DAM SAFETY, REHABILITATION AND MONITORING

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Commissioner for Projects Formulation & Ex-Officio Secretary – I&CAD Dept.,
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Safety of Structures

• There should be proper organisational arrangements at the National and State levels for ensuring the safety of storage dams and other water related structures consisting of specialists in investigation, design, construction, hydrology, geology etc.

• A dam safety legislation may be enacted to ensure proper inspection, maintenance and surveillance of existing dams and also to ensure proper planning, investigation, design and construction for safety of new dams.

• The guidelines on the subject should be periodically updated and reformulated.

• There should be a system of continuous surveillance and regular visits by Experts.

A Draft Legislation (Draft Act 2002) on Dam Safety had been prepared and circulated to the State Governments for being adopted by them.

The issue was discussed in the NCDS and the Draft Act 2002 duly approved by MOWR was circulated to all members of NCDS for enacting in their State Legislative Assemblies.

No State Government (except Kerala) has so far enacted the legislation in their assembly.
• The Central Government received requests for enactment of this legislation by the Parliament of India from the two states, namely the States of Andhra Pradesh (combined) and West Bengal.
• The Andhra Pradesh Legislative Assembly adopted a Resolution on 24.3.2007 that the Dam Safety Legislation should be regulated in the State of Andhra Pradesh by an Act of Parliament.
• The West Bengal Legislative Assembly also passed a Resolution (West Bengal Legislative assembly Bulletin Part–I dated 24.07.07) empowering the Parliament of India to pass the necessary Dam Safety Act under Article 252 of the Constitution of India.
• The updated Dam Safety Bill 2010 is yet to be passed by Parliament.
LARGE DAMS

International Commission on Large Dams (ICOLD) Definition

• Dams above 15 m in height
• Dams between 10 m and 15 m in height provided
  a) length of crest of the dam > 500 m
  b) reservoir capacity > one million cubic metres
  c) maximum flood discharge > 2000 m³/sec
  d) specially difficult foundation problems, and/or
  e) unusual design.
Some of the Tallest Dams in the world
This is a list of the tallest dams in the world over 135 m (443 ft) in height.

Currently, the tallest dam in the world is the *Nurek Dam*, an embankment dam in Tajikistan at 300 m (984 ft) high.

The tallest arch dam is the recently completed 292 m (958 ft) high *Xiaowan Dam* in China.

For gravity dams, the tallest is the 285 m (935 ft) high *Grande Dixence Dam* in Switzerland.

When completed, a 335 m (1,099 ft) tall *Rogun Dam* also in Tajikistan could be the tallest, depending on the chosen design.

Next in line is the 312 m (1,024 ft) *Shuangjiangkou Dam* currently under construction in China.
Nurek Dam in Tajikistan

Grande Dixence Dam in Switzerland
Vajont Dam in Italy

Inguri Dam in Georgia
Tehri Dam in India

Mica Dam, in Canada
Srisailam Dam in India

Oroville Dam in United States.
El Cajón Dam in Honduras

Bhakra Dam in India.
Luzzone Dam in Switzerland

Hoover Dam in the United States
Verzasca Dam in Switzerland.
Mrlatinje Dam in Montenegro
The 5 Biggest Dams in India
1. **Tehri Dam**: Tehri Dam located on the Bhagirathi River, Uttarakhand (Now become Uttarakhand). Tehri Dam is the highest dam in India, with a height of 261 meters and the eighth tallest dam in the World.
2. **Bhakra Dam**: Bhakra Dam is a gravity dam across the Sutlej river, Himachal Pradesh. Bhakra is one of the largest dams in India, with a height of 225 meters and second largest Dam in Asia. Its reservoir, known as the “Gobind Sagar Lake” is the second largest reservoir in India, the first being Indira Sagar.
3. **Hirakud Dam:** Hirakud dam built across the Mahanadi River in Orissa. Hirakud Dam is one of the longest dams in the world about 26 km in length. There are two observation towers on the dam: one is “Gandhi Minar” and another one is “Nehru Minar”.
4. **Nagarjunasagar Dam**: Nagarjuna Sagar Dam is the world’s largest masonry dam with a height of 124 meters, built across Krishna River in Andhra Pradesh. Nagarjuna Sagar Dam is certainly the pride of India-considered the largest man-made lake in the
5. **Sardar Sarovar Dam**: Sardar Sarovar Dam also known as “Narmada Dam” is one of the largest dams built, with a height of 138 meters, over the Sacred Narmada River in Gujarat. Drought prone areas of Kutch and Saurashtra will get irrigated by this project. The Narmada dam is India’s most controversial dam.
Dam Safety in India-Overview

