F. No. 3-70/2020-IA.III [141127]
Government of India
Ministry of Environment, Forest and Climate Change
(IA Division)

Indira Paryavaran Bhawan
Jor Bagh Road, Aliganj,
New Delhi - 110003

Dated: 12th July, 2023

OFFICE MEMORANDUM

Subject: Clarification on the exemption from EC provided vide Notification S.O. 1224 (E) dated 28.03.2020 for dredging and de-silting of dams, reservoirs, weirs, barrages, river and canals for the purpose of their maintenance, upkeep and disaster management – reg.

The Ministry, vide Notification S.O. 1224 (E) dated 28.03.2020, amended the appendix IX of EIA Notification to inter-alia provide exemption from Environmental Clearance (EC) for "*Dredging and de-silting of dams, reservoirs, weirs, barrages, river and canals for the purpose of their maintenance, upkeep and disaster management.*"

2. Subsequently, the above mentioned Notification was challenged before the National Green Tribunal, Principal Bench in Original Application No. 190/2020 in the matter of Noble M. Paikada Vs. Union of India & Ors., wherein the Hon'ble Tribunal while disposing of the application vide order dated 28.10.2020, *inter-alia* held that "*.....the exemption should strike balance and instead of being blanket exemption, it needs to be hedged by appropriate safeguards such as the process of excavation and quantum...*" and directed to revisit the impugned notification dated 28.03.2020.

3. Subsequently, the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation in consultation with the MoEF&CC issued the National Framework for Sediment Management. The document deals with the issue of environmental safeguards pertaining to desilting/ dredging of dams, reservoirs etc.

4. The above mentioned framework was referred to the concerned Expert Appraisal Committee (EAC) for deliberation. After due deliberation, the EAC opined that the framework addresses the environmental concerns associated with the sediment management practices in dam/reservoirs/barrages in a comprehensive and holistic manner.

5. Based on the recommendations of the EAC and keeping in view the direction of Hon'ble NGT, the matter has been examined by the Ministry in detail and it is hereby directed that the exemption from EC provided vide S.O. 1224 (E) dated 28.03.2020 for dredging and desilting of dams, reservoirs, weirs, barrages, river and canals shall be subject to Environmental Safeguards as proposed in the National Framework for Sediment Management (*copy enclosed*) issued by the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation as enclosed to this Office Memorandum.

6. This is issued with the approval of the Competent Authority.

Encl: as above.

12/07/23

(Sundar Ramanathan)
Scientist 'E'

To

1. Chairman, Central Pollution Control Board (CPCB)
2. Chairman and Member Secretaries of SEIAA/ SEACs
3. Chairpersons/Member Secretaries of all SPCBs/UTPCCs
4. All the Officers of I.A. Division

Copy for information to:

1. PS to Hon'ble Minister for Environment, Forest and Climate Change
2. PS to Hon'ble MoS (EF&CC)
3. PPS to Secretary (EF&CC)
4. PPS to DGF&SS (EF&CC)
5. PPS to AS(TK)/PPS to JS (SKB)
6. Website, MoEF&CC/Guard file

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development
and Ganga Rejuvenation

National Framework for Sediment Management

`FOR OFFICIAL USE ONLY

सत्यमेव जयते

जल बचत – जल संचय

NATIONAL FRAMEWORK FOR SEDIMENT MANAGEMENT

MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

NEW DELHI
October, 2022

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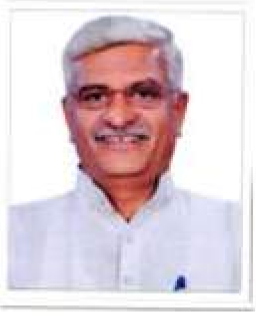
गजेन्द्र सिंह शेखावत
Gajendra Singh Shekhawat

जल शक्ति मंत्री
भारत सरकार
Minister for Jal Shakti
Government of India



सत्यमेव जयते

FOREWORD

Rivers are extremely valuable natural resource and important part of human life. They are a major source of fresh water; a source of sustenance and featuring strongly in our cultures and religious practices. Rivers also act as agents of rich deposits of sediment which forms the flood plains and valleys. Often dams are constructed on rivers to store water and manage it for human use.

In present times, due to rapid urbanization and development, many new issues are coming up, leading to change in the river dynamics. Reservoirs are also loosing their storage capacity because of sedimentation. Hence, comprehensive sediment management has how become the need of the hour for the sustainable development of the water resources of the country.

Ministry of Jal Shakti (MoJS) is actively involved in overall planning, policy formulation, coordination and management of the water resources of the country. MoJS has taken several policy initiatives and enacted legislations for managing the rivers from time to time. In yet another milestone, MoJS has come up with the Framework for Sediment Management, for managing the sediments in a holistic manner. This framework lays emphasis on sediment management through integrated river basin management plan. It provides reference of all existing guidelines/policies dealing with the various aspects of the sediment management.

The Framework will facilitate the concerned stakeholders such as the State Governments, other Ministries, departments etc. in planning strategies and implementation of projects giving due consideration to environment and ecology.

(Gajendra Singh Shekhawat)

जल शक्ति अभियान

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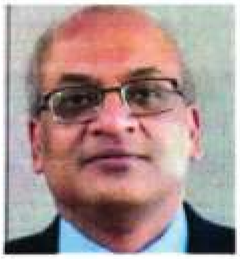
PANKAJ KUMAR
सचिव
SECRETARY

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION



PREFACE

Rivers are our lifelines. They are enablers of human development. Rivers serve as an important source of drinking water, provide pathways for navigation as well as sediments to the floodplains. These sediments enrich the soil with nutrients. Deltas and river banks, where much sediment is deposited, are often the most fertile agricultural areas in a region. Areas rich in sediments are often rich in biodiversity. Sediments carried by the rivers include good quality sand which is extensively used in the construction industry.

However, rapid urbanization and development, impact natural processes of the river. Dams and barrages constructed across the river for various uses alter the flow dynamics and sediment distribution pattern. The impact of climate change on river flows presents another challenge. Sediment transport being a complex phenomenon, integrated sediment management in a river basin should be the way forward for sustainable management of sediment.

Ministry of Jal Shakti has prepared a "National Framework for Sediment Management". The formulation of the National Framework on Sediment Management is the result of the efforts put in by various officers of Department of Water Resources, River Development & Ganga Rejuvenation (DoWR,RD&GR) and Central Water Commission (CWC). The document has been prepared after extensive discussion and consultation with the State Governments/Union Territories and stakeholding Ministries/Departments.

The National Framework document will serve as a guidance document for management of sediment across the river basin. It is hoped that the National Framework will be made use of by stakeholders in line with other existing guidelines/policies for efficient and sustainable sediment management in the country.

(Pankaj Kumar)

आज़ादी का
अमृत महोत्सव

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Abbreviations

BC Ratio	:	Benefit Cost Ratio
BIS	:	Bureau of Indian Standards
CWC	:	Central Water Commission
DoWR, RD & GR	:	Department of Water Resources, River Development and Ganga Rejuvenation
DPR	:	Detailed Project Report
DRIP	:	Dam Rehabilitation and Improvement Project
EPC	:	Engineering, Procurement and Construction
GIS	:	Geographic Information System
GoI	:	Government of India
GSI	:	Geological Survey of India
HKKP	:	Har Khet Ko Pani
IWAI	:	Inland Waterways Authority of India
MCM	:	Million Cubic Meter
MoEF&CC	:	Ministry of Environment, Forest and Climate Change
MoPSW	:	Ministry of Ports, Shipping and Waterways
MoRTH	:	Ministry of Road Transport and Highways
NHAI	:	National Highways Authority of India
NHIDCL	:	National Highways & Infrastructure Development Corporation Limited
NOC	:	No Objection Certificate
O&M	:	Operation and Maintenance
PMKSY	:	Pradhan Mantri Krishi Sinchayee Yojana
PSU	:	Public Sector Undertaking
RRR	:	Repair, Renovation and Restoration
SLUSI	:	Soil & Land Use Survey of India
SPCB	:	State Pollution Control Board
TAC	:	Technical Advisory Committee
ToR		Terms of Reference
UTPCC	:	Union Territory Pollution Control Committee

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Glossary of Terms

Aggradation	:	to raise the level of (a river valley, a stream bed, etc.) by depositing sediment, or the like.
Appurtenant structure	:	consists of spillways, low level outlet structure and water conduits, hydro-mechanical equipment, energy dissipation and river training structure and other associated structures acting integrally with the dam.
Bathymetry	:	a type of hydrographic survey that allow us to measure the depth of a water body as well as map the underwater features.
Bed Load	:	the sediment which is in almost continuous contact with the bed, carried forward by rolling, sliding or hopping.
Channel	:	a feature that conveys surface water and is open to the air.
Channelization	:	the straightening and deepening of a stream channel to permit the water to move faster or to drain a wet area for farming.
Contour Bunding and Trenching	:	the hill side is split up into small compartments on which the rain is retained and surface run-off is modified with prevention of soil erosion.
Degradation	:	process of lowering of channel bed due to the erosion of sediment
Density Current	:	as clear water of reservoir comes in contact with muddy inflow, due to the difference in densities a "stratified flow" condition occurs and the underflow is called as "density current".
Dredging	:	process that removes deposited sediment from the bottom of rivers/reservoirs using different techniques.
Estuary	:	an area where a freshwater river or stream meets the ocean.
Lateral connectivity	:	connectivity between channel-riparian and floodplain
Longitudinal connectivity	:	upstream and downstream connectivity
NOC	:	No Objection Certificate.
Riparian	:	pertaining to the banks of streams, wetlands, lakes or tidewater.
Sediment Budgeting	:	an accounting of the inflow, outflow, and storage changes of sediment in a river/reservoir system.

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Suspended Load	:	part of the total sediment transport which is maintained in suspension by turbulence in the flowing water for considerable periods of time without contact with the stream bed.
Trap efficiency	:	the ratio of total deposited sediment to the total sediment inflow.
Wash Load	:	consists of fine particles, which do not exist on the bed of the reach under consideration, which remain in suspension throughout the reach.
Watershed	:	an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake or an ocean.

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NATIONAL FRAMEWORK FOR SEDIMENT MANAGEMENT

PREAMBLE

Sediment transport, bank erosion and associated channel mobility represent key physical processes of rivers; their understanding is of crucial importance for defining river restoration and management strategies. 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 along the river bank or on river itself and in the riparian zone. Rapid urbanization and industrialization in flood plains, encroachment of river beds, changes due to various human activities and deforestation in catchment area of rivers etc are the main causes of increased sedimentation in rivers. Problem of sedimentation in rivers is somewhat moderated by trapping sediment in reservoirs. However, it results in loss of reservoir storage thereby reducing its benefits and serviceable life.

Sediment management in reservoirs and dams is becoming crucial to water resources development and management. Reservoirs have been used worldwide to provide reliable water supply for irrigation, domestic, industrial, hydro power generation, and flood management etc. Dams have contributed significantly towards economic development, food production security, resilience building against natural disaster (droughts and floods) and mitigation of ill effects of climate changes. Old dams have traditionally been designed with a certain "design life", typically 50 or 100 years, which were determined by sedimentation rate, trap efficiency, provision of sediment storage pool volume (dead storage). Most reservoirs are therefore gradually being filled up. The annual reservoir storage loss globally due to sedimentation is around 0.5 to 1 % in average but varies easily between 0 and 5% depending on the location. Half of the dams in India are more than 25 years old. As the ageing dams approach the end of their original design lives and depletion of their storage capacity due to sedimentation, water scarcity will be more widespread. Thus, there is an urgent need to update policies and guidelines for exploring all options for alleviating the impact of reservoir sedimentation.

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 and management of sediments at the basin scale; (ii) a wider application of available scientific knowledge.

While keeping rivers in pristine condition is the ultimate goal, development of civilization has always been on the banks of the rivers, to utilise blessings of the rivers and their water. Dams and barrages have to be constructed across the river to utilise the water resources for overall development of the country and the society. Therefore, sediment issues in dams, barrages and rivers cannot be dealt separately. For a sensible sustainable sediment management in rivers and reservoirs, it is necessary to adopt a scientific framework for sediment management at national level. This national framework document highlights the key issues related to sediment management and recommendations for policy-makers and stakeholders. The document is prepared to take appropriate actions and measures by the concerned Departments and other stakeholders.

1.0 COMPOSITION OF SEDIMENT AND TRANSPORT:

Sediment transport is the movement of organic (humus, decomposing material such as algae, leaves etc.) and inorganic particles by water. This is related with the total energy available with water, composition of the river bank material/catchment soil composition & topography along with other factors like seismic/tectonic activity and anthropogenic factors. In other words, greater the quantity of flow and velocity, the more sediment will be conveyed. Water flow can be strong enough to suspend particles in the water column as they move downstream, or simply push them along the bottom of a waterway. The intermediate type of movement where particles move downstream in a series of bounces or jumps, sometimes touching the bed and sometimes carried along in suspension until they fall back to the bed is called saltation. Transported sediment may include mineral matter, chemicals, pollutants and organic material. The total transported sediment load includes all particles moving as bed load, suspended load and wash load (very fine particles). As per BIS Code IS: 6339 (as been revised in 2013), the classification of coarse, medium and fine sediment is as under:

Sediment type	Particle size
Coarse sediment	D> 0.25 mm
Medium sediment	D = 0.062 mm to 0.25mm
Fine sediment	D < 0.062 mm

1.1 Sedimentation in Rivers and Reservoirs

Deposition and erosion of sediment along the length of river is a natural phenomenon. However, sediment deposition at any place in river depends on many factors such as the stages of rivers, catchment/ watershed/ drainage characteristics, its size, geological disposition along the course of the river and human interventions, whereas erosion of soil in the catchment of a river is greatly governed by rainfall & its intensity, slope, soil characteristics, forestation etc. of the catchment area.

Siltation is a natural process through which river tries to reach to a stable regime condition.

Similarly, sedimentation in reservoirs is also a natural process. The detailed process of siltation/sedimentation in rivers and reservoirs is given at **Annexure-I.** Policy intervention requires due attention in the reaches where human settlement and economic activities are extended. Sediment is a socio-economic, environmental and geo-morphological resource, as well as a tool of nature. However, changes in sediment quantity and quality can have a significant impact both in rivers and reservoirs and prove to be resource as well as menace in its own manner.

1.1.1 Rivers:

Sediment in rivers mainly contains boulders, cobbles, pebbles, sand, silt and clay. Sand has high economic value and is a valuable material largely used in construction works. Due to huge demand of sand, MoEF&CC, Govt. of India has come up with "Sustainable Sand Mining Management Guidelines – 2016 and supplemental document "Enforcement and monitoring guidelines for sand mining-2020".Boulders, cobbles and pebbles are also very important for construction industry.

