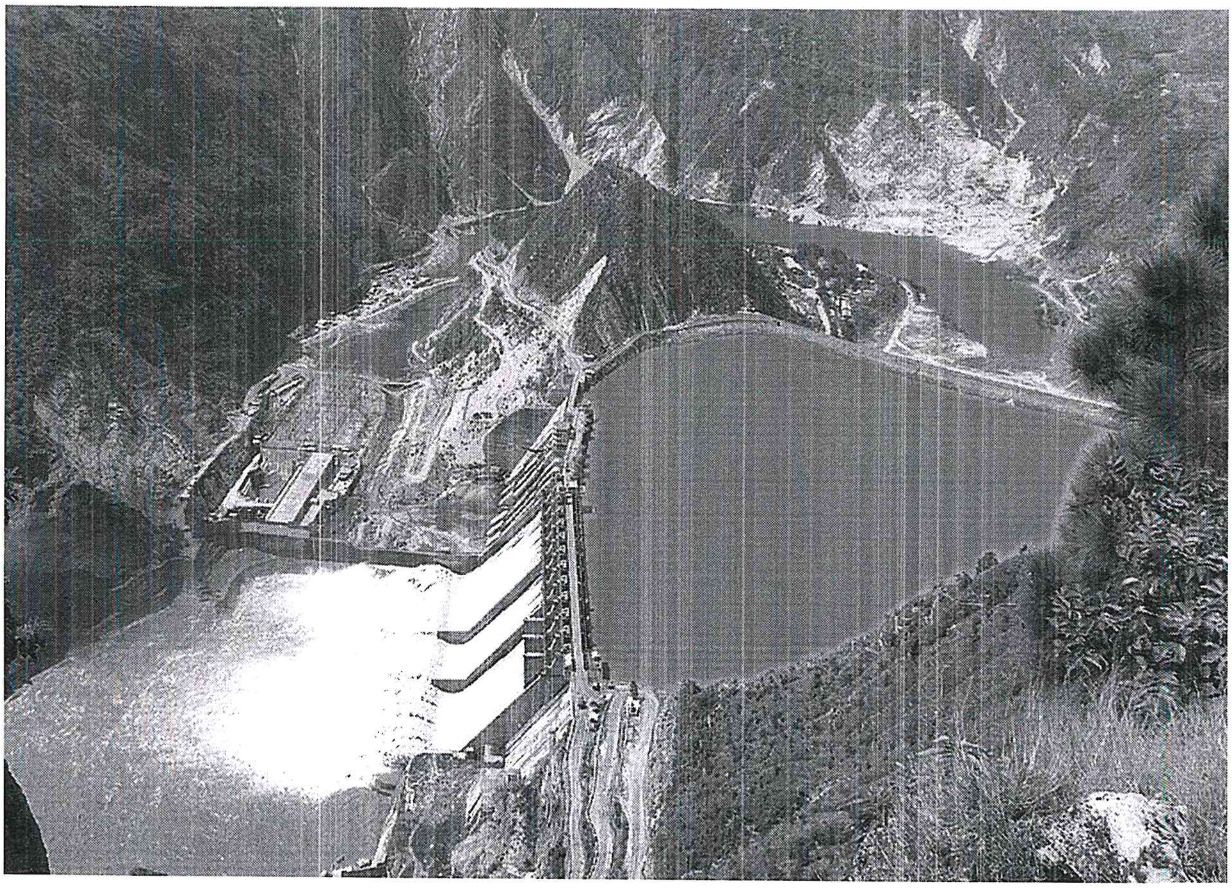
MINISTRY OF POWER

CENTRAL ELECTRICITY AUTHORITY

STANDARD OPERATING PROCEDURE FOR MANAGEMENT OF SILT IN HYDRO ELECTRIC PROJECT



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1. Introduction

1.1 Sedimentation embodies the process of erosion, transportation, deposition and the compaction of sediments. Erosion and sedimentation are part of the natural evolution of landscape. Most alluvial rivers have experienced increased sedimentation or bed load deficit, both due to natural processes and series of human interventions in the river catchment or on river itself. Rapid urbanization in flood plains, encroachment of river beds, changes due to human activity and deforestation in catchment area of rivers are causing sedimentation in rivers. Problem of sedimentation is somewhat moderated by trapping sediment in reservoirs, dams.

