BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

(*Not to be reproduced without the permission of BIS or used as an Indian Standard*)

भारतीय मानक मसौदा

जलाशयों की क्षमता निश्चित करना — विधियाँ
भाग 1 सामान्य आवश्यकताएँ

[IS 5477 (Part 1) *का दूसरा पुनरीक्षण*]

Draft Indian Standard

FIXING THE CAPACITIES OF RESERVOIRS — METHODS
PART 1 GENERAL REQUIREMENTS

[*Second Revision of* IS 5477 (Part 1)]

Reservoirs and Lakes Sectional Committee, WRD 10 — Last Date for Comments: **1/12/2025**

FOREWORD
(*Formal clauses of the foreword will be added later*)

A dam built across a river creates a reservoir behind it to store a part of the run-off from the catchment upstream of the dam. Run-off is stored when it is in excess of the demand. Demand of water for various purposes like irrigation, power, water supply, etc, is met from the reservoir storage during the lean periods, when demand exceeds the run-off.

Reservoir storage generally consists of three parts as follows:

a) Inactive storage including dead storage;
b) Active or conservation storage; and
c) Flood and surcharge storage.

The standard 'Fixing the Capacities of Reservoirs' consists of four parts:

IS 5477	Fixing the capacities of reservoirs – Methods
(Part 2) : 1994	Dead storage
(Part 3) : 1969	Live storage

(Part 4) : 1971 Flood storage

This standard IS 5477 (Part 1) was first published in 1969. The first revision was published in 1999 which incorporated inclusion of aspects related to engineering, geology, economic analysis, committed and future upstream uses, density currents, location of outlets, etc. Brune's curve for calculation of trap efficiency was omitted from this standard and reference was given to IS 12182: 1987 'Guidelines for determination of effects of sedimentation in planning and performance of reservoirs' which covers additional details for calculation of trap efficiency. This revision (second revision) has been brought out to bring the standard in the latest style and format of the Indian Standards. In addition, the following major changes have been incorporated:

a) Clause 4.1.2 has been modified to account for sedimentation aspects.
b) Clause 4.9 has been modified to account for GLOFs in the inflow design flood.

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 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft Indian Standard

FIXING THE CAPACITIES OF RESERVOIRS — METHODS
PART 1 GENERAL REQUIREMENTS

[*Second Revision of* IS 5477 (Part 1)]

Reservoirs and Lakes Sectional Committee, WRD 10 Last Date for Comments: **1/12/2025**

---

1 SCOPE

This standard (Part 1) deals with data and information required for the location and fixing the capacity of reservoirs, and specifies the post-construction data to be collected during the operation of the reservoirs.

2 REFERENCES

The standards given below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards.

IS No.	*Title*
IS 12182 : 2025	Determination of effects of sedimentation in planning and performance of reservoirs — Guidelines (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 12182 and the following shall apply.

3.1 Full Reservoir Level

It is the level corresponding to the storage which includes both inactive and active storages as also the flood storage, if provided for.

3.2 Sediment Yield

It is the total quantity of sediment brought in a year to a reservoir as a result of erosion in the watershed. Sediment yield is dependent on the hydro-physical conditions of the watershed. It is expressed in millimetres over unit area of the watershed/catchment per year.

3.3 Trap Efficiency

The trap efficiency of the reservoir is defined as the ratio of the total deposited sediment in the reservoir to the total sediment inflow in a year. It is expressed as a percentage of the annual sediment inflow.

3.4 Buffer Storage

The space located just above the dead storage level (DSL) up to minimum draw down level (MDDL) is termed as buffer storage. As the name implies, this zone is a buffer between the active and dead storage zones and releases from this zone are made in dry situations to cater for essential requirements only. Dead storage and buffer storage together is called inactive storage (*see* **Fig**. 1).

3.5 Dead Storage

It is the storage between the dead storage level (DSL) and the ground level. Generally this is occupied by sediment (*see* **Fig**. 1).

3.6 Surcharge Storage

Surcharge storage is the storage between the full reservoir level (FRL) and the maximum water level (MWL) of a reservoir which may be attained with the spillway surplussing at full capacity the reservoir being at FRL to start with (*see* **Fig**. 1).

3.7 Within-the-Year Storage

This term is used to denote the storage of a reservoir meant to meet the demands of a specific hydrologic year used for planning the project.

