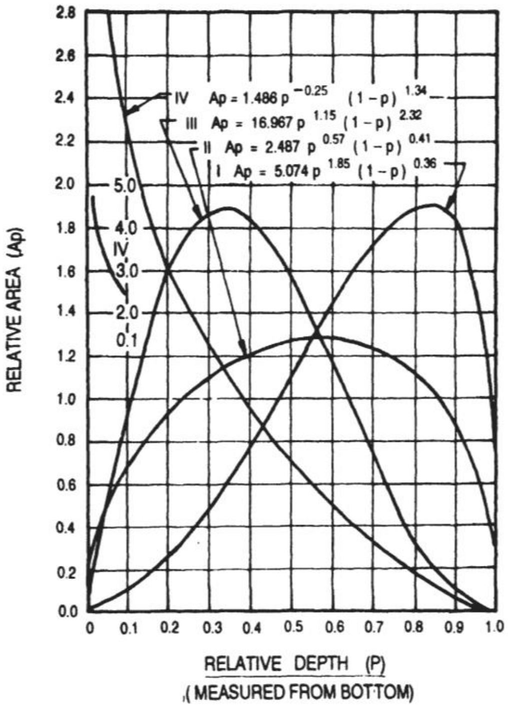


FIG. 2 SEDIMENT DISTRIBUTION – AREA DESIGN CURVES (BASED ON RESERVOIR STORAGE CURVES)

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.

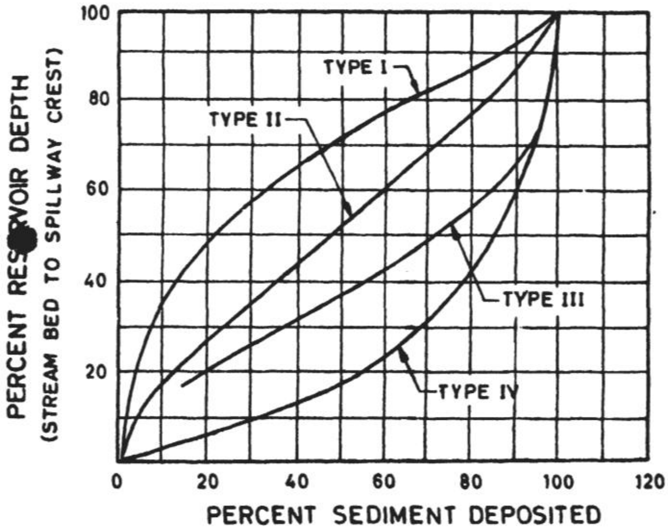
The basic equation in this method is:

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

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



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,

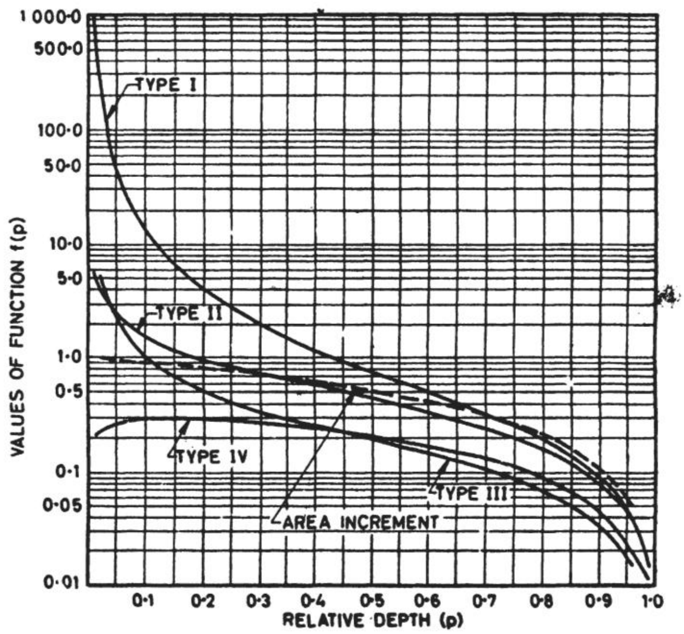
H = the total depth of reservoir for normal water surface in metres, and

$A(pH)$ = 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**

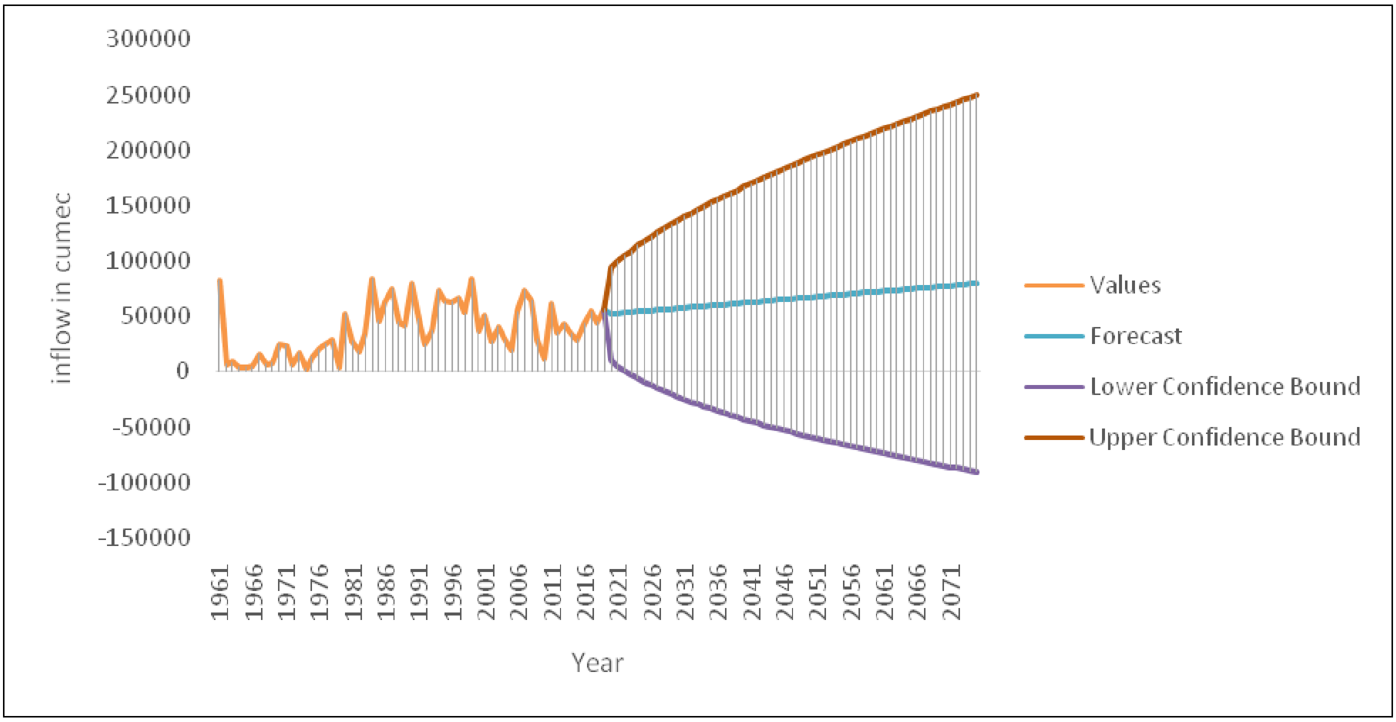
The Mathematical modeling study has been prepared by the above software and this study is completely prepared by Shri Arun Roy.

23.0 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	82530			
1962	6825			
1963	9028			
1964	5031			
1965	4140			
1966	5152			
1967	16634			
1968	6514			
1969	8755			
1970	24853			
1971	24244			
1972	6803			
1973	17450			
1974	3124			
1975	13091			
1976	20811			
1977	25567			
1978	28639			
1979	4100			
1980	52538			
1981	28459			
1982	18578			
1983	33890			
1984	83955			
1985	45956			
1986	62453			
1987	74619			
1988	45077			
1989	42879			
1990	80330			
1991	47443			
1992	25623			
1993	36776			
1994	73743			
1995	63857			
1996	62990			
1997	67639			
1998	53617			
1999	83317			

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
2000	37607			
2001	51667			
2002	28190			
2003	40693			
2004	29937			
2005	20231			
2006	54697			
2007	74037			
2008	65002			
2009	28937			
2010	11619			
2011	61674			
2012	36092			
2013	43396			
2014	34738			
2015	29295			
2016	43855			
2017	54876			
2018	45214			
2019	56778	56778.00	56778.00	56778.00
2020		52396.64	10270.17	94523.10
2021		52897.65	5779.98	100015.32
2022		53398.66	1752.84	105044.48
2023		53899.67	-1924.07	109723.42
2024		54400.69	-5324.33	114125.70
2025		54901.70	-8499.04	118302.45
2026		55402.71	-11485.45	122290.87
2027		55903.73	-14311.62	126119.07
2028		56404.74	-16999.38	129808.86
2029		56905.75	-19566.07	133377.58
2030		57406.77	-22025.75	136839.28
2031		57907.78	-24389.97	140205.53
2032		58408.79	-26668.41	143486.00
2033		58909.81	-28869.24	146688.85
2034		59410.82	-30999.43	149821.07
2035		59911.83	-33065.00	152888.67
2036		60412.85	-35071.18	155896.87
2037		60913.86	-37022.55	158850.27
2038		61414.87	-38923.15	161752.90
2039		61915.89	-40776.56	164608.33
2040		62416.90	-42585.96	167419.76
2041		62917.91	-44354.22	170190.04
2042		63418.92	-46083.91	172921.76
2043		63919.94	-47777.36	175617.23

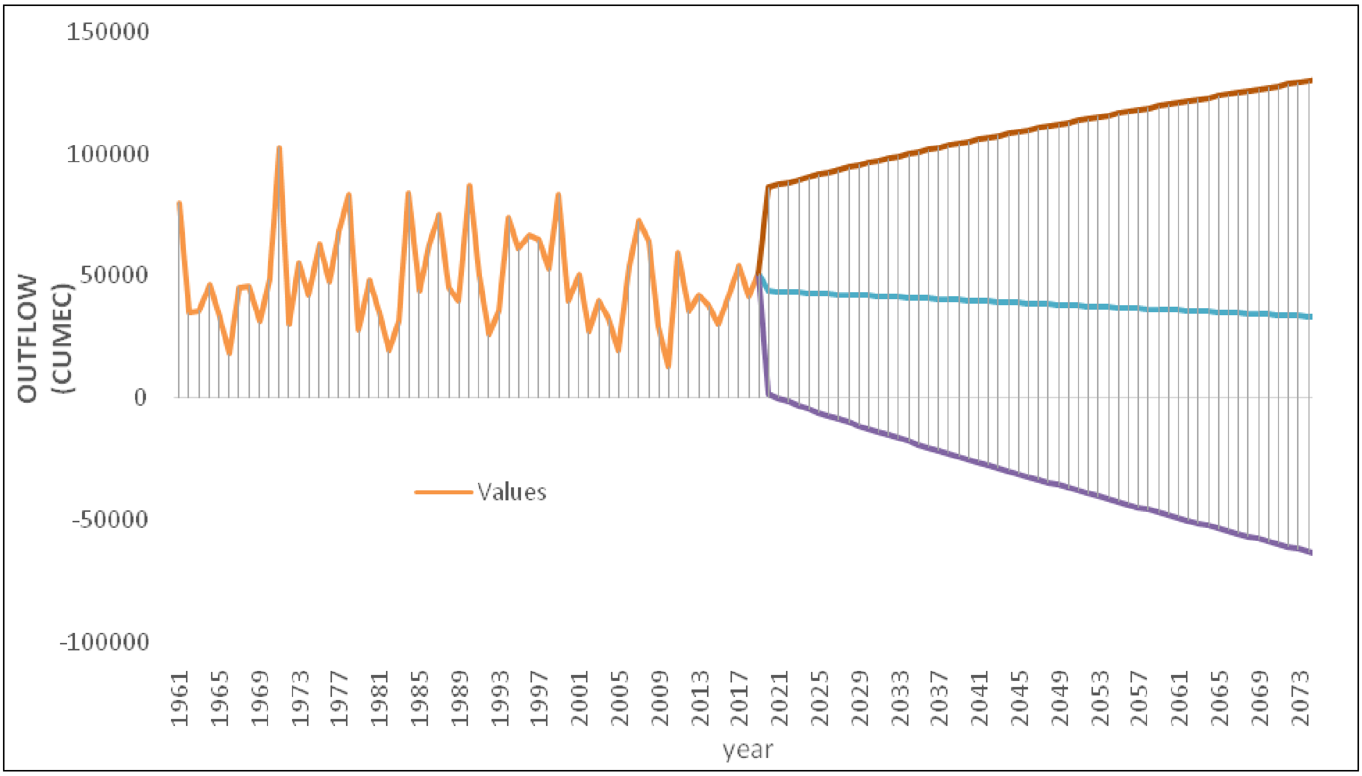
Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
2044		64420.95	-49436.67	178278.58
2045		64921.96	-51063.78	180907.71
2046		65422.98	-52660.44	183506.40
2047		65923.99	-54228.26	186076.24
2048		66425.00	-55768.71	188618.72
2049		66926.02	-57283.16	191135.19
2050		67427.03	-58772.87	193626.93
2051		67928.04	-60239.01	196095.10
2052		68429.06	-61682.67	198540.78
2053		68930.07	-63104.83	200964.97
2054		69431.08	-64506.46	203368.62
2055		69932.10	-65888.41	205752.60
2056		70433.11	-67251.52	208117.74
2057		70934.12	-68596.55	210464.79
2058		71435.14	-69924.22	212794.49
2059		71936.15	-71235.20	215107.50
2060		72437.16	-72530.15	217404.47
2061		72938.17	-73809.65	219686.00
2062		73439.19	-75074.28	221952.65
2063		73940.20	-76324.56	224204.97
2064		74441.21	-77561.02	226443.45
2065		74942.23	-78784.12	228668.58
2066		75443.24	-79994.33	230880.81
2067		75944.25	-81192.08	233080.59
2068		76445.27	-82377.77	235268.31
2069		76946.28	-83551.81	237444.37
2070		77447.29	-84714.55	239609.14
2071		77948.31	-85866.36	241762.98
2072		78449.32	-87007.58	243906.22
2073		78950.33	-88138.53	246039.19
2074		79451.35	-89259.51	248162.20
2075		79952.36	-90370.82	250275.54


300000
250000
200000
150000
100000
50000
0
-50000
-100000
-150000
inflow in cumec
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
2056
2061
2066
2071
Year
Values
Forecast
Lower Confidence Bound
Upper Confidence Bound

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
1961	79782			
1962	35069			
1963	35769			
1964	46155			
1965	33372			
1966	18259			
1967	45279			
1968	45814			
1969	31441			
1970	48658			
1971	102620			
1972	29877			
1973	55483			
1974	42163			
1975	62973			
1976	47476			
1977	68427			
1978	83172			
1979	27558			
1980	48365			
1981	35207			
1982	19253			
1983	31048			
1984	84267			
1985	44169			
1986	63312			
1987	75283			
1988	45081			
1989	39678			
1990	86775			
1991	49684			
1992	26013			
1993	35487			
1994	73913			
1995	61025			
1996	66613			
1997	64602			
1998	53102			

Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
1999	83619			
2000	39802			
2001	50271			
2002	26949			
2003	39929			
2004	32489			
2005	19247			
2006	54366			
2007	72390			
2008	64439			
2009	28778			
2010	12777			
2011	59560			
2012	35726			
2013	42048			
2014	38026			
2015	30046			
2016	40841			
2017	54073			
2018	41787			
2019	51004	51004.00	51004.00	51004.00
2020		43762.13	1455.11	86069.15
2021		43571.92	-47.43	87191.28
2022		43381.72	-1521.65	88285.09
2023		43191.51	-2969.96	89352.99
2024		43001.31	-4394.45	90397.06
2025		42811.10	-5796.97	91419.17
2026		42620.89	-7179.17	92420.96
2027		42430.69	-8542.51	93403.88
2028		42240.48	-9888.29	94369.25
2029		42050.28	-11217.69	95318.24
2030		41860.07	-12531.77	96251.91
2031		41669.86	-13831.49	97171.22
2032		41479.66	-15117.74	98077.05
2033		41289.45	-16391.31	98970.21
2034		41099.25	-17652.92	99851.42
2035		40909.04	-18903.27	100721.35
2036		40718.83	-20142.95	101580.62
2037		40528.63	-21372.55	102429.81
2038		40338.42	-22592.59	103269.44

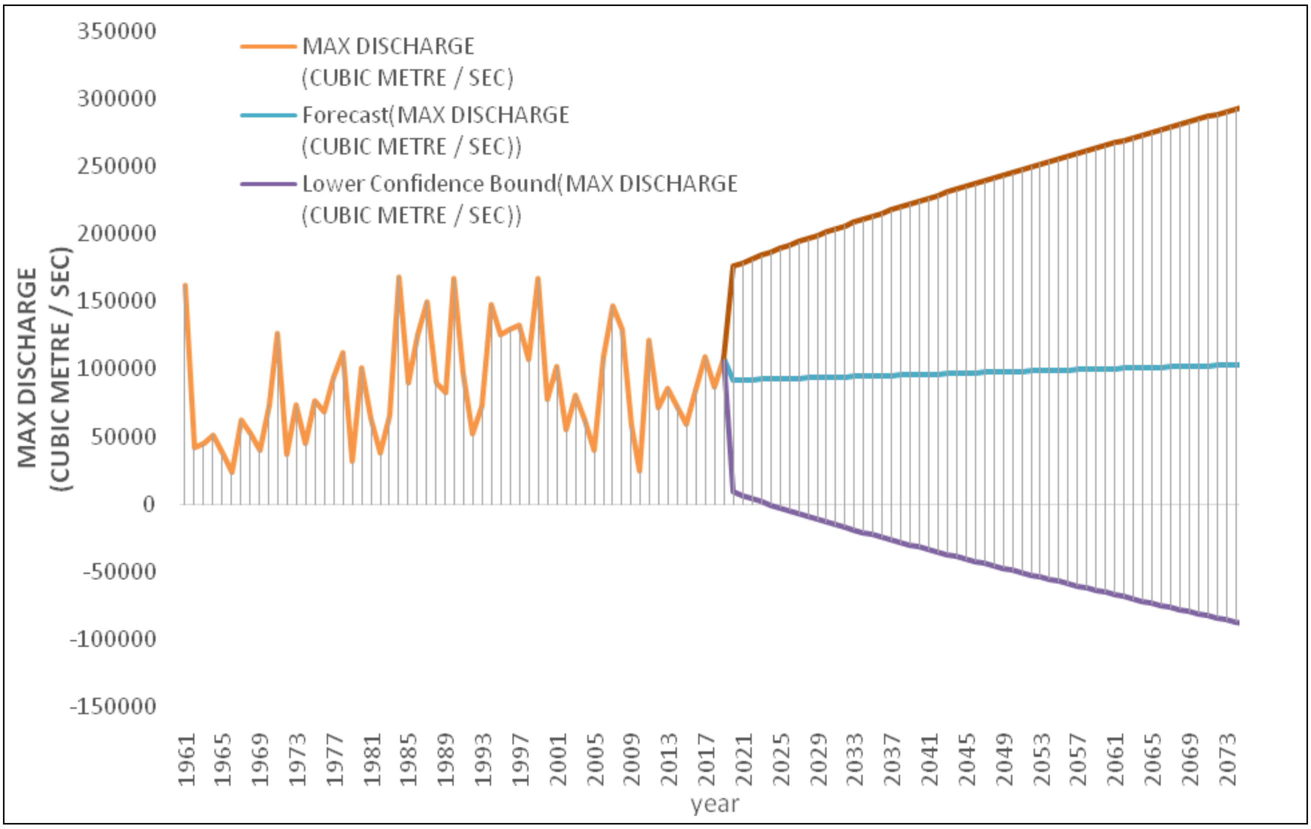
Timeline	Values (Cumec)	Forecast (Cumec)	Lower Confidence Bound (Cumec)	Upper Confidence Bound (Cumec)
2039		40148.22	-23803.57	104100.00
2040		39958.01	-25005.93	104921.95
2041		39767.80	-26200.10	105735.70
2042		39577.60	-27386.47	106541.67
2043		39387.39	-28565.42	107340.21
2044		39197.19	-29737.29	108131.66
2045		39006.98	-30902.41	108916.36
2046		38816.77	-32061.07	109694.61
2047		38626.57	-33213.56	110466.70
2048		38436.36	-34360.16	111232.88
2049		38246.16	-35501.12	111993.43
2050		38055.95	-36636.67	112748.57
2051		37865.74	-37767.04	113498.53
2052		37675.54	-38892.45	114243.52
2053		37485.33	-40013.10	114983.76
2054		37295.13	-41129.18	115719.43
2055		37104.92	-42240.87	116450.71
2056		36914.71	-43348.36	117177.78
2057		36724.51	-44451.79	117900.80
2058		36534.30	-45551.33	118619.93
2059		36344.09	-46647.13	119335.32
2060		36153.89	-47739.34	120047.11
2061		35963.68	-48828.08	120755.44
2062		35773.48	-49913.48	121460.44
2063		35583.27	-50995.68	122162.22
2064		35393.06	-52074.79	122860.92
2065		35202.86	-53150.92	123556.63
2066		35012.65	-54224.18	124249.48
2067		34822.45	-55294.68	124939.57
2068		34632.24	-56362.51	125626.99
2069		34442.03	-57427.78	126311.85
2070		34251.83	-58490.57	126994.22
2071		34061.62	-59550.97	127674.21
2072		33871.42	-60609.07	128351.90
2073		33681.21	-61664.94	129027.36
2074		33491.00	-62718.68	129700.69
2075		33300.80	-63770.34	130371.94


150000
100000
50000
0
-50000
-100000
OUTFLOW (CUMEC)
Values
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
year

YEAR	MAX DISCHARGE (CUBIC METRE / SEC)	Forecast(MAX DISCHARGE (CUBIC METRE / SEC))	Lower Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))	Upper Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))
1961	162312			
1962	41894			
1963	44797			
1964	51186			
1965	37512			
1966	23411			
1967	61913			
1968	52328			
1969	40196			
1970	73511			
1971	126864			
1972	36680			
1973	72933			
1974	45287			
1975	76064			
1976	68287			
1977	93994			
1978	111811			
1979	31658			
1980	100903			
1981	63666			
1982	37831			
1983	64938			
1984	168222			
1985	90125			
1986	125765			
1987	149902			
1988	90158			
1989	82557			
1990	167105			
1991	97127			
1992	51636			
1993	72263			
1994	147656			
1995	124882			
1996	129603			
1997	132241			
1998	106719			
1999	166936			