1.2 Dam construction creates an impounded river reach characterized by extremely low flow velocities and sediment trapping. The impounded reach will accumulate sediment and lose storage capacity. Declining storage reduces and eventually eliminates the capacity for flow regulation and with it all water supply and flood control benefits, besides benefits that depend on releases from storage such as, hydropower, navigation, recreation and environmental.

1.3 Common practices carried out by river management agencies demonstrate that sediment management has rarely been based upon best practices developed on scientific knowledge. For these reasons, a different approach to sediment management is desirable, incorporating: (i) knowledge of management of sediments at the basin scale; (ii) a wider application of available scientific knowledge.

1.4 Further, water with high silt content & abrasive in nature, if allowed to pass through underwater components of hydro power stations including turbines, cooling water system, etc., would not only reduce the operating useful life of such equipment & component but also reduce operational efficiency and regularly cause high recurring cost on maintenance of these items.

1.5 The impact of silt has been assuming greater proportions. The loss in generation has been estimated as around 1% of the overall generation. Apart from loss in MU generation, the shutdown of hydro power stations to avoid operating under such conditions also leads to loss of peaking (MW) availability. It also indirectly impact the power grid and involves issues of grid security in handling such operational matters arising out of big capacity at single location or in cascade operation going out of operation.

1.6 As such, need has been felt to have some guidelines on the subject of management of silt in Hydro Electric Projects, which could serve as a guide to the project authority in planning, designing and operating their project in an efficient and optimal way, thereby maximising benefits to the public at large. These guidelines would serve all hydro generating utilities in framing minimum common approach to silt mitigation measures besides framing of additional measures by utilities in projects being unique by virtue of their project specific features including geographical/ geological particulars, design considerations, etc. as well as their operational experience.

2. Approach to the Sediment Management of Rivers

2.1 Storage Reservoirs - The reservoirs are built to store water either on annual or carry over basis. Incidentally, these reservoir act as settling tanks for the sediment and trap the sediment carried by the river. Therefore, the sediment concentration of the water released from the reservoir is effectively reduced depending on the size of reservoir.

Run-of-the River Reservoirs - These reservoirs, with live storage limited from few hours to few days, are built specifically for hydro power generation. These reservoirs have insignificant reservoir capacity compared to the average annual inflow, thus the trap efficiency of the sediment in these reservoirs is very limited.

2.2 The river stream has to complete its geo-morphological cycles from youth, maturity to old age. A stable river is able to constantly transport the flow of sediments produced by watershed such that its dimensions (width and depth) pattern and vertical profile are maintained without aggrading (building up) or degrading (scouring down).

a) **Youthful stage** - In this stage, the rivers have steep slopes and high sediment transport capacity. In this stage, the following sediments management practices may be adopted for controlling the silt in the river:-

i) **Catchment Area Treatment** - Catchment Area Treatment and Watershed Development works along with good agricultural practices and river bank protection/anti-erosion works are necessary to reduce silt inflow into the river system and must be undertaken in a comprehensive way. Catchment area treatment on watershed approach plays an important role in minimizing sedimentation. Watershed management programme needs to be integrated with river basin management programme appropriately.

ii) **Regrading & Check dams** - Regrading of river bed slope and construction of check dams may be suitably adopted for management of degradation of river beds as per techno-economic feasibility.

iii) **Controlled construction activities** of roads and houses also reduces the silt intake in hilly areas.

iv) **Prevention of Occurrence of landslides/ landslips** in hilly areas especially with heavy rainfall need to be controlled by proper slope stability measures.

b) **Maturity Stage**- In this stage, the river enters and flows in plains, meandering mostly on bed of fine sand, has wide riverbed and flood plain. Most importantly, modified through human interventions in terms of huge quantities of water diversion/abstraction and subjected to high degree of pollutant loads from domestic, industrial and agricultural activities. In this stage, following sediments management practices could be adopted for control of silt in the river:-

i) **River training works such as bank protection, spurs etc.** -River training works are used to control the erosion of river banks. Erosion control of riverbank reduces the sediments intake in river

ii) **Submerged Vanes & Bundling** - Theses methods may be adopted for management of localized aggradations within the river course as per techno-economic feasibility.

iii) **Sand Mining** - In this stage, sand is deposited in the river. If these are mined at this stage and used for construction purpose, then a major portion of sediment can be reduced.

c) **Old Stage** - In this stage, the river experiences considerable changes in the sediment transport and deposition. The delta formation occurs generally due to heavy siltation, which leads to drainage congestion. Generally, the mouth of river gets choked, causing wide spread flooding, and also resulting in frequent changes in the channel path/ delta formation.

d) **Desiltation** - Desilting using sluicing & flushing and dredging operations are part of Desiltation process done near water resources infrastructure and which prove to be very effective in increasing their serviceability.