However, when sediment in rivers is deposited at undesirable place, it turns into a menace. It may cause aggradation and degradation. Further, it also causes meandering, braiding and widening of rivers, which in turn causes erosion of river banks and endangers the embankments and settlements on the banks of rivers. Sedimentation in rivers also causes reduction of navigable depth and rising of river beds causing drainage congestion. In such cases, it becomes necessary to remove the sediment by suitable means at selected places.

1.1.2 Reservoirs:

Due to reduction of velocity of water in reservoirs, part of incoming sediment gets trapped. Sedimentation in reservoir results in loss of capacity, impacts dam safety, risk to downstream habitation etc. as sedimentation in reservoirs is generally accumulative. By removal of sediment, the capacity and life of a reservoir can be extended, planned operational benefits can be ensured, and minimise the risk to downstream stakeholders.

2.0 BASIC PRINCIPLES OF SEDIMENT MANAGEMENT

2.1 Sediment Management in Watershed

It is imperative to minimise the sediment intake to a minimum level for a dam or reservoir for its optimal functionality and longevity. This involves a two-pronged approach: catchment area treatment and appropriate land use planning to address unsustainable land use to reduce soil erosion & sediment production. Catchment area interventions need to be given priority as it arrests silt within the boundary of a watershed which will help in minimizing siltation in river bed & reservoirs. Details on catchment area treatment/intervention are given in **Annexure II.** The steps to reduce sediment inflow must include determination of inflow of silt into the river/reservoir. Sediment inflow assessment may be based on soil erosion modelling and silt monitoring along with assessment of agronomic practices and other land-based activities, point& non-point source of pollutions, agriculture run-off in the catchment, which is essential to determine quantity and quality of sediment and the reservoir's rate of sedimentation.

To reduce sediment production in the watershed sustainably, the following actions should be taken:

- (i) study watershed characteristics
- (ii) current status of watershed management activities
- (iii) assess the vulnerability of watershed in terms of soil erosion by using available observed sediment data at various streams G&D sites, water reservoirs (if hydrographic survey data available), soil loss modelling, to identify and prioritise the degraded micro-watershed for treatment with biological and engineering measures for erosion control,
- (iv) stream bank erosion control using various river training works
- (v) trapping sediment upstream in river before entering into reservoir and
- (vi) planting trees to provide vegetation cover and retention to the soil for preventing erosion.

To start with, the Digital Micro Watershed Atlas of India- 2019 of Soil and Land Use Survey of India (SLUSI), Ministry of Agriculture can be followed for delineation & management planning. The "Common Guidelines for Watershed Development Projects", Department of Land Resources, 2008, Ministry of Rural Development, Govt. of India may be referred for development of watershed projects. For implementation of the watershed programme, a synergy is required to ensure the convergence of various programs implemented by the various central ministries and State Governments.

2.2 Sediment Management in Rivers

The following basic principles should be followed for sediment management of Indian rivers:-

1. Sediment management should become a part of integrated river basin management plan. Regular sediment budgeting for all basins should be done especially which are affected by heavy siltation problem.

2. Removal of sediments from river bed may help in channelization of river flow during the lean season and improve the navigability, but will not have any considerable effect on flood levels.

3. There is natural deposition of sediments upstream of any barrage, but this attains equilibrium after few years. Desiltation in upstream of a barrage may be taken for channelization of stream flow. However proper operation of Gates should be ensured for reducing sediment deposition in the upstream of the Barrages/Wier.

4. Urbanization and infrastructure development works like buildings, roads, embankments etc. require large amount of sediment. The quantity of sediment removed in such cases from the river shall be limited to the extent to which it does not harm the ecology of river or gainfully utilized in developmental works, whichever amount is less. Exploitable quantity should be determined "a-priori" and the reach should be monitored for excessive exploitative practices.

5. There is a need to pursue the de-siltation/dredging schemes with utmost care backed by scientific study, including simulations through mathematical and/or physical model study at appropriate scales and employing consistent formulations applicable to the given site. Mathematical and/or physical model study is exempted for dredging/de-siltation carried out for navigation purpose by Inland Waterways Authority of India.

6. If necessary, permanent observation stations may be opened for collecting data such as cross-section, hydrological observation etc. This should be coupled with periodic monitoring of various morphological changes with space technology such as formation of shoals, meandering tendency of the river, effect of construction of hydraulic structures, damages to the bank, effect of afforestation/ deforestation and tectonic occurrences. Data sharing mechanism is to be established in case of an inter-state river.

7. Different approaches of sediment management may be resorted to in rivers depending upon the stages of the river. The details of the same, along with some other management strategies are given in **Annexure-II**.

8. Sediment management action must follow best practices to minimize damage to the environment and river morphology. Restriction details for de-siltation/dredging are placed at **Annexure-III**.

9. In case, if it is not possible to utilise sediment removed by dredging/de-silting of rivers; a proper utilisation/disposal plan needs to be prepared, with the consideration that it does not create any environmental, ecological and social issues.

2.2.1 Effect of De-siltation in Reducing Floods

In general, de-silting of rivers does significantly affect flood levels. In this regard, it is mentioned that the Mittal Committee was constituted by the erstwhile Ministry of Water Resources in the year 2001, under the Chairmanship of Dr. B.K. Mittal, Former Chairman, Central Water Commission. The main objectives of the Committee were to identify the cause and extent of siltation in rivers, to suggest measures to minimize siltation, to examine as to whether de-silting is a technically feasible means to minimize magnitude of floods in rivers, to suggest appropriate technology/ methods of de-silting of rivers, to propose a realistic operational programme in a time-bound manner and other related aspects. The findings/recommendations of the Committee were as follows:

(i) De-silting of rivers for flood control is not an economically viable solution;
(ii) Dredging in general has been found to be inadequate and should not be resorted to, particularly in major rivers;
(iii) There are, of course, some locations such as tidal rivers, confluence points with narrow constrictions and the like which can be tackled by de-silting after thorough examination and techno-economic justification;
(iv) Selective dredging is suggested depending upon local conditions; and
(v) De-silting of rivers can marginally minimize the magnitude of floods and be effective only for a short period.

However, selective need-based dredging of certain reaches of rivers coupled with structural and non-structural measures may be considered in order to protect habitation, agriculture land, airports, industrial and institutional installations etc.

2.2.2 Extraction for Navigational Purpose

Inland Waterways Authority of India (IWAI) is required to carry out dredging to clear shoals/shallow patches on fairways in National Waterways as a mandatory functional requirement in terms of provisions of Section 14 (Chapter IV) of IWAI Act, 2016 (82 of 85).

The above dredging shall be necessitated to be carried out at frequent intervals as and when shoals are surfaced and identified based on continuous fortnightly/monthly bathymetric surveys being carried out by IWAI. This maintenance dredging is also required to be taken up at short notice and complete the dredging in a time bound manner to facilitate navigation. The above maintenance activities of dredging including its disposal are also exempted from obtaining clearance from MoEF&CC.

2.2.3 Extraction for Economic Uses

Sediment deposit in both rivers and reservoirs at some places contains considerable quantity of sand. In places where sediment deposits are having good sand content (of the order of 30% - 40%), it is possible to extract sand from sediment to meet the ever-increasing demand of sand. Sediment component such as silt and clay bears comparatively lesser economic value but still can be used in many works such as for brick making, as filling material, construction of embankments, roads, constructing raised platforms for flood proofing etc. Its different uses are given at **Annexure-IV**. There is possibility of revenue generation in such cases.

2.2.4 Indispensable Removal

Many a time, excess deposition of sediment at undesirable places causes bank erosion, shifting of river course and navigational issues. Sediment deposition on the mouth of a river may cause large scale flooding due to drainage congestion. At many places, sediment needs to be removed from a river to channelize it to bring it to its original course especially during pre-monsoon and post monsoon. In such cases, it is imperative to remove the sediment by practically suitable means. Similarly, in some old reservoirs, especially those which are supplying drinking water, sediment removal becomes necessary to regain their capacity. In hydro-power projects, excess deposition of sediment just below the intake level of turbines hamper their operation and has to be removed with suitable means.

2.3 Sediment Management in Reservoirs

The importance of reservoir sedimentation management is evident when one considers that the cost of replacing storage lost annually due to sediment deposition throughout the world is significant. If sedimentation can be managed successfully, the loss in reservoir storage space due to this phenomenon can be lowered and life of reservoir can be prolonged significantly. The benefit of effective reservoir sedimentation management is enormous.

It is possible to successfully manage reservoir sedimentation by using comprehensive sediment management strategy coupled with measures to reduce sediment yield from watershed, route sediments around or through storage, and recover the lost capacity of reservoir through de-silting. Integrated management of reservoir sedimentation is easy to manage for new reservoirs which can be integrated at planning stage itself. In the existing reservoirs, one or combination of more than one technique can be explored in a holistic way. None of single technique/measure can be 100% effective for long term sustainability of sediment management in reservoirs. Due consideration shall be given to address environmental and social safeguards during the planning stage. In addition to this, robust institutional and sound financing mechanism forms the integral part of comprehensive planning and implementation strategy for sediment management.

The brief detail of framework for addressing sediment problems in reservoirs are given in the following paras.

2.3.1 Measures to Minimise Sediment Deposition in Reservoirs

The main source of incoming sediment to any reservoir is catchment erosion. Therefore, the first step to address the root cause of incoming sediment is watershed management through various engineering and bio-engineering techniques to arrest sediment erosion effectively. The next step is to manage the sediment deposited in the river by routing the sediment around or through the storage by various kinds of sediment by-pass and sediment pass-through interventions. There are structural and non-structural techniques for sediment routing. Sediment Bypass, include Flood Bypass Channel or Tunnel and off-stream reservoirs for bypassing sediment inflows away from reservoirs. Sediment pass-through strategies including draw-down flushing(complete and partial), pressure flushing, sluicing and venting turbid density currents are non-structural interventions comprising operational techniques for evacuating sediment from the reservoirs.

There are several techniques for sediment routing that take advantage of temporal variation in sediment discharge, managing flows during periods of highest sediment yield to minimize sediment trapping in the reservoir. The basic strategy is to impound the clear water and release the sediment-laden flood flows. Sediment routing techniques require a part of the river inflow and storage volume for transporting sediment around or through the reservoir. Consequently, this may not be feasible in reservoirs, where all the inflow is being captured and stored. However, as reservoir capacity is diminished by sedimentation, sediment routing may become more feasible.

The sediment not arrested through the above referred two stages, partially gets deposited in the reservoir and part of it is discharged downstream of the reservoir (suspended and colloidal). The deposited sediment in the reservoir is to be dredged to restore the lost capacity to the possible extent keeping in view techno-economic and environmental feasibility.

2.3.2 De-silting of Reservoirs

Sediment deposit in reservoirs may have adverse impact on storage, as well as safety of dams. The safety of reservoirs is directly having huge consequences to the downstream habitations as well as other vital installations along with the planned benefits. Dam safety requirement shall be complied with, when it comes to enforcing constructive or operational sediment management measures; at no time should such measures lead to an unacceptable state of dam safety.

Sediment management measures to reclaim live storage, to improve operations or for environmental reasons shall be in compliance with applicable environmental requirement, unless they are necessary to preserve immediate dam safety, and prevent an uncontrolled release of reservoir water that could lead to even larger environmental damages or cause loss of life, injuries or large damages to properties in the downstream area.

At the same time, for existing reservoirs; in case of high sediment inflow, long term integrated watershed management shall be explored effectively. In some of existing large reservoir(s), watershed management has resulted substantial reduction in erosion in turn reduced the sediment inflow viz. in Maithon Reservoir, initial average annual loss of capacity of 7.38 MCM reduced currently to 1.37 MCM over a period of time.

Annual loss of overall storage of Panchet Reservoir was reduced from 14.98 MCM/year (years 1959-66) to 4.06 MCM/year (years 1996- 2019) considering the maximum flood management pool of 132.62m (435 ft.) mainly on the ground of construction of Tenughat Dam upstream of Panchet Dam."

MAITHON DAM WATERSHED MANAGEMENT

- Maithon dam (Damodar Valley Corporation - DVC) is a 56.08 m high composite dam constructed across river Barakar, Dhanbad District (Jharkhand). **The initial gross storage capacity of Maithon dam is 1196 MCM with live storage of 607 MCM considering the Maximum flood management pool of 150.91 m (495 ft.) and minimum drawdown level of 132.62 m (435 ft.)**
- It is a multipurpose dam with main function of flood control, supplying water for irrigation, Municipal & Industrial use, hydro power generation, and tourism. The construction commenced in December' 1951 and completed in September' 1957.
- Damodar Valley Corporation is working **since 1949-50** to tackle the soil erosional problems in upper Damodar-Barakar catchment area through **soil and water conservation/integrated watershed management programs** with multidisciplinary approach by its **Soil Conservation Department** located at Hazaribagh.

Drainage line treatment

Rainwater harvesting structures

Key Soil Conservation Measures

- ✓ Afforestation, Pastoral Development, Contour Trenching
- ✓ Field hedge, pasture and horticultural development, drainage line treatments, silt detention dams, ponds' renovation, reclamation of land, demonstrations on moisture conservation
- ✓ Construction of water harvesting structures

- Measures have played a significant role in arresting sediment deposition by more than 60% which has resulted, among other benefits, in **reducing loss rates in storage capacity from 7.38 MCM/year (years 1955-65) to 1.37 MCM/Year (years 2002-19).**

The structural invention(s) which includes renovation of low-level permanent river outlet with appropriate replacement provision for original valve with a new gate to allow sluicing during high flow event, renovation of power plant penstocks by replacing few penstock with a sluicing pipe and modifying the other penstock for electricity generation, retrofitting of dams by providing de-silting tunnel(s), silt-bypass weir/tunnel(s))/ tank/ chamber(s),de-silting etc. can be explored on case to case basis keeping in view engineering and techno-economic and environmental feasibility in providing such modifications. Such typical strategies have been experimented in Shihmen reservoir, Taiwan.