YEAR	MAX DISCHARGE (CUBIC METRE / SEC)	Forecast(MAX DISCHARGE (CUBIC METRE / SEC))	Lower Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))	Upper Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))
2000	77409			
2001	101938			
2002	55139			
2003	80622			
2004	62426			
2005	39478			
2006	109063			
2007	146427			
2008	129441			
2009	57715			
2010	24396			
2011	121234			
2012	71818			
2013	85444			
2014	72764			
2015	59341			
2016	84696			
2017	108949			
2018	87001			
2019	107782	107782.00	107782.00	107782.00
2020		92233.53	8743.50	175723.55
2021		92431.78	6351.94	178511.62
2022		92630.04	4016.27	181243.80
2023		92828.29	1731.76	183924.83
2024		93026.55	-505.76	186558.86
2025		93224.80	-2699.94	189149.54
2026		93423.06	-4854.00	191700.11
2027		93621.31	-6970.83	194213.46
2028		93819.57	-9053.02	196692.16
2029		94017.82	-11102.89	199138.53
2030		94216.08	-13122.52	201554.68
2031		94414.33	-15113.83	203942.49
2032		94612.59	-17078.54	206303.71
2033		94810.84	-19018.22	208639.90
2034		95009.10	-20934.32	210952.52
2035		95207.35	-22828.18	213242.88
2036		95405.61	-24701.00	215512.22
2037		95603.86	-26553.92	217761.64
2038		95802.12	-28387.97	219992.21
2039		96000.37	-30204.13	222204.88
2040		96198.63	-32003.29	224400.55
2041		96396.88	-33786.29	226580.06

YEAR	MAX DISCHARGE (CUBIC METRE / SEC)	Forecast(MAX DISCHARGE (CUBIC METRE / SEC))	Lower Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))	Upper Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))
2042		96595.14	-35553.91	228744.19
2043		96793.39	-37306.87	230893.66
2044		96991.65	-39045.87	233029.16
2045		97189.91	-40771.52	235151.33
2046		97388.16	-42484.45	237260.77
2047		97586.42	-44185.21	239358.04
2048		97784.67	-45874.33	241443.67
2049		97982.93	-47552.31	243518.16
2050		98181.18	-49219.63	245581.99
2051		98379.44	-50876.73	247635.60
2052		98577.69	-52524.04	249679.42
2053		98775.95	-54161.95	251713.84
2054		98974.20	-55790.84	253739.25
2055		99172.46	-57411.08	255756.00
2056		99370.71	-59023.01	257764.43
2057		99568.97	-60626.95	259764.88
2058		99767.22	-62223.21	261757.65
2059		99965.48	-63812.08	263743.04
2060		100163.73	-65393.86	265721.32
2061		100361.99	-66968.80	267692.77
2062		100560.24	-68537.16	269657.64
2063		100758.50	-70099.19	271616.18
2064		100956.75	-71655.12	273568.63
2065		101155.01	-73205.17	275515.19
2066		101353.26	-74749.57	277456.10
2067		101551.52	-76288.51	279391.55
2068		101749.77	-77822.20	281321.74
2069		101948.03	-79350.81	283246.87
2070		102146.28	-80874.54	285167.11
2071		102344.54	-82393.56	287082.64
2072		102542.80	-83908.03	288993.62
2073		102741.05	-85418.12	290900.22
2074		102939.31	-86923.98	292802.59
2075		103137.56	-88425.76	294700.88


350000
300000
250000
200000
150000
100000
50000
0
-50000
-100000
-150000
MAX DISCHARGE (CUBIC METRE / SEC)
MAX DISCHARGE (CUBIC METRE / SEC)
Forecast(MAX DISCHARGE (CUBIC METRE / SEC))
Lower Confidence Bound(MAX DISCHARGE (CUBIC METRE / SEC))
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
year

- **CAPACITY SURVEY OF PANCHET RESERVOIR IN DIFFERENT YEAR IN DIFFERENT ZONES:-**

Capacity in Panchet Hill Reservoir in Different Years In Different zones (Capacity In ACRE FEET (MCM), Elevation in ft./m)					
ZONE	**Dead storage**	**Live Storage**	**Actual Flood Zone**	**Design Flood Zone**	**Overall**
YEAR	**El. 392.0& below (119.5 m)**	**El.392.0-410.0 (119.5-125.0 m)**	**El. 410.0-435.0 (125.0-132.6 m)**	**El. 410.0-445.0 (125.0-135.6 m)**	
1956	191500 (236.20)	204500 (252.30)	565700 (697.78)	885700 (1092.50)	1281700 (1581.00)
1962	149700 (184.70)	184400 (227.40)	563400 (694.94)	883400 (1089.7)	1217500 (1501.80)
1964	140700 (173.50)	182400 (225.00)	560300 (691.12)	880000 (1085.80)	1203400 (1484.30)
1966	140000 (172.70)	178000 (219.60)	557900 (688.16)	877900 (1082.90)	1195900 (1475.20)
1974	124100 (153.10)	168200 (207.50)	551700 (680.51)	871700 (1075.20)	1164000 (1435.80)
1985	101400 (125.10)	157400 (194.10)	552600 (681.62)	872700 (1076.50)	1131400 (1395.60)
1996	96590 (118.99)	148970 (184.01)	535447 (660.46)	855440 (1055.09)	1101000 (1358.09)
2020	86389.59 (106.56)	139167.02(171.66)	479786.6 (591.81)	808889.07(997.75)	1034437.60(1275.96)

Table-I

- **Peak Flood and Annual monsoon flow at Panchet Reservoir:-**

YEAR	INFLOW (CUMEC)	OUTFLOW (CUMEC)	MAX DISCHARGE (CUBIC METRE / SEC)
1961	82530	79782	162312
1962	6825	35069	41894
1963	9028	35769	44797
1964	5031	46155	51186
1965	4140	33372	37512
1966	5152	18259	23411
1967	16634	45279	61913
1968	6514	45814	52328
1969	8755	31441	40196
1970	24853	48658	73511
1971	24244	102620	126864
1972	6803	29877	36680
1973	17450	55483	72933
1974	3124	42163	45287
1975	13091	62973	76064
1976	20811	47476	68287
1977	25567	68427	93994
1978	28639	83172	111811
1979	4100	27558	31658
1980	52538	48365	100903
1981	28459	35207	63666
1982	18578	19253	37831
1983	33890	31048	64938
1984	83955	84267	168222
1985	45956	44169	90125
1986	62453	63312	125765
1987	74619	75283	149902
1988	45077	45081	90158
1989	42879	39678	82557
1990	80330	86775	167105
1991	47443	49684	97127
1992	25623	26013	51636
1993	36776	35487	72263
1994	73743	73913	147656
1995	63857	61025	124882
1996	62990	66613	129603
1997	67639	64602	132241
1998	53617	53102	106719
1999	83317	83619	166936
2000	37607	39802	77409
2001	51667	50271	101938
2002	28190	26949	55139

YEAR	INFLOW (CUMEC)	OUTFLOW (CUMEC)	MAX DISCHARGE (CUBIC METRE / SEC)
2003	40693	39929	80622
2004	29937	32489	62426
2005	20231	19247	39478
2006	54697	54366	109063
2007	74037	72390	146427
2008	65002	64439	129441
2009	28937	28778	57715
2010	11619	12777	24396
2011	61674	59560	121234
2012	36092	35726	71818
2013	43396	42048	85444
2014	34738	38026	72764
2015	29295	30046	59341
2016	43855	40841	84696
2017	54876	54073	108949
2018	45214	41787	87001
2019	56778	51004	107782

Table 8-Peak Flow of Panchet Reservoir in different year

- **Gumbel Distribution Method Showing Prediction Stream flow of Panchet Reservoir (E.J.Gumbel-1935-54):**

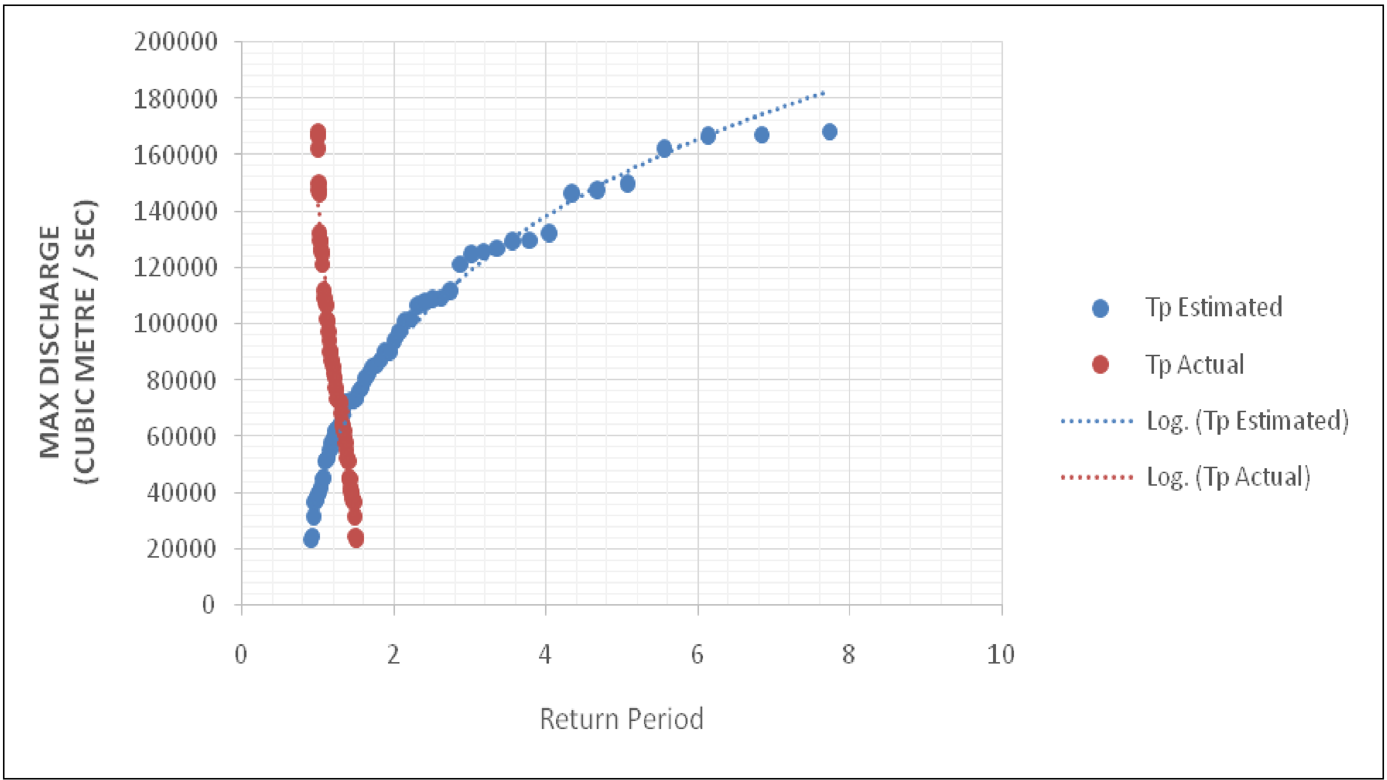


Table 9- Prediction of Stream flow by Gumbel distribution method

Table-II

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

YEARS	Reservoir Level (m)		Reservoir Level (Ft.)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
1961	116.98	131.57	383.79	431.66
1962	119.51	126.79	392.09	415.98
1963	119.6	129.79	392.39	425.82
1964	122.08	128	400.52	419.95
1965	117.25	127.57	384.68	418.54
1966	104.48	123.61	342.78	405.54
1967	111.14	127.78	364.63	419.23
1968	121.63	131.24	399.05	430.58
1969	119.83	127.80	393.14	419.29
1970	12.67	2260.83	41.57	7417.42
1971	119.82	433.14	393.11	1421.06
1972	109.73	128.44	360.01	421.39
1973	117.04	131.84	383.99	432.55
1974	110.4	129.04	362.20	423.36
1975	116.46	128.66	382.09	422.11
1976	112.04	130.39	367.59	427.79
1977	118.46	129.11	388.65	423.59
1978	119.47	214.19	391.96	702.72
1979	119.9	129.55	393.37	425.03
1980	120.32	127.23	394.75	417.42
1981	118.88	126.37	390.03	414.60
1982	115.56	128.22	379.13	420.67
1983	114.13	127.29	374.44	417.62
1984	119.59	131.46	392.36	431.30
1985	116.7	129.06	382.87	423.43
1986	119.49	128.74	392.03	422.38
1987	115.98	129.58	380.51	425.13
1988	119.49	127.47	392.03	418.21
1989	119.48	128.99	391.99	423.20
1990	119.98	129.29	393.64	424.18
1991	119.51	128.92	392.09	422.97
1992	119.62	126.79	392.45	415.98
1993	119.52	128.89	392.13	422.87
1994	119.05	127.92	390.58	419.69
1995	116.74	130.72	383.01	428.87
1996	120.08	129.97	393.96	426.41
1997	119.51	128.73	392.09	422.34
1998	119.49	130.24	392.03	427.30
1999	119.75	129.97	392.88	426.41
2000	119.52	130.15	392.13	427.00
2001	119.04	127.71	390.55	419.00
2002	119.5	128.75	392.06	422.41

YEARS	Reservoir Level (m)		Reservoir Level (Ft.)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
2003	119.22	129.42	391.14	424.61
2004	119.23	128.44	391.17	421.39
2005	119.97	127.01	393.60	416.70
2006	118.49	130.98	388.75	429.72
2007	121.08	130.77	397.24	429.04
2008	119.34	128.38	391.54	421.19
2009	119.9	131.33	393.37	430.87
2010	119.7	126.03	392.72	413.48
2011	120.79	128.53	396.29	421.69
2012	120.19	128.6	394.32	421.92
2013	123.15	130.71	404.04	428.84
2014	122.42	128.32	401.64	421.00
2015	119.82	128.75	393.11	422.41
2016	119.72	129.24	392.78	424.02
2017	120.75	131.24	396.16	430.58
2018	120.99	127.99	396.95	419.91
2019	120.63	129.19	395.77	423.85

Table 10-Range of Operation of Panchet Reservoir

- **Rate of Sedimentation of Panchet hill reservoir:-**

Rate of sediment deposition in the different survey period are completed taking the sediment producing area 3830 Sq. Miles (9920 Sq. km) up to year 1974 including Tenughat catchment and there after excluding Tenughat catchment area which is tabulated below.

Total drainage area of river Damodar upto

Panchet hill Reservoir = 4200 Sq. Miles

Drainage area of Konar Reservoir = 325 Sq. Miles

Drainage area of Tenughat Reservoir = 1730 Sq. Miles

Water spread area of Panchet Reservoir = 46 Sq. Miles

Hence,

Net Sediment contributory area of is taken for Panchet Hill Reservoir from the year 1985 -

{4200-(325+1730+46)} Sq. Mile = 2100 Sq. Mile

Table-III

Rate of Sediment Deposition in Panchet Hill Reservoir

Sediment Deposition Rate in Panchet Reservoir					
Between Years	No. of	Volume of Deposit		Sediment Deposition Rate	
	years	Acre feet	MM^3	Aft./Sq.mile/year	M3/Sq km/year
1956-62 ($)	6	64200	79	2.8	1330
1956-64($)	8	78300	97	2.6	1238
1956-66 ($)	10	85800	106	2.2	1050
1956-74 ($)	18	117700	145	2.1	1000
1974-85 (#)	11	32600	40	1.4	670
1974-96 (#)	22	63000	78	1.36	648
1974-2020 (#)	46	129562	160	1.34	638

Note:- **($) - For Panchet Hill catchment including Tenughat Catchment.**

(#) - For Panchet Hill catchment excluding Tenughat Catchment.

Table-III A

Average Annual volume of Deposit

Average Annual Volume Of Deposit In Panchet Hill Reservoir AF (MCM)							
	1962	**1964**	**1966**	**1974**	**1985**	**1996**	**2020**
1956	10707(13.207)	9770(12.051)	8578(10.581)	6539(8.066)	5182(6.392)	4517(5.570)	3863 (4.76)
1962	------	7040(9.30)	5385(6.642)	4456(5.496)	3141(4.614)	3426(4.220)	3156 (3.89)
1964	------	------	3730(4.601)	3939(4.859)	3427(4.277)	3197(3.940)	3017 (3.72)
1966	------	------	------	3991(4.923)	3395(4.187)	3164(3.90)	2989 (3.68)
1974	------	------	------	------	2961(3.652)	2863(3.531)	2816 (3.47)
1985	------	------	------	------	------	2762(3.400)	2770 (3.41)
1996	------	------	------	------	------	------	2773 (3.42)

Table-IV

CAPACITY OF PANCHET RESERVOIR FOR DIFFERENT YEAR:-

Capacity of Panchet Reservoir (Acre ft) was computed up to E.l. 445 ft. (135.6m). The Below table shows reservoir capacity at 10 feet (3m) depth interval in different year as here under:-

Elevation in Feet (meter)	CAPACITY IN ACRE FEET (MCM)							
	1956	1962	1964	1966	1974	1985	1996	2020
320 (97.5)	0	0	0	0	0	0	0	0
330 (100.5)	800 (0.986)	0	0	0	0	0	0	0
340 (103.6)	3800 (4.687)	600 (0.740)	600 (0.740)	800 (0.986)	600 (0.740)	700 (0.863)	60 (0.074)	121.6 (0.15)
350 (106.6)	12300 (15.171)	5600 (6.907)	5300 (6.537)	6000 (7.400)	4900 (6.044)	2100 (2.590)	1810 (2.232)	2075.4 (2.56)
360 (109.7)	27000 (33.304)	18400 (22.696)	18200 (22.449)	19000 (23.436)	16800 (20.722)	12100 (14.925)	11240 (13.864)	10060.9 (12.41)
370 (112.7)	59000 (72.775)	41100 (50.696)	40100 (49.462)	40800 (50.326)	36300 (44.775)	28900 (35.644)	27390 (33.785)	24386.2 (30.08)
380 (115.8)	107700 (132.845)	77700 (95.841)	74000 (91.277)	74400 (91.771)	66300 (81.77)	34400 (42.43)	51650 (53.709)	46972.72 (57.94)
390 (118.8)	173200 (213.639)	133900 (165.163)	125200 (154.43)	125000 (154.185)	110200 (135.929)	91100 (112.370)	87000 (107.312)	77058.28 (95.05)
400 (121.9)	264700 (326.502)	213000 (262.731)	202700 (250.026)	199700 (246.326)	179300 (221.163)	151900 (187.365)	144770 (178.571)	127857.57 (157.71)
410 (125.0)	396000 (488.46)	334100 (412.106)	323100 (398.537)	318000 (392.247)	292300 (360.546)	258800 (319.225)	245560 (302.893)	225548.51 (278.21)
420 (128.0)	573500 (707.401)	509800 (628.829)	496500 (612.423)	490600 (605.146)	460900 (568.511)	425800 (525.216)	403970 (498.289)	376430.34 (464.32)
430 (131.0)	801700 (988.882)	737500 (909.692)	723400 (892.300)	715900 (883.049)	684000 (843.701)	651400 (803.490)	621010 (766.00)	575030.75 (709.29)
435 (132.6)	961700 (1186.24)	897500 (1107.05)	883400 (1089.66)	875900 (1080.41)	844000 (1041.06)	811400 (1000.85)	781007 (963.36)	705335.1 (870.02)
445 (135.6)	1281700 (1580.953)	1217500 (1501.764)	1203400 (1484.372)	1195900 (1475.120)	1164000 (1437.00)	1131400 (1395.561)	1101000 (1358.063)	1034437.60 (1275.96)

Table 11- Capacity of Panchet reservoir at 10 feet (3 mtr)

Table-V

Capacity Table –Panchet Reservoir, 2020 (Pre-Monsoon):-

The Elevation with capacity table of Panchet Reservoir 2020 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 in the next page:-

Elevation in Ft.	Capacity in Acre Ft.	Capacity in M.C.M		Elevation in Ft.	Capacity in Acre Ft.	Capacity in M.C.M		Elevation in Ft.	Capacity in Acre Ft.	Capacity in M.C.M
335	0	0.00		376	37505.88	46.26		417	331567.78	408.98
336	7.99	0.01		377	39752.50	49.03		418	347958.86	429.20
337	22.27	0.03		378	42077.47	51.90		419	364848.18	450.03
338	42.86	0.05		379	44485.00	54.87		420	376430.34	464.32
339	70.67	0.09		380	46972.72	57.94		421	400069.14	493.48
340	121.6	0.15		381	49553.68	61.12		422	418357.12	516.04
341	152.61	0.19		382	52221.64	64.41		423	437090.97	539.14
342	210.88	0.26		383	54983.77	67.82		424	456297.64	562.83
343	292.91	0.36		384	57840.08	71.34		425	472021.54	582.23
344	550.34	0.68		385	60801.26	75.00		426	496210.40	612.07
345	730.63	0.90		386	63877.98	78.79		427	516909.52	637.60
346	951.81	1.17		387	67070.24	82.73		428	538161.27	663.81
347	1213.91	1.50		388	70385.74	86.82		429	560032.42	690.79
348	1529.61	1.89		389	73836.01	91.08		430	575030.75	709.29
349	1917.97	2.37		390	77058.28	95.05		431	605680.22	747.10
350	2075.4	2.56		391	81157.89	100.11		432	629496.29	776.47
351	2928.59	3.61		392	86387.60	106.56		433	653979.05	806.67
352	3538.20	4.36		393	89126.82	109.94		434	679226.11	837.81
353	4207.86	5.19		394	93415.83	115.23		435	705335.07	870.02
354	4937.59	6.09		395	97958.91	120.83		436	732305.91	903.29
355	5736.11	7.08		396	102793.90	126.79		437	760487.12	938.05
356	6612.18	8.16		397	107920.82	133.12		438	790401.37	974.95
357	7565.80	9.33		398	113389.06	139.86		439	822222.89	1014.20
358	8590.46	10.60		399	119272.77	147.12		440	855739.95	1055.54
359	9676.42	11.94		400	127857.57	157.71		441	890317.31	1098.19
360	10060.9	12.41		401	132370.30	163.28		442	925531.47	1141.63
361	12022.56	14.83		402	139622.56	172.22		443	961382.43	1185.85
362	13283.13	16.38		403	147372.64	181.78		444	997731.38	1230.68
363	14602.31	18.01		404	155620.56	191.96		445	1034437.60	1275.96
364	15980.09	19.71		405	164401.21	202.79		-	-	-
365	17418.59	21.49		406	173749.51	214.32		-	-	-
366	18919.90	23.34		407	194188.51	239.53		-	-	-
367	20484.02	25.27		408	205377.91	253.33		-	-	-
368	22111.23	27.27		409	217253.38	267.98		-	-	-
369	23801.96	29.36		410	225548.51	278.21		-	-	-
370	24386.2	30.08		411	242903.05	299.62		-	-	-
371	27375.26	33.77		412	256507.78	316.40		-	-	-
372	29261.21	36.09		413	270619.15	333.80		-	-	-
373	31215.88	38.50		414	285200.61	351.79		-	-	-
374	33239.27	41.00		415	300215.61	370.31		-	-	-
375	35334.80	43.58		416	315664.14	389.37		-	-	-