- Dams have played a key role in fostering rapid and sustained agricultural and rural growth and development in India.
- Over the last fifty years, India has invested substantially in dams and related infrastructure.
- 5254 large dams have been completed and another 447 under construction (NRLD 2017). Storage capacity created by these large infrastructures is 253 BCM. Another 51 BCM storage under construction stages.
<table>
<thead>
<tr>
<th>S No</th>
<th>Country</th>
<th>No. of Dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>23842</td>
</tr>
<tr>
<td>2</td>
<td>United States of America</td>
<td>9261</td>
</tr>
<tr>
<td>3</td>
<td>India</td>
<td>5102</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>3112</td>
</tr>
<tr>
<td>5</td>
<td>Brazil</td>
<td>1411</td>
</tr>
<tr>
<td>6</td>
<td>Canada</td>
<td>1170</td>
</tr>
<tr>
<td>7</td>
<td>South Africa</td>
<td>1114</td>
</tr>
<tr>
<td>8</td>
<td>Spain</td>
<td>1063</td>
</tr>
<tr>
<td>9</td>
<td>Turkey</td>
<td>972</td>
</tr>
<tr>
<td>10</td>
<td>Iran</td>
<td>802</td>
</tr>
</tbody>
</table>
STATEWISE DISTRIBUTION OF LARGE DAMS (COMPLETED AND UNDER CONSTRUCTION) IN INDIA

- Andhra Pradesh: 167
- Bihar: 26
- Chhattisgarh: 250
- Gujarat: 632
- Himachal Pradesh: 20
- Jammu & Kashmir: 17
- Jharkhand: 79
- Karnataka: 231
- Kerala: 62
- Madhya Pradesh: 906
- Maharashtra: 2354
- Odisha: 204
- Punjab: 16
- Rajasthan: 211
- Tamil Nadu: 116
- Telangana: 184
- Uttar Pradesh: 130
- Uttarakhand: 25
- West Bengal: 30
- Other States: 33

Other States includes: Andaman & Nicobar(2), Arunachal(4), Assam(4), Goa(5), Haryana (1) Manipur(4), Meghalaya(8), Nagaland(1) Sikkim(2) & Tripura(1). (Mizoram, 1)
Age-wise distribution of large dams in India

- 0-50 Years: 79.70%
- 50-100 Years: 3.63%
- More Than 100 Years: 3.97%
- Age not Known: 12.70%
Height-wise distribution of large dams in India

- 10-15 M: 11.45%
- 15-30 M: 36.14%
- 30-100 M: 0.49%
- >100 M: 51.92%
Type-wise distribution of large dams in India

- Earth Dam: 85.4%
- Gravity Dam: 6.0%
- Composite Dam: 7.7%
- Others: 0.8%
Type-wise distribution of Large Dams in India

- Earth Dam: 85.4%
- Gravity Dam: 6.0%
- Composite Dam: 0.8%
- Others: 7.7%
The Dam Safety Organisation, Central Water Commission was set up in May 1979 on the recommendation of the first State Irrigation Ministers’ Conference, 1975.