SHIHMEN DAM (TAIWAN) SEDIMENT MANAGEMENT

- The reservoir management in Taiwan faces lots of challenge. The main source of rainfall is the northeast monsoon. Mean annual precipitation is about 2500 mm/year. On an average 3 to 4 typhoon strike the country every year. **Soil erosion is very high, almost having a rate of 3 to 6 mm/year.** Shihmen dam is located very near to Taoyuan city of Taiwan. It was commissioned in year 1964
- The gross storage capacity is 309 MCM. **This dam is a classic example of post construction retrofitting for integrated sediment management.** The journey of sediment management started by construction of 121 check dams which majority of these got filled by year 2007. **It is estimated that annual inflow of sediment in reservoir is 3.42 MCM.**

SUSTAINABLE SEDIMENT MANAGEMENT STRATEGIES AT SHIHMEN DAM

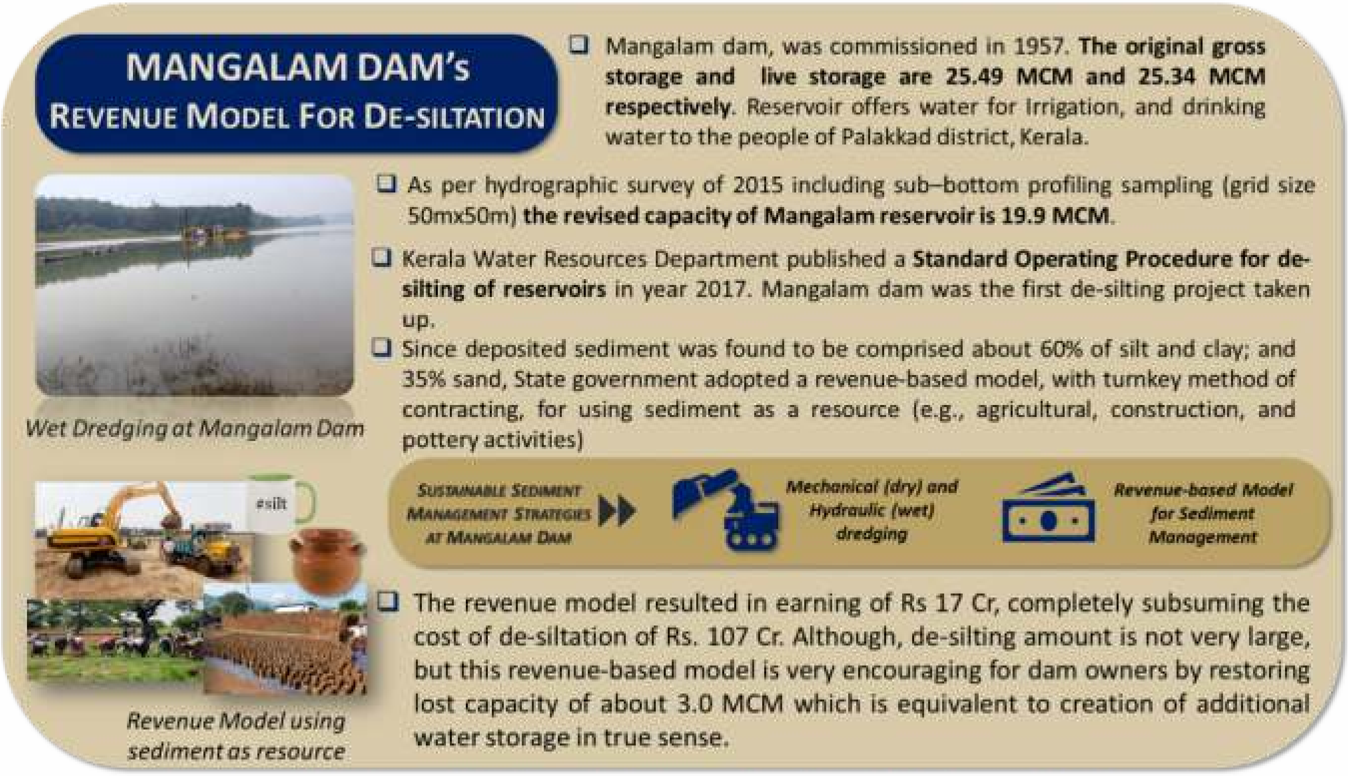
- *Sediment yield reduction (Check Dams)*
- *Mechanical &Hydraulic Dredging*
- *Sluicing*
- *Routing-venting turbidity currents*

Simultaneous operation of spillway and penstock sluice venting turbid density current

- Then structural inventions included modification of permanent river outlet gates (4%) by replacing the original Howell-Bunger valve with a jet flow gate to allow sluicing during high flow events , renovated the power plant penstocks, replacing one penstock with a sluicing pipe and modifying the other penstock for electricity generation (55%), introduction of two nos of sediment-bye pass tunnels i.e. Dawanping (21%, under construction) and amuping (19%, commissioned) silt sluice tunnels. Also, some part is managed by dredging near dam(15%) and dredging upstream of dam(12%). **This arrangement is almost balancing the inflow sediment with outgoing sediment volume**

A majority of Indian reservoirs have been built through conventional design life approach rather than life cycle management approach. The latter approach considers storage as renewable as compared to exhaustible by first one. Furthermore, abandoning dam sites may not be affordable in any respect, as available sites for new reservoirs are very limited. Hence, there exist ample scope and cost-effectiveness in prolonging their lifetime.

De-silting plan for a given reservoir should be comprehensive. It shall be prepared based on latest bathymetry survey inputs along with representative sub profiling data of a given reservoir. The basic information shall include various methods of dredging along with their utilities and performances in accordance with different specific site conditions, proposed method with justification, estimated cost and proposed dredging volume, revenue and non-revenue models, cost benefit analysis vis-a-vis restored capacity, disposal plan of dredged material with detail of sediment stacking and processing yard, method of contract which include EPC/turnkey or work contract method with fixed time schedule, environment and social safeguards and monitoring mechanism etc. The de-silting of Manglam Dam in Kerala is a classic example of revenue model under implementation.



The following basic principles should be followed in De-silting of reservoirs:

i. Regular monitoring of sediment deposition in reservoir should be carried out. Integrated Bathymetry survey with sub-profiling sampling needs to be done to determine the actual quantity of sedimentation in reservoirs and estimation of the rate of sedimentation.

ii. For reservoirs selected for potential intervention, it is necessary to perform a diagnosis of the sedimentation problem, formulate and select the most viable management alternative, prior to implementing the selected measures.

iii. In case, if it is not possible to utilise sediment removed by dredging/de-silting / flushing from reservoirs; a proper utilisation/disposal plan needs to be prepared, with the consideration that it does not create any environmental, ecological and social issues.

iv. De-siltation for restoring the lost capacity of the reservoirs may be carried out by comparative analysis of revenue and non-revenue models. For reservoirs, which are constructed for providing drinking water supply as well as other strategic services, de-silting may be done on need basis including non-revenue model. Also for safety of dam, it requires the de-silting; this may be preceded to other concern keeping in view associated disaster consequences.

v. De-siltation/Dredging/Flushing in the cascade of reservoirs depends on the natural sediment load and may be shared between reservoirs. Appropriate monitoring mechanism along with institutional strengthening provision shall be inbuilt items in any programme of sedimentation management of reservoirs especially once the reservoir located in a lower riparian State is affected, when carried out in the reservoir, due care should be taken so that it does not affect downstream reservoirs. Proper consultation, with the reservoir authorities of downstream projects should be done. In case of hydro-power plants, each project or cascade projects should have coordinated Standard Operating Procedure (SOP), so that to the extent possible, sediment concentration may follow normal river regime during flushing.

vi. De-siltation/dredging work shall not affect any existing structures/ facilities. De-siltation, especially in reservoirs shall be done in such a manner that it does not induce any landslides and slip circle failure in case of quick drawdown conditions. Restriction details for de-siltation/dredging are placed at **Annexure-III**.

vii. In financing for new facilities, sediment management measures are considered to be an integral part of the facility cost. A life-cycle management approach shall always be recommended. For de-silting existing reservoirs, recurrent measures are financed through O&M budget. Reclamation of live storage is to be considered as like creating a new facility. Also, de-silting for reinstating safe operation is financed like other rehabilitation works (e.g. DRIP).

viii. Financing de-silting in cascades of reservoirs depends on the natural sediment load and may be shared between the reservoirs. Appropriate monitoring mechanism along with institutional strengthening provision shall be inbuilt items in any program of sedimentation management. Also, in case de-silted material is discharged or dumped in the downstream of dam, impacting immediate downstream reservoir located in lower riparian State, proposed Plan may also be shared with lower riparian State. In case of a reservoir having interstate implications, the downstream states should have a member in the State/Central TAC.

ix. The dredged material is a resource and the beneficial reuse in convergence with various concern organisation/agencies will not only bring direct economic values, but also social and environmental merits. Hence its end use should be part of comprehensive action plan. The possible major use of dredged material includes land reclamation, improvement & filling, construction & protection materials (for highways, railways, flood protection embankment etc.), top soil enhancement and agricultural use, habitat creation and restoration, beach nourishment and shore protection, river management (e.g. sand plug for channel closure) etc.

x. A Feasibility Report should be prepared considering various techniques of removal of sediment. The economic analysis of long term benefits owing to consideration of removed sediment as a resource should be an important part of the feasibility report. Restored capacity of reservoir should be considered equivalent to creation of new live storage and apart from the intended benefits in terms of various uses of reservoir water (irrigation, drinking water, industrial water, hydro power, fisheries, tourism etc.), the benefits from selling of sand for construction purpose, silt and clay for pottery and tiling industries in the open market by the contractor should also be considered for cost-benefit analysis. The use of revenue model shall be invariably explored. However, in case of strategic restoration of lost capacity (like drinking water, trans-boundary rivers etc.), even the non-revenue model may be considered. In order to ensure credible and bankable competitive bidding, the bid document shall be supported in terms of proposed volume and composition of dredged sediment through a latest close interval sub-bed profiling data of reservoir.

The details about the measures that can be adopted for sediment management of reservoir are listed in **Annexure-V.**

2.3.3 Data Base & Survey:

i. Dam owners / Project Authority must carry out integrated bathymetry survey with sub-profiling sediment sampling of all large reservoirs of the country, keeping in view proper intervention for reclaiming of storage to improve water security. The survey is to be carried out at prescribed as per Compendium on sedimentation of reservoirs in India (2020).

ii. For preparation of strategic action plan for handling the challenge of reservoir sedimentation in future, integrated Bathymetry Survey and Sub-bottom Profiling should be conducted compulsorily. The sub bottom profiling would give the thickness of underwater sediment, its composition (type), density etc.

iii. Remote sensing Technique can be used for regular sediment assessment.

iv. GIS-based model for predicting sediment quantity and quality based on basin characteristics and river flow can be developed.

v. Video documentation of entire exercise of de-siltation, dredging, and other interventions executed for sediment management can be made so that cross learning can be promoted.

2.3.4 Retrofitting of Existing Dams

Retrofitting of existing dams: keeping in view availability of very limited sites for construction of new storage reservoir(s) along with various other challenges including R&R and environment impacts, dam owner(s)/Project Authority/(ies) may explore for retrofitting of few dams at a marginal cost. This retrofitting can be in many forms i.e. increasing the height of dam to the safe extent possible to create additional storageto meet extra demand, harnessing the available much easy hydroelectric potential at appropriate location(s), pumped storage option(s) etc. to make these reservoirs part of climate resilient strategies.

2.3.5 Institutions and Financing:

Certain guiding principles determine the arrangement of institutional setup and financing: Firstly, sediment management measures must never compromise dam safety and result in unacceptable state of dam safety. Secondly, sediment management measures must comply with prevailing environmental requirements, unless dam safety requires otherwise. Thirdly, reservoir sediment management is to be considered as an integral part of planning, design and operation of any new facility. Finally, sediment management decisions follow similar considerations, needs, rules, processes as those for other environmental projects.

For de-silting of existing reservoirs, recurrent measures are financed through O&M budget. In order to handle the challenge of reservoir sedimentation on long term basis, all owners of reservoirs shall initiate policy interventions for earmarking certain percentage of dam revenues for carrying out de-siltation activities for sustainable dam operation and maintenance. Reclamation of live storage is to be considered akin to creating a new facility.

Financing de-silting in cascades of reservoirs depends on the natural sediment load and may be shared between reservoirs. Appropriate monitoring mechanism along with institutional strengthening provision shall be inbuilt items in any programme of sedimentation management.

2.4 Sediment Management for Lakes/Water Bodies

Lakes and water bodies constitute important habitats and food resources for a diverse array of fish, aquatic life, and wildlife. These are of great importance to mankind. They regulate the flow of river. During the rainy season, they prevent flooding and they help to maintain the flow of water during the dry season. Therefore, sediment management for Lakes and Water bodies are equally important for their sustenance. The scheme, namely, "Repair, Renovation & Restoration (RRR) of Water Bodies" is under implementation by Ministry of Jal Shakti, GoI with the objective of comprehensive improvement and restoration of water bodies in the country presently covered under the "Guidelines for the scheme on Repair, Renovation and Restoration (RRR) of Water Bodies under PMKSY (HKKP) – 2022".

3.0 CLIMATE CHANGE PERSPECTIVE

Climate change is now an unequivocally accepted phenomenon, which in turn will result in increased hydrologic variability. This is an emerging challenge for development and sustainability of water resources management. The water storage infrastructure more generally, are appropriate focal points for both sustainable development and climate resilience. In turn, sediment management is a necessary element of sustainable and climate-resilient plan that includes reservoir storage and hydro-power generation.

Climate change, such as more frequent and intense rain events, can increase erosion and result in greater amounts of sediment washing from watershed, reaching into rivers and reservoirs. To mitigate adverse impact of climate change in reliability of water supply, construct reservoir storage spaces as large as possible. In reservoir sediment management context, developing and retaining enough reservoir storage space to satisfy water supply needs over the very long term requires inclusion of reservoir sediment management facilities in dam and reservoir designs right from the start, at project conception. It requires abandoning the conventional design life approach to dam design and adopting a life-cycle management approach.

In run-of-river projects, sediment management aims to improve operational efficiency. If sediment is not removed from run-of-river facilities before it enters the canal heads/the turbines, it may cause heavy siltation in canals and clogging of the cooling water intakes of the electro-mechanical equipment and also abrasion of the blades of the turbine, which decrease the efficiency as well as increase operation and maintenance costs and diminish the amount of power that can be generated. The objective of sediment management in storage projects is to ensure project longevity for storing large amounts of water for planned benefits and use during droughts. Such storage also provides the opportunity to attenuate floods up to some extent.

The life cycle of dams and reservoirs consists of operation and maintenance, continued and regular implementation of reservoir sediment management approaches, and regular refurbishment of the dam and its appurtenant structures. Reservoir sediment management and refurbishment of the dam and its appurtenant structures allow for continued use of the dam and its reservoir, ideally in perpetuity. In principle, the approach does not include the element of disposal. A major difference between the life-cycle management approach and the design life approach is the focus on preventing storage loss caused by reservoir sedimentation. It eliminates the threat of losing the reservoir's ability to store water over the very long term and promotes continued use of the dam and reservoir, providing utility to both current and future generations.