Table 12-Capacity of Panchet dam at 01 feet depth interval

Table-VI

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

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

Capacity in Panchet Hill Reservoir in Different Years In Different zones (Capacity In ACRE FEET (MCM), Elevation in ft./m)					
ZONE	**Dead storage**	**Live Storage**	**Actual Flood Zone**	**Design Flood Zone**	**Overall**
YEAR	**El. 392.0& below (119.5 m)**	**El.392.0-410.0 (119.5-125.0 m)**	**El. 410.0-435.0 (125.0-132.6 m)**	**El. 410.0-445.0 (125.0-135.6 m)**	
1956	191500 (236.20)	204500 (252.30)	565700 (697.78)	885700 (1092.50)	1281700 (1581.00)
1962	149700 (184.70)	184400 (227.40)	563400 (694.94)	883400 (1089.7)	1217500 (1501.80)
1964	140700 (173.50)	182400 (225.00)	560300 (691.12)	880000 (1085.80)	1203400 (1484.30)
1966	140000 (172.70)	178000 (219.60)	557900 (688.16)	877900 (1082.90)	1195900 (1475.20)
1974	124100 (153.10)	168200 (207.50)	551700 (680.51)	871700 (1075.20)	1164000 (1435.80)
1985	101400 (125.10)	157400 (194.10)	552600 (681.62)	872700 (1076.50)	1131400 (1395.60)
1996	96590 (118.99)	148970 (184.01)	535447 (660.46)	855440 (1055.09)	1101000 (1358.09)
2020	86389.59 (106.56)	139167.02(171.66)	479786.6 (591.81)	808889.07(997.75)	1034437.60(1275.96)

Table-VII

- **Loss of Storage Capacity in Panchet hill 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
1956-62	6	64,200	79	10700	13.19
1956-64	8	78,300	97	9788	12.07
1956-66	10	85,800	106	8580	10.58
1956-74	18	117700	145	6539	8.06
1956-85	29	150300	185	5183	6.43
1956-96	40	180700	223	4518	5.57
1956-2020	64	247262.4	305	3863	4.76

Table-VII A

- **Progressive Loss in Capacity in Panchet Hill Reservoir in Different Years in Different Zones :-**

(Capacity in ACRE FEET (MCM), Elevation in ft./meter					
ZONE	Dead storage	Live Storage	Actual Flood Zone	Design Flood Zone	Overall
YEAR	El. 392.0& below (119.5 m)	El.392.0-410.0 (119.5-125.0 m)	El. 410.0-435.0 (125.0-132.6 m)	El. 410.0-445.0 (125.0-135.6 m)	
1956	-	-	-	-	-
1962	41800 (51.5)	20100 (24.9)	2300 (2.8)	2300 (2.8)	64200 (79.2)
1964	50800 (62.7)	22100 (27.3)	5400 (6.7)	5700 (6.7)	78600 (96.95)
1966	51500 (63.5)	26500 (32.7)	7800 (9.6)	7800 (9.6)	85800 (105.8)
1974	67400 (83.1)	36300 (44.8)	14000 (17.3)	14000 (17.3)	117700 (145.2)
1985	90100 (111.1)	47100 (58.2)	13100 (16.0)	13000 (16.0)	150300 (185.3)
1996	94910 (117.21)	55530 (68.29)	30253 (37.32)	30260 (37.41)	180700 (222.91)
2020	105110 (129.65)	65333 (80.58)	85913.4 (105.97)	76811 (94.74)	247263 (304.99)

Table-VIII

- **Progressive Loss Percent in Capacity in Panchet Hill Reservoir in Different Years in Different Zones :-**

Elevation in Feet					
ZONE	Dead storage	Live Storage	Actual Flood Zone	Design Flood Zone	Overall
YEAR	El. 392.0& below	El.392.0-410.0	El. 410.0-435.0	El. 410.0-445.0	
1956	-	-	-	-	-
1962	21.8	9.8	0.4	0.3	5.0
1964	26.5	10.8	1.00	0.6	6.1
1966	27	13	1.38	0.9	6.7
1974	35.2	17.8	2.5	1.6	9.2
1985	47	23	2.3	1.5	11.8
1996	49.6	27.1	5.3	3.4	14.1
2020	54.9	31.9	15.2	8.6	19.3

Table-VIII A

- **Progressive Annual Loss Percent in Capacity in Panchet Hill Reservoir in Different Years in Different Zones :-**

	Elevation in Feet				
ZONE	Dead storage	Live Storage	Actual Flood Zone	Design Flood Zone	Overall
YEAR	El. 392.0& below	El.392.0-410.0	El. 410.0-435.0	El. 410.0-445.0	
1956	-	-	-	-	-
1962	3.7	1.7	Negligible	Negligible	0.8
1964	3.4	1.4	0.1	Negligible	0.8
1966	2.7	1.3	0.1	Negligible	0.7
1974	2	1	0.1	Negligible	0.5
1985	1.6	1	Negligible	Negligible	0.4
1996	1.23	0.67	0.1	Negligible	0.35
2020	0.85	0.49	0.2	0.13	0.30

Table-VIII B

- **Loss of Sedimentation in different zone i.e. Flood, Dead and Live zone between the year 1996 and 2020:-**

EL IN M.	CAP IN MCM		CAP-LOSS 1996-2020
	1996	2020	
135.6	1358.09	1275.96	82.13
131.1	770.11	718.54	51.57
128.0	496.91	464.32	32.59
125.0	304.49	278.21	26.28
121.9	177.95	157.71	20.24
119.5	119.40	106.56	12.84
118.9	107.94	97.04	10.90
115.8	63.47	57.94	5.53
112.8	34.01	31.52	2.49
109.7	13.69	12.41	1.28
109.2	11.15	10.60	0.55
105.0	0.78	0.68	0.10
102.6	0.04	0.03	0.01
102.0	0.03	0.00	0.03
101.0	0.00	0.00	0.00

LOSS OF CAP IN FLOOD ZONE			
EL	135.6	125.0	CAPACITY
YEAR	CAP IN MCM		
1996	1358.09	304.49	1053.60
2020	1275.96	278.21	997.75
LOSS OF CAP IN FLOOD ZONE			**55.85**

LOSS OF CAP IN LIVE ZONE			
EL	125.0	119.5	CAPACITY
YEAR	CAP IN MCM		
1996	304.49	119.40	185.09
2020	278.21	106.56	171.66
LOSS OF CAP IN LIVE ZONE			**13.43**

LOSS OF CAP IN DEAD ZONE			
EL	119.5	101	CAPACITY
YEAR	CAP IN MCM		
1996	119.40	0.00	119.40
2020	106.56	0.00	106.56
LOSS OF CAP IN DEAD ZONE			**12.84**

Total Loss of Capacity- 82.13 MCM (66583.87 Acre Feet)

- **<u>Graph of Loss of Capacity in the Year between 1996 and 2020:-</u>**

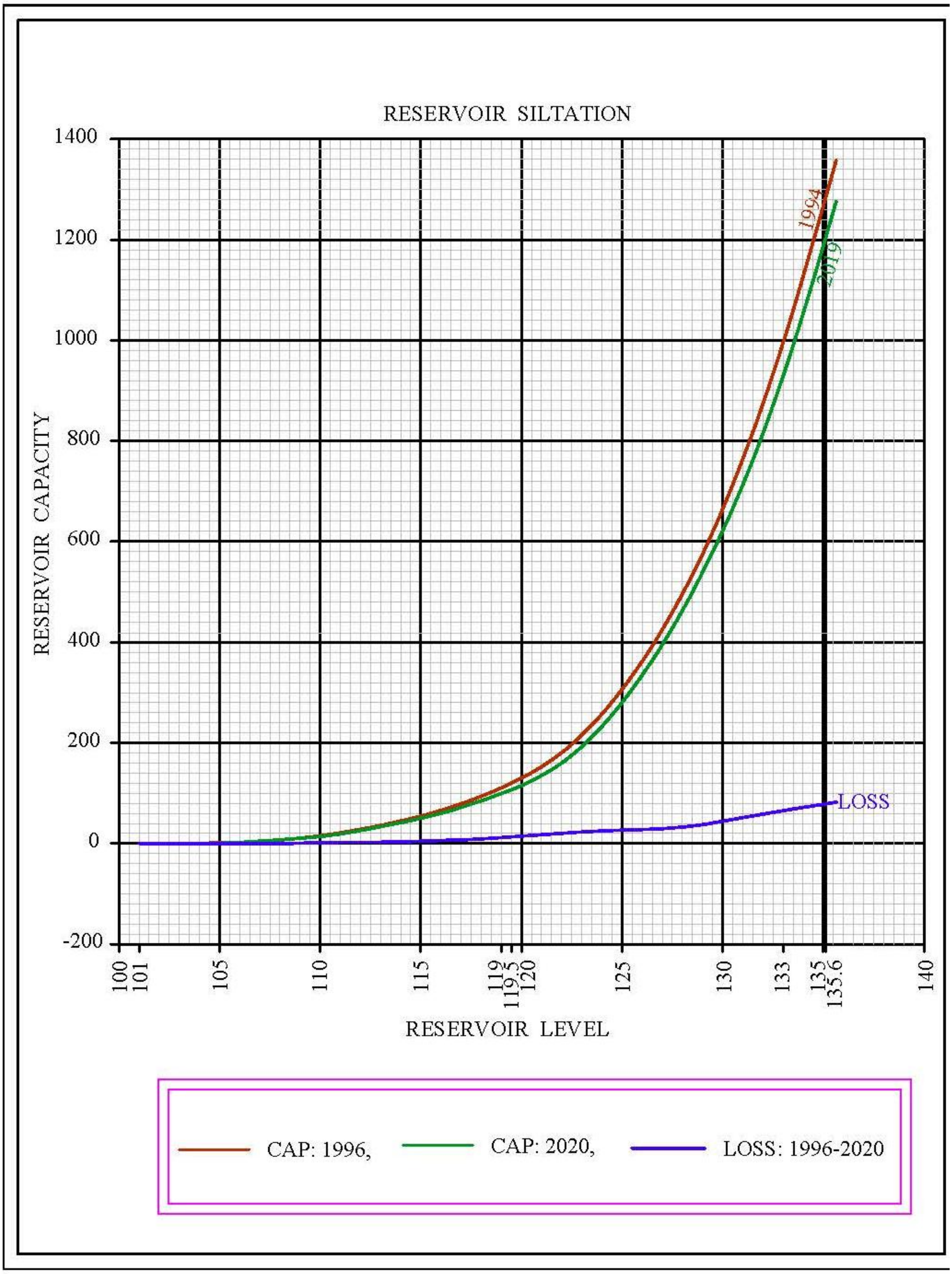


Table-IX

- **Distribution of Sediment Deposit in Different Reaches of Panchet Reservoir:-**

Reach Wise Location Of Deposit In Panchet Hill Reservoir (Damodar River) (Percentage of Total Deposit)										
Distance from U/S ,Mile	**0-2**	**2-4**	**4-6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-19**	**Total Vol. of Deposit Acre Ft. (MCM)**
1962	12	9	2	7	31	26	3	10	0	64,200 (79)
1964	8	8	3	10	30	20	4	8	0	78,300 (97)
1966	7	7	3	10	39	22	4	8	0	85,800 (106)
1974	8	6	4	14	37	20	4	7	0	117700 (145)
1985	18	6	6	16	30	17	3	4	0	150300 (185)
1996	12	9	9	15	29	18	3	4	1	180700 (223)
2020	11	10.8	17.6	20.1	17.3	11.2	6.9	3.7	1.4	247254.3 (305)

Reach Wise Location Of Deposit In Panchet Hill Reservoir (Utla River) (Percentage of Total Deposit based on aerial survey maps 1956 with 10 ft. contour interval				
Distance from U/S ,Mile	**0-2**	**2-4**	**4-6**	**Total Vol. of Deposit Acre Ft. (MCM)**
2020	54.4	31.8	13.8	72370.3 (89.3)

- **Reach wise Sediment Distribution in Panchet Reservoir:-**

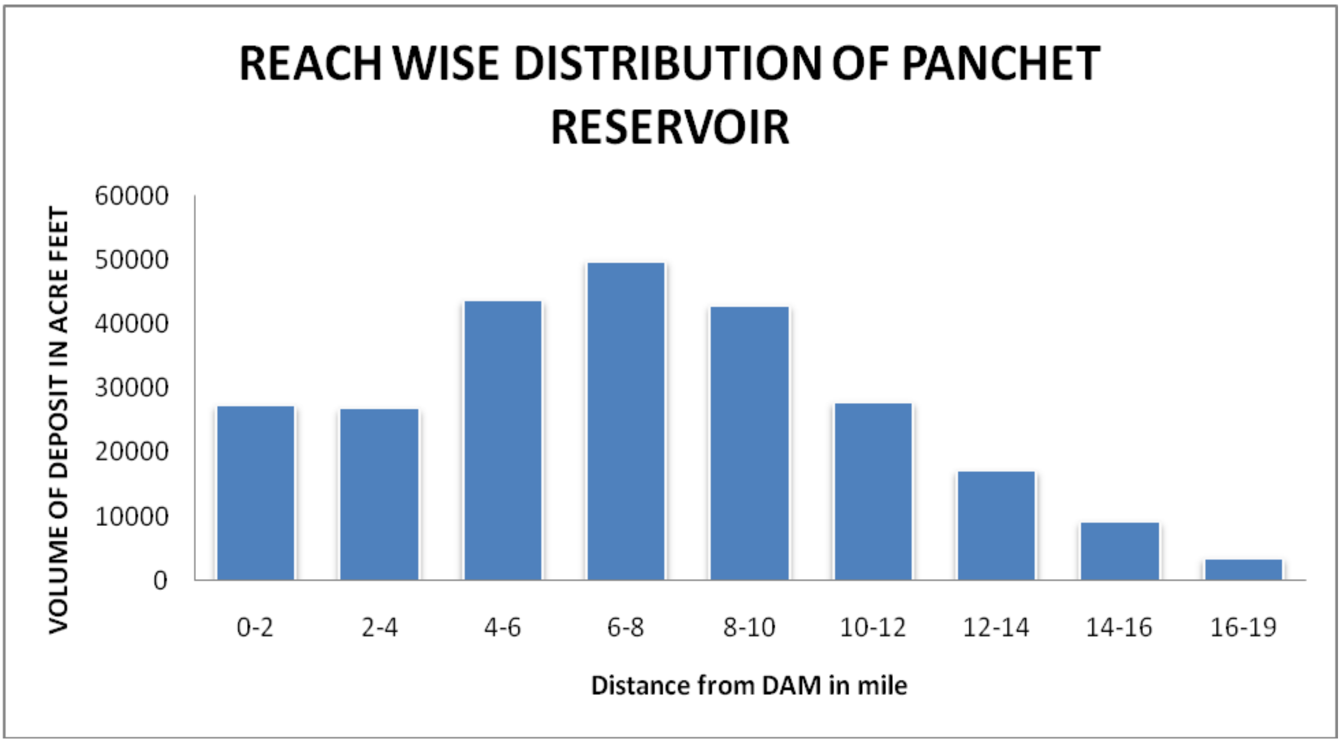


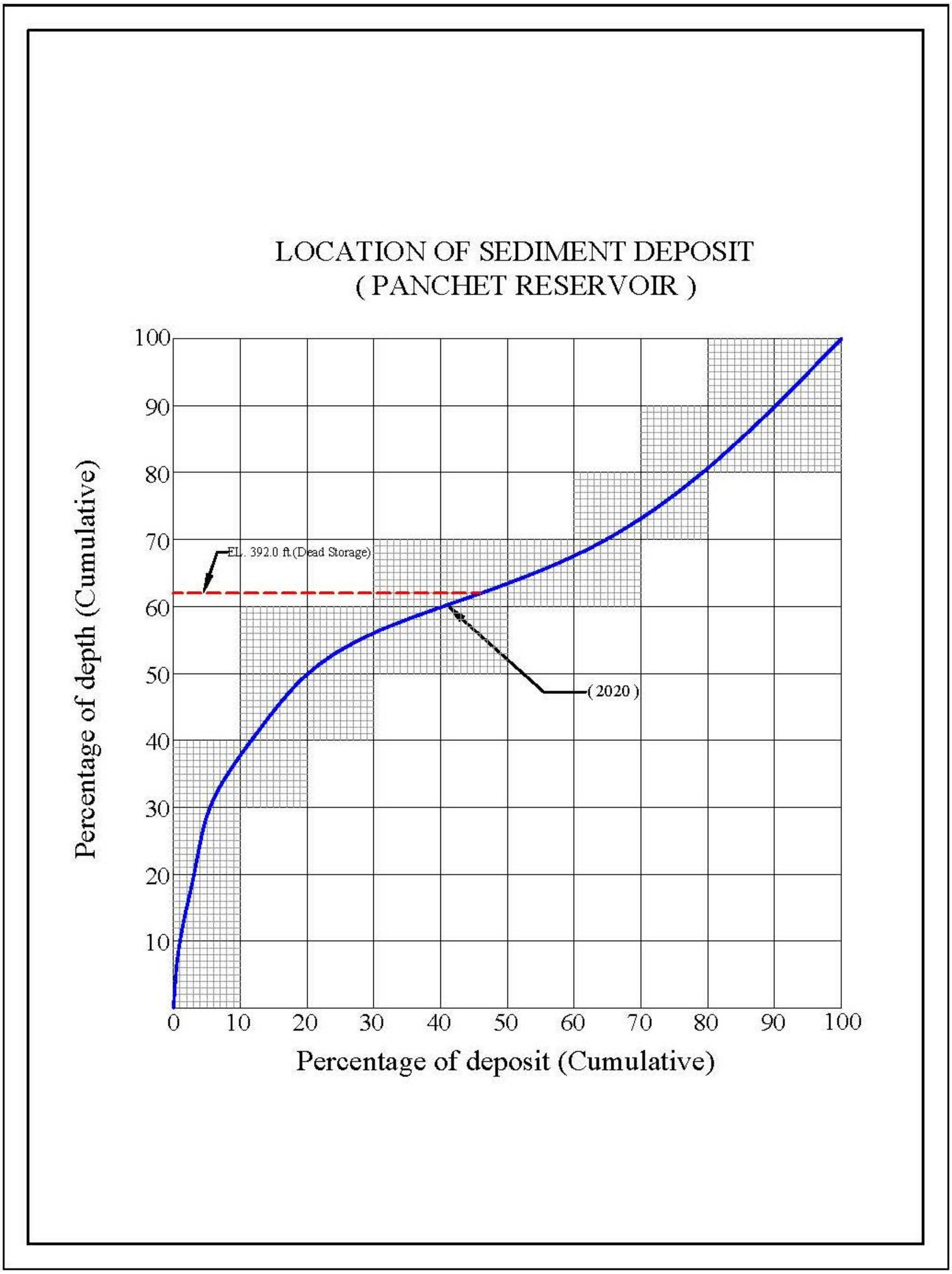
Table-X

- **Depth Wise location of Deposit in Percentage of Panchet Reservoir:-**

Depth Wise Location of Deposit in Panchet Hill Reservoir (Percentage of total deposit)									
Bet El. Ft./m	**320-330 (97.5-100.5)**	**330-340 (100.5-103.6)**	**340-350 (103.6-106.6)**	**350-360 (106.6-109.7)**	**360-370 (109.7-112.7)**	**370-380 (112.7-115.8)**	**380-390 (115.8-118.8)**	**390-400 (118.8-121.9)**	**400-430 (121.9-131)**
Depth Ft./m	**0-10 (0-3.0)**	**10-20 (3.0-6.0)**	**20-30 (6.0-9.1)**	**30-40 (9.1-12.1)**	**40-50 (12.1-15.2)**	**50-60 (15.2-18.2)**	**60-70 (18.2-21.3)**	**70-80 (21.3-24.3)**	**80-110 (24.3-33.5)**
1962	1	4	5	3	14	19	14	19	19
1964	1	3	5	2	13	19	19	18	20
1966	1	2	4	2	12	17	17	20	24
1974	1	2	4	2	10	17	18	19	28
1985	1	2	4	3	10	15	19	20	25
1996	-	2	3	3	9	13	17	19	34
2020	-	1.0	2.1	2.4	6.2	8.5	20.2	24.4	35.2

Table 13-Depth wise location of Deposit in Percentage of Panchet Reservoir

- **<u>Location of Sediment Deposit in Panchet Reservoir:-</u>**



ANALYSIS OF BED MATERIAL SAMPLES

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

24.0 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.