3.8 Carry-Over Storage

When the entire water stored in a reservoir is not used up in a year, the unused water is stored as carry-over storage for use in subsequent years.

3.9 Flood Control Storage

This is the storage capacity provided to attenuate the flood peak depending on its volume and downstream releasing constraints.

3.10 Field Storage

The water which is above full reservoir level (FRL) spreading towards the catchment area constitutes field storage.

3.11 Sedimentation Zones

The space occupied by the sediment in the reservoir can be divided into separate zones. A schematic diagram on sedimentation zones of reservoirs is given in **Fig**. 2.

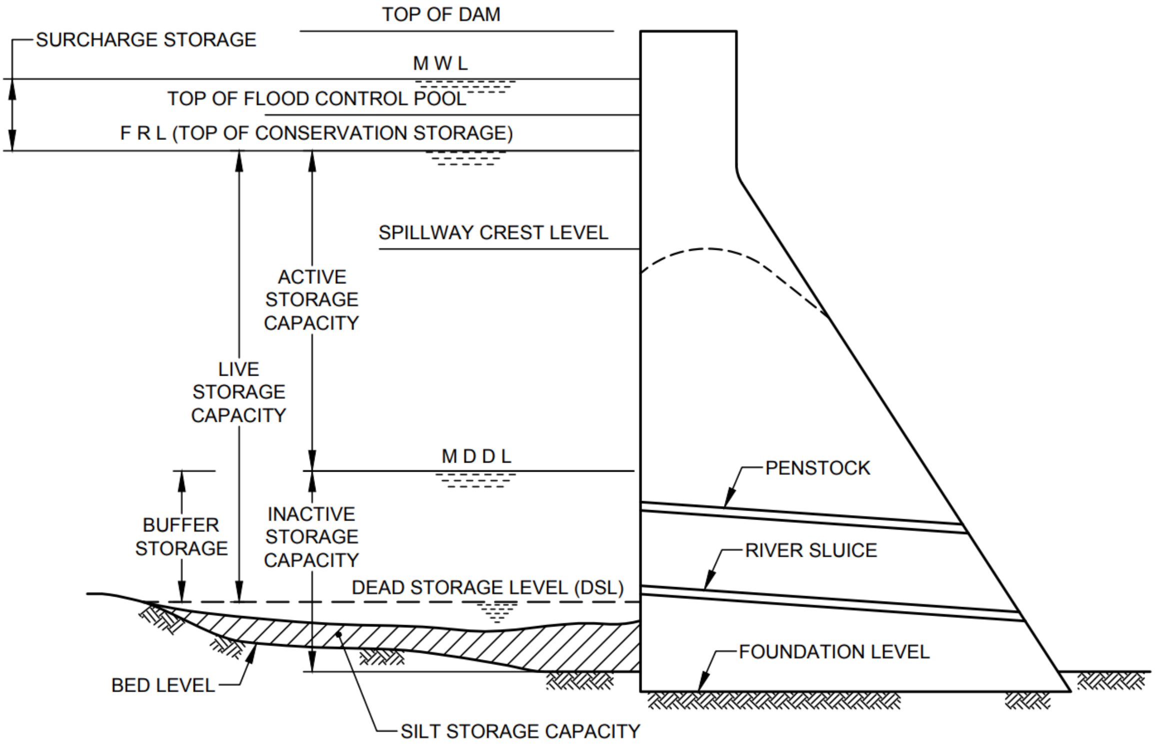

FIG. 1 SCHEMATIC DIAGRAM SHOWING STORAGE (CAPACITY) NOMENCLATURE

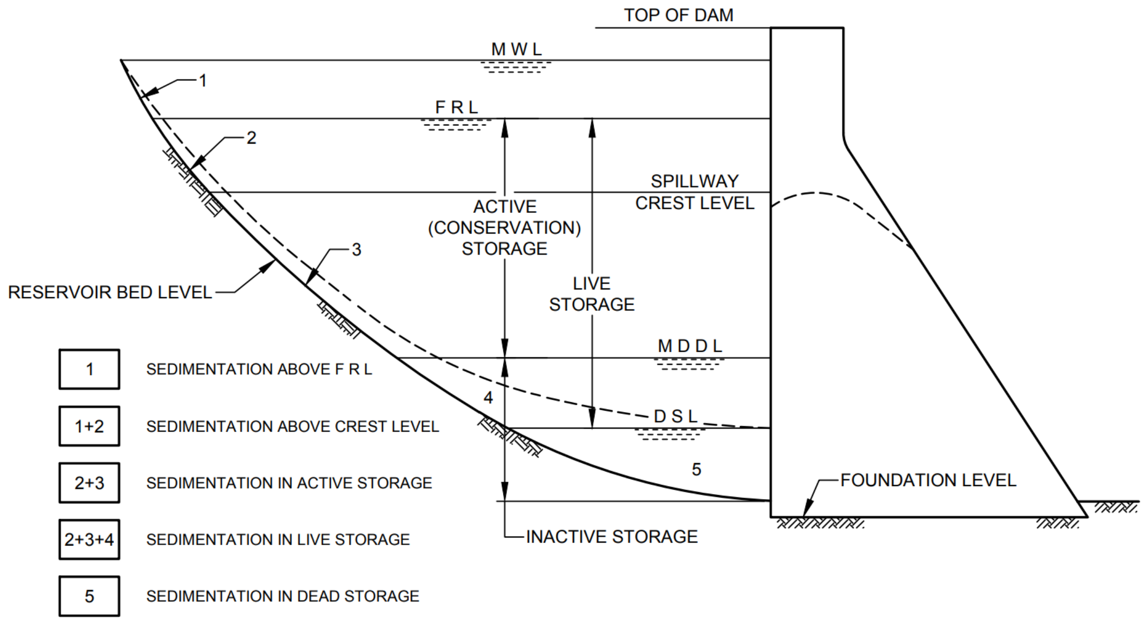

FIG. 2 SCHEMATIC DIAGRAM SHOWING ZONES OF RESERVOIR SEDIMENATION

4 GENERAL ASPECTS OF STORAGE

4.1 Inactive Storage Including Dead Storage

4.1.1 Inactive storage including dead storage pertains to storage at the lowest level up to which the reservoir can be depleted. This part of the storage is set apart at the design stage for anticipated filling, partly or fully, by sediment accumulations during the economic life of the reservoir and with sluices/outlets so located that it is not susceptible to full depletion. In case power facility is provided, it is also the storage below the minimum draw down level (MDDL).

4.1.2 Sill level of lowest outlets for any reservoir is fixed from command considerations in case of irrigation purposes and minimum draw down level on considerations of efficient turbine operation in the case of power generation purpose and for consideration for sedimentation aspects also. The lowest sill level should be kept above the new zero elevation expected after the feasible service period according to IS 12182 which is generally taken as 100 years for irrigation projects and 70 years for power projects supplying power to a grid.