4.0 ENVIRONMENT AND SOCIAL SAFEGUARDS

Dredging and de-silting of dams, reservoirs, weirs, barrages, rivers and canals for purpose of their maintenance, upkeep and disaster management is exempted from environment clearance as per S.O.141(E) of MoEF&CC dated 15th January, 2016. However, reservoir sediment management methods such as by-passing, flushing or de-silting of existing reservoirs are associated with environment & social risks and impacts, which are to be identified based on interventions proposed and locational sensitivity, if any, such as dam/reservoir located in protected area, reservoirs notified as wetlands/bird sanctuaries, etc. and some of the above interventions would involve creation of new infrastructures. In such cases all statutory clearances will be required. Wild life clearance would be applicable if reservoir is in a notified protected area. For structural intervention for sediment by-passing in existing dams or any other activity, if the land required is forest land, diversion of forest land would attract forest clearance process as per Forest Conservation Act, 1980.

For the de-siltation activity, a proper Feasibility Report along with Environment Management Plan to dispose the silt is required to be prepared as per the guidelines provided in the "Handbook for Assessing and Managing Reservoir Sedimentation", CWC,2019. "Operational Procedures for Assessing and Managing Environmental Impacts in Existing Dam Projects", Central Water Commission, November 2020 with competent level approval of MoEF&CC, can be referred for the environmental and social safeguard issues related to de-silting in the existing dams in context of various statutory and regulatory norms.

5.0 DISPOSAL OF DREDGED / DESILTED MATERIALS

a) The proposal for de-siltation/ dredging activities shall be prepared as per applicable guidelines and prior approval may be taken from concerned agencies to ensure hassle free implementation. River gravels/sands/silts are valuable resource and could be used gainfully in construction works, including housing, roads, embankment and land reclamation activities.

b) Appropriate sediment disposal plan shall be a part of Feasibility Report along with applicable Environment and Social safeguards. Dredged material shall be disposed as per the approved Environmental Management Plan. It should not contaminate any water body, adverse impact to the flora and fauna existing adjacent to the disposal site(s) etc.

c) Desilted material should not be used for filling up of wetlands and water bodies including oxbow lakes, as these are important for recharging ground water and providing base flow in rivers during lean season.

d) In the case of de-silting of reservoirs, regarding applicability and procedures for Environment Clearance, Forest Clearance and Wildlife Clearance, activity listed at Sl. No.18, Table 2.2, can be referred in the "Operational Procedures for Assessing and Managing Environmental Impacts in Existing Dam Projects" CWC, November, 2020. This referred guideline has the competent level approval of MoEF&CC.

e) NOC from State Pollution Control Board (SPCB)/Union Territory Pollution Control Committee (UTPCC) as well as concerned local authorities is required in advance for disposal site for disposal of dredged materials. Requirement of NOC from State/Union Territory Pollution Control Board and from local authorities for disposal of dredged material is exempted for dredging carried out for navigation purpose by Inland Waterways Authority of India.

6.0 EVALUATION OF SEDIMENT MANAGEMENT PROJECTS

Dredging/de-silting projects including all components and their techno-economic performances need to be evaluated. An ongoing monitoring program is essential for optimizing sediment management. Short and long-term monitoring plans should be developed as an integral aspect of the Sustainable Management Plan.

7.0 APPRAISAL OF THE PROPOSAL

7.1 Regarding Environmental Clearance of project other than de-silting of reservoirs, "Procedure for Environmental Clearance for Mining of Minor Mineral including Cluster", as enumerated in appendix XI of MOEF&CC Gazette notification no. S.O. 141 (E) dated 15.01.2016 (as amended from time to time) may be followed; including the exemptions. The exemption given in Appendix XI of MOEF&CC Gazette notification regarding dredging and de-silting of dams, reservoirs, weirs, barrages, river and canals will be applicable for purpose of annual/routine maintenance/upkeep and disaster management only.

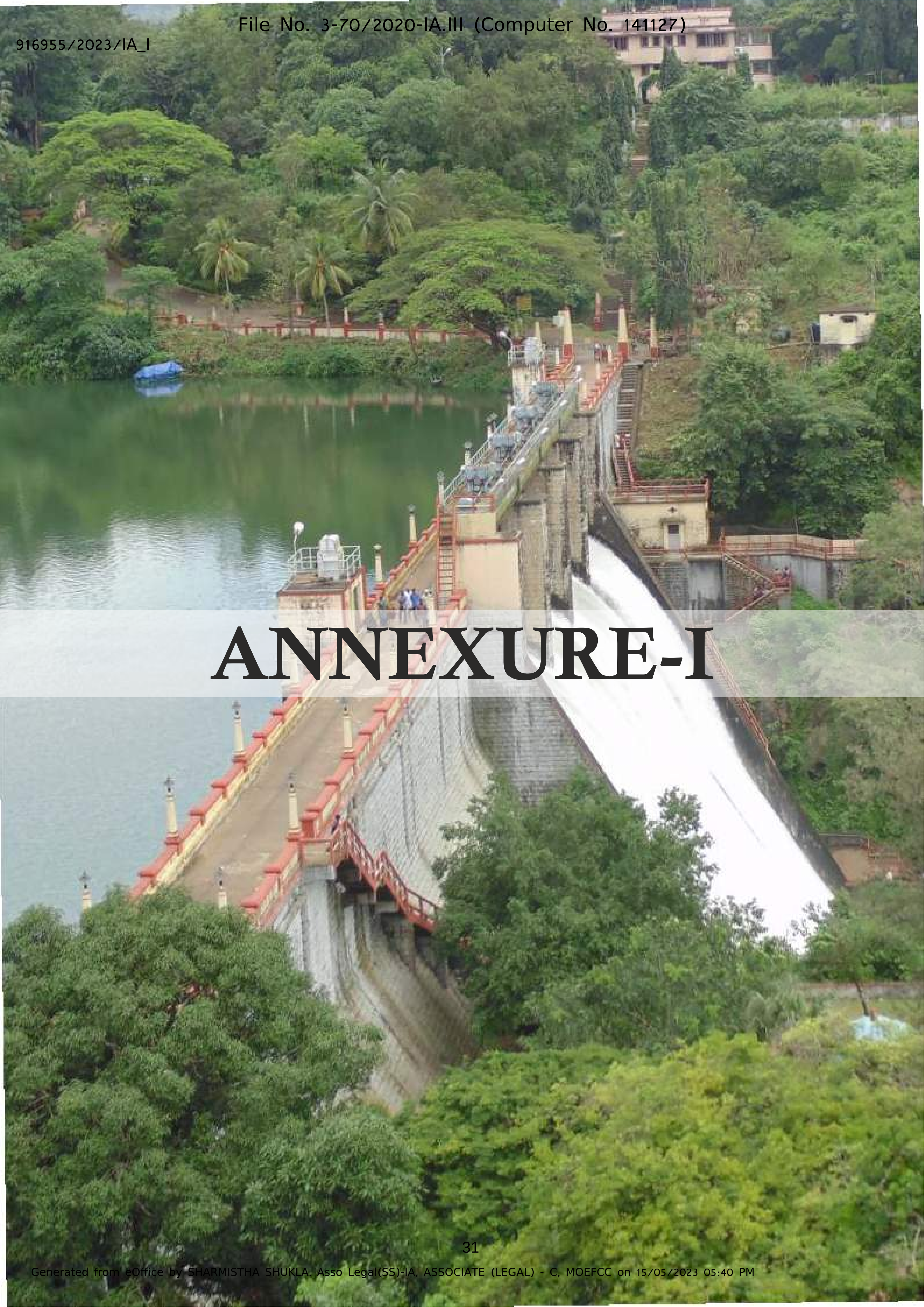
7.2 There are instances of sediment removal from dams/rivers for different purposes and activities like for commercial purposes, restoration of storage capacity of reservoirs, channelization of rivers, etc. Such activities generally do not fall under regular maintenance/ upkeep or disaster management and will be governed by this national framework for sediment management.

7.3 The detailed procedure for appraisal, environmental & other clearances and monitoring of the proposals of sand and gravel mining has been described in the "Sustainable Sand Mining Management Guidelines, 2016" of MoEF&CC".

Further, the detailed Guidelines for de-silting of reservoirs, its applicability and procedures for Environment Clearance, Forest Clearance, and Wildlife Clearance, activity listed at Sl. No.18, Table 2.2, in the "Operational Procedures for Assessing and Managing Environmental Impacts in Existing Dam Projects" CWC, November, 2020 may also be referred.

7.4 For de-silting/ dredging of sediment from rivers/ reservoirs; comprehensive DPR may be prepared by the State Authority/ Project authority/ PSU/private company etc. A Technical Advisory Committee (TAC) may be constituted by concerned State for appraisal and approval of the DPR for the techno-economic viability. Concerned regional Chief Engineer of CWC or his representative should be included as one of members of the State TAC. Suggested composition of State TAC is enclosed at **Annexure-VI.**

ANNEXURE-I



ANNEXURE-I

SEDIMENTATION PROCESS IN RIVERS AND RESERVOIRS

All rivers and streams flowing in alluvial plains tend towards a stable flow condition maintaining a balance between the silt load carried, silt load deposited, and the resulting volume and velocities achieved. This is generally called a stable sediment regime for the river. When underlying parameters of volume and velocities are disturbed, either due to lower gradient (entering into plain reaches) or encroachment in flood plain, widening of the channel (braiding of river streams), suspended silt particles in the river water settle down, this is called siltation. This phenomenon is normally called sedimentation when it occurs in a reservoir.

Main factors responsible for the siltation / sedimentation are:

(i) Physical and hydrological characters of the catchment, such as slope, geology and structures, land use, land cover, urbanisation, agricultural practices, deforestation and forest degradation etc.,

(ii) Intensity of erosion in the catchment (sheet, rill, gully and stream channel erosion) including over-exploitation of minerals,

(iii) Occurrence of landslides/landslips especially in hilly areas with heavy rainfall

(iv) Construction of Roads, Houses etc. in the flood plain.

(v) Quality, quantity and concentration of the sediment brought down by the river,

(vi) Size, shape and length of the reservoir and operation strategies impacting trap efficiency of the reservoir,

(vii) Some additional sources of silt generation are as follows:

   a) In rural areas, the erosion source is typically soil degradation due to intensive or inadequate agricultural practice thereby resulting in an increased amount of silt and clay in the water bodies that drain the area.
   b) In urban areas, the additional siltation sources are construction activities and seepage & sewage sludge discharged from household/business establishments with no septic tanks/wastewater treatment facilities.
   c) In water, the main pollution source is sediment from dredging, and the deposited dredged material near water shore.

The detailed phenomena of sedimentation in rivers and reservoirs are explained as under:-

SEDIMENTATION IN RIVERS

Rivers are natural channels to drain water from highlands to lowlands/seas. Erosion and aggradations are the most important geological processes which have brought down large amounts of sediments from the higher elevations to the plains and have formed large fertile plains, which were adopted by the hominoid races for their development and sustenance. Big towns were located on the banks of rivers to meet needs of water and navigation. These sediments are responsible for formation of delta of a river and providing sand to sea beaches. Further, flora and fauna (e.g. Mangrove forest) depend on water and sediment supply from rivers. Fishes and other aquatic organisms choose specific sediment types of river environments for feeding, breeding and spawning. Over time, the high lands of an area get worn down. The material thus eroded is utilized further downstream to build banks and flood plains.

Sediment carrying capacity of a river is directly proportional to the kinetic energy of water. With more kinetic energy water is capable of carrying larger amount of sediment and of bigger size. However, due to human interventions on rivers (e.g. Dams, bund, barrages etc.) natural regime of river is disturbed. Traditional flood plains remain no longer available for offloading the excess sediments and river is forced to deposit sediment in its channel or nearby. Further, as the river flows from high gradient to low gradient, momentum of the flow is reduced progressively by consumption of the kinetic energy in overcoming the flow resistance and consequently reducing its capacity to carry the sediments by tractive forces along the bed and suspension of coarser particles through turbulence, inducing thereby silt deposition en route. In the Indian context, which is essentially having monsoon type climate, there is huge variation of flows in different seasons.

Further, during floods also the rate of increase and decrease of flow is very high. As sediment carrying capacity of river is directly proportional to the quantity and velocity of water, during high flows considerable sediment is carried in the river which is deposited as the flow reduces. This rapid change of flows causes erosion and deposition at different places. This is also the main cause of change of cross-sections in alluvial rivers.

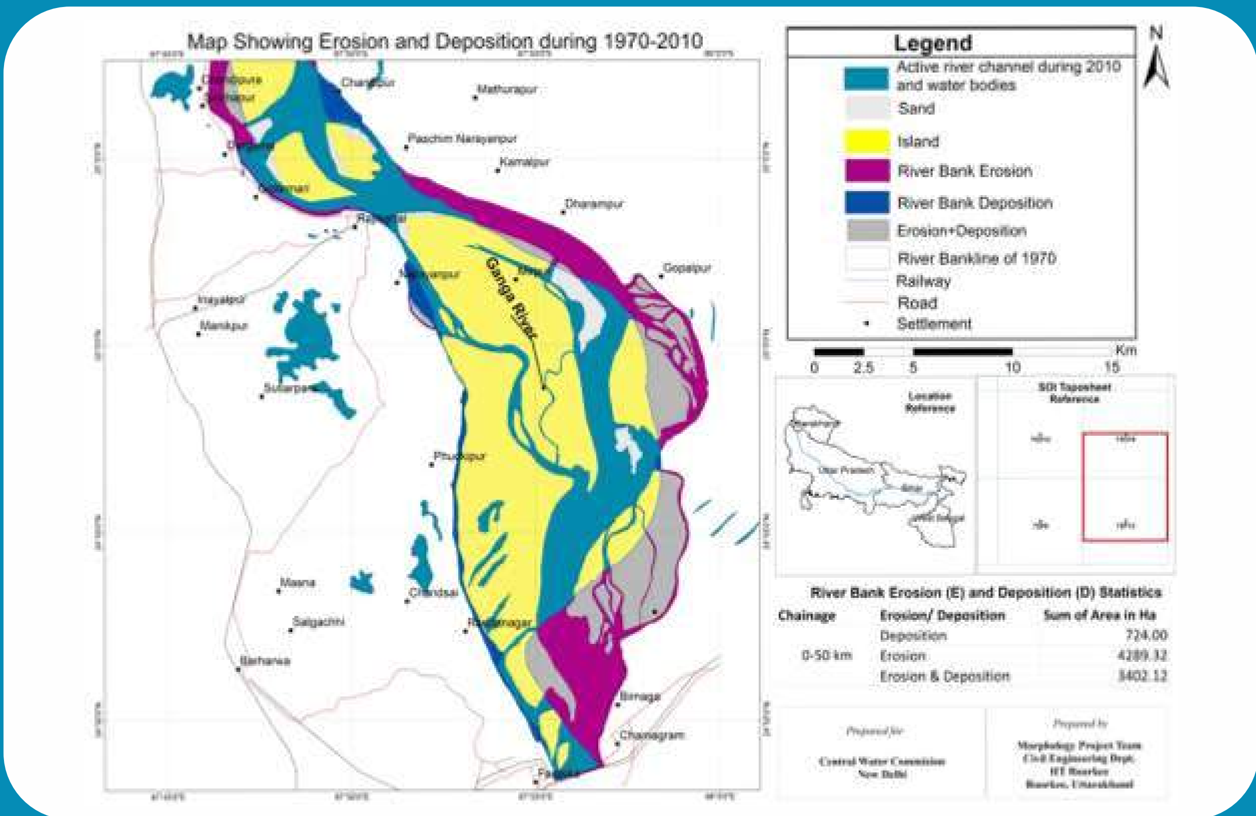


Fig 1 Sedimentation in River Ganga (near Farakka)
Source: Report of Morphological Study of River Ganga

SEDIMENTATION IN RESERVOIRS

Reservoirs are generally a part of the river system and quantity of sediment entering in the reservoir is dependent on the catchment area, type of soil, vegetation cover and gradient of river upstream of the reservoir. The river water entering the reservoir carries sediments which settle at various reaches in the reservoir. River systems erode material from the ground they flow over; these sediments are then transported downstream. When a river is dammed, the velocity of the water is slowed down and thus its ability to transport these sediments is reduced. When the velocity is too low the sediments in the river water will begin to settle down. The largest particle will settle first, near the upstream end of the reservoir, and often cause what is known as backwater delta. The finer suspended colloidal material (silts and clays) will settle down close to the dam where velocities are even lower. Some of the finer particles will remain in suspension and will flow through/over the outlet structures. The backwater delta will move forward towards the dam wall as time progresses. Depending on the shape, density, viscosity, size of the particle and flow, sediment settles in a reservoir in different patterns. The layer of water containing fine particles travel further down towards the dam as density current and may deposit there or near the rim of the reservoir. A major secondary effect is the downstream degradation of the river channel caused by the releases of clearer water. Siltation in rivers may or may not be accumulative; whereas sedimentation in reservoirs is generally accumulative.