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

SITE: PANCHYET DAM (MAITHON)

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	2613129.00	470916.00	23°37'42.687"	86°42'53.518"	Light grey, silty clay with sand	0.00	4.56	42.90	52.54	61.20	2.589	Non-uniform
2	2	2613643.00	472168.00	23°37'59.481"	86°43'37.671"	Brownish grey, clayey silt with sand	0.00	15.39	44.87	39.74	57.50	2.604	Non-uniform
3	3	2614672.00	472674.00	23°38'32.972"	86°43'55.462"	Brownish grey, clayey silt with sand	0.00	9.40	49.26	41.34	59.80	2.597	Non-uniform
4	4	2615938.00	474042.00	23°39'14.221"	86°44'43.668"	Deep grey, silty clay with sand	0.00	0.12	45.74	54.14	62.80	2.587	Non-uniform
5	5	2617687.00	473971.00	23°40'11.089"	86°44'41.052"	Deep grey, silty clay with sand	0.00	1.60	47.10	51.30	58.90	2.595	Non-uniform
6	6	2619370.00	474076.00	23°41'05.822"	86°44'44.653"	Brownish grey, clayey silt with sand	0.00	12.70	44.36	42.94	52.60	2.602	Non-uniform
7	7	2620835.00	473856.00	23°41'53.447"	86°44'36.792"	Brownish grey, clayey silt with sand	0.00	15.04	45.22	39.74	55.70	2.600	Non-uniform
8	8	2621194.00	471924.00	23°42'05.003"	86°43'28.544"	Brownish grey, clayey silt with sand	0.00	10.76	44.70	44.54	63.70	2.589	Non-uniform
9	9	2619789.00	471005.00	23°41'19.258"	86°42'56.191"	Brownish grey, clayey silt with sand	0.00	14.05	47.12	38.83	58.80	2.602	Non-uniform
10	10	2620334.00	468715.00	23°41'36.826"	86°41'35.291"	Brownish grey, clayey silt with sand	0.00	9.70	45.76	44.54	61.20	2.596	Non-uniform
11	11	2618969.00	468001.00	23°40'52.389"	86°41'10.185"	Light grey, silty clay with sand	0.00	5.50	48.36	46.14	60.70	2.592	Non-uniform
12	12	2619895.00	465820.00	23°41'22.339"	86°39'53.103"	Brownish grey, clayey silt with sand	0.00	11.90	51.56	36.54	59.40	2.612	Uniform
13	13	2618709.00	464741.00	23°40'43.69"	86°39'15.105"	Brownish grey, clayey silt with sand	0.00	9.70	50.56	39.74	65.20	2.607	Non-uniform
14	14	2618804.00	463144.00	23°40'46.65"	86°38'18.712"	Deep grey, silty fine sand with clay binder	0.00	60.05	30.61	9.34	42.50	2.632	Non-uniform
15	15	2617887.00	462185.00	23°40'16.752"	86°37'44.937"	Brownish grey, clayey silt with sand	0.00	16.70	48.36	34.94	56.90	2.601	Non-uniform

24.2 Bulk Density of the samples:-

Sample - 1

			Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	4.56						
Silt (%)	42.90						
Clay (%)	52.54		Cont. Submerged	256	91	0	1.74
			Periodic drwadown	135	29	0	0.83
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	751.49	751.78	751.97	752.13	752.25	752.35	752.01	752.31	752.53	752.70	752.84
Periodic drwadown	836.25	836.39	836.48	836.56	836.6	836.67	836.50	836.65	836.75	836.83	836.90
Resvr. normally empty	882.57	882.57	882.57	882.57	882.6	882.57	882.57	882.57	882.57	882.57	882.57

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

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	15.39					
Silt (%)	44.87					
Clay (%)	39.74	Cont. Submerged	256	91	0	1.43
		Periodic drwadown	135	29	0	0.67
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	844.85	845.09	845.25	845.37	845.47	845.56	845.28	845.53	845.71	845.84	845.96
Periodic drwadown	911.44	911.56	911.63	911.69	911.7	911.78	911.65	911.76	911.85	911.91	911.96
Resvr. normally empty	947.72	947.72	947.72	947.72	947.7	947.72	947.72	947.72	947.72	947.72	947.72

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

Sand (%)	9.40	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	49.26					
Clay (%)	41.34	Cont. Submerged	256	91	0	1.51
		Periodic drwadown	135	29	0	0.70
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	831.79	832.04	832.21	832.34	832.45	832.54	832.24	832.51	832.69	832.84	832.96
Periodic drwadown	901.58	901.70	901.78	901.84	901.9	901.93	901.79	901.92	902.00	902.07	902.13
Resvr. normally empty	939.58	939.58	939.58	939.58	939.6	939.58	939.58	939.58	939.58	939.58	939.58

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

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	0.12					
Silt (%)	45.74					
Clay (%)	54.14	Cont. Submerged	256	91	0	1.80
		Periodic drwadown	135	29	0	0.86
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	738.89	739.19	739.40	739.55	739.68	739.79	739.43	739.75	739.98	740.15	740.29
Periodic drwadown	826.54	826.69	826.78	826.86	826.9	826.97	826.80	826.95	827.06	827.14	827.21
Resvr. normally empty	874.43	874.43	874.43	874.43	874.4	874.43	874.43	874.43	874.43	874.43	874.43

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 (%)	1.60	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	47.10					
Clay (%)	51.30	Cont. Submerged	256	91	0	1.74
		Periodic drwadown	135	29	0	0.83
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

Reservoir condition :	Miller's Method W1	W2	W3	W4	W5	W6	Lane's Method W2	W3	W4	W5	W6
Cont. Submerged	759.33	759.62	759.82	759.97	760.09	760.20	759.85	760.16	760.38	760.55	760.68
Periodic drwadown	843.13	843.27	843.37	843.44	843.5	843.55	843.38	843.53	843.63	843.71	843.78
Resvr. normally empty	888.88	888.88	888.88	888.88	888.9	888.88	888.88	888.88	888.88	888.88	888.88

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 - 6

Sand (%)	12.70	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	44.36					
Clay (%)	42.94	Cont. Submerged	256	91	0	1.50
		Periodic drwadown	135	29	0	0.71
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	821.51	821.76	821.94	822.07	822.2	822.26	821.96	822.23	822.42	822.56	822.68
Periodic drwadown	892.65	892.77	892.85	892.91	893.0	893.00	892.86	892.99	893.07	893.14	893.20
Resvr. normally empty	931.44	931.44	931.44	931.44	931.4	931.44	931.44	931.44	931.44	931.44	931.44

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

			B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	15.04	Reservoir condition:				
Silt (%)	45.22					
Clay (%)	39.74	Cont. Submerged	256	91	0	1.43
		Periodic drwadown	135	29	0	0.67
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	844.74	844.98	845.14	845.27	845.4	845.46	845.17	845.42	845.60	845.74	845.85
Periodic drwadown	911.41	911.52	911.60	911.66	911.7	911.74	911.61	911.73	911.81	911.88	911.93
Resvr. normally empty	947.72	947.72	947.72	947.72	947.7	947.72	947.72	947.72	947.72	947.72	947.72

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

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	10.76		Reservoir condition:				
Silt (%)	44.70						
Clay (%)	44.54		Cont. Submerged	256	91	0	1.55
			Periodic drwadown	135	29	0	0.73
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	809.67	809.93	810.10	810.24	810.3	810.44	810.13	810.40	810.60	810.75	810.87
Periodic drwadown	883.19	883.31	883.40	883.46	883.5	883.55	883.41	883.54	883.63	883.70	883.76
Resvr. normally empty	923.29	923.29	923.29	923.29	923.3	923.29	923.29	923.29	923.29	923.29	923.29

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 (%)	14.05	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	47.12					
Clay (%)	38.83	Cont. Submerged	256	91	0	1.42
		Periodic drwadown	135	29	0	0.66
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	850.85	851.09	851.25	851.38	851.5	851.56	851.28	851.53	851.71	851.85	851.96
Periodic drwadown	916.58	916.69	916.77	916.82	916.9	916.91	916.78	916.89	916.98	917.04	917.09
Resvr. normally empty	952.36	952.36	952.36	952.36	952.4	952.36	952.36	952.36	952.36	952.36	952.36

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 (%)	9.70	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	45.76					
Clay (%)	44.54	Cont. Submerged	256	91	0	1.56
		Periodic drwadown	135	29	0	0.73
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	809.35	809.61	809.79	809.92	810.0	810.13	809.82	810.09	810.29	810.44	810.56
Periodic drwadown	883.08	883.21	883.29	883.35	883.4	883.45	883.30	883.43	883.53	883.60	883.65
Resvr. normally empty	923.29	923.29	923.29	923.29	923.3	923.29	923.29	923.29	923.29	923.29	923.29

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

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	5.50					
Silt (%)	48.36					
Clay (%)	46.14	Cont. Submerged	256	91	0	1.62
		Periodic drwadown	135	29	0	0.76
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	796.82	797.10	797.28	797.42	797.5	797.63	797.31	797.60	797.80	797.96	798.09
Periodic drwadown	873.40	873.53	873.61	873.68	873.7	873.78	873.63	873.76	873.86	873.93	873.99
Resvr. normally empty	915.15	915.15	915.15	915.15	915.1	915.15	915.15	915.15	915.15	915.15	915.15

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

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	11.90					
Silt (%)	51.56					
Clay (%)	36.54	Cont. Submerged	256	91	0	1.40
		Periodic drwadown	135	29	0	0.64
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	866.33	866.56	866.72	866.85	866.9	867.03	866.75	867.00	867.17	867.31	867.42
Periodic drwadown	929.62	929.73	929.80	929.86	929.9	929.94	929.82	929.93	930.01	930.07	930.12
Resvr. normally empty	964.01	964.01	964.01	964.01	964.0	964.01	964.01	964.01	964.01	964.01	964.01

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 (%)	9.70	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	50.56					
Clay (%)	39.74	Cont. Submerged	256	91	0	1.48
		Periodic drwadown	135	29	0	0.68
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	843.14	843.39	843.56	843.68	843.8	843.88	843.59	843.85	844.03	844.17	844.29
Periodic drwadown	910.88	910.99	911.07	911.13	911.2	911.22	911.08	911.20	911.29	911.35	911.41
Resvr. normally empty	947.72	947.72	947.72	947.72	947.7	947.72	947.72	947.72	947.72	947.72	947.72

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 - 14

Sand (%)	60.05	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	30.61					
Clay (%)	9.34	Cont. Submerged	256	91	0	0.52
		Periodic drwadown	135	29	0	0.21
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	1072.26	1072.35	1072.41	1072.45	1072.5	1072.52	1072.42	1072.51	1072.57	1072.62	1072.66
Periodic drwadown	1091.93	1091.96	1091.99	1092.01	1092.0	1092.03	1091.99	1092.03	1092.06	1092.08	1092.09
Resvr. normally empty	1102.46	1102.46	1102.46	1102.46	1102.5	1102.46	1102.46	1102.46	1102.46	1102.46	1102.46

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 - 15

Sand (%)	16.70	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	48.36					
Clay (%)	34.94	Cont. Submerged	256	91	0	1.33
		Periodic drwadown	135	29	0	0.61
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	879.03	879.26	879.41	879.52	879.6	879.70	879.43	879.67	879.84	879.97	880.07
Periodic drwadown	939.37	939.47	939.54	939.59	939.6	939.67	939.55	939.66	939.74	939.80	939.84
Resvr. normally empty	972.16	972.16	972.16	972.16	972.2	972.16	972.16	972.16	972.16	972.16	972.16

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

24.3 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	Sample-14	Sample-15
0	D0															
10	D10														0.002	
20	D20														0.008	
30	D30														0.017	
40	D40		0.002					0.0018		0.0024			0.056	0.0025	0.076	0.0046
50	D50		0.027	0.017			0.005	0.028	0.007	0.009	0.006	0.0044	0.017	0.016	0.150	0.012
60	D60	0.006	0.068	0.067	0.004	0.008	0.030	0.068	0.020	0.022	0.018	0.013	0.027	0.033	0.200	0.028
70	D70	0.050	0.070	0.070	0.063	0.064	0.066	0.07	0.065	0.065	0.064	0.05	0.065	0.065	0.270	0.068
80	D80	0.067	0.074	0.071	0.067	0.068	0.072	0.074	0.07	0.07	0.07	0.067	0.07	0.07	0.400	0.074
90	D90	0.072	0.150	0.077	0.070	0.073	0.135	0.2	0.1	0.17	0.078	0.074	0.013	0.078	1.000	0.33
100	D100	2.36	1.180	4.750	0.300	1.180	4.750	4.75	4.75	4.75	4.75	1.18	4.75	2.36	4.750	2.36
84	D84	0.070	0.090	0.073	0.068	0.069	0.074	0.08	0.074	0.073	0.72	0.07	0.0715	0.072	0.500	0.1
16	D16	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-

For Sample-1

Dia (mm)	For Sample-1	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40		40				
D50		50				
D60	0.006	60				
D70	0.050	70	10	0.017	0.173	-0.761
D80	0.067	80	10	0.058	0.579	-0.237
D90	0.072	90	10	0.069	0.695	-0.158
D100	2.360	100	10	0.412	4.122	0.615
D84	0.070	84				
D16		16				

da	0.139	mm
dg	0.988	mm
σg	-	
M	0.000	

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	0.000	30				
D40	0.002	40	10			
D50	0.027	50	10	0.007	0.073	-1.134
D60	0.068	60	10	0.043	0.428	-0.368
D70	0.070	70	10	0.069	0.690	-0.161
D80	0.074	80	10	0.072	0.720	-0.143
D90	0.150	90	10	0.105	1.054	0.023
D100	1.18	100	10	0.421	4.207	0.624
D84	0.090	84				
D16		16				

da	0.120	mm
dg	0.974	mm
σg	-	
M	0.010	

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		30				
D40		40				
D50	0.017	50				
D60	0.067	60	10	0.034	0.337	-0.472
D70	0.070	70	10	0.068	0.685	-0.164
D80	0.071	80	10	0.070	0.705	-0.152
D90	0.077	90	10	0.074	0.739	-0.131
D100	4.750	100	10	0.605	6.048	0.782
D84	0.073	84				
D16		16				

da	0.170	mm
dg	0.997	mm
σg	-	
M	0.000	

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-4

Dia (mm)	For Sample-4	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40		40				
D50		50				
D60	0.004	60				
D70	0.063	70	10	0.016	0.159	-0.799
D80	0.067	80	10	0.065	0.650	-0.187
D90	0.070	90	10	0.068	0.685	-0.164
D100	0.300	100	10	0.145	1.449	0.161
D84	0.068	84				
D16		16				

da	0.0736	mm
dg	0.977	mm
σg		
M	0.000	

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		30				
D40		40				
D50		50				
D60	0.008	60				
D70	0.064	70	10	0.022	0.220	-0.658
D80	0.068	80	10	0.066	0.657	-0.182
D90	0.073	90	10	0.070	0.705	-0.152
D100	1.180	100	10	0.293	2.935	0.468
D84	0.069	84				
D16		16				

da	0.113	mm
dg	0.988	mm
σg		
M	0.000	

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		20				
D30		30				
D40		40				
D50	0.005	50				
D60	0.030	60	10	0.013	0.127	-0.895
D70	0.066	70	10	0.044	0.445	-0.352
D80	0.072	80	10	0.069	0.689	-0.162
D90	0.135	90	10	0.099	0.986	-0.006
D100	4.750	100	10	0.801	8.008	0.904
D84	0.074	84				
D16		16				

da	0.205	mm
dg	0.988	mm
σg		
M	0.000	

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-7

Dia (mm)	For Sample-7	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40	0.002	40				
D50	0.028	50	10	0.007	0.071	-1.149
D60	0.068	60	10	0.044	0.436	-0.360
D70	0.070	70	10	0.069	0.690	-0.161
D80	0.074	80	10	0.072	0.720	-0.143
D90	0.200	90	10	0.122	1.217	0.085
D100	4.750	100	10	0.975	9.747	0.989
D84	0.080	84				
D16		16				

da	0.215	mm
dg	0.983	mm
σg		
M	0.006	

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-8

Dia (mm)	For Sample-8	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40		40				
D50	0.007	50				
D60	0.020	60	10	0.011	0.114	-0.943
D70	0.065	70	10	0.036	0.361	-0.443
D80	0.070	80	10	0.067	0.675	-0.171
D90	0.100	90	10	0.084	0.837	-0.077
D100	4.750	100	10	0.689	6.892	0.838
D84	0.074	84				
D16		16				

da	0.178	mm
dg	0.982	mm
σg		
M	0.000	

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-9

Dia (mm)	For Sample-9	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40	0.002	40	10			
D50	0.009	50	10	0.005	0.046	-1.333
D60	0.022	60	10	0.014	0.141	-0.852
D70	0.065	70	10	0.038	0.378	-0.422
D80	0.070	80	10	0.067	0.675	-0.171
D90	0.170	90	10	0.109	1.091	0.038
D100	4.750	100	10	0.899	8.986	0.954
D84	0.073	84				
D16		16				

da	0.189	mm
dg	0.960	mm
σg		
M	0.004	

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						
D40						
D50	0.0060	50	50			
D60	0.0180	60	10	0.010	0.104	-0.983
D70	0.0640	70	10	0.034	0.339	-0.469
D80	0.0700	80	10	0.067	0.669	-0.174
D90	0.0780	90	10	0.074	0.739	-0.131
D100	4.7500	100	10	0.609	6.087	0.784
D84	0.7200	84				
D16		16				

da 0.159 mm

dg 0.978 mm

σg

M 0.000

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-11

Dia (mm)	For Sample-11	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40		40				
D50	0.0044	50				
D60	0.0130	60	10	0.008	0.076	-1.121
D70	0.0500	70	10	0.025	0.255	-0.594
D80	0.0670	80	10	0.058	0.579	-0.237
D90	0.0740	90	10	0.070	0.704	-0.152
D100	1.1800	100	10	0.295	2.955	0.471
D84	0.0700	84				
D16	-	16				

da	0.091	mm
dg	0.963	mm
σg		
M	0.000	

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-12

Dia (mm)	For Sample-12	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40	0.0560	40				
D50	0.0170	50	10	0.031	0.309	-0.511
D60	0.0270	60	10	0.021	0.214	-0.669
D70	0.0650	70	10	0.042	0.419	-0.378
D80	0.0700	80	10	0.067	0.675	-0.171
D90	0.0130	90	10	0.030	0.302	-0.520
D100	4.7500	100	10	0.248	2.485	0.395
D84	0.0715	84				
D16	-	16				

da	0.073	mm
dg	0.958	mm
σg		
M	0.075	

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		30				
D40	0.0025	40	10			
D50	0.0160	50	10	0.006	0.063	-1.199
D60	0.0330	60	10	0.023	0.230	-0.639
D70	0.0650	70	10	0.046	0.463	-0.334
D80	0.0700	80	10	0.067	0.675	-0.171
D90	0.0780	90	10	0.074	0.739	-0.131
D100	2.3600	100	10	0.429	4.290	0.633
D84	0.0720	84				
D16	-	16				

da	0.108	mm
dg	0.958	mm
σg		
M	0.010	

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-14

Dia (mm)	For Sample-14	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	0.002	10				
D20	0.008	20	10	0.004	0.040	-1.398
D30	0.017	30	10	0.012	0.117	-0.933
D40	0.076	40	10	0.036	0.359	-0.444
D50	0.15	50	10	0.107	1.068	0.028
D60	0.2	60	10	0.173	1.732	0.239
D70	0.27	70	10	0.232	2.324	0.366
D80	0.4	80	10	0.329	3.286	0.517
D90	1	90	10	0.632	6.325	0.801
D100	4.75	100	10	2.179	21.794	1.338
D84	0.5	84				
D16	0.0055	16				

da	0.412	mm
dg	1.012	mm
σg	-	
M	0.045	

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-15

Dia (mm)	For Sample-15	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20		20				
D30		30				
D40	0.0025	40				
D50	0.0160	50	10	0.006	0.063	-1.199
D60	0.0330	60	10	0.023	0.230	-0.639
D70	0.0650	70	10	0.046	0.463	-0.334
D80	0.0700	80	10	0.067	0.675	-0.171
D90	0.0780	90	10	0.074	0.739	-0.131
D100	2.3600	100	10	0.429	4.290	0.633
D84	0.0720	84				
D16	-	16				

da	0.108	mm
dg	0.958	mm
σg		
M	0.010	

Remarks: Sediment is non - uniform

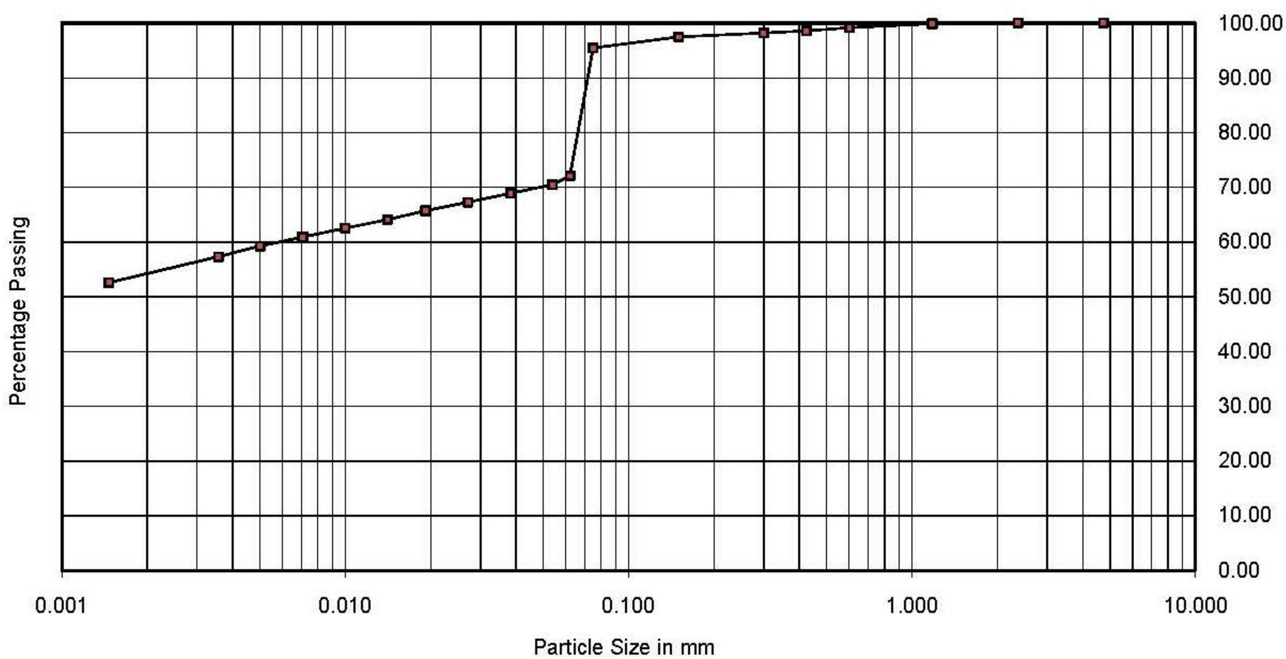
Where,

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

24.4 Grain Size Distribution curves:-

GRAIN SIZE DISTRIBUTION CURVES

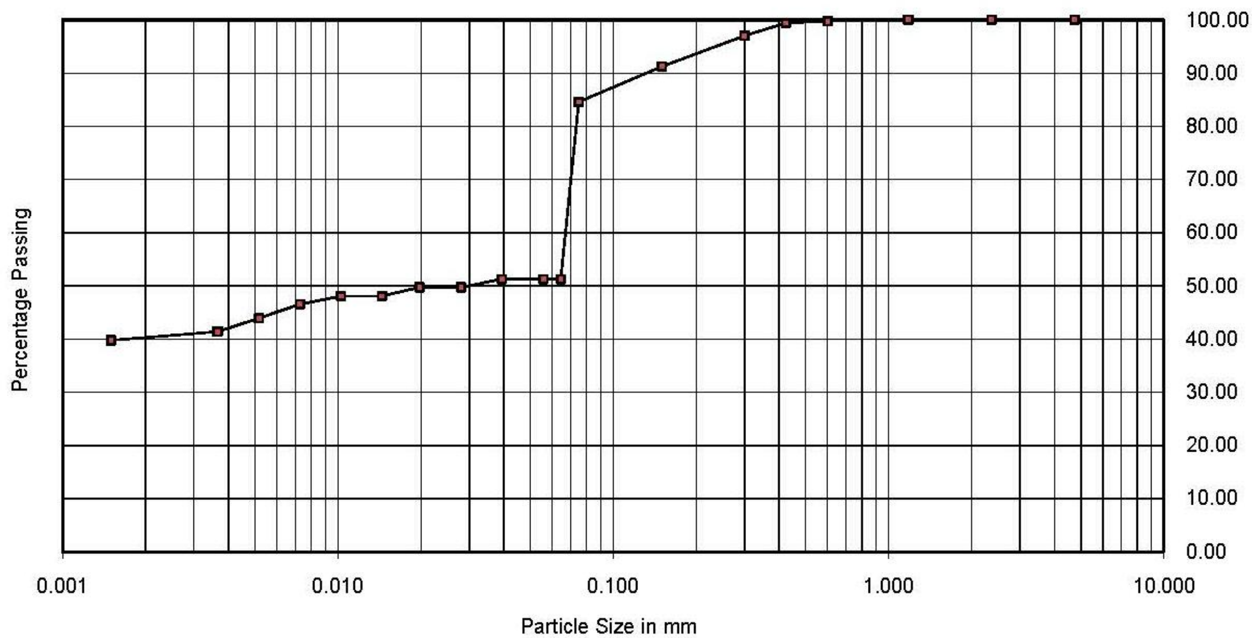
Site:	Panchyet Dam (Maithon)
Sample No.	1