4.2 Active or Conservation Storage

4.2.1 Active or conservation storage assures the supply of water from the reservoir to meet the actual demand of the project whether it is for power, irrigation, or any other demand water supply.

4.2.2 The active or conservation storage in a project should be sufficient to ensure success in demand satisfaction, say 75 percent of the simulation period for irrigation projects, whereas for power and water supply projects success rates should be 90 percent and 100 percent respectively. These percentages may be relaxed in case of projects in drought prone areas. The simulation period is the feasible service period as determined in 4.1 but in no case be less than 40 years. Storage is also provided to satisfy demands for maintaining draft for navigation and also maintaining water quality for recreation purpose as envisaged in design.

4.3 Flood and Surcharge Storage

4.3.1 In case of reservoirs having flood control as one of the purposes, a separate flood control storage is to be set apart above the storage meant for power, irrigation and water supply. Flood control storage is meant for storing flood waters above a particular return period temporarily and to attenuate discharges up to that flood magnitude to minimise effects on downstream areas from flooding. Flood and surcharge storage between the full reservoir level (FRL), and maximum water level (MWL) attainable even with full surplussing by the spillway takes care of high floods and moderates them.

4.3.2 *Flood Control Storage*

Storage space is provided in the reservoir for storing flood water temporarily in order to reduce peak discharge of a specified return period flood and to minimize flooding of downstream areas for all floods equal to or lower than the return period flood considered. In the case of reservoirs envisaging flood moderation as a purpose and having separate flood control storage, the flood storage is provided above the top of conservation pool.