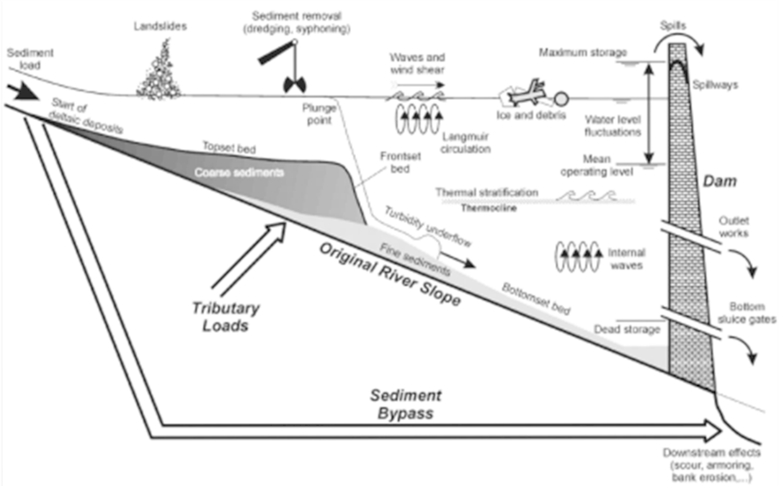
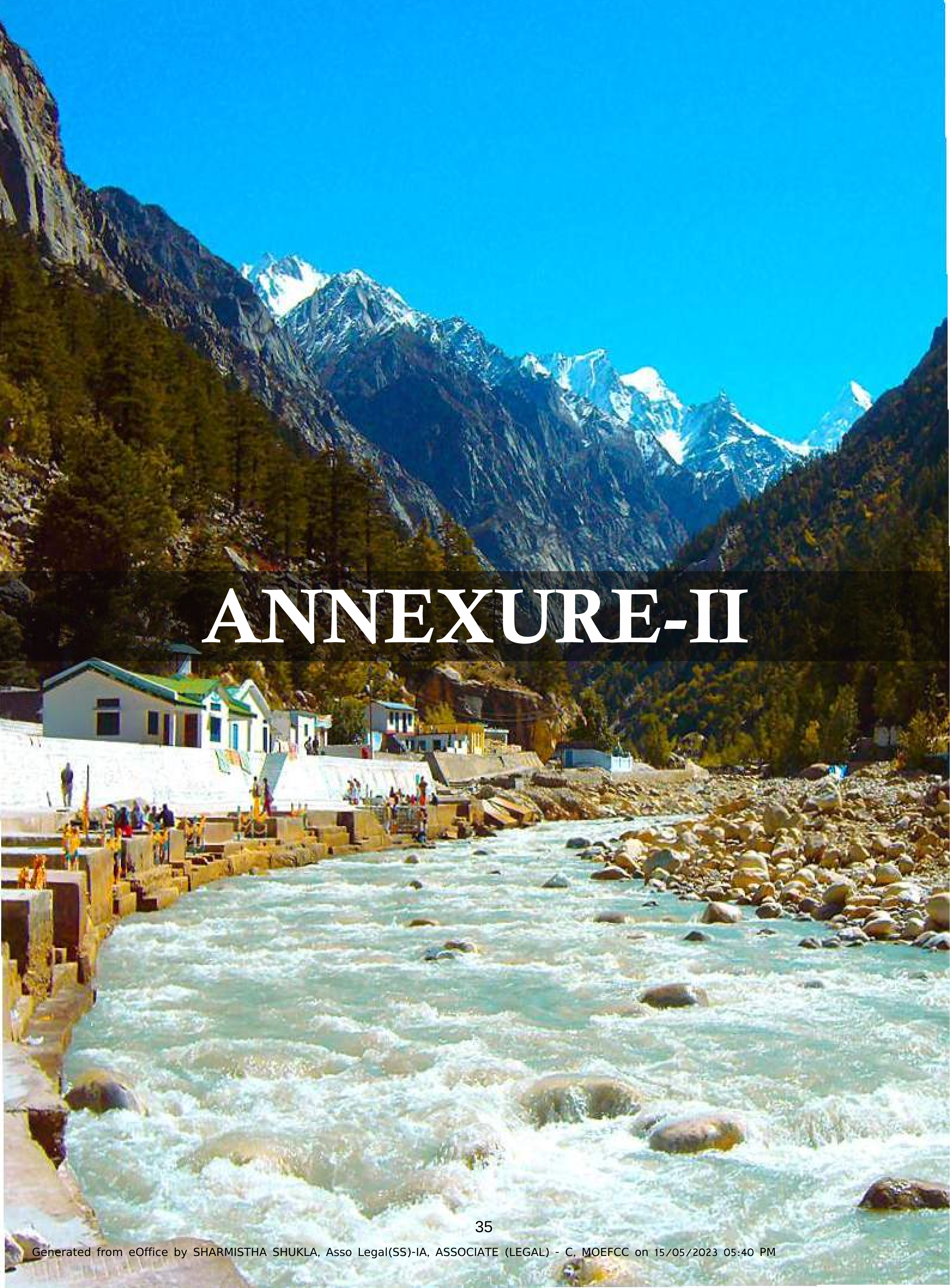


Fig 2 Sedimentation Pattern in Reservoir (USBR, 2006)

Sedimentation processes in a reservoir are quite complex because of the wide variation of the many influencing factors, the most important being, (1) hydrological fluctuations in water and sediment inflow, (2) sediment particle size variation, (3) reservoir operation fluctuations, and (4) physical controls or size and shape of the reservoir. Other factors that for some reservoirs may be quite important are: vegetative growth in upper reaches, turbulence and/or density currents, erosion of deposited sediments and/or shoreline deposits, and operation for sluicing of sediment through the dam.



ANNEXURE-II

ANNEXURE-II

APPROACH FOR SEDIMENT MANAGEMENT OF RIVERS

To reduce sediment production in the watershed sustainably, the main actions include (i) study watershed characteristics, (ii) assess the vulnerability of watershed in terms of soil erosion & sediment production using modelling and to identify & prioritise the degraded micro-watershed for treatment, (iii) treatment of the prioritised micro watersheds with biological and engineering erosion control measures, (iv) stream bank erosion control using river training works like spurs etc., and (v) trapping sediment upstream of reservoir (in river) .

Identification of hotspots may be carried out for prioritizing the action plans for Sediment Management thereby helping in targeted, cost-effective interventions. It is recommended to quantify the sediment load in order to identify effectiveness and type of interventions required.

A. **Upper course-** In this stage, the rivers have steep slopes and high sediment transport capacity. The following sediments management practices may be adopted-

a. **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. An effective and permanent method of sediment control is soil conservation in the catchment.

The method to be adopted in catchment may include-

i. Afforestation and forest management

ii. Regrading and grassland management

iii. Cultivation practices, such as crop rotation, increasing organic matter, mulching, seasonal cover crops, contour cultivation, strip cropping and terracing.

iv. Gully control and check dams- contour bunding and trenching.

v. Appropriate land use controls for protecting areas of importance.

vi. The various on-farm practices to control the soil detachment to reduce silt load may include the following practices:

- To maintain grass cover on soil
- To control sediment generation through film trap

vii. Adoption of practice of bio-filter strips, field borders, sediment retention terraces and ponds

b. **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.

c. Controlled construction activities of roads and houses also reduce the silt intake in hilly areas.

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

e. **Storage Reservoirs-** The reservoirs are built to store water. Incidentally, these act as settling tanks for sediment and trap the sediment carried by the river. Therefore, the sediment concentration of the water released from the reservoir gets effectively reduced depending upon the size of the reservoir.

f. River training works such as bank protection, spurs etc. should also be made for the vulnerable reaches to check the river bank erosion.

g. **Boulder/Gravel/ Sand Mining-** In the upper course, boulder, gravels and sand (course & fine) are deposited in the river. If these are mined at this stage and used for construction purpose, then Boulder/ Gravel/sand mining can be done strictly as per following guidelines-

    I. "Sustainable Sand Mining Management Guidelines – 2016" of MoEF&CC

    ii. "Sand Mining Framework" released by Ministry of Mines in March, 2018

    iii. GSI Guidelines for riverbed gravel/ sand mining.

B. **Middle course-** In this stage, the river exits the hills, enters the plains, gets meandered mostly on bed of fine sand, has a wide river bed and flood plain. Most importantly, the river gets 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 may be adopted:-

a. **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

b. **Submerged Vanes & Bandalling-** These methods may be adopted for management of localized aggradations within the river course as per techno-economic feasibility.

c. **Sand Mining -** In this stage, sand is deposited in the river. If these are mined at this stage and used for construction or other purposes, then a major portion of sediment can be reduced. Sand mining can be done as per the guidelines mentioned above.

d. **De-siltation/Dredging-** De-silting using sluicing and flushing near water resources infrastructure is very effective in increasing their serviceability. However, there exist some locations such as congestion at the mouth of tidal rivers, confluence points and the likes which can be tackled by de-silting after thorough examination. For navigation purpose the river reaches in the waterway path can be dredged, to have minimum required draft for plying vessels. De-silting improves the hydraulic efficiency if done near outlets and intakes.

When the meander loop extends substantially in the lateral direction, the friction loss over the meander length generates a head loss thereby resulting in a rise in the flood levels. Over the course of time, when the water path around a meander lengthens, arising to a critical level, a natural cut-off takes place. Construction of artificial cut-offs (cunnette) can be utilized as a method for flood control.

It is necessary to appreciate that de-silting does not always lead to reduction of flood levels as the levels in the river are essentially controlled by the hydraulic conditions persisting 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. On the other hand, unsystematic dredging may have the effect on bank destabilisation.

C. **Lower course-** In this stage, the river experiences considerable changes in the sediment transport and deposition, causes wide spread flooding, undergoes frequent changes in the channel path/ delta formation.

The following sediments management practices may be adopted:-

(a) **Desiltation/ Dredging-** In this stage, generally delta formation occurs due to heavy siltation, which leads to drainage congestion and the mouth of river gets choked. In these areas, dredging/ de-silting works may be undertaken to maintain flow continuity and ensure sediments transportation to sea.

(b) **River training works wherever possible may be taken up for sediment management.**

General Guidelines for carrying out de-siltation/dredging work

(i) A study of the river reach may be selected for de-siltation/ dredging by appropriate mathematical and/ or physical model studies by employing consistent practices. Based on the outcome, the DPR may be prepared.

(ii) Dredging for de-silting of Indian rivers may be adopted only in exceptional circumstances or when no other sustainable alternative is available. However, dredging for maintaining the necessary draft for maintaining the navigation may be done as and where required. However, it shall be ensured that such dredging does not cause any considerable pollution to river water and not harm flora and fauna.

(iii) The de-silting of any river reach needs to be justified bringing out clearly the flooding caused due to siltation along with technical comparisons of the alternative flood mitigation measures with "do nothing" or "proposed de-silting/ dredging" being other options. It should invariably be associated with sediment flux studies and morphological studies to confirm no significant adverse effect on downstream or upstream reach of the river including the safety and effectiveness of river crossings, water intakes, existing river bank / flood protection measures, etc. Post dredging, sediment flux studies should also be carried out to quantify the amount of silt likely to be deposited in future i.e. Sediment modelling studies for the river may be done before taking up any such project.

(iv) Negative impact on ecology and environment due to de-silting may also be studied along with other studies and should be invariably made a part of DPR.

(v) The quantity of sediments needed to be removed from rivers is usually very high. Since it may not be easy to find lands for silt disposal, therefore it should be ensured that all silt removed from river should be utilized in some works in association with concerned state government.

(vi) The proposal for de-siltation/ dredging work should also contain environmentally acceptable, practically possible silt disposal/ utilisation plan. River gravels/sands/silts are valuable resource and could be used gainfully in construction works, including housing, roads, embankment and reclamation works. Since it is very difficult to find lands for silt disposal therefore it should be ensured that all silt removed from river is utilized in some works in association with concerned state governments. However, in the critical cases where it becomes necessary to remove the silt for free flow of water or protection of any installation, action may be taken up with the prior approval of the committee.

(vii) Under no circumstances, disposal should create any contamination of water bodies, harmful to the flora and fauna existing adjacent to the disposal sites or disposed material should come back into the river again.

(viii) Desilted material should not be used for filling up of wetlands and water bodies including oxbow lakes, as these are important for recharging the ground water and providing base flow in rivers during lean season.

(ix) The modus operandi for sediment disposal should be finalized before carrying out dredging. No project should be executed before formulating a suitable and sustainable action plan for sediment disposal and be preceded by EIA Study, as per MoEF& CC notification dated 15.01.2016 to avoid damage to ecology. The methodology to be adopted (say use of dredgers etc.) should be clearly laid down in the proposal so that its co-relation with the environmental hazards can be made.