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
1	52.54	42.90	4.56	0.00

GRAIN SIZE DISTRIBUTION CURVES

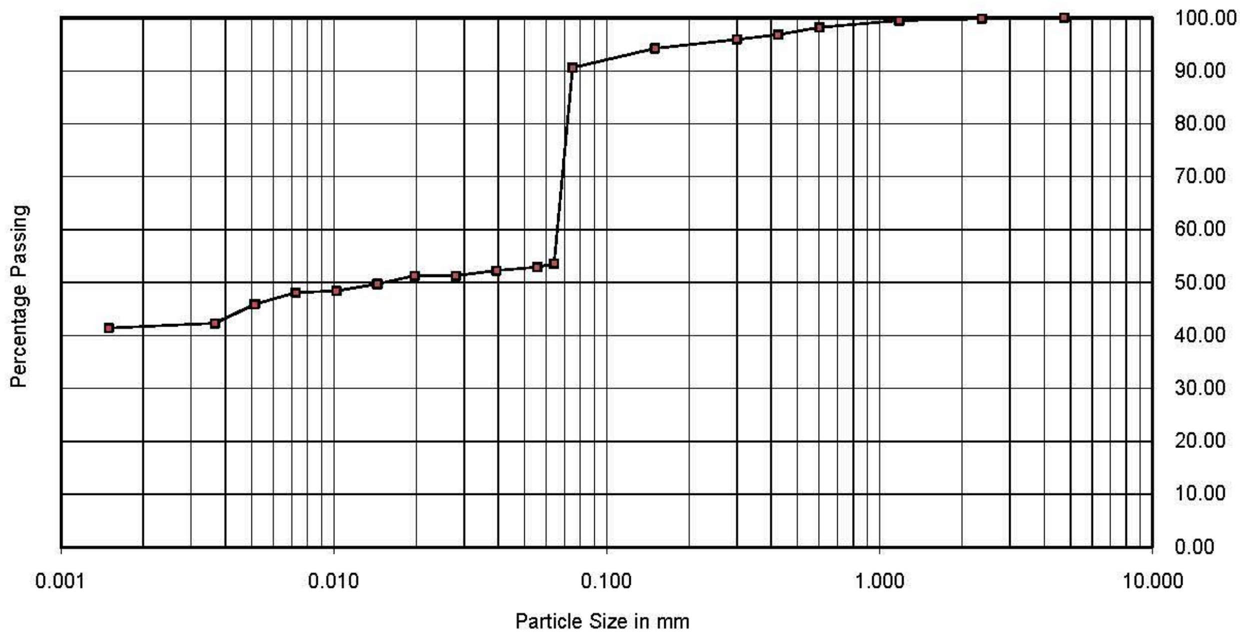
Site:	Panchyet Dam (Maithon)
Sample No.	2



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
2	39.74	44.87	15.39	0.00

GRAIN SIZE DISTRIBUTION CURVES

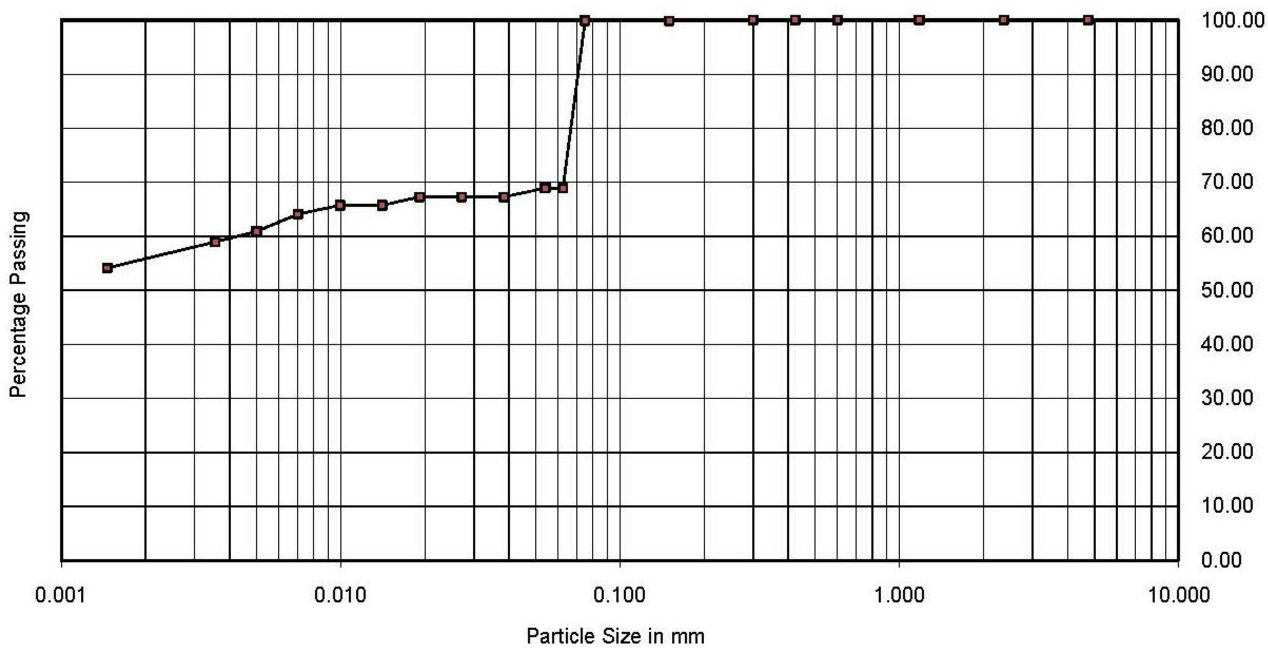
Site:	Panchyet Dam (Maithon)
Sample No.	3



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
3	41.34	49.26	9.4	0.00

GRAIN SIZE DISTRIBUTION CURVES

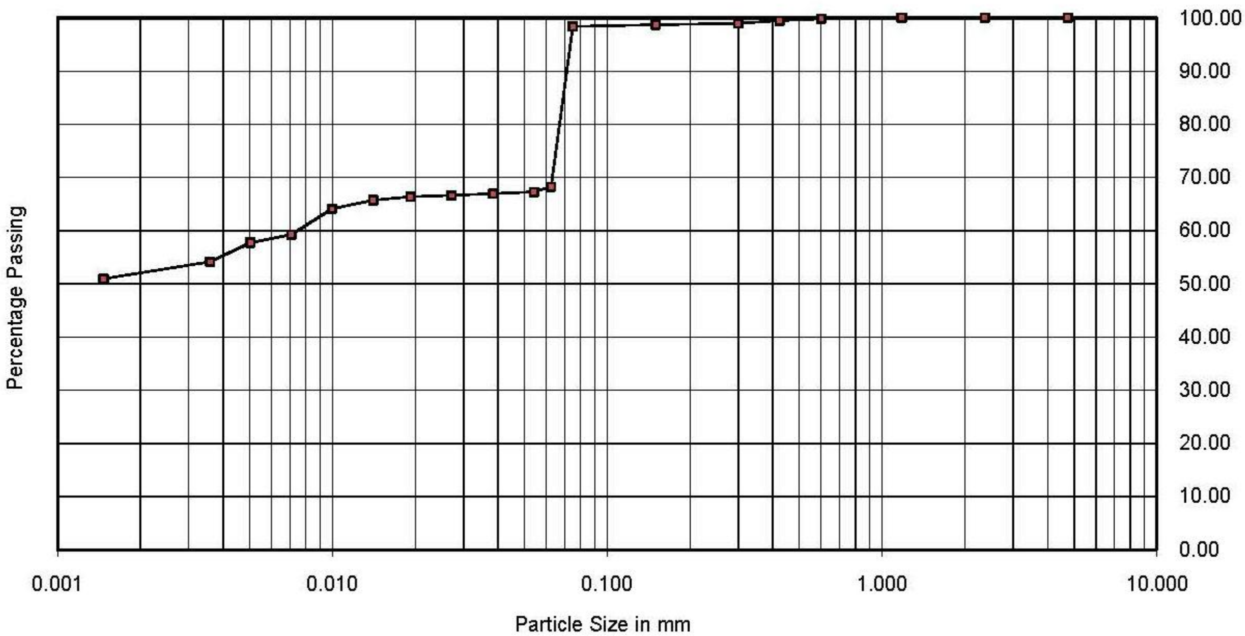
Site:	Panchyet Dam (Maithon)
Sample No.	4



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
4	54.14	45.74	0.12	0.00

GRAIN SIZE DISTRIBUTION CURVES

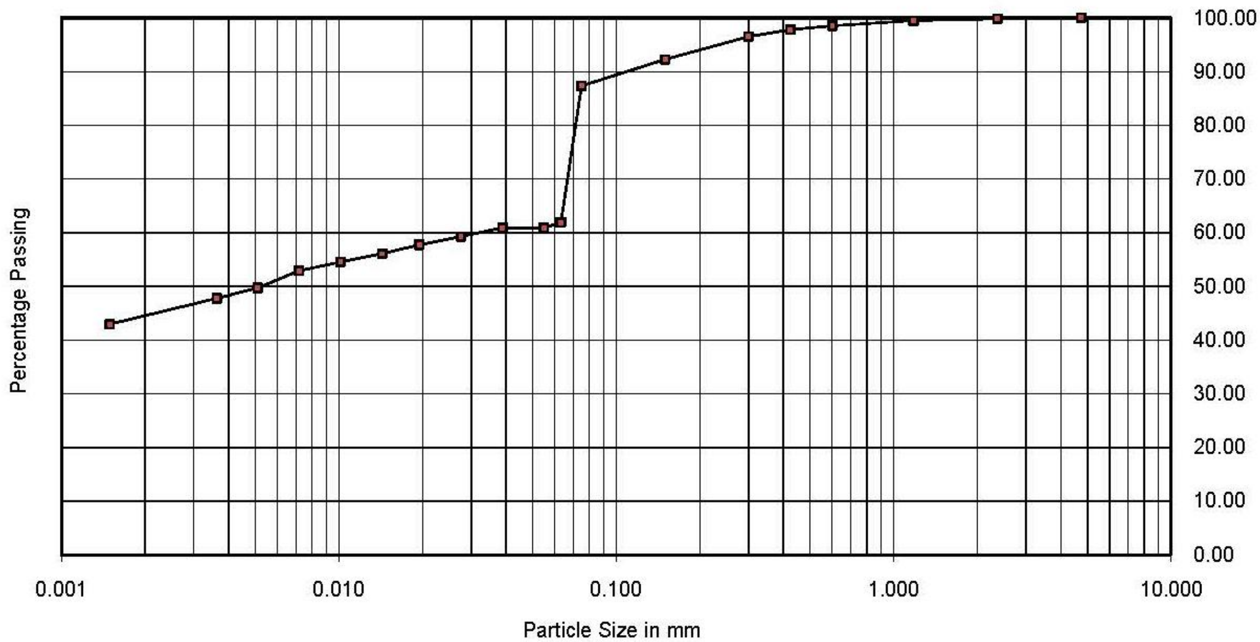
Site:	Panchyet Dam (Maithon)
Sample No.	5



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
5	50.94	47.46	1.6	0.00

GRAIN SIZE DISTRIBUTION CURVES

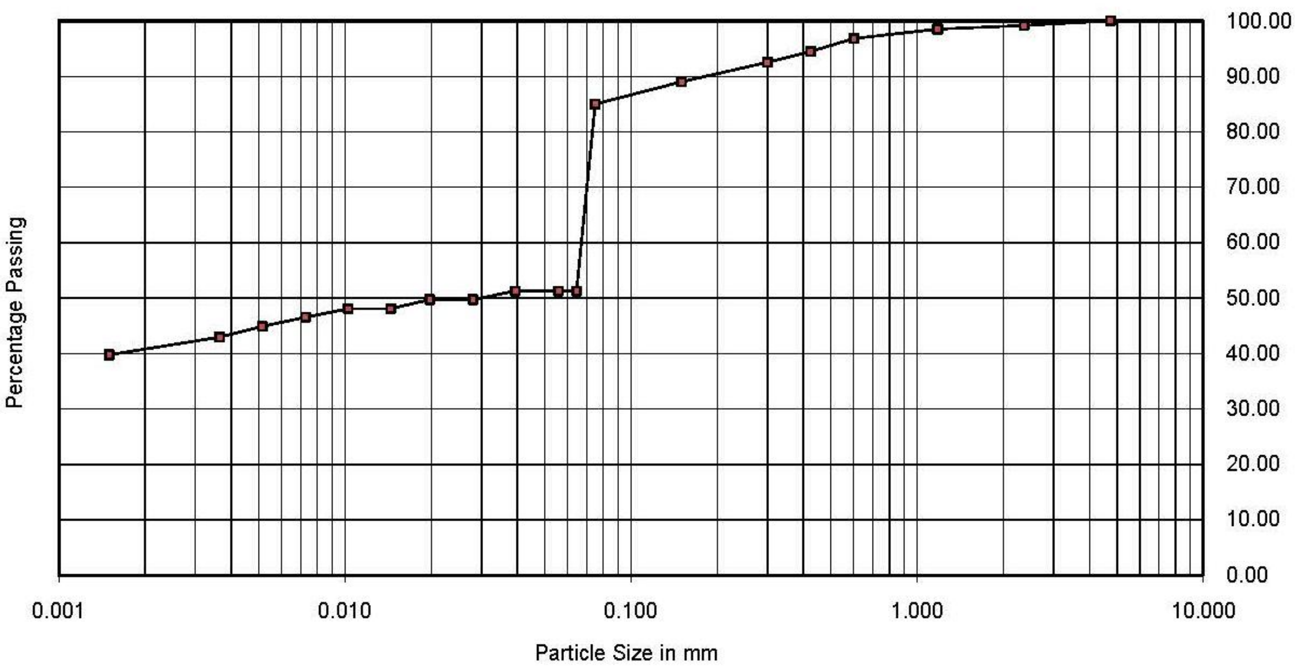
Site:	Panchyet Dam (Maithon)
Sample No.	6



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
6	50.94	36.36	12.7	0.00

GRAIN SIZE DISTRIBUTION CURVES

Site:	Panchyet Dam (Maithon)
Sample No.	7

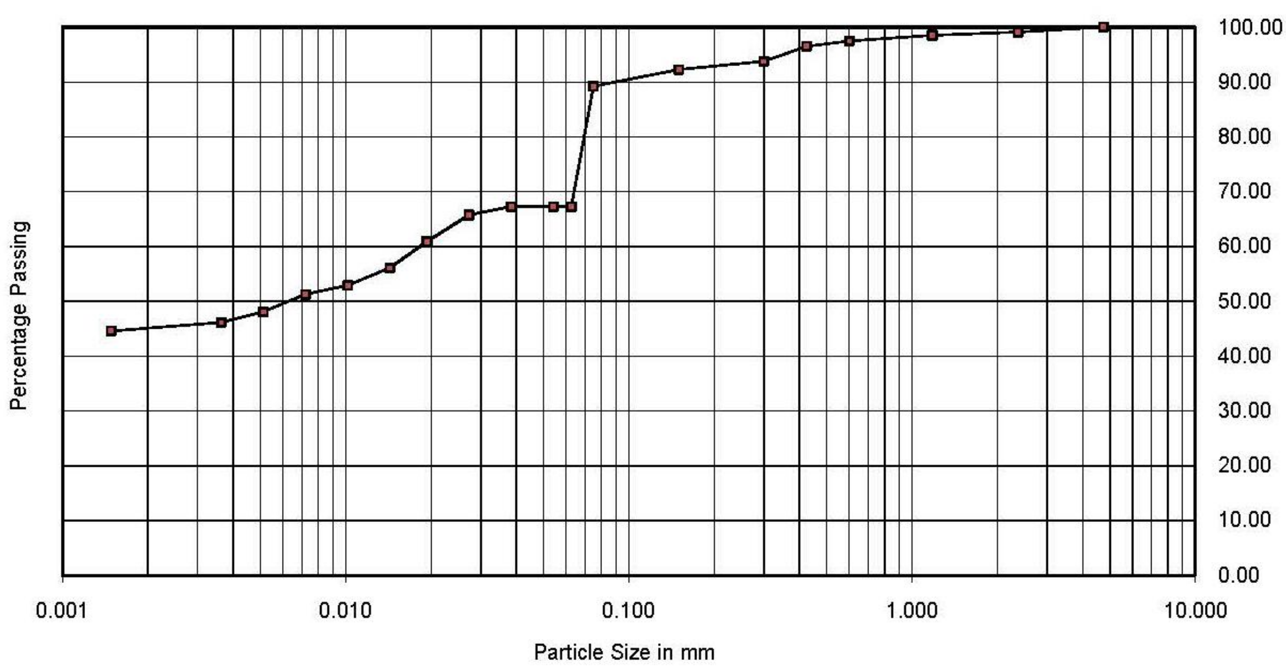


Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
7	39.74	45.22	15.04	0.00

GRAIN SIZE DISTRIBUTION CURVES

Site: Panchyet Dam (Maithon)

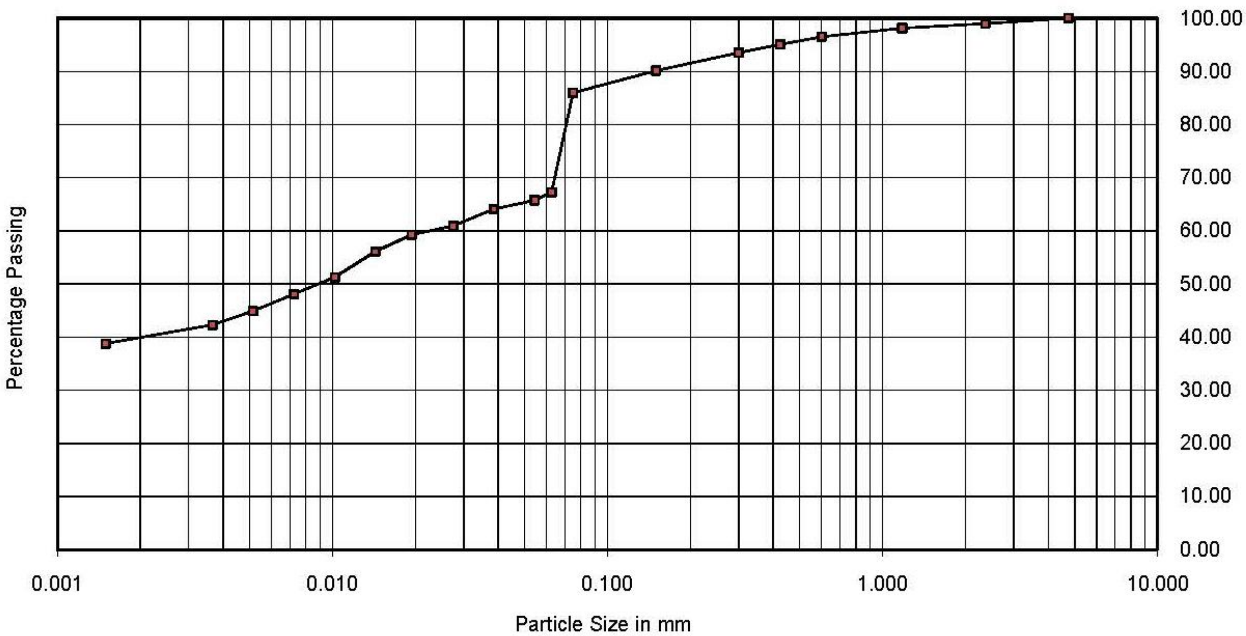
Sample No. 8



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
8	44.54	44.70	10.76	0.00

GRAIN SIZE DISTRIBUTION CURVES

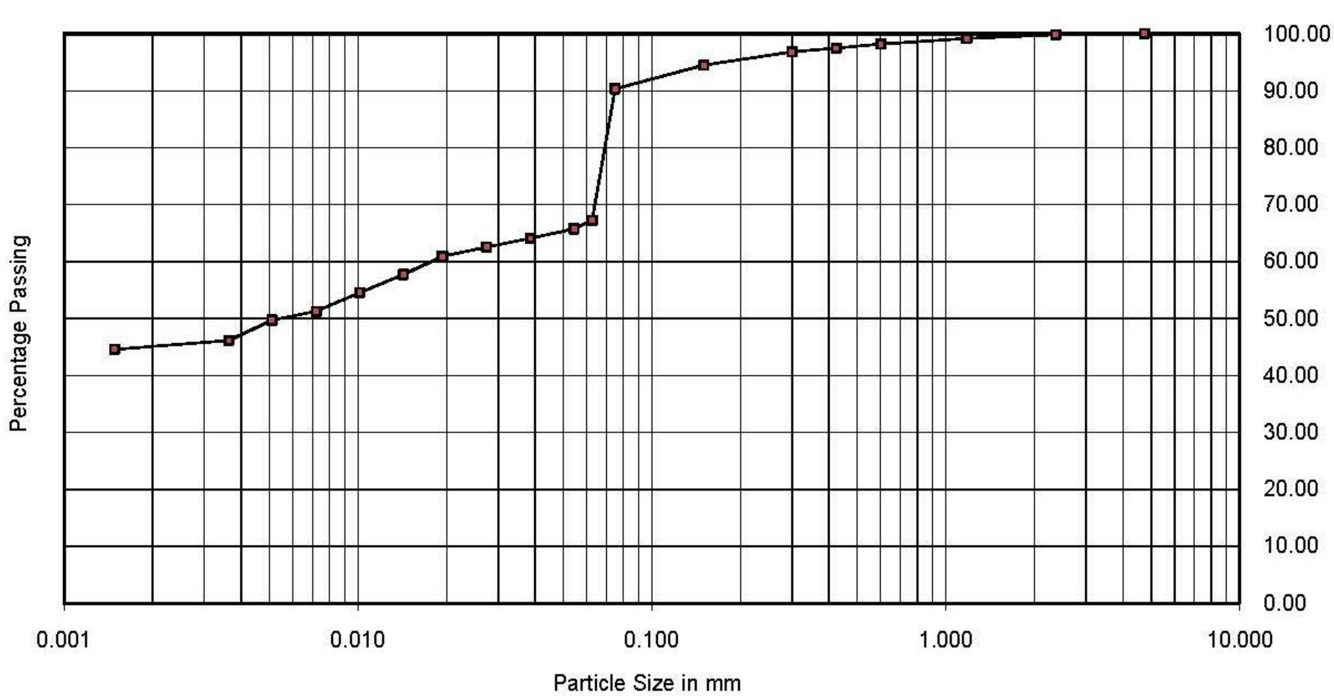
Site:	Panchyet Dam (Maithon)
Sample No.	9