4.3.3 *Surcharge Storage*

Surcharge storage is the storage between the full reservoir level (FRL) and the maximum water level (MWL) of a reservoir which may be attained with capacity exceeding the reservoir at FRL to start with. The spillway capacity has to be adequate to pass the inflow design flood making moderation possible with surcharge storage.

5 DATA AND INFORMATION REQUIRED

The following factors govern the design storage capacity of reservoirs:

a) Precipitation, run-off and sedimentation records available in the region;
b) Erodibility of catchment upstream of reservoir for estimating sediment yield;
c) Area capacity curves at the proposed location;
d) Trap efficiency;
e) Losses in the reservoir;
f) Water demand from the reservoir for different uses;
g) Committed and future upstream uses;
h) Criteria for assessing the success of the project;
j) Density current aspects and location of outlets;
k) Data required for economic analysis; and
m) Data on engineering and geological aspects.

5.1 Precipitation, Run-Off and Sedimentation Record

The network of precipitation and discharge measuring stations in the catchment upstream and near the project needs to be considered to assess the capacity of the same to adequately sample both spatially and temporally the precipitation and the stream flows.

The measurement procedures and gap filling procedures in respect of missing data as also any rating tables or curves need to be critically examined so that they are according to guidelines of World Meteorological Organization (WMO). Long-term data has to be checked for internal consistency between rainfall and discharges, as also between data sets by double mass analysis to highlight any changes in the test data for detection of any long term trends as also for stationarity. It is only after such testing that the data should be used for generating the long term inflows of water (volumes in 10 days, 15 days, monthly or yearly inflow series) into the reservoir.

Sufficiently long term precipitation and run-off records are required for preparing the water inflow series. For working out the catchment average sediment yield, long-term data of sediment measurement records from existing reservoirs are essential. These are pre-requisites for fixing the storage capacity of reservoirs.

5.1.1 If long term run-off records are not available, concurrent rainfall and run-off data may be used to convert long term rainfall data (which is generally available in many cases) into long-term run-off series adopting appropriate statistical/conceptual models. In some cases regression analysis may also be resorted to for data extension.

5.1.2 *Estimation of Average Sediment Yield from the Catchment Area Above the Reservoir*

It is usually attempted using river sediment observation data or more commonly from the experience of sedimentation of existing reservoirs with similar characteristics. Where observations of stage/flow data is available for only short periods, these have to be suitably extended with the help of longer data on rainfall to estimate as far as possible sampling errors due to scanty records. Sediment discharge rating curve may also be prepared from hydraulic considerations using any of the standard sediment load formulae, such as, Modified Einstein's procedure, Young's stream power, etc. It is also necessary to account for the bed load which may not have been measured. Bed load measurement is preferable and when it is not possible, it is often estimated as a percentage generally ranging from 5 to 20 percent of the suspended sediment load. However, actual measurement of bed load 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 of the reservoir and the likely unit weight of sediment deposits, along with time average over the period selected. The trap efficiency would depend on the capacity inflow ratio but would also vary with the locations of controlling outlets and reservoir operating procedures. Computations of reservoir trap efficiency may be made using the trap efficiency curves such as those developed by Brune and by Churchill.

5.2 Elevation Area Capacity Curves

Topographic survey of the reservoir area should form the basis for obtaining these curves, which are respectively the plots of elevation of the reservoir versus surface area and elevation of the reservoir versus volume. For preliminary studies, in case suitable topographic map with contours, say at intervals less than 2.5 m is not available, stream profile and valley cross sections taken at suitable intervals may form the basis for computing the volume. Aerial survey may also be adopted when facilities are available.

5.3 Trap Efficiency

Trap efficiency of reservoir, over a period, is the ratio of total deposited sediment to the total sediment inflow. Fig. 1 and 2 given in Annex A of IS 12182 cover relationship between sedimentation index of the reservoir and percentage of incoming sediment and these curves may be used for calculation of trap efficiency.

5.4 Losses in Reservoir

Water losses mainly of evaporation and seepage occur under pre-project conditions and are reflected in the stream flow records used for estimating water yield. The construction of new reservoirs and canals is often accompanied by additional evaporation and infiltration. Estimation of these losses may be based on measurements at existing reservoirs and canals. The measured inflows and outflows and the rate of change of storage are balanced by computed total loss rate.