(x) Normally, funds required for dredging projects are enormous. Before embarking on a major de-silting operation in any of the rivers, the financial implications may be discussed in detail.

(xi) The dredging/de-siltation/mining activities thereby disturbing the river regime may result into some adverse impacts, i.e., (a) River bed degradation; (b) Bank erosion; (c) Channel widening; (d) Lowering of water surface elevations in the river channel; (e) Lowering of water table elevations adjacent to the river; (f) Reduction in the structural integrity of bridges, pipelines, jetties, barrages, weirs, foundations supporting high tension lines, existing bank protection works and other man-made structures; and (g) Loss of environmental values resulting from (a) through (e). Restrictions as presented in **Annexure III** need to be enforced before planning and executing any dredging/ de-silting / mining activities. These restrictions may be modified only after proper study and monitoring the effects of dredging / de-silting / mining.

OTHER STRATEGIES

1. Silt management upstream of bridges, barrages & weirs

Shoal formation upstream of barrages/bridges in the pond area is a natural phenomenon. Reduced velocities of water in upstream of barrage leads to deposit of silt, but sometime after construction, this attains equilibrium and the incoming silt is washed away through the under sluices and during the flood season when all gates of the barrage are open.

I. Upstream reaches of construction works, like barrages/bridges, etc., tend to get silted leading to wandering of river. As the waterway provided for design flood condition is much larger than actual waterway required in normal condition, there is a tendency for shoal formation upstream of barrages. Possibly, proper operation of gates verified on the basis of physical or mathematical modelling, river training, cut-off developments and provision of extra water way near the constrictions could be tried after proper assessment without impacting the morphology of river elsewhere. The area freed from the development in the form of oxbow lakes should be used for flood moderation rather than reclaiming it for other purposes.

II. Sediment sluicing may be incorporated to maintain sediment continuity from upstream to downstream reaches after carrying out necessary studies.

2. Lateral Connectivity for Sediment Management- Construction of embankment has resulted in breaking the lateral connectivity of river with its flood plain. Therefore, the silt carried by the river is being deposited in river bed only leaving the flood plains devoid of sediments. This has resulted in rising of river bed and causing bank erosion at high flood levels. In order to provide lateral connectivity to the river with its flood plains, sluice gates may be provided at appropriate places in the embankment to allow controlled flooding in flood plains. This will allow silt carried by the river to be deposited in its flood plains in thin layers distributed over vast areas and will ultimately result in reduction of silt loads in rivers and will make the agriculture fields in flood plains fertile. This will benefit in multiple ways-

(a) Reduced high flood levels in downstream.
(b) Increased fertility of flood plains. Thus reducing the dependency of farmers on chemical fertilizers.
(c) Recharge of ground water.
(d) Rejuvenation of the water bodies etc.

Here, it may be mentioned that the sluice gates which allow incoming of flood waters in country side will be used for discharging extra water in river again when flood levels in rivers go down. Such sluice gates will also reduce drainage congestion on country side, if any.

3. Floodplain Management

River tends to achieve equilibrium on its own given the hydrology, sediment and natural bed and bank disposition. It is necessary to provide the river sufficient flood plain areas and lakes along the river to moderate the flood level. Any encroachment of flood plain, reclamation of lakes or disconnection of lakes from river should be avoided. Rather, adjoining lakes/depressions may be de-silted to increase their storage capacities. The de-silting of lakes, etc., should be in such a manner that the sediment continuity is maintained and should not lead to head cut that creates safety issues for the river crossings, water intakes or river training works locally or upstream.

To maintain the hydrological and ecological balance, regulation of different activities in the river bed and different zones of flood plain is essential. The River Regulation Zoning for demarcating necessary zones should be implemented as early as possible. Central Water Commission in 1975 has already prepared a draft Flood Plain Zoning Bill in this regard.

4. Solid Waste Management

Solid waste from community including garbage, rubbish, agricultural waste, toxic Industrial discharge, construction debris, landfills in the catchment area etc. all contributes to pollution in rivers which damages highly sensitive and fragile river ecosystem. Such anthropogenic activities cause aggradations and morphological changes in the river. The disposal of solid waste needs to be controlled by the community, local municipal bodies and government bodies.

Special care should be taken for solid waste generated out of industrial processes. Many times, the same contains toxic materials and intermixing with other silt may render the same unusable for food chain use. Such waste should not be allowed to be dumped in the river.

5. River rejuvenation / Environmental flow

There is need to construct storages with sufficient flood cushion. The stored water needs to be released during the non-monsoon period in such a way that environmental flow and silt carrying capacity of river is by and large maintained. This will also improve the ecology of river. In this regard, DoWR, RD & GR, Ministry of Jal Shakti, GoI has issued guidelines on e-flow for river Ganga in 2018 vide notification dated 09.10.18

6. Bed-load management

Bed-load relocation (dredging) and artificial bed load supply, etc. Flood Control Programs-Detention basins (holding ponds), energy dissipaters in channels (culvert outlet controls, forced hydraulic jumps, drop structures, stilling wells, etc. Land use controls: these are used to reduce storm runoff), Embankments/dyke/levee construction, Periodic flushing of rivers, etc may be used to control the sediments.

7. Land Management and Soil Conservation Techniques

Check dams, settling basins, vegetation covers, agricultural practices, etc. may be adopted to control sedimentation.

8. Artificial Nourishment (with sediments) in the River

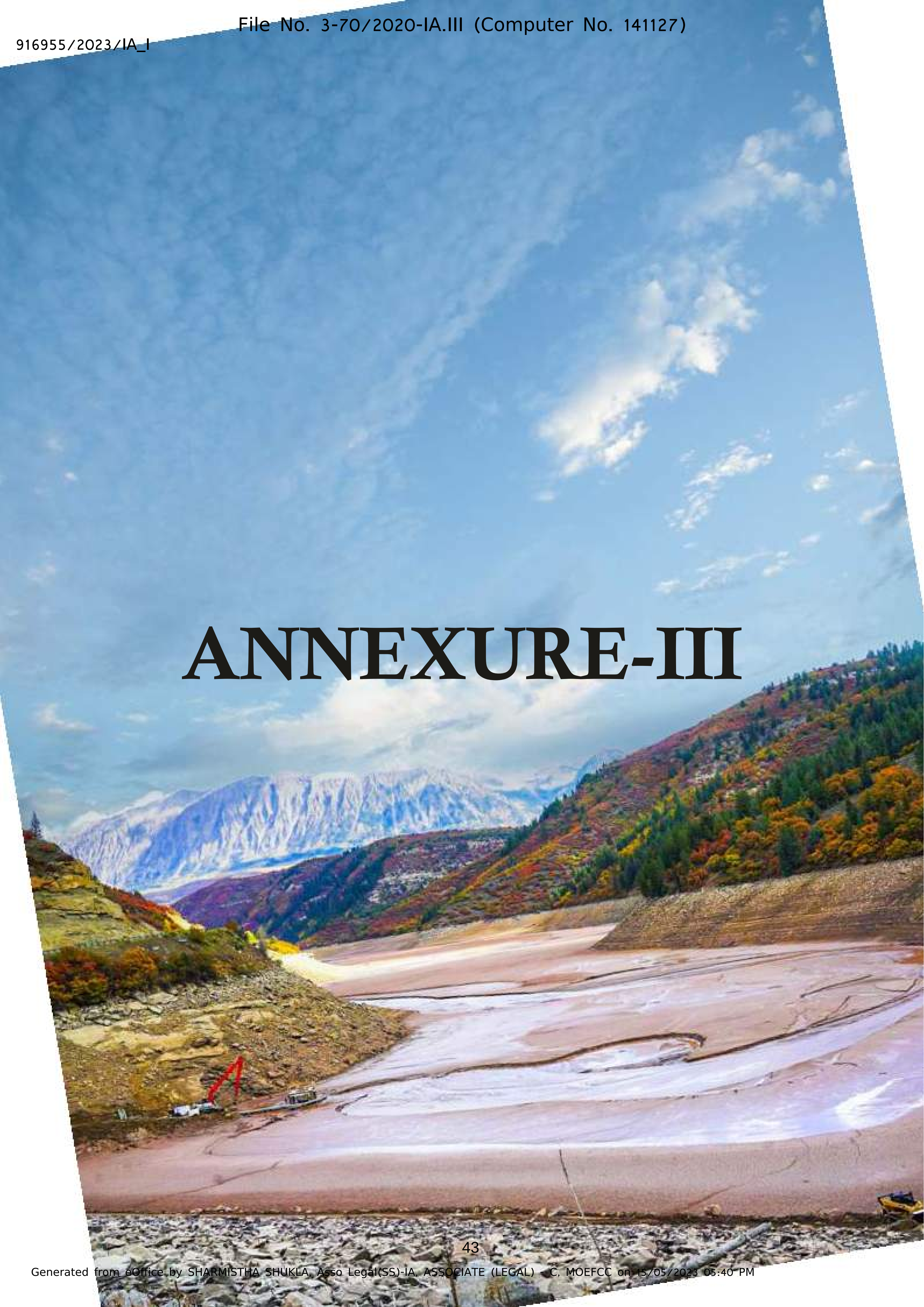
Due consideration has to be given for artificial nourishment (with sediment) in River stretches/ Reaches that contain inadequate quantity of bed sediments. This is very important to protect psammophilc/ lithophilic organism that are inhibiting in river stretches devoid of adequate supply of sediments.

Further, artificial sediment nourishment is required, in certain cases, to contain the adversities of hungry water effect in river environment. This will also minimise the ill-effect on coastal and near shore environment as well.

9. Application of Multi-Temporal High-resolution Satellite Imagery

Multi-temporal high-resolution satellite imagery may be used for identification of hotspots (heavily sediment-laden stretches). However, there are some limitations for monitoring suspended sediment concentration using remote sensing such as availability of satellite data for the study period as sediment yield is time-dependent and simultaneous satellite imagery might not be available. Therefore, more research is necessary to harness the advancements in satellite remote sensing for studying the suspended sediment dynamics and sediment management in river stretches.

ANNEXURE-III



ANNEXURE-III

DREDGING/DE-SILTING/ MINING RESTRICTIONS

The dredging/ de-silting/ mining restrictions are intended to limit the adverse impacts associated with it. They are intended to limit those impacts to a level which will have limited and manageable minor effect on the morphology and ecology of the river. These are guiding principles and de-silting works should be done only and after detailed studies are undertaken. If the State Government/local bodies have any regulatory law in this regard, conservative restriction shall be followed. However, dredging by Government agencies like IWAI, PSUs etc. for maintaining the necessary draft for maintaining the navigation may be done as and where required.

1.0 Restriction on River Bed Degradation

The magnitude of dredging-induced river bed degradation is a key factor influencing the degree of instability of the river channel. This may result in secondary impacts such as bank erosion, channel widening, lowering of water surface elevations adjacent to the river, alteration of aquatic and terrestrial habitat, and a reduction in the structural integrity of man-made structures. Since secondary impacts increase as riverbed degradation increases, the degree of dredging/ de-silting/ mining induced river channel instability can be limited by identifying and selecting appropriate reaches for suitably controlling the amount of dredging related degradation. The dredging /de-silting / mining of the river reach shall be altered or terminated if the average river bed degradation over a10 km reach length is more than 1 meter. A reach of river which has been dredged / de-silted /mined out and closed for further dredging will not be reopened until sufficient materials have accumulated to support renewed dredging activities for a reasonable period of time.

2.0 Restrictions Concerning Man-made Structures

2.1 Barrage or weirs or jetties

The barrages or weirs act as a river bed control structures across river and have huge influence on the river bed. If they fail, it could induce unintended severe riverbed degradation, bank erosion and channel widening due to design and other related issues. The unregulated dredging/ de-silting can result in Structural/functional failure of the structure in addition to the ill effects on river regime. To safeguard the structural integrity of the barrage or a weir, following restrictions shall apply:-

a) Dredging/ de-silting/ mining activity upstream of structure will be allowed only beyond 200 m or L/5 whichever is more (Where L is the length of barrage/weir).

b) Dredging/de-silting/ mining activities downstream of the structures will be allowed only beyond a distance of 800 m or L whichever is less (Where L is the length of barrage/weir).

c) The region of extraction shall be decided in upstream so as to have a positive effect on hydraulics of the pond and channel.

d) Maximum volume of extraction on downstream shall be decided by proper monitoring so that it will not have any effect on the integrity of the structure.

2.2 Water Intake Structures

No dredging below the natural bed level will be allowed within 150 m distance from the intake structures for safeguarding structural integrity. However, dredging can be carried out, if the water flow to the intake structures has been obstructed by excessive sedimentation. The dredging activity shall be restricted so that the water level reduction will not lead to functional difficulties in diverting water in to the intakes.

2.3 Bridges

No dredging will be allowed below the level of top of raft/bottom of pier within 150 m of any bridge crossing to safeguard the structural integrity of the bridge. This shall not be applied where water way has been obstructed by excessive sediment deposit and is causing flooding of upstream reaches.

2.4 Pipelines

2.4.1 Pipelines buried in the riverbed have a high potential to be adversely impacted by dredging activities. If degradation of the riverbed exposes pipelines, damage could occur through sagging, buoyancy or displacement of the line downstream due to an accumulation of debris. The following restrictions will limit the potential for dredging/ de-silting/ mining induced localized degradation to expose buried pipelines:

a) No dredging will be allowed within 60 m of any pipelines that is buried 3 m or below the river bed.

b) No dredging will be allowed within 150 m from any pipeline that is buried less than3 m below the river bed. Additional restrictions may be required for any pipeline located on or above the river bed. Such restrictions could be developed on a case by case basis.

2.4.2 Laying of pipelines/telecommunication lines/internet cables etc. below the bed of any river should be done only after the approval of the concerned competent authority.

2.5 Bank Stabilization Structures

No dredging will be allowed within 60 m of the most upstream and downstream point of the bank stabilization structure. Dredging/ de-silting/ mining restrictions as shown in Figure 1 & 2 and the limit given in Guidelines/Notification 2020 of MoEF&CC shall apply for the bank stabilization structures. The same restrictions shall apply to levees or embankments also.

2.6 Other structures

The support structure for high tension lines passing over the river shall also be treated as bridge piers and relevant restrictions as provided in clause.2.3 for bridges shall apply. Restrictions regarding other man-made structures not identified in this section may be determined on a case to case basis.