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
9	38.78	47.17	14.05	0.00

GRAIN SIZE DISTRIBUTION CURVES

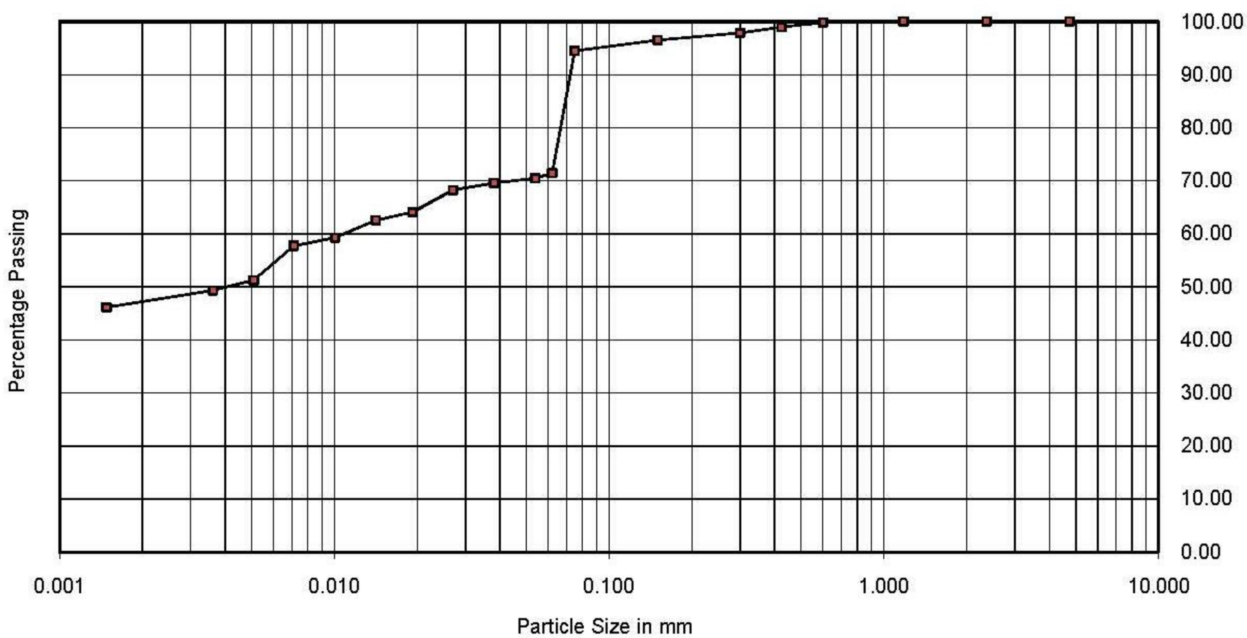
Site:	Panchyet Dam (Maithon)
Sample No.	10



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
10	44.54	45.76	9.7	0.00

GRAIN SIZE DISTRIBUTION CURVES

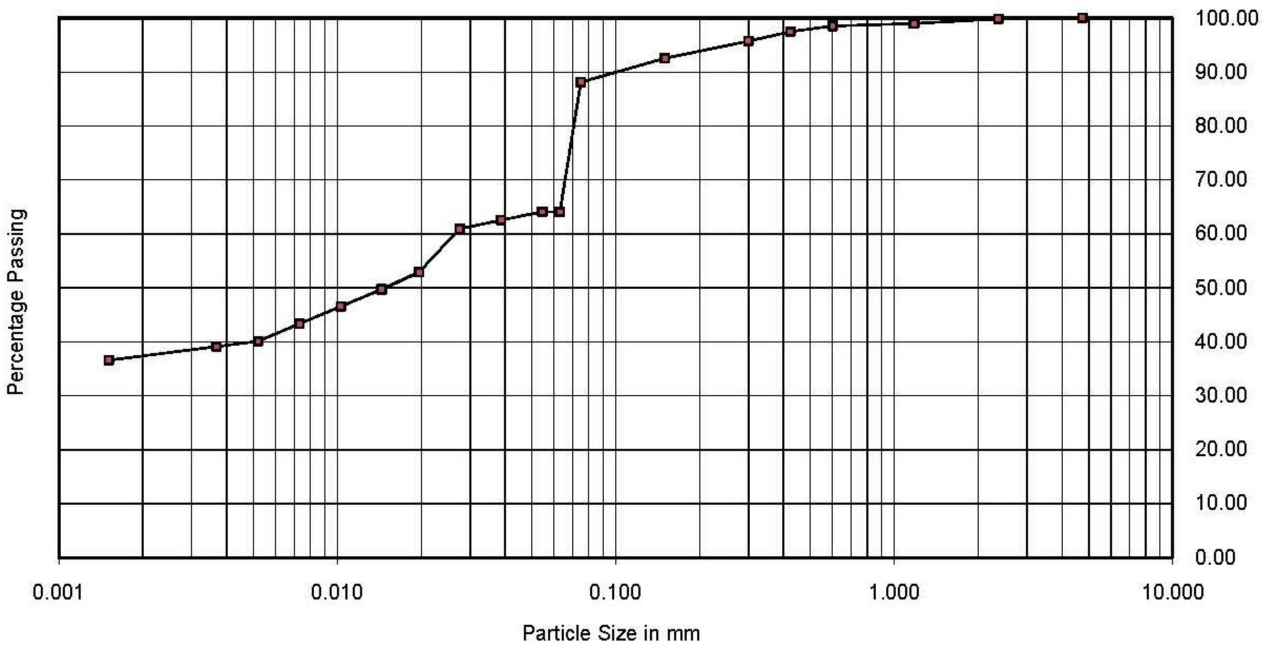
Site:	Panchyet Dam (Maithon)
Sample No.	11



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
11	52.54	41.96	5.5	0.00

GRAIN SIZE DISTRIBUTION CURVES

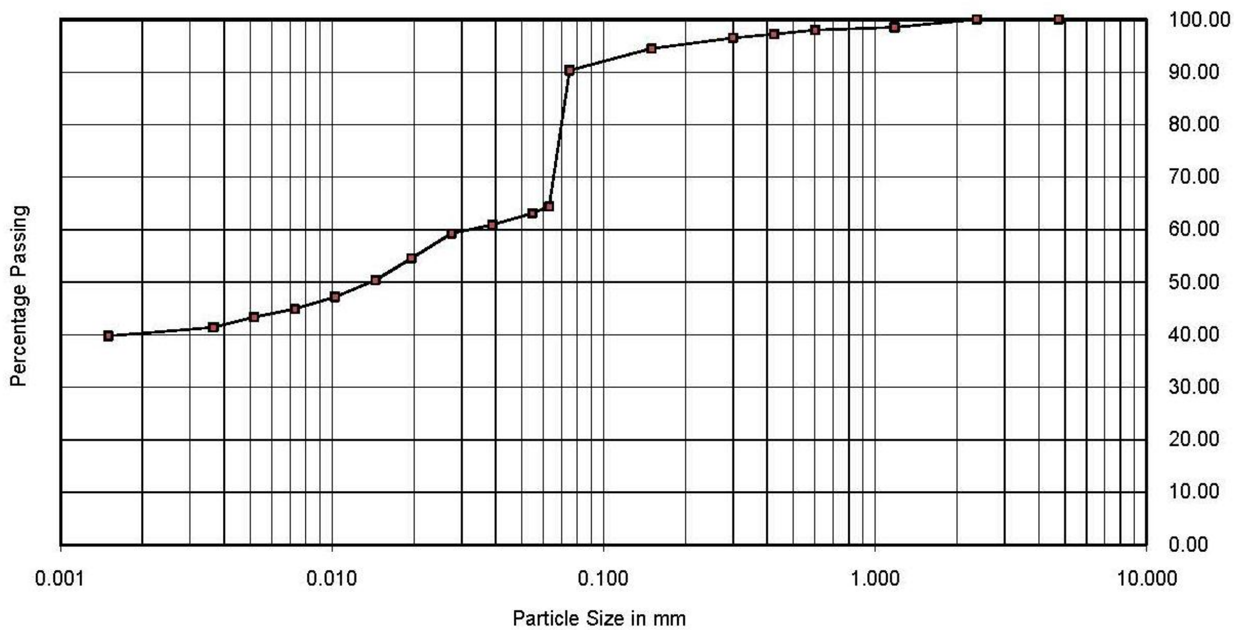
Site:	Panchyet Dam (Maithon)
Sample No.	12



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
12	51.56	36.54	11.9	0.00

GRAIN SIZE DISTRIBUTION CURVES

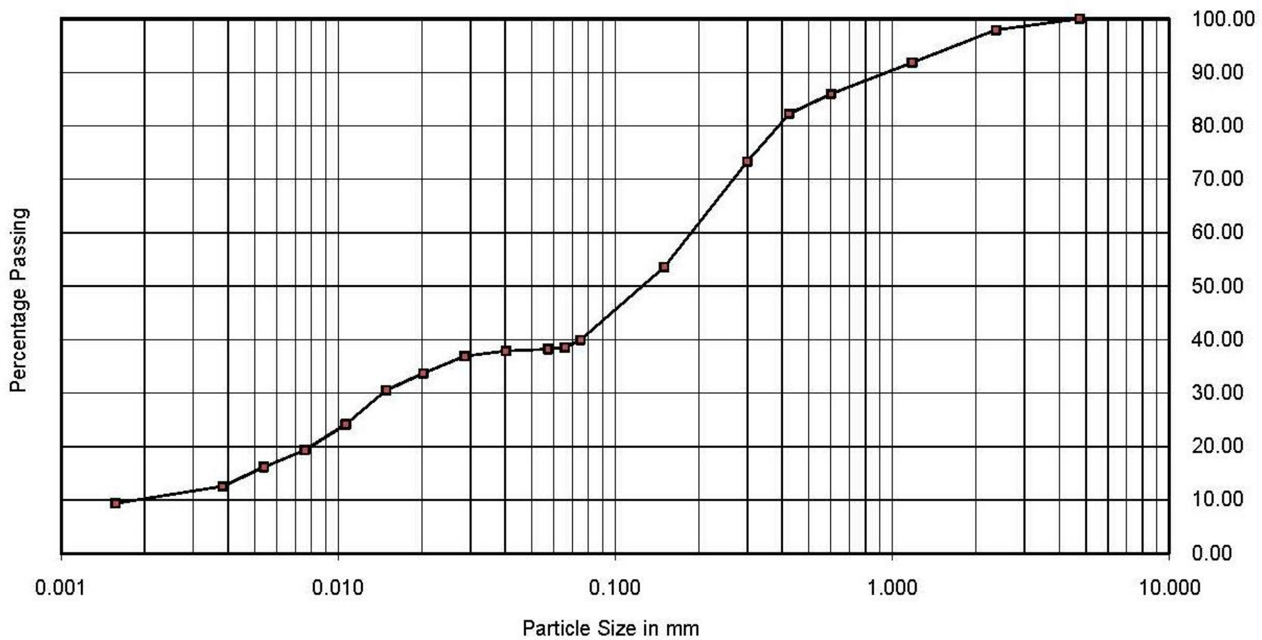
Site:	Panchyet Dam (Maithon)
Sample No.	13



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
13	39.74	50.56	9.7	0.00

GRAIN SIZE DISTRIBUTION CURVES

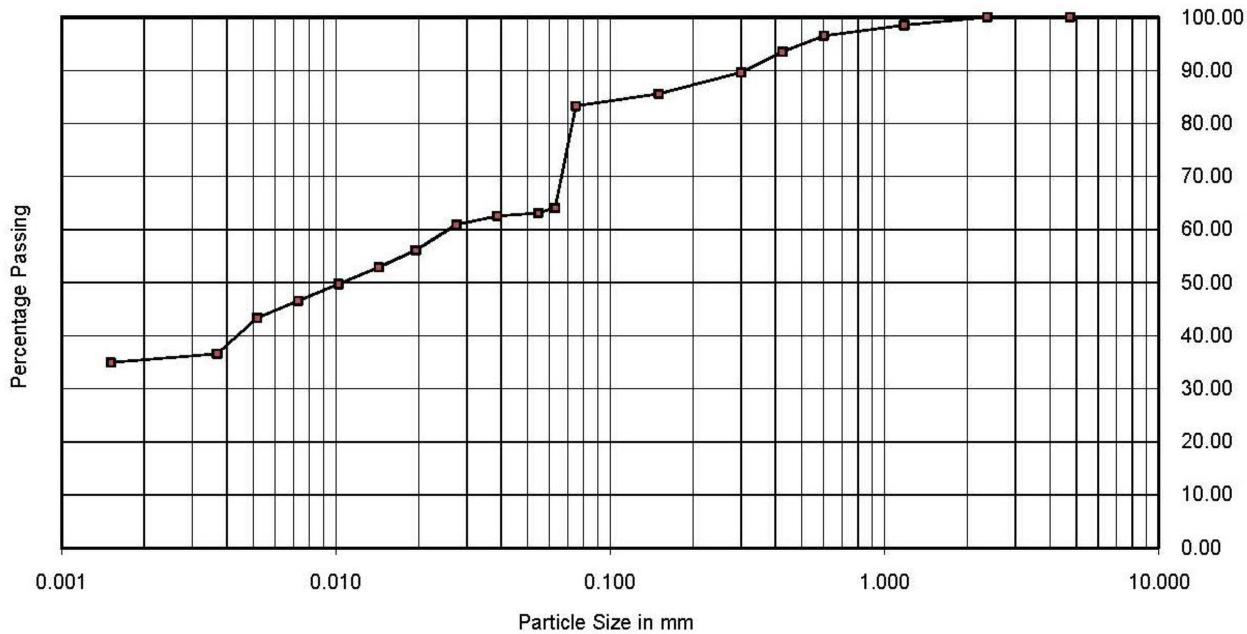
Site:	Panchyet Dam (Maithon)
Sample No.	14



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
14	9.34	30.61	60.05	0.00

GRAIN SIZE DISTRIBUTION CURVES

Site:	Panchyet Dam (Maithon)
Sample No.	15



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
15	39.74	43.56	16.7	0.00

TRAP EFFICIENCY

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

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

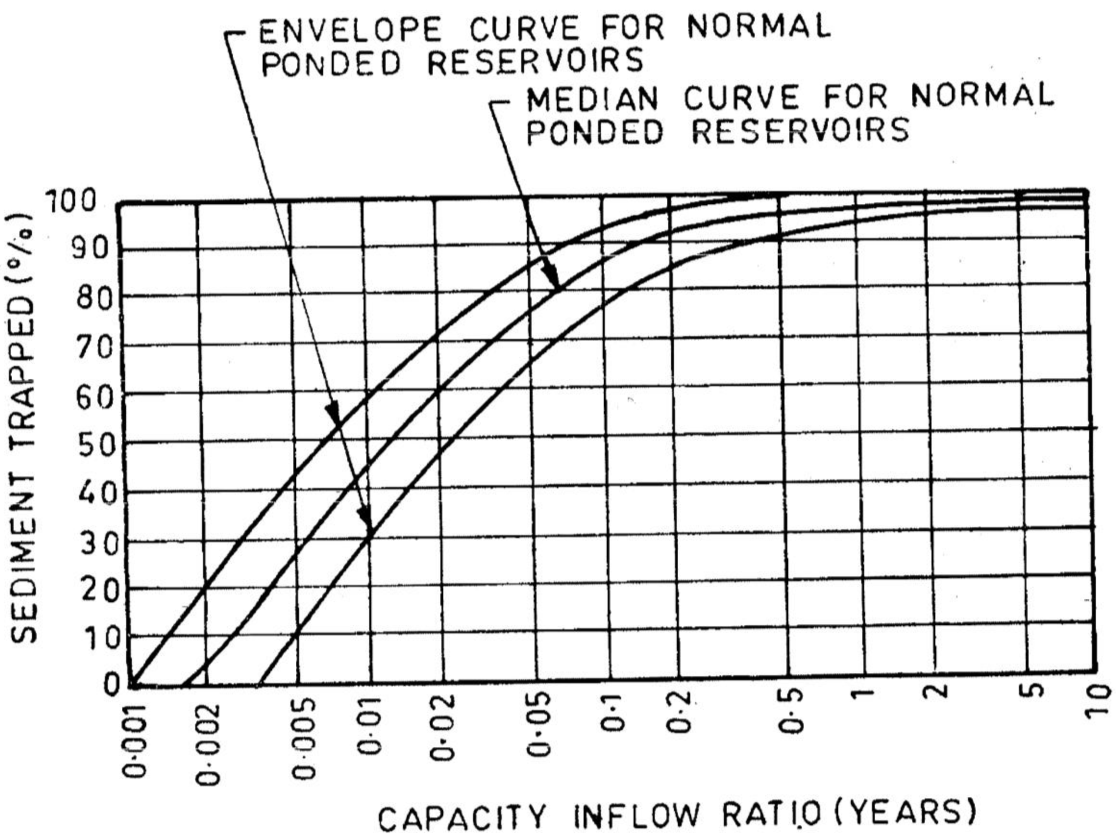
The Trap efficiency of Panchet reservoir has been calculated according to Brune'S trap efficiency curve as per I.S 12182-1987 "Guidelines for determination of effects of sedimentation of Effects of sedimentation in planning and performance of Reservoirs".