Dredging / desilting/ mining close to riverbanks, however, has a high potential to adversely impact the stability of those banks, especially when dredging/ de-silting/ mining occurs near the outside of sharp river bends. Bank erosion induced by such dredging can result in the loss of land, damages to man-made structures, and adverse impact to environmental resources. Therefore, necessary restrictions need to be imposed to limit the potential for dredging/ de-silting/ mining induced local bed degradation which adversely impact the river bank stability. Also, mechanical desilting (i.e. dredging) in large reservoirs may not be techno-economically feasible. However, there exist some locations such as congestion at the mouth of tidal rivers, confluence points etc. which could be tackled by dredging after thorough examination. Dredging works may be carried out in the areas to maintain the flow continuity and sediments transportation to sea. For navigation purpose also, the river reaches in the waterway path can be dredged, to have minimum draft for plying vessels. Dredging also improves the hydraulic efficiency if done near outlets and intakes. On the other hand, unsystematic dredging may have effects of banks destabilisation.

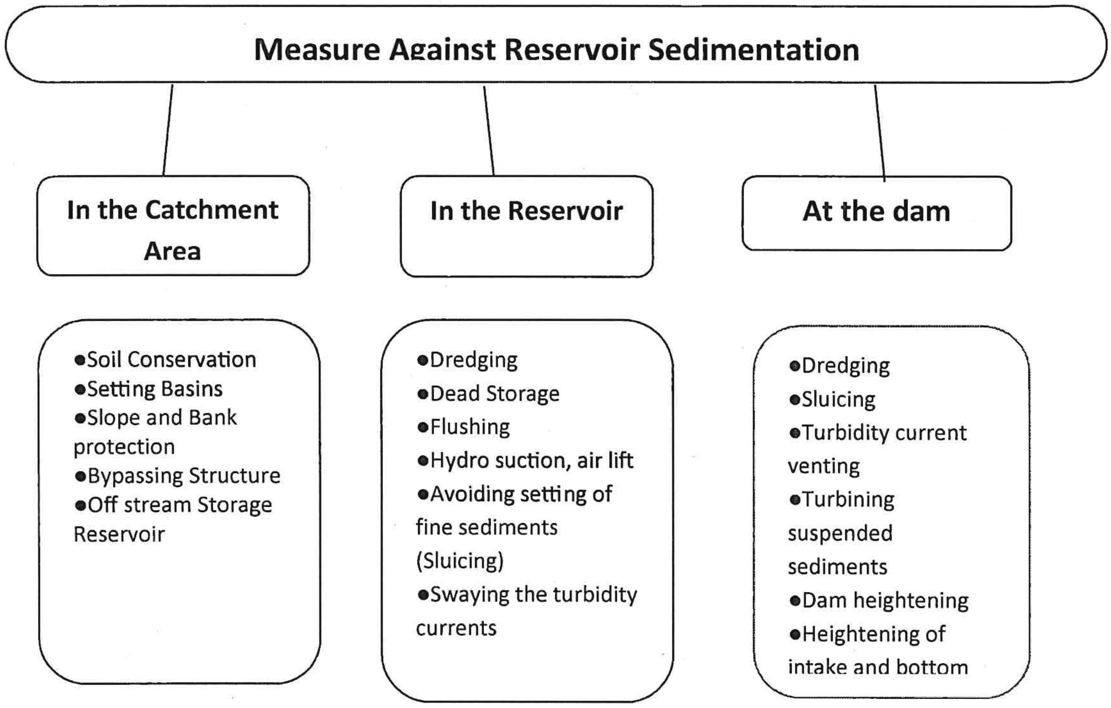
Sediment pass-through, also known as sluicing, is another way of abating sediment deposition in Run-of-the-River and small Storage projects. For this method, the reservoir level is drawn down during the flood season and allowed to flow through the sluice gates to maintain the incoming sediment in suspension. Drawdown flushing, is also one of the method for removing sediment deposition during flood season Run-of-the-River and small Storage projects. Drawdown flushing is done at the reservoir level generally for the sediments that are not fine, whereas sluicing is done for fine sediments.