The depth of water evaporated from the reservoir surface may vary from about 400 mm in cool and humid climate to more than 2500 mm in hot and arid regions. Therefore, evaporation is an important consideration in many projects and deserves careful attention. Various methods like water budget method, energy budget method, etc may be applied for estimating the evaporation from reservoir. However, to be more accurate, evaporation from reservoir is estimated by using data from pan-evaporimeters or pans exposed to atmosphere with or without meshing in or near the reservoir site and suitably adjusted.

Seepage losses from reservoirs and irrigation canals may be significant if these facilities are located in an area underlain by permeable strata. Avoidance in full or in part of seepage losses may be very expensive and technical difficulties involved may render a project unfeasible. These are generally covered under the conveyance losses in canals projected on the demand side of simulation studies.

5.5 Demand, Supply and Storage

The demand should be compared with supplies available year by year. If the demand is limited and less than the available run-off, storage may be fixed to cater to that particular demand which is in excess of the run-off. The rough and ready method is the mass curve method for initial sizing.

Even while doing the above exercise, water use data are needed to assess the impact of human activities on the natural hydrological cycle. Sufficient water use information would assist in implementing water supply projects, namely, evaluating the effectiveness of options for demand management and in resolving problems inherent in competing uses of water, shortages caused by excessive withdrawal, etc. Water demands existing prior to construction of a water resource project should be considered in the design of project

as failure to do so may result in losses apart from legal and social problems at the operation stage.

5.6 Committed and Future Upstream Uses

The reservoir to be planned should serve not only the present day requirements but also the anticipated future needs. The social, economic and technological developments may bring in considerable difference in the future needs/growth rate as compared to the present day need/growth rate. Committed and upstream future uses should also be assessed in the same perspective.

5.7 Criteria for Assessing the Success of the Project

Water Resources Projects are to be designed for achieving specified success. Irrigation projects are to be successful for 75 percent period of simulation. Likewise power projects and water supply projects are to be successful for 90 percent and nearly 100 percent period of simulation respectively.

5.8 Density Current Aspects and Location of Outlets

Density current is defined as the gravitational flow of one fluid under another having slightly different density. The water stored in reservoir is generally free from sediment but the inflow during floods is generally muddy. There are, thus two layers having different densities resulting in the formation of density currents. The density currents separate the water from the clearer water and make the turbid water flow along the river bottom. The reservoir sedimentation rate can be reduced by venting the density currents by properly locating and operating the outlets and sluice ways.

5.9 Data Required for Economic Analysis

Economic Analysis is carried out to indicate the economic desirability of the project. ‘benefit cost ratio, Net benefit, internal rate of return are the parameters in this direction. It is desirable to have the benefit cost ratio in the case of irrigation projects and flood mitigation projects to be above 1.5 and 1.1 respectively. For economical analysis cost function of the reservoir, water utilisation for irrigation, power, water supply etc, are to be determined. Similarly, operation and maintenance costs for projects are to be assessed. Benefit functions for reservoir and water utilisation for irrigation, power, water supply etc, are also to be determined judiciously. Cost-benefit functions are obtained as continuous functions using variable cost/benefit against reservoir storage/net utilisation of water and from benefit functions the benefit from unit utilisation of water can be determined. The spillway capacity has to be adequate to pass the inflow design flood duly accounting for the glacial lake outburst flood (GLOF) using moderation possible with surcharge storage or any other unobstructed capacity in the reservoir without endangering the structural safety as provided elsewhere in the standard. In the event of the inflow design flood passing the reservoir, the design needs to ensure that dam break situation does not develop or induce incremental damage downstream.

5.10 Data on Engineering and Geological Aspects

Under engineering and geological aspects, the following items of work shall invariably be carried out:

a) Engineering

1) Preliminary surveys to assess the catchment and reservoir;
2) Control surveys like topographical surveys;
3) Location of nearest Railway lines/Roads and possible access; and
4) Detailed survey for making area capacity curves for use in reservoir flood routing.

b) Geology

1) General formations and foundation suitability;
2) Factors relating to reservoir particularly with reference to water tightness;
3) Contributory springs;
4) Deleterious mineral and salt deposits; and
5) Location of quarry sites, etc.

6 POST CONSTRUCTION DATA

After the reservoir comes into operation information on inflow, outflow, periodic sedimentation and capacity surveys, seepage losses and wave heights, reservoir levels and evaporation losses should be collected and recorded as an extension to the available data used for design. The same may be made use of as a basis for improved reservoir operation.