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:

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

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)=135.6m
b) Mean operating Pool elevation = 125.0m
c) Capacity at FRL, C_1= 1275.96 MCM
d) Capacity at mean Operating Pool elevation, C_2 = 278.21 MCM
e) Average inflow, I, over the study period of 10 years, in volume-tric units= 3808.692MCM
f) Length of Reservoir, L, at the mean operating level= 51.000 km

- **Brune'S Method:-**

Capacity Inflow ratio

C_1 / I = 1275.96/3808.692=0.335

Trap efficiency corresponding to above ratio C/I as read from median curve for normally ponded reservoir = 93 percent

Year	Inflow (MCM)
2010	123.823
2011	660.100
2012	384.643
2013	462.424
2014	370.274
2015	312.205
2016	467.380
2017	584.830
2018	308.781
2019	134.232
	Average inflow in 10 years- 3808.692 MCM

CHARTS/DRAWINGS

26.0 Charts/Drawing:-

26.1 Grid Plan of Panchet Reservoir:-

26.2 Topographical Plan of Panchet Reservoir:-

26.3 Contour Plan of Panchet Reservoir:-

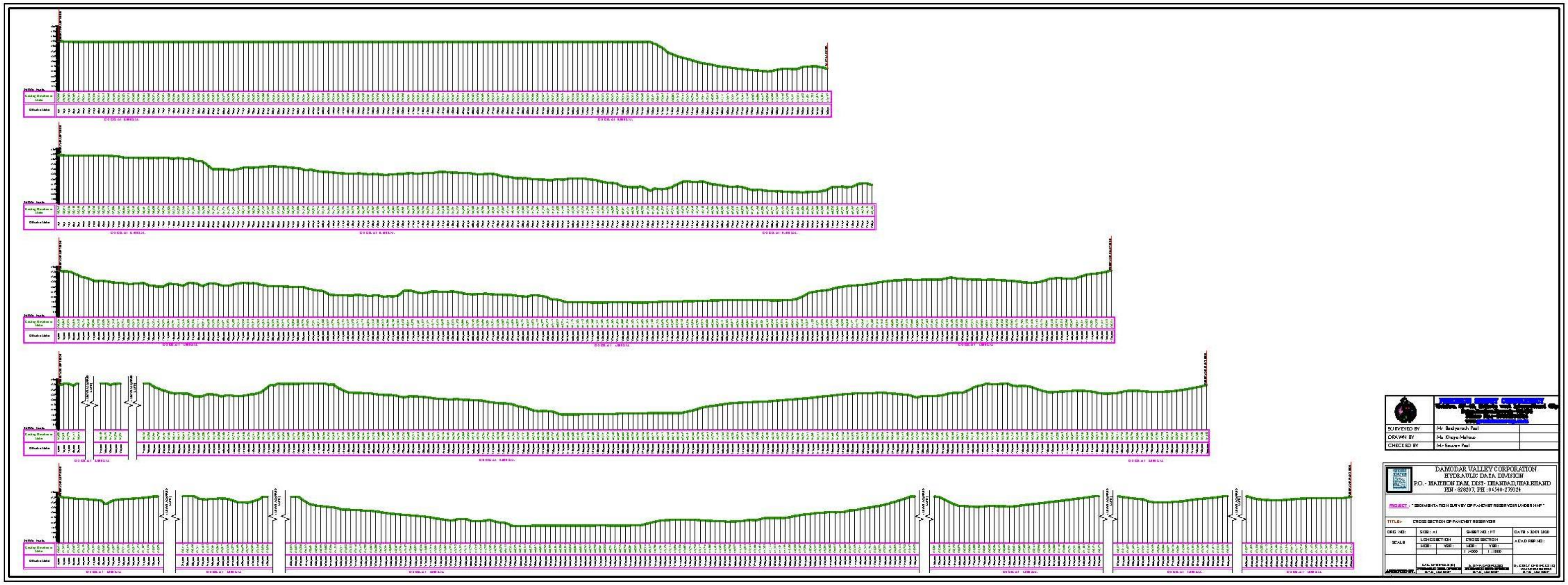
27.0 Area of Contour in Panchet Reservoir:-

Panchet Reservoir_ Area (Contour)			
SL.NO.	Contour EL	Area	
		in Sqm.	In Sq. Km.
1	102.0	19890.081	0.020
2	102.3	45789.829	0.046
3	102.6	71689.576	0.072
4	102.9	97589.324	0.098
5	103.2	131115.446	0.131
6	103.5	168454.757	0.168
7	103.8	205794.067	0.206
8	104.1	273334.360	0.273
9	104.4	401276.622	0.401
10	104.7	529218.883	0.529
11	105.0	657161.144	0.657
12	105.3	825346.689	0.825
13	105.6	993532.234	0.994
14	105.9	1161717.779	1.162
15	106.2	1434364.109	1.434
16	106.5	1759240.833	1.759
17	106.8	2084117.556	2.084
18	107.1	2383012.190	2.383
19	107.4	2629942.646	2.630
20	107.7	2876873.101	2.877
21	108.0	3123803.557	3.124
22	108.3	3442639.363	3.443
23	108.6	3761475.170	3.761
24	108.9	4080310.976	4.080
25	109.2	4345697.327	4.346
26	109.5	4584358.950	4.584
27	109.8	4823020.572	4.823
28	110.1	5062456.478	5.062
29	110.4	5303440.948	5.303
30	110.7	5544425.419	5.544
31	111.0	5785409.889	5.785
32	111.3	6043659.614	6.044
33	111.6	6301909.339	6.302
34	111.9	6560159.063	6.560
35	112.2	6820750.490	6.821
36	112.5	7082512.767	7.083
37	112.8	7344275.043	7.344
38	113.1	7612973.787	7.613

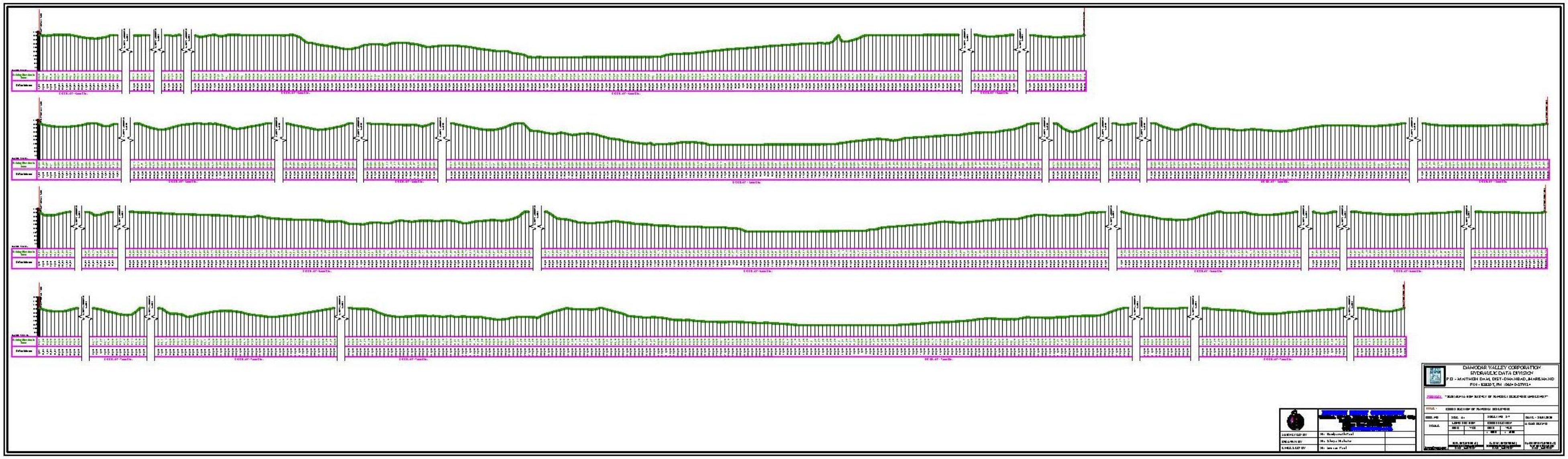
Panchet Reservoir_ Area (Contour)			
SL.NO.	Contour EL	Area	
		in Sqm.	In Sq. Km.
39	113.4	7895545.463	7.896
40	113.7	8178117.139	8.178
41	114.0	8460688.815	8.461
42	114.3	8771297.521	8.771
43	114.6	9081906.226	9.082
44	114.9	9392514.932	9.393
45	115.2	9726216.498	9.726
46	115.5	10071464.496	10.071
47	115.8	10416712.493	10.417
48	116.1	10775955.224	10.776
49	116.4	11163187.424	11.163
50	116.7	11550419.623	11.550
51	117.0	11937651.823	11.938
52	117.3	12412724.652	12.413
53	117.6	12887797.480	12.888
54	117.9	13362870.309	13.363
55	118.2	13901172.802	13.901
56	118.5	14471090.129	14.471
57	118.8	15041007.456	15.041
58	119.1	15656267.355	15.656
59	119.4	16362212.399	16.362
60	**119.5**	16597527.414	16.598
61	119.7	17190208.651	17.190
62	120.0	18079230.507	18.079
63	120.3	19279477.104	19.279
64	120.6	20479723.701	20.480
65	120.9	21679970.298	21.680
66	121.2	23286584.213	23.287
67	121.5	25096381.786	25.096
68	121.8	26906179.359	26.906
69	122.1	28795001.138	28.795
70	122.4	30841871.326	30.842
71	122.7	32888741.514	32.889
72	123.0	34935611.702	34.936
73	123.3	37269545.833	37.270
74	123.6	39603479.963	39.603
75	123.9	41937414.094	41.937
76	124.2	44595969.194	44.596
77	124.5	47416834.779	47.417
78	124.8	50237700.364	50.238
79	**125.0**	52118277.421	52.118
80	125.1	52812644.627	52.813

Panchet Reservoir_ Area (Contour)			
SL.NO.	Contour EL	Area	
		in Sqm.	In Sq. Km.
81	125.4	54895746.244	54.896
82	125.7	56978847.861	56.979
83	126.0	59061949.478	59.062
84	126.3	60844483.878	60.844
85	126.6	62627018.278	62.627
86	126.9	64409552.678	64.410
87	127.2	66369420.922	66.369
88	127.5	68417956.088	68.418
89	127.8	70466491.254	70.466
90	128.1	72443240.094	72.443
91	128.4	74276416.281	74.276
92	128.7	76109592.468	76.110
93	129.0	77942768.655	77.943
94	129.3	79997777.782	79.998
95	**129.54**	81641785.083	81.642
96	129.6	82052786.909	82.053
97	129.9	84107796.036	84.108
98	130.2	86105450.092	86.105
99	130.5	88652187.511	88.652
100	130.8	91198924.929	91.199
101	131.1	93810483.278	93.810
102	131.4	96551683.489	96.552
103	131.7	99292883.699	99.293
104	132.0	102034083.909	102.034
105	132.3	105577852.652	105.578
106	132.6	109121621.394	109.122
107	132.9	112665390.137	112.665
108	133.2	119074627.227	119.075
109	133.5	126916598.492	126.917
110	133.8	134758569.757	134.759
111	134.1	140859315.670	140.859
112	134.4	143477610.878	143.478
113	134.7	146095906.087	146.096
114	135.0	148714201.295	148.714
115	135.3	150190894.830	150.191
116	**135.6**	151667588.364	151.668

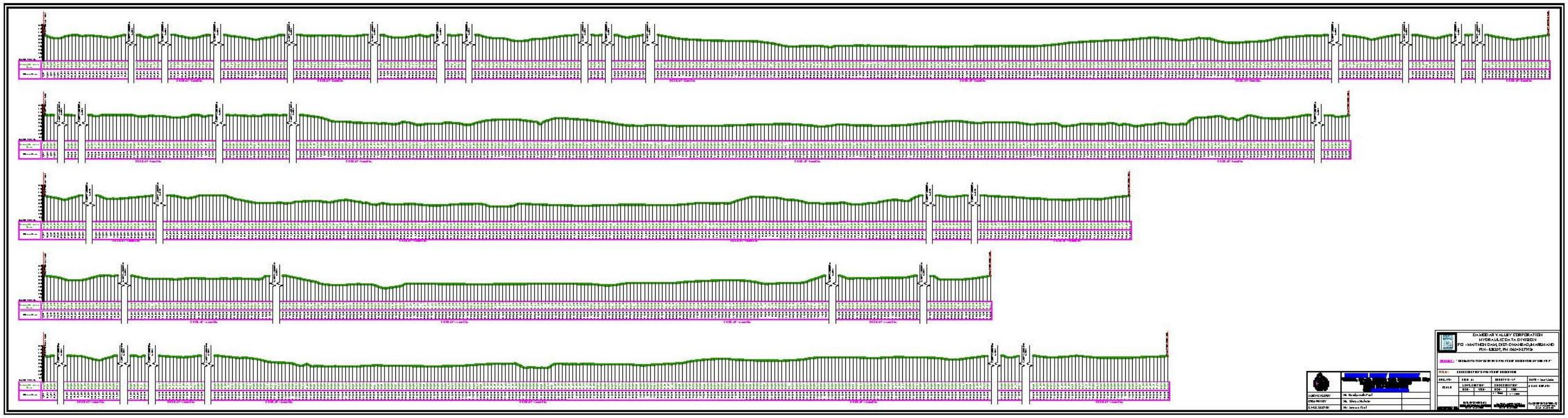
28.0 Cross Sectional Plan at Damodar River near Chainage 0.000 km to 3.0 km:-



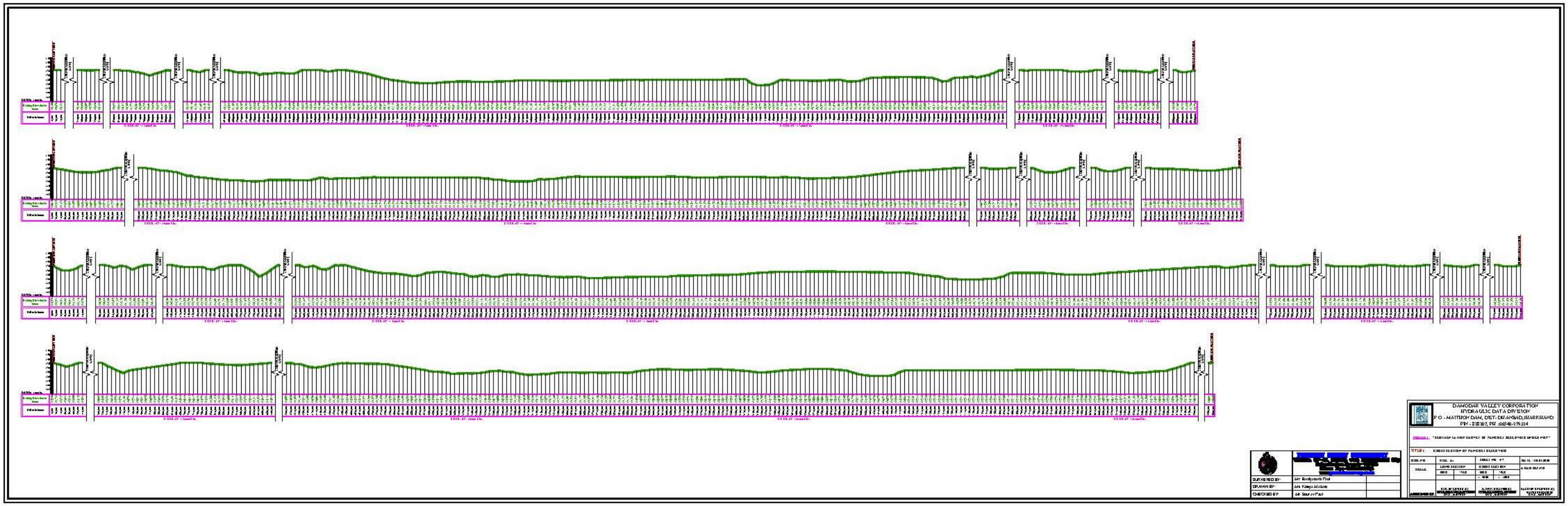
28.1Cross Sectional Plan at Damodar River near Chainage 4.000 km to 7.000 km :-



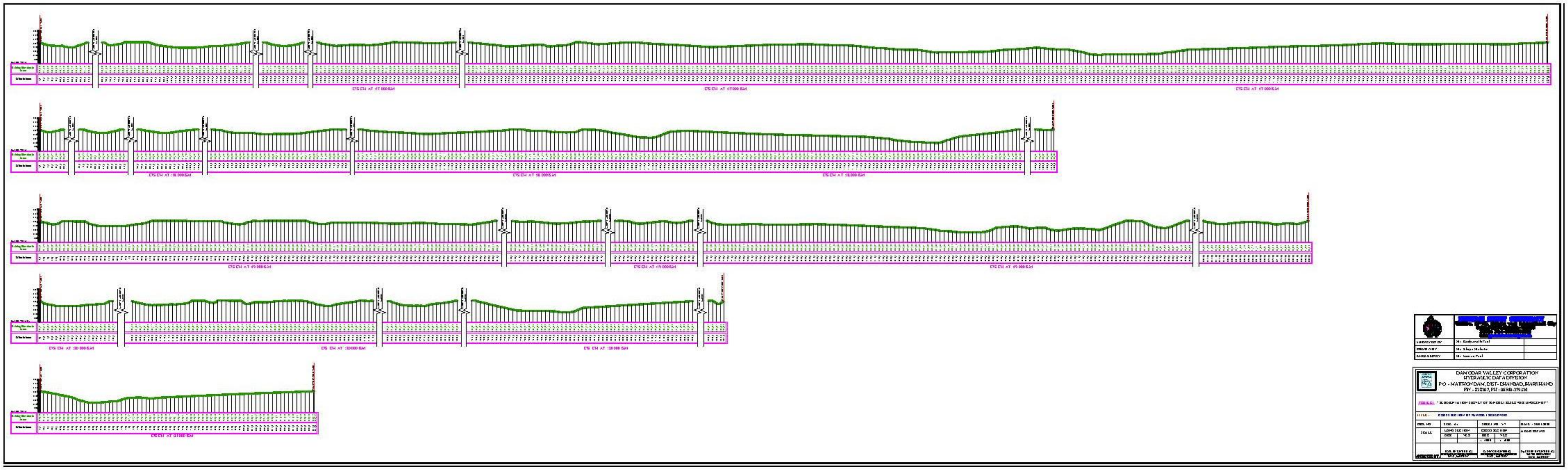
28.2 Cross Sectional Plan at Damodar River near Chainage 8.000 km to 12.000 km:-



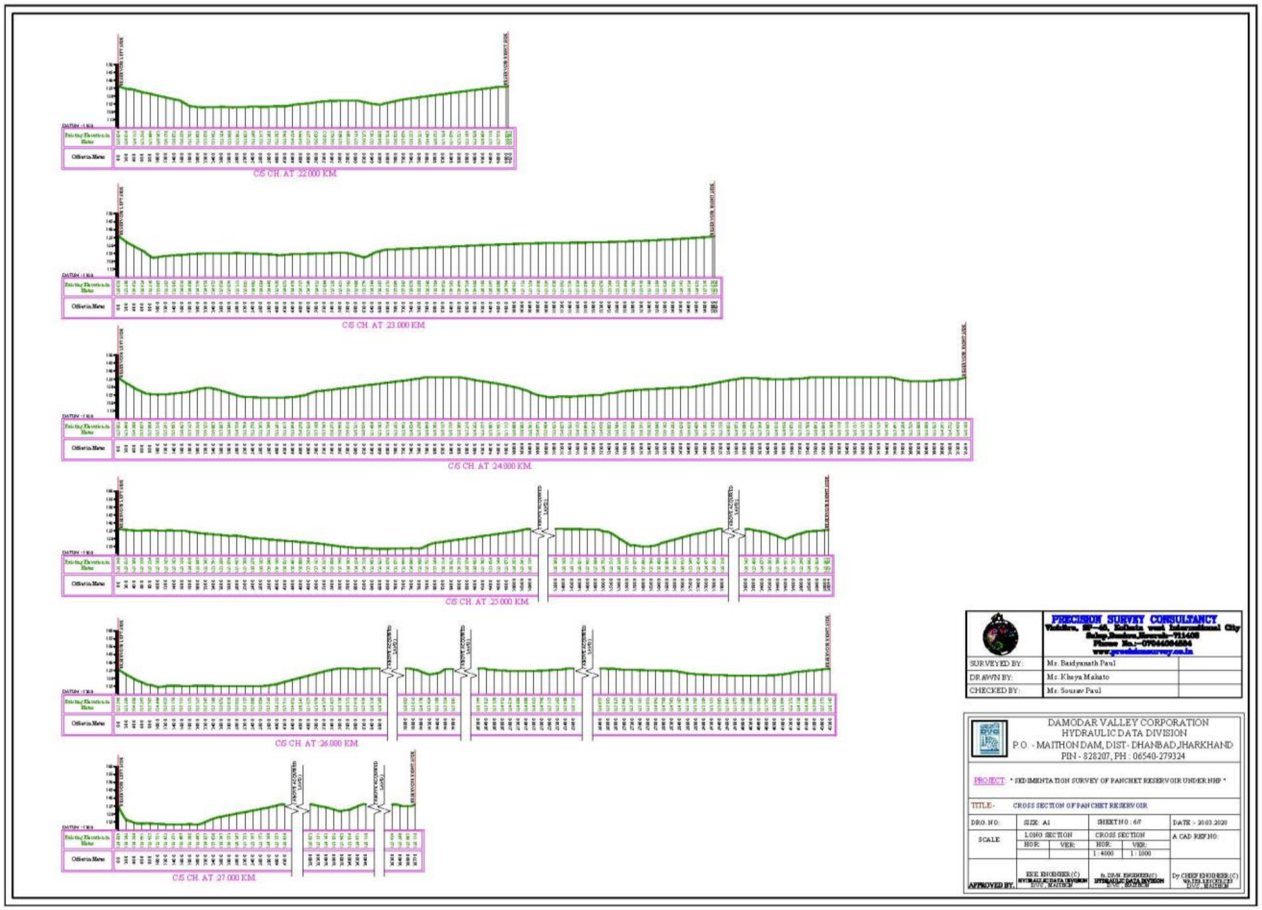
28.3 Cross Sectional Plan at Damodar River near Chainage 13.000 km to 16.000 km:-



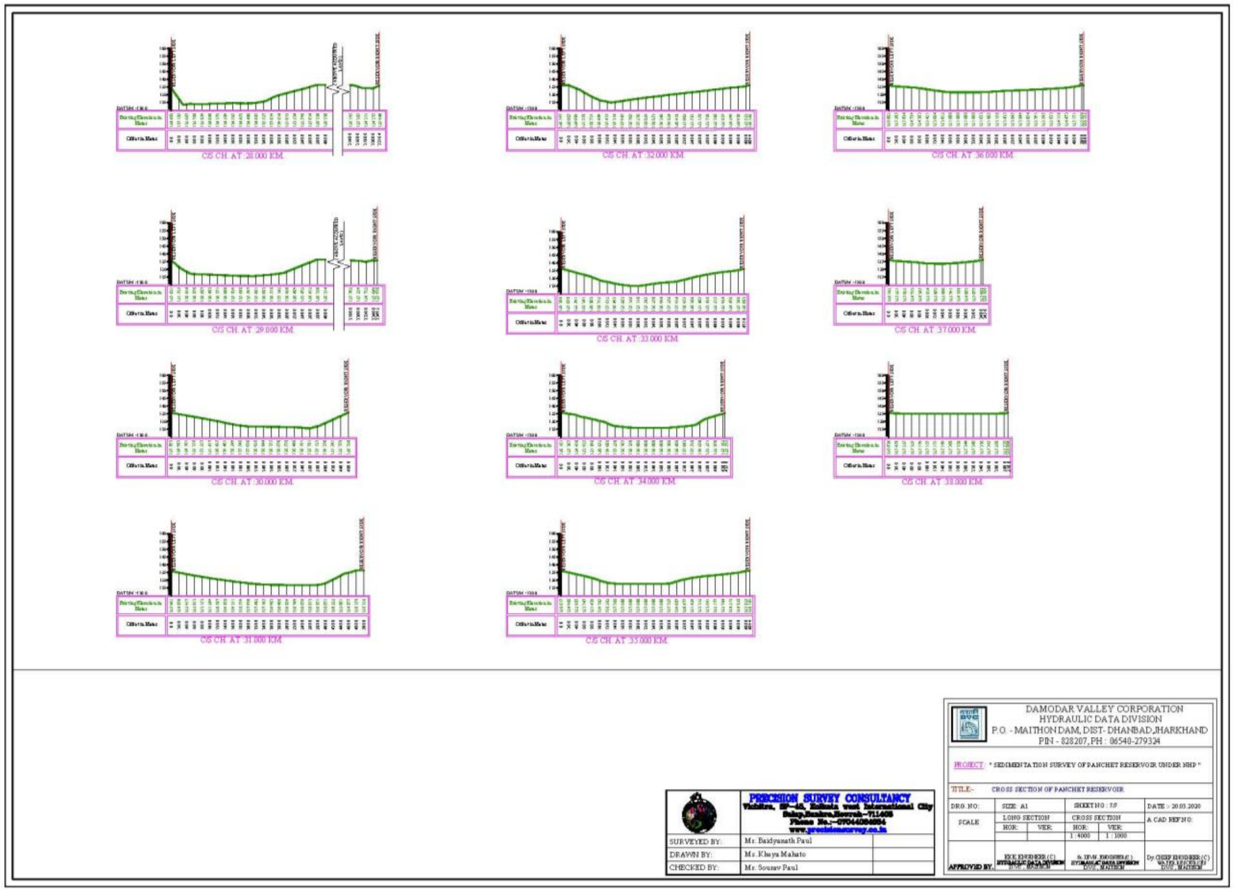
28.4 Cross Sectional Plan at Damodar River near Chainage 17.000 km to 21.000 km:-