It is necessary to appreciate that the desilting process does not always lead to the reduction of flood levels as the levels in the river are essentially controlled by the hydraulic conditions obtained at the cross sections forming upstream and downstream boundaries of the reach. The lowering of the bed level within the reach may not have influence on them consequently leading back to drainage problems within the season or within a few years.

e) Diverting of clear water into reservoir while selectively excluding sediment laden flood water flows and bypassing the sediment laden flood flows around an on-stream reservoir by constructing sediment bypass structure viz, flood bypass channel or bypass tunnel etc. has been adopted in some of the projects in countries like Japan and Switzerland etc. for bypassing heavily sediment laden flows which could be used for warping. On rivers with high sediment loads, diversions to off-channel reservoirs located on tributaries can be used. Canals or tunnels with water diversion under gravity can also be used. This, however, involves considerable construction cost and thus, need to be studied for implementation on project to project basis.

3. Reservoir Sedimentation Management

The measures that can be adopted for reservoir sediment management are indicated in Figure below-



4. Management of Silt - Planning and Design Stage Considerations

4.1 CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations shall be complied by the project authority.

4.2 For estimating the average sediment load from the catchment, long-term silt measurement data is essential which pre-requisites for fixing the reservoir levels and corresponding storage capacity such as Active Storage Capacity, Live Storage Capacity, Dead Storage etc. in case of reservoir based projects.

4.3 In case of ROR and canal-hydel projects, necessary arrangements are normally provided for exclusion of sediments larger than a particular size (usually 0.2mm) from the water entering into turbines. In such projects, when silt load is very heavy, sediment exclusion should be done by sediment excluders and ejectors, which form part of the head works in the river.

At present, devices like sediments excluders and extractors are designed using thumb rules and model studies which give only qualitative information. As a result, even though some excluders and extractors are working satisfactorily, the performance of others is unsatisfactory. Hence, there is need for rationalizing their design procedures taking into account the theory of sediment transport.

Desilting Chambers, also known as Silting Tanks, Settling Basins, Sediment Traps, Decantation Chambers should be used for removing sediments larger than the required size, which enter into the water conductor system wherever, the silt issues are envisaged during operation of the project. Further, desilting chambers need to be made more effective by automatic operational flushing valve by placing load sensors etc.

4.4 The chemical analysis of water and silt data including the petrographic analysis should be taken into consideration while designing the turbine, main inlet valve and other auxiliary equipment susceptible to abrasive effects of silt.

4.5 Gates at desilting arrangements require appropriate features suitable for exclusion of silt and control of discharges under high heads. These gates require sealing and bearing arrangements such that constant flow of silt loaded water has no long term detrimental effects on the gate components. These gates are quite often of small size and are required to be operated under partial open conditions. Due to heavy silt load, these gates require frequent operation.

In view of the above, hydraulic hoists for the operation of various gates in power station including desilting chambers should be encouraged, wherever possible since drum hoists are often found inconvenient and modern installations adopt hydraulically operated gates for maintaining partial operation.

4.6 The need for installation of sediment removal system at hydro projects using a Hydro Suction System could be envisaged/ suitably explored at planning and design stage. The system allows sediment dredging in reservoir by hydro-suction without input of power of any kind and utilises excess water during monsoon season, so no water is lost for production.

4.7 The possibility of providing low level sluices should mandatory be explored in the new projects since it is an effective solution for carrying out flushing of reservoir in run-of-the-river projects.

4.8 In case of the projects planned in the silt-affected areas, provision for providing blank panels at the intake crest level should be made to restrict silt ingress in water conductor system.

5. Management of Silt - Operational Stage Considerations

5.1 Every hydroelectric project is a unique identity and has different set of problems. Generation utilities should prepare project specific guidelines and standard operating procedures for management of sediments for each of the project in operation.

5.2 The impact of sediment on the hydroelectric project needs to be assessed in a structured format. All costs associated on account of sediment management be captured by generation utilities for each power plant in order to quantify the losses due to sediments.

Each power producer should assess the loss of efficiency of machines due to sedimentation and should quantify the generation as well as water loss on monthly basis during the monsoon and seasonal basis during non-monsoon period.

5.3 Wherever, hydroelectric projects having diversion structure with small storage capacity or projects where live storage capacity has been reduced considerably due to sedimentation, utilities should prepare detailed instructions for carrying out flushing operations during monsoon season to prolong the useful life of the project and for its desired performance.

5.4 To minimize effect of damage to underwater parts of HE station due to high silt content in the river water, suitable materials, protective hard coating (i.e. Tungsten Carbide) by High Velocity Oxy Flame (HVOF) spray method or any other state of the art technology should be employed to resist silt abrasion, wherever required, as per the site conditions.