3.0 Restrictions Concerning Natural Formations

3.1 Natural Rock or Hard Deposits in River Channel

Natural rock or hard deposits located on or in the riverbed may act as riverbed controls and/or may increase aquatic habitat diversity. The importance of rock or hard deposit is dependent upon extent of its area, its thickness and other relevant factors. Based on these hard deposits, river is restrained to flow along a predefined alignment. Dredging/ de-silting/ mining shall not dislodge such hard deposits or dredging of collected silt upstream or downstream of such hard stratum shall not in turn displace it, whereby the river loses its control. Therefore, restrictions concerning natural rock deposits will have to be dealt case by case basis. River Ganga flows along important ghats of Varanasi and other such places, where people gather in large numbers. It is held to flow along these ghats due to peculiar alignment formed by rock or hard strata and silt deposits together. Hence, dredging / de-silting / mining shall be avoided at these places entirely along the width and at least 5 km upstream and downstream of such congregational areas. However, for navigational purpose, limited dredging will be allowed in such shallow reaches as recommended in DPR.

3.2 River Banks

Dredging/ de-silting/ mining close to riverbanks have 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, to limit the potential bed/bank degradation, restrictions as per notifications and guidelines being notified under Environment (Protection) Act, 1986 (latest Guidelines/Notification 2020 of MoEF&CC) shall apply on Dredging/ de-silting/ mining. The restrictions as shown in Figures 1 and 2 may be used as a guide as documented for river Ganga in the report of the Committee constituted for preparation of guidelines for works on de-siltation from Bhimgauda (Uttarakhand) to Farakka (West Bengal) prepared in 2017. Such restrictions for other rivers need to be derived by studies.

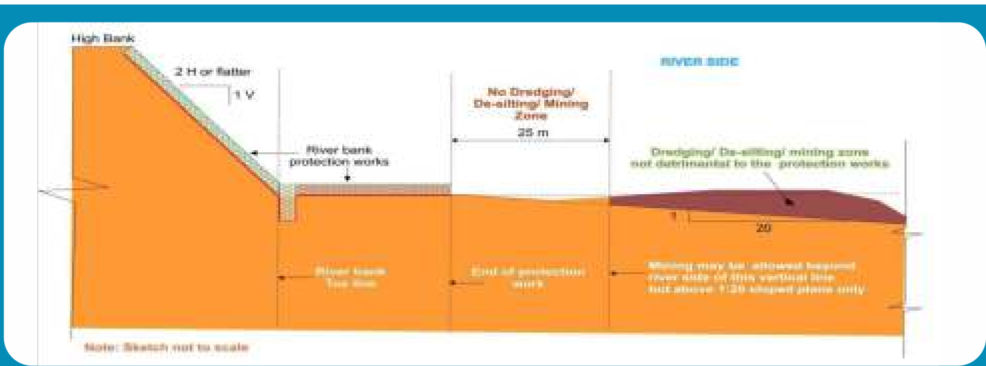


Figure 1: Typical Dredging / De-silting / Mining Restrictions for protecting river bank with bank protection works

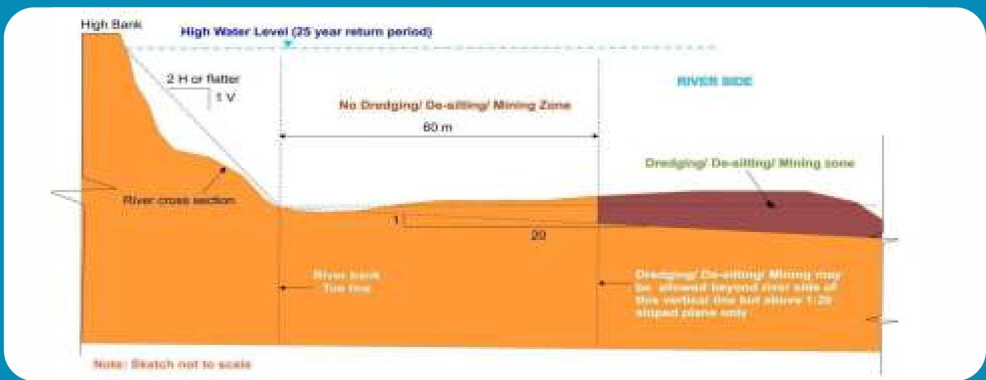


Figure 2: Typical Dredging / De-silting / Mining Restrictions for protecting natural river banks

ANNEXURE-IV

ANNEXURE-IV

SEDIMENT-A RESOURCE

NATURAL FUNCTIONS OF SEDIMENT

The presence of the sediment in rivers is very important and equally beneficial. It is important because it often enriches the soil with nutrients. This deposited sediment on the banks and flood plains of a river which is highly mineral-rich makes excellent and the most fertile farmlands. This even reduces the need of fertilisers and pesticides to be used for cropping.

Areas rich in sediments are often also rich in biodiversity. They also provide the spawning bed for fishes. Further, deltas are the wetlands that form as rivers empty their water and sediment into oceans/seas. These deltas are important wetland habitats. Plants such as lilies and hibiscus grow in deltas, as well as herbs such as wort, which are used in traditional medicines. Many animals (Hilsa fish, crustaceans such as oysters, etc) are indigenous to the shallow, shifting waters of a delta. River sediment is an important source of beach nourishment. Sediment starvation may result in receding riparian zones and wetland.

BENEFICIAL USES OF SEDIMENT

Most dredged/removed/extracted material can be a valuable resource and should be considered for beneficial uses. Potential beneficial uses of dredged material should be thoroughly examined as part of pre-project planning studies. Preliminary surveys should be made during the reconnaissance phase of new studies and detailed aerial and ground surveillance should be conducted for feasibility studies. Modern tools such as remote sensing, visual data management systems and automatic data processing may be employed to help determine the most appropriate locations and best uses for dredged material.

Depending upon the geological formation a river passes through, the dredged material will vary in its composition. Therefore, the suitability of the dredged material has to be investigated/ assessed for its optimal application. Physical, engineering and chemical characteristics of dredged material proposed for beneficial use must be determined during the initial stages of planning. A number of standard soil properties are used to determine the physical and engineering characteristics of dredged material. Soil tests mainly would include grain-size analysis, Atterberg's Limits, bulk density, specific gravity and compaction characteristics. Engineering tests may mainly include shear strength, compressibility and permeability parameters. The chemical characteristics determination may include chemical constituents, cation exchange capacity, Nitrogen, Sulphur, Heavy metals, water quality considerations, concentration, organic content and contamination depending on the potential use.

The most common beneficial use of the dredged material is as a substrate for habitat development which refers to the establishment and management of relatively stable and biologically productive plant and animal habitats. This can range from wetland, upland, aquatic to island habitats. The river dredged material, if suitable can be used for construction, raising and strengthening of embankments, dykes, levees for bank protection works, raised platforms for flood proofing etc. This would serve the dual purpose of increasing the water flow area in the river as well as a resource material for use in river bank protection works.

Shore erosion is a major issue along the country's coastline and one of the most desirable, cost-effective shore protection alternatives is beach nourishment, which is usually accomplished by transporting sand/ sandy dredged material from inshore or offshore locations by truck, hopper dredge or hydraulic pipeline to an eroding beach.

Other uses for dredged material include agriculture, forestry, horticulture, aquaculture industries, reclamation of abandoned strip mine sites, capping of solid waste landfills, protect landfills, manufacture bricks and hardened material that could be moderately contaminated and still be acceptable.

The dredged material is generally a good fill material for a variety of construction projects and serves as foundation material for road projects. Industrial/commercial development near waterways can be aided by the availability of hydraulic fill material from nearby dredging activities. The use of dredged material to expand or enhance river bank or port-related facilities has the potential benefits to the local economy.

In spite of the sometimes poor foundation qualities, dredged material containment areas have become useful sites of high and low rise residential and business complexes. However, it is mandatory to ascertain the competency and suitability of the dredged material when it is proposed to be used in the foundation or as a construction material. Success has been attained where the properties of the dredged material have been properly accounted for in the residential design. A number of coastal areas have been built on dredged material foundations in areas where insufficient land was available for a commercial airport and use of dredged material was easily justified both economically and socially.

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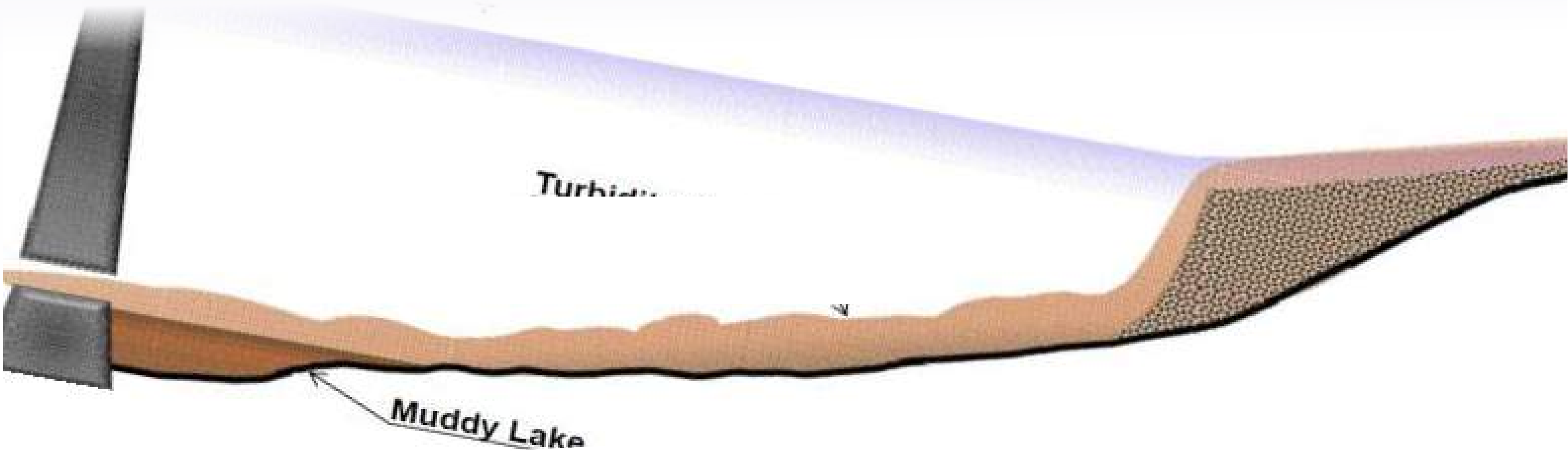
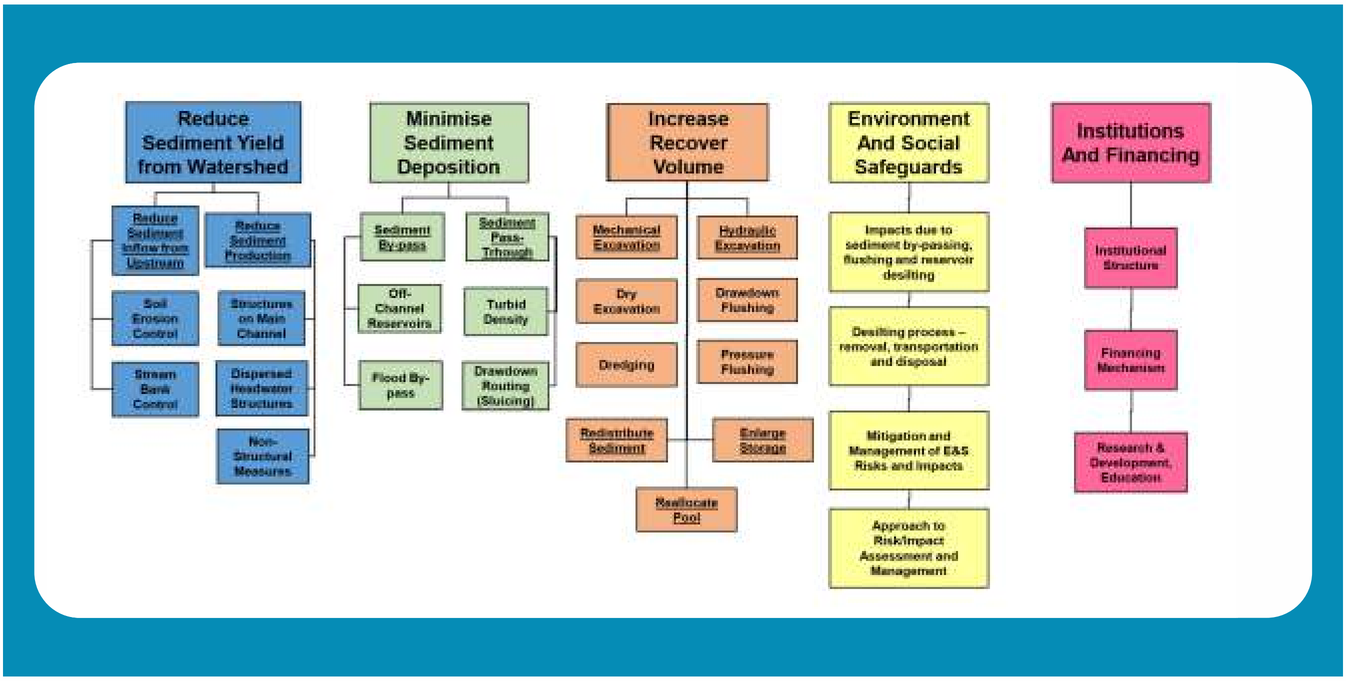
ANNEXURE-V



ANNEXURE-V

MEASURES FOR SEDIMENT MANAGEMENT IN RESERVOIR



Measures to reduce sediment yield from watershed are common for rivers as well as reservoirs. The approach given under **Annexure-II** may be referred for further details.

The other strategies for sediment management in reservoirs are described hereunder:

A. Minimize Sediment Deposition

1.0 Sediment Bypass

It is a technique for reducing sediment inflow/deposition into reservoirs. This can be further sub divided into two categories:

1.1 Flood Bypass Channel or Tunnel

The purpose of a bypass is to divert sediment laden flood flows around a reservoir to downstream of the dam. By-passing a reservoir by making use of conveyance structures (tunnel or channel) is often only feasible when favorable hydrological, topographical and morphological conditions exist. The ideal geometry for sediment bypass is one where the river makes a sharp turn between the point of sediment collection and the point of sediment reintroduction to minimize the length of the conveyance device and take advantage of the relatively steeper gradient for gravity flow. Where that ideal condition does not exist, the technique is most practical where the reservoir is relatively short, as there must be sufficient gradient to drive the transport of sediment through the diversion tunnel or diversion channel.This measure has considerable financial implication in construction of diversion infrastructures, hence may not be preferable options for many reservoirs.