DSO, CWC was established with a view to
– evolve proper dam safety procedures in the country
– assist the dam owners in implementing them
– assist in identifying causes of potential distress, and
– recommend measures for their redressal.
Dam Safety Organisation
Central Water Commission

Chief Engineer [DSO]

- Dam Safety Monitoring Directorate
- Dam Safety Rehabilitation Directorate
- Foundation Engg. & Special Analysis Dte.
- Instrumentation Directorate
- Software Management Directorate
Risk of Dam Failure

- As per an ICOLD publication – Lessons from Dam Incidents (1973) – there have been about 200 notable failures of large dams in the world up to 1965.
- Globally, about 2.2% of dams built before 1950 have failed, while the failure rate of dams built since 1951 has been less than 0.5%.
- India too has had its share of dam failures. However, the performance of Indian dams mirrors the International trends.
- The first such failure was recorded in Madhya Pradesh during 1917 when the Tigra Dam failed due to overtopping. The worst dam disaster was the failure of Machu dam (Gujarat) in 1979 in which about 2000 people have died.
- There are 36 reported failures cases so far.
Decade-wise Dam Failures in India

- Up to 1950: 3
- 1951-1960: 10
- 1971-1980: 3
- 1981-1990: 1
- 1991-2000: 3
- 2001-2010: 9
However, no definite conclusion can be drawn about the state of dam health in respective states.
Dam Failures

- Out of 36 failures, 30 in respect of earth dams.

<table>
<thead>
<tr>
<th>Type of Dam</th>
<th>Nos of Failures</th>
<th>% Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth dams</td>
<td>30</td>
<td>83.33%</td>
</tr>
<tr>
<td>Composite dams</td>
<td>3</td>
<td>8.33%</td>
</tr>
<tr>
<td>Masonry dams</td>
<td>3</td>
<td>8.33%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>83.33%</strong></td>
</tr>
</tbody>
</table>

- Despite more than 83% failure share, risks associated with earth dams not to be heightened (their total proportion in India over 85%). Even if no failure recorded in case of concrete dam, it may not emphasise its safety aspects.
• The most common cause of dam failures in India has been breaching – accounting for about 44% of cases – followed by overtopping that accounted for about 25% failures.

• Majority of Indian dams have failed immediately after construction or at the time of first full-load, which can be clearly attributed to factors of either inadequate design or poor quality of construction.
<table>
<thead>
<tr>
<th>Age of Dam at failure</th>
<th>Number of failure</th>
<th>% Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 5 years</td>
<td>16</td>
<td>44.44%</td>
</tr>
<tr>
<td>5 - 10 years</td>
<td>7</td>
<td>19.44%</td>
</tr>
<tr>
<td>10 - 15 years</td>
<td>1</td>
<td>2.77%</td>
</tr>
<tr>
<td>15 - 20 years</td>
<td>1</td>
<td>2.77%</td>
</tr>
<tr>
<td>50 - 100 years</td>
<td>6</td>
<td>16.67%</td>
</tr>
<tr>
<td>&gt; 100 years</td>
<td>2</td>
<td>5.56%</td>
</tr>
<tr>
<td>Age not defined</td>
<td>3</td>
<td>8.33%</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>
DAM SAFETY—WHY A PRIORITY CONCERN FOR INDIA

‘Dam Safety’ is important for:
- Safeguarding huge investments in infrastructure;
- Safeguarding human life, and properties of the people living downstream of the dams.
- With increasing number of dams becoming older and older, the likelihood of dam failures in India is expected to be an ascending path.
- Many dams have varied structural deficiencies and shortcomings in operation and monitoring facilities, while a few do not meet the present design standards—both structurally and hydrologically.
- Most of the States have been failing to provide sufficient budgets for maintenance and repair of the dam. Many States also lack the institutional and technical capacities for addressing dam safety issues.
**Dam Safety Institutional Framework in India**

- **National Committee on Dam Safety (NCDS)**
  - Constituted by Govt. of India in 1987.
  - Chaired by Chairman, CWC and is represented by all the States having significant number of large