The abrasion resistant coating on the underwater parts of turbine, often, gets eroded due to water silt content of abrasive nature during the course of operation. / As such, this coating needs to be reapplied in case it is found eroded during visual inspection or according to established maintenance practice of the utility based on operational experience.

5.5 Sediment rating curves, discharge v/s suspended sediment load, should be prepared for every medium and major hydroelectric project on monthly basis for the monsoon season. Rating curves may also be prepared for non-monsoon period.

Based on the above and the operational experience of the developer, plant should be shut down if the silt content measurement in water upstream of power house increases beyond pre-defined limit of silt content in the river which is for example 5000 ppm in case of Nathpa Jhakri.

Efforts should also be made by the utility for forecasting of the flows in the upstream for planning in advance of the operational measures in the eventuality of the shutdown of the station due to high level of silt.

5.6 In order to reduce siltation of live storage capacity in case of run-of-the-river schemes or projects having small storage capacities, operation of reservoirs at/ near MDDL during monsoon/ high flow periods, while discharges are more than the design discharge, could be considered. This would especially in respect of the project experiencing large inflows of silt ensure sediment free environment in front of power intake as well as sediment balance between upstream and downstream of dam/barrage is maintained and thus natural river regime remains close to original profile.

5.7 For projects in cascade lying in close vicinity of each other, flushing may be carried out to the extent possible in tandem so that the sediment flushed out from the upstream reservoir are not allowed to settle in the downstream reservoir. A co-ordinated and synchronized silt flushing approach should be studied based on river slope and its sediment carrying capacity and the flushing/guildlines need to be prepared for the project accordingly. The last reservoir flushing shall be carried out at the end of high flow seasons with coordination of upstream project to avoid any accumulation of silt in the reservoir so that it does not affect the performance of the machines during the balance month of entire lean season.

5.8 Depending upon type and size of deposited sediments in the reservoir and tributaries meeting the river/reservoir, dredging would be carried out in the following manner:

During lean season, wherever feasible, to maintain the flow continuity and sediments transportation to sea. Each project proponent would explore possibility of allowing dredging of deposited sand and aggregates, either free of cost or on payment of royalty etc. in consultation with the State Govt. However, it need to be ensured that original river bed and flow course of the river and banks of the reservoir are not excavated during the removal process of such deposits. Statutory requirements for such operations, as specified by MOEF, Ministry of Mines, MOWR etc., should, however, be kept into consideration.

5.9 For effective operation of the Desilting chambers in existing stations, the possibility for automation of the operation of flushing valves, depending upon sediments deposition inside the desilting chambers by placing the load sensors, should be examined by the utilities, if required, which minimise choking of the desilting chambers and would also optimise water requirement for flushing operations. The frequency of the operation of the desilting chamber valves would, however, depend on the incoming sediment load during the monsoon and non-monsoon period and need to be estimated by the utility based on their operational experience.

5.10 Wherever possible, efforts would be made for real-time coordination among different hydro generating utilities, in order to have effective regulation and to supplement the peak generation from projects having diurnal storage or large volume storage especially during the period of closure of plant(s) due to heavy silt load.

5.11 Wherever possible and required, provision for providing blank panels at the intake crest level be made in the existing projects.

5.12 Hydrographic survey of the reservoir should be carried out every year at fixed locations, which shall permanently be marked along the reservoir length by constructing concrete pillars duly marked with reach lengths. Power utilities should carry out systematic and quantitative budgeting of sediments by taking into account, inflow sediment load, sediments deposited in the reservoir, flushing of sediments, dredging of sediments and sediments passing through the turbines

5.13 For effective management of sediments, feasibility of lowering of spillway crest and converting them into low level sluices, in the existing dams, by cutting body of the dam or any modifications by suitable techniques (wire-line cutting technology etc.) may be explored on case-to-case basis.

5.14 The effectiveness of Catchment Area Treatment Plans need to be assessed from time-to-time by the generating utility and requisite works identified to restore the old treatment works as well as new ones should be taken up on priority to reduce the sediment yield.

Efforts should be made to reduce the sediment yield from catchment area of the project. Generation utilities need to follow the methodology of catchment area treatment, including construction of small check dams, plantation/

forestation along river embankments to check soil erosion, embankment protection works to check landslide debris at identified/ prone weaker geological zones, etc. The effectiveness of these treatment plans be assessed from time to time.

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