1.2 Off-stream reservoir

Off-channel/Off-stream storage reservoirs are built adjacent to the main river channel (e.g., a small tributary or on the flood plain). Water from the main river is diverted into the reservoir during times of low sediment concentrations. It is an alternate approach to sediment bypass tunnel, such that the diversions from the weir are clear-water diversions, while sediment-laden water is left in the river to pass downstream. Similar to sediment bypass, there needs to be sufficient gradient to drive flow through diversion channels or tunnels to the off-channel storage feature. One advantage of this approach is that all bed load entering into reservoirs can be excluded.

2.0 Sediment Pass-through

It is the technique for evacuation of sediments from reservoir. There are various methods for pass-through described here under:

2.1 Reservoir drawdown/sluicing

Sluicing is an operational technique by which a substantial portion of the incoming sediment load is passed through the reservoir and dam before the sediment particles can settle, thereby reducing the trap efficiency of the reservoir. This is accomplished in most cases by operating the reservoir at a lower level during the flood season in order to maintain sufficient sediment transport capacity (turbulent and colloidal) through the reservoir. Higher flow velocities and higher sediment transport capacities in the water flowing through the reservoir result from operating the reservoir at these lower levels. The increased sediment transport capacity of the water flowing through the reservoir reduces the volume of sediment that is deposited. After the flood season, the pool level in the reservoir is raised to store relatively clear water. Effectiveness of sluicing operations depends mainly on the availability of excess runoff, on the grain size of the sediments and on reservoir morphology. One advantage of this approach is that deposition in the reservoir is minimized and the sediment continues to be transported downstream during the flood season when sediment is naturally discharged by the river. Finer sediments are more effectively transported through the reservoir than coarse sediments. A drawdown and sluicing strategy may be employed at reservoirs of all sizes, but the duration of sluicing depends on the watershed size and the time scale of flood events.

2.2 Vent turbid density currents

In some instances sediments can flow into a reservoir as a density current. This phenomenon can occur when the sediment concentration in the inflow is much higher than the water in the impoundment and/or there is a significant temperature difference between the incoming flow and the impounded water. Under such circumstances the density current may flow under the impounded water in the reservoir toward the dam. If the density current is not allowed to flow through the dam by means of low-level gates, a technique known as density current venting, it will curl up at the dam and its return-flow will mix with the clearer water in the reservoir. The sediment thus mixed into the clearer water will deposit with time. Most dams have been designed with a dead storage capacity below which there are no outlets and therefore the water in this zone cannot be used. Many designers incorrectly assumed that sediments would naturally deposit in this dead storage.

B. Increase/Recover Volume

1.0. Mechanical Excavation

1.1. Dry Excavation

By dry excavation, sediment which is temporarily above water is removed from the reservoir bed. At the upper delta area of the reservoir with coarse sediment deposits from flood events, the reservoir bed can be dried out and excavated by lowering the reservoir level, for instance on a seasonal basis if water level variations over the seasons are predictable. Earth-moving equipment such as bulldozers, scrapers, excavators and trucks are used. Dry excavation in the delta may be done in combination with installing a sediment check dam at the upstream end of the reservoir and mechanically removing sediment captured in the check dam.

By completely emptying the reservoir of water, access is allowed to dry excavation of the finer sediment in the lower part of the reservoir. Dry excavation in this part will in general be more challenging due to the finer material which tends to have higher water content if unconsolidated, and considerable time may be required for the sediment to dewater and consolidate. Furthermore, the access road by truck along the reservoir bed to transport the excavated sediment away may be difficult to establish. Costs of emptying the reservoir should also consider the lost benefits of power production, flood control, water supply for irrigation etc.

Coarse sediment at the upper delta consisting of sand and gravel, usually represent a higher commercial value than fine silty or clayish material from the lower part of the estuary. Such added benefits of reusable sediment which could be transported directly to the buyer of such sediment, should be considered.

The feasibility of mechanical excavation as compared to alternatives also depends on the volume of material involved to be transported from the reservoir by truck and the difficulty of obtaining suitable sites for placement of the excavated material within an economic distance with least environmental and social impact.

As dry excavation with complete emptied reservoir is performed by shutting down the dam for one year or more, it will be a larger investment in terms of lost benefits, and the interval in between such operations should be a specified number of years to be determined by careful sedimentation analyses. In case of cascade of reservoirs, the lost benefits may be alleviated by de-silting reservoirs in rotation.

1.2. Dredging

By dredging, sediment is removed from the reservoir bed from beneath the water. Mechanical excavators mounted on barges represent one option whereas hydraulic dredging with use of slurry pipelines by which a mix of sediment and water is pumped onshore is another option. Mechanical excavators are most efficient with coarse and/or well consolidated sediment in shallow areas. While excavating and lifting sediment from the bottom to the water surface, spill may occur, and the softer/finer material, the more spill.

Hydraulic dredging is a common solution to sediment removal in the deeper part of the reservoir. Transport and disposal of sediment are key factors to consider. One option is to discharge the dredged material downstream of the dam in a way, so that the downstream river has capacity for this extra sediment load. In such case, hydrosuction dredging or siphon dredging utilising the gravity of force can be considered to reduce pump energy requirements. Another option is to pump the slurry to nearby containment areas, from where the water can be drained, and the dredged material can settle and consolidate for either permanent disposal or transport by other means (trucks) to other disposal sites.

Important considerations for accessing the feasibility are the cost and efficiency of the dredging equipment itself, power supply, the dredging operation including synchronisation with the river flow, natural as well as released flow downstream, the transport and disposal of the slurry and/or excavated sediment, the sediment spilling including adverse effects this may have on the environmental conditions within the reservoir. Transport of heavy dredging equipment, spare parts, fuel etc. to and from the reservoir site is another consideration.

Pump energy, abrasion of equipment, and availability of nearby containment areas (including the river downstream) are main factors which determine the feasibility of dredging. Considering that sedimentation is of increasing concern in many countries, substantial product development goes on and many new technologies such as submersible dredge pumps emerge. Thus, awareness of the newest solutions within dredging is important to identify the best technical solutions.

Every dam site has its own constraints and opportunities when it comes to de-silting and solutions may be very different for e.g. small irrigation dams and for large hydro-power reservoirs

2.0. Hydraulic Excavation

2.1. Draw-down Flushing

Flushing is a technique whereby the flow velocities in a reservoir are increased to such an extent that deposited sediments are re-mobilized and transported through low-level outlets in the dam. For flushing to be successful, in general the ratio of reservoir storage to mean annual flow should not exceed 4%, because with larger storage the reservoir cannot be easily drawn down. Also flushing flows need to pass through the low-level outlet without appreciable backwater; it may not be feasible to use large floods which exceed low-level gate capacity as flushing event.

Two approaches to flushing exist: complete draw-down flushing and partial draw-down flushing. Complete draw-down flushing reservoir is emptied during the flood season), resulting in the creation of river-like flow conditions in the reservoir. Partial draw-down flushing occurs when the reservoir level is drawn down only partially. In this case the sediment transport capacity in the reservoir increases, but usually only enough to allow sediment within the reservoir to be re-located, i.e., sediment is moved from upstream locations in the reservoir basin to locations further downstream and closer to the dam.

2.2. Flushing Sediment for Dams in Series

In flushing sediment through a series of dams, simultaneous flushing can be accomplished by releasing the flushing pulse first from the upstream reservoir. Just before that pulse reaches the next downstream reservoir, its lower level gates are also opened to pass the sediment. After finishing the sediment flush, the reservoirs are refilled and clear water released from upper level gates to flush the downstream channel of deposited sediment. The basic sequence of operations is to draw down the reservoir water level, maintaining a free-flow state over several hours (the duration being determined by the amount of sediment to be flushed), and then allowing the reservoir water level to recover.

2.3. Pressure flushing

This technique is a variant of draw-down flushing, rather than drawing the reservoir down so that it is acting like a river in carrying its sediment load, pressure flushing works only to remove sediment directly upstream of the dam to keep intakes operational. The reservoir level is not lowered, but outlets are opened to remove sediments a short distance upstream of the outlet, creating a cone-shaped area of scour just upstream of the outlet, the scour hole being created in a fraction of the time it would take to refill. However, the scale of sediment removal by this technique is much smaller than with draw-down flushing. Rather, pressure flushing serves to reduce sediment concentrations to the intake and thereby reduce abrasion of hydraulic structures by sediment. To maintain or restore reservoir capacity, pressure flushing is not an effective technique.

3.0. Adaptive Strategies

As an alternative to actively handling sediment, the lifetime of reservoirs may be prolonged through other approaches. This must be considered in the feasibility studies of de-silting. A non-exhaustive list of options is described below.

3.1. Reconfigure Reservoir Layout

Other than from siltation over the last decades of an ageing reservoir, the hydrological design basis may have altered (e.g. different hydrograph inflow due to climate change, upstream watershed characteristics etc.), and the water resource demands downstream may also have changed considerably.

With new design criteria, consideration of new benefits and new costs (including environmental and social safeguarding costs), definition of minimum requirements, a redesign of the existing reservoir may therefore be considered. With relevant modifications, a conversion of the current layout of the reservoir into a different reservoir (although located at the same place) may be investigated.

Reconfiguration could be by dividing the existing pool into two or more interlinked pools, some possibly off-channel. Pools could serve different purposes (flood control, water supply for irrigation and other, hydro-power, fishery, tourism etc). Each pool will have better steering of sediment processes such as siltation of fine sediment in some pools and coarse sediment in other (upstream) pools. Efficient sediment handling strategies will be devised for each. The overall storage capacity will most likely be less (as existing siltation is still there), but the remaining capacity is better utilised.

A reconfiguration of the reservoir layout and utilisation will be an attempt to convert the design into a life cycle management mode instead of the original finite lifetime mode. Re-establishing a natural long-term balance of sediment considering the need for natural sediment transport processes in the downstream river should be part of this approach.

3.2. Modify Reservoir Structures

The lifetime of the reservoir may be extended by few passive modifications of the structures in the reservoir or addition of new structures.

Check dams upstream of the reservoir will arrest coarse sediment, which can subsequently be dry excavated. Other guiding structures could be built in parts of the reservoir (or sub-pools) to manipulate the flow pattern and thereby the sediment transport and siltation pattern. Submerged guiding walls could steer the near-bed sediment processes like fluid mud. The elevation of outlets could be increased. Sediment screens could protect inlets. Eddy formations in front of penstocks which cause high suspended sediment concentrations could be arrested by structural measures to reduce coarser abrasive sediment that reaches turbines. Protective coatings of gates, pipelines, and other equipment exposed to scour or abrasion by sediment.

The crest of the dam may be elevated to increase the storage volume, and the elevation of the spillway can be increased and thereby modifying the overall rules of reservoir operation. This will, however, not address the overall siltation issue, but simply extent the lifetime of the reservoir.

3.3. Improve Operational Efficiency

The efficiency of the storage capacity allocated for different purposes must be considered as an alternative to increase the storage volume. The feasibility of such solutions may be many times more beneficial but may involve participation of other stakeholders also. Examples are provided in the following.

Flood control is usually based on decades-old operating rules. With modern technology and use of low-cost internet-of-things sensor technologies, real-time hydrological data can be collected, processed and used as the backbone of dynamic rule-curves.

The same real-time data technology is applicable for hydro-power production, which may also take other parameters into account in a dynamic multi-criteria optimisation using real-time data of grid demands, electricity spot pricing forecasts, as well as conjunctive use of stored water for multiple purposes (power production during flood prone season, or crop-growth season etc.).

The loss of water in irrigation canal systems (transmission losses), as well as the field efficiency in the command area (equal distribution between fields, use of drip and sprinkler irrigation etc.), and the crop efficiency of water use (crop-per-drop) can in most cases be substantially improved. Examples of water loss of 50-80% are not uncommon in irrigation systems and should be considered as options alongside with desilting reservoirs. Other water-intensive activities drawing water from the reservoir may also be optimised.

4.0. Mechanical Removal of Silt

During low season (low flow conditions) when the reservoir is dry or marginally filled, silt may be removed from the live storage area and transported to a desired safe location. Though Environmental impact during dry excavation is generally not very high, as dry earth is being removed, it should not contribute to sediment runoff during subsequent rainy/flood conditions. This dumping place should be selected in such a way that neither it becomes a cause of sedimentation of the same reservoir from which the sediment is removed nor cause of deposition in subsequent reservoirs. Further, the temporary approach roads laid for truck movements for silt removal shall be cleared off on completion of the work as it may affect the flow path of water into the reservoir later.

5.0. Handling of Removed Sediment

Disposal or use of sediment which is removed from the reservoir is a major consideration which must be investigated thoroughly as part of the feasibility analysis. The characteristics of the sediment: Quantity as well as Quality, must be clarified as part of the long-term sediment monitoring programme as well as additional sediment analysis in connection with de-silting projects. The quality of sediment is related to its physical properties (grain size, density, load-bearing capacity, cohesiveness etc.) as well as chemical and biological properties (toxicity, nutrient contents, metal contents, organic contents, sediment oxygen demand etc.) and determines its environmental impact and potential utilisation. Different options for handling the sediment must be considered for planning de-siltation actions. The available strategies are Disposal of Sediment below Dam, Transport and Disposal Off-channel, filling up old abandoned mineral mines to reduce land subsidence, Redistribute sediment within reservoir, utilisation as resource, etc.

ANNEXURE-VI

ANNEXURE-VI

Suggestive composition of State Technical Advisory Committee (TAC) for Techno-economic Appraisal of Sediment Management Schemes

S No	Committee Composition	
1	Principal Secretary(Irrigation/Flood Control/ water Resources)	Chairman
2	Representative of State Finance Department	Member
3	Chief Engineer of CWC of concerned basin	Member
4	Representative from State Environment & Forest Department	Member
5	Member (Technical). Inland Waterways Authority of India and Development Advisor (Ports) MoPSW.	Member
6	Representative from Dept of Mining	Member
7	Representative from District Administration of concerned area	Member
8	Engineer- in-Chief (Flood control/ Water Resources/ Navigation/ Irrigation)	Member
9	Representative from Ministry of Earth Sciences	Member
10	Representative from Building Construction Dept/ Road Construction Dept	Member
11	Regional Officer, MoRTH/NHAI/NHIDCL	Member
12	Member from Downstream State (in case of Inter State implication)	Member
13	Chief Engineer/General Manager (Dam Owner/ Project Authority	Member Secretary

Terms of Reference (ToR) of the Committee:

1. The Committee shall examine the proposal in detail from Technical, Environmental and Financial and social aspects including BC ratio.
2. Committee shall examine details critically and ensure that the proposed works are not repetitive in nature.
3. Source of funding of scheme may be mentioned.
4. Committee shall check the DPR prepared as per guidelines and having all relevant information.
5. Committee may co-opt any member as Special Invitee.
6. Committee shall ensure that works are not broken in pieces to reduce the level of approval.

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Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development
and Ganga Rejuvenation

National Framework for Sediment Management