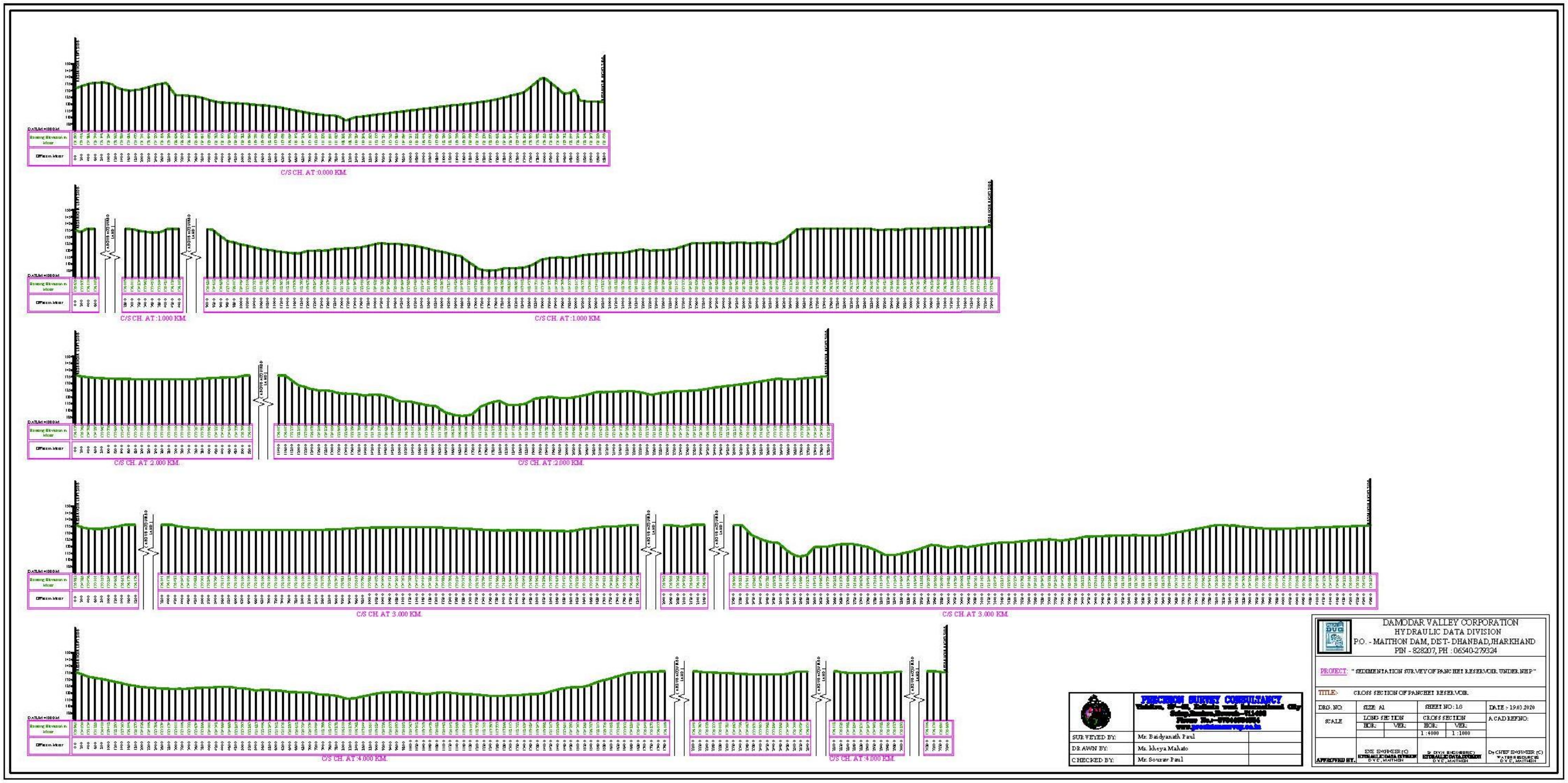
28.5 Cross Sectional Plan at Damodar River near Chainage 22.000 km to 27.000 km:-



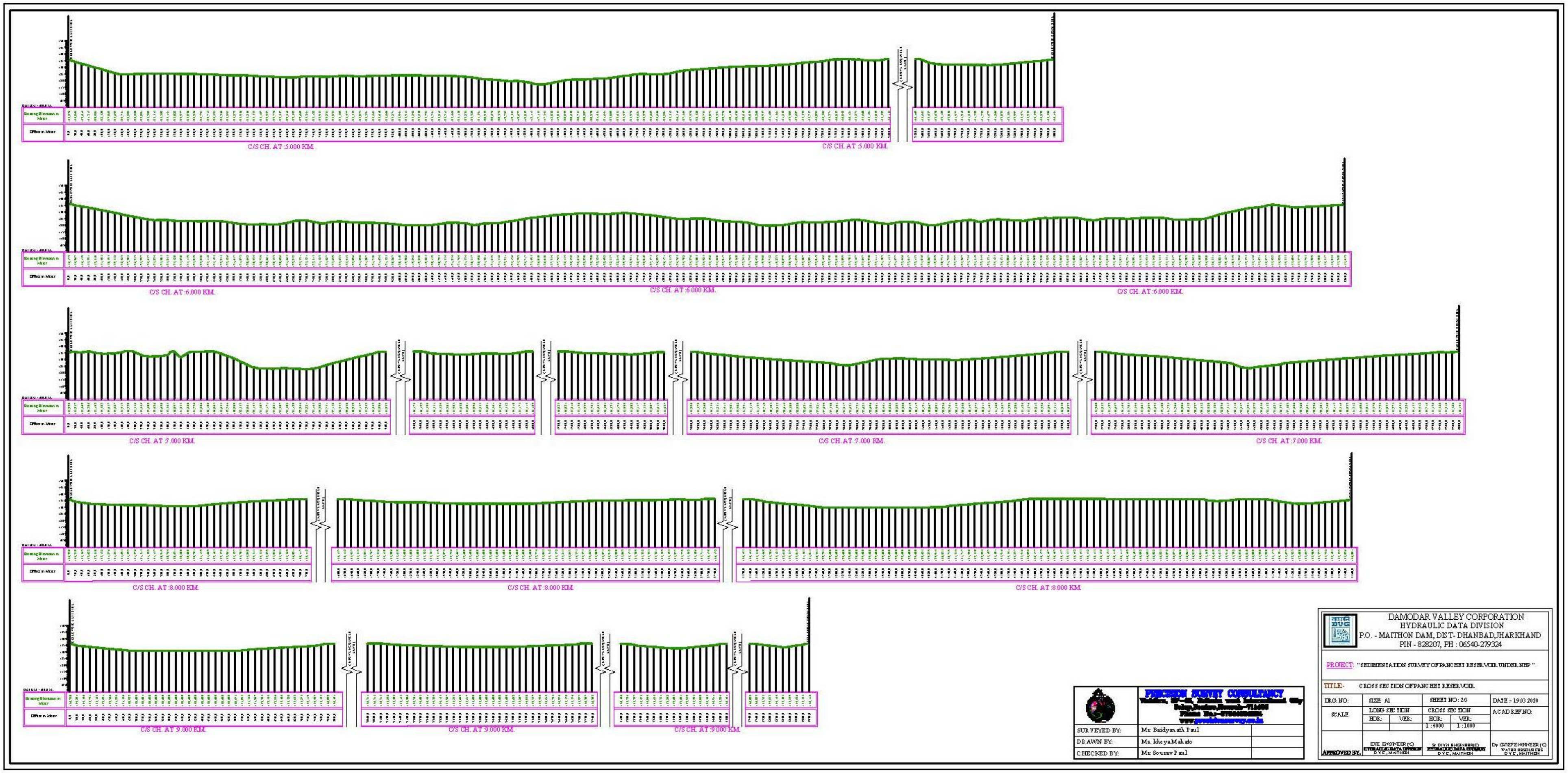
28.6 Cross Sectional Plan at Damodar River near Chainage 28.000 km to 38.000 km: -



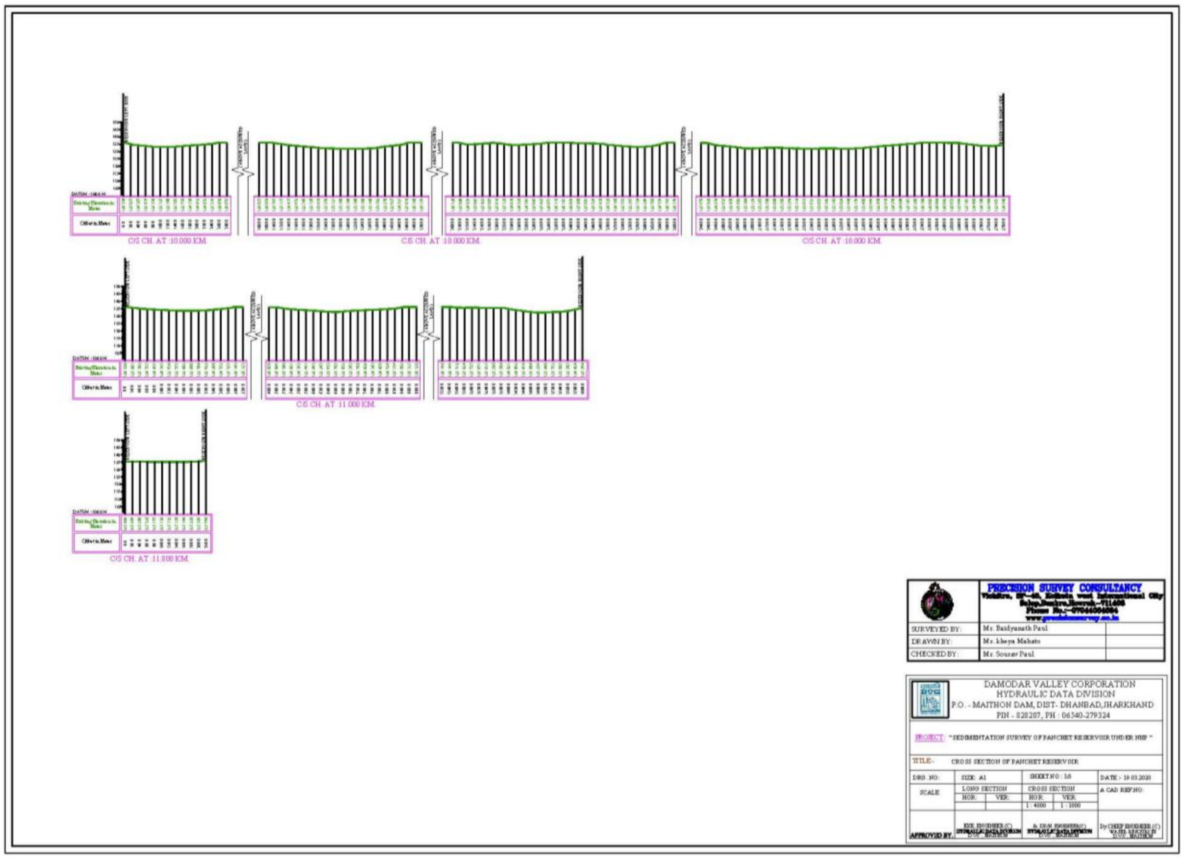
28.7 Cross Sectional Plan near Utla River near Chainage 0.000 km to 4.000 km:-



29.8 Cross Sectional Plan near Utla River near Chainage 5.000 km to 9.000 km:-

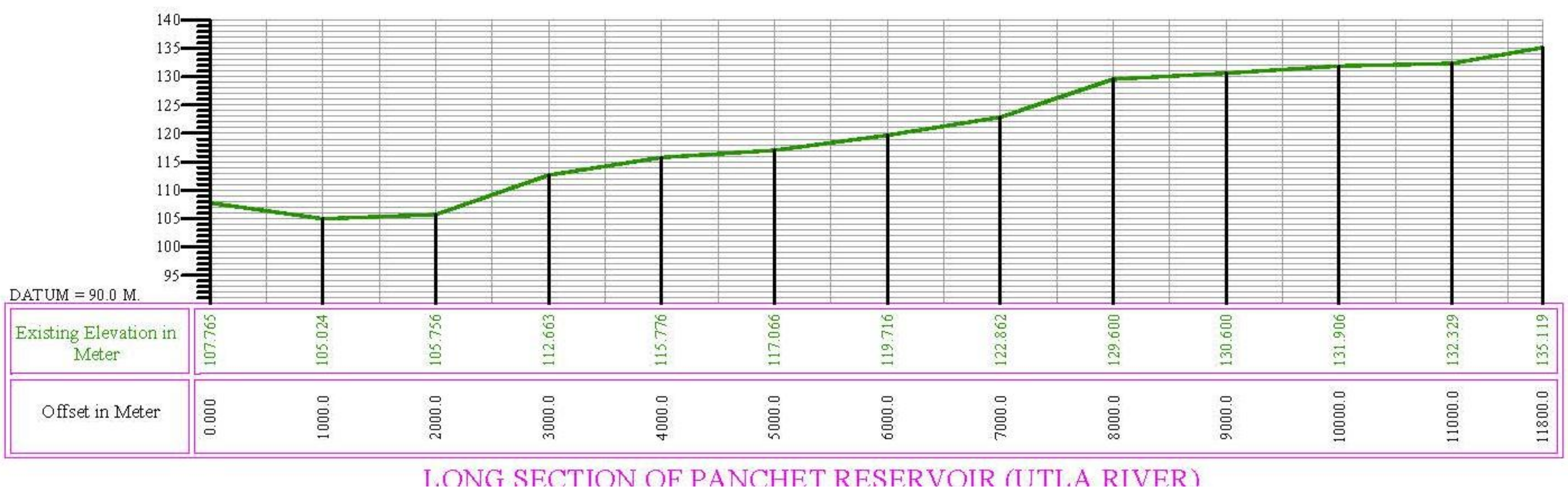


29.8.1 Cross Sectional Plan near Utla River near Chainage 10.000 km to 11.800 km:-



30.0 Long Section of Panchet Reservoir at Damodar River:-

30.1 Long Section of Panchet Reservoir at Utla River:-



CONCLUSIONS/RECOMMENDATIONS

31.0 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 4600.49 acre feet of annual deposit on the basis of 2300247.07 acre feet of monsoon flow (1961 to 2019). Taking 2100 square miles (5438.97 square km) as the net sediment producing area, the average annual deposition rate works out to 2.19 acre feet per square miles per year (1043 M3/Sq. Km/year) of the catchment area.

31.1 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 Barrages, Reservoir, canals, and river beds, (5) only four large dams (i.e., Panchet, Konar, Mithon and Tilaiya), 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 floodplain.

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 31% and 43% respectively**.
ii) **From source the most of the deposition will find near 6-8 mile reach.**

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. Removal of deposited sediment :-

The most practical means of maintaining the storage capacity are those designed to prevent accumulation of permanent deposits as the removal operations are extremely expensive, unless the material removed is usable. Therefore, the redemption of lost storage by removal should be adopted as a last resort. The removal of sediment deposit implies in general, that the deposits are sufficiently compacted or consolidated to act as a solid and, therefore, are unable to flow along with the water. The removal of sediment deposits may be accomplished by a variety of mechanical and hydraulic or methods, such as excavation, dredging, siphoning, draining, flushing, flood sluicing, and sluicing aided by such measures as hydraulic or mechanical agitation or blasting of the sediment. The excavated sediments may be suitably disposed off so that, these do not find the way again in the reservoir.

5. Excavation:-

The method involves draining most of or all the water in the basin and removing the sediment by hand or power operated shovel, dragline scraper or other mechanical means. The excavation of silt and clay which constitute most of the material in larger reservoirs is more difficult than the excavation of sand and gravel. Fine-textured sediment cannot be excavated easily from larger reservoirs unless it is relatively fluid or relatively compact.

6. Dredging :-

This involves the removal of deposits from the bottom of a reservoir and their conveyance to some other point by mechanical or hydraulic means, while water storage is being maintained.

Dredging practices are grouped as :

a) Mechanical dredging by bucket, ladder, etc;

b) Suction dredging with floating pipeline and a pump usually mounted on a barrage; and

c) Siphon dredging with a floating pipe extending over the dam or connected to an opening in the dam and usually with a pump on a barrage.

7. 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.

8. 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.

9. Sluicing with Hydraulics and Mechanical Agitation :-

Methods that stir up, break up or move deposits of a 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.

32.0 Personnel:-

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

Survey:-

1. Shri Baidyanath Pal, Surveyor

2. Shri Biswajit Samanta, Surveyor
3. Shri Rakhe hari Das, Surveyor

Checked by the Following Personnel:-

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

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

32.1 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)

Name-Bimalendu Ghosh

Designation- Senior Survey Consultant

The Institution of Surveyors (Delhi)

32.2 Certificate of Arun Roy:-

भाअजप्रा
IWAI

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:
011M1223142101	-	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

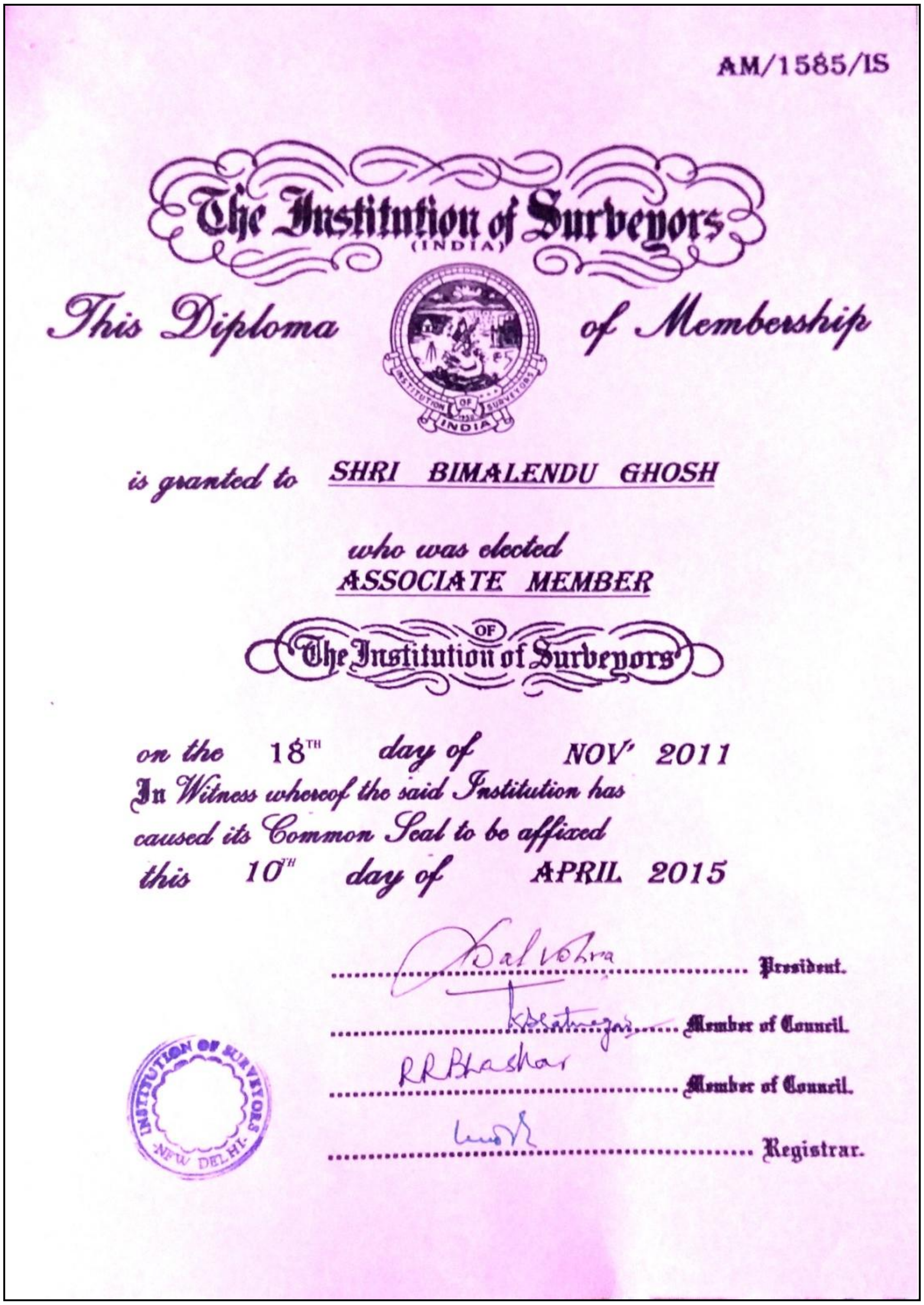
Sl.No.	Particular	Pensioner	Spouse/Family (only in Service Pension PPO)
1.	Name	Sh. Arun Roy	Smt. Disha Roy (Wife)
2.	Date of Birth	20.11.1954	09.07.1968
3.	PAN Number	ADLPR1433J	
4.	Aadhaar Number	8090 5548 6311	
5.	Telephone/Mobile Number		
6.	E-mail ID	arunroy1@yahoo.com	
7.	Pre-Revised Basic Pension/Family 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)

HYDROSOLUTIONS
RIVER RESEARCH &

.

32.3 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

Bal Vohra .... President.

.... Member of Council.

R R Bhaskar .... Member of Council.

.... Registrar.

INSTITUTION OF SURVEYORS NEW DELHI

SITE IMAGES

33.0 Site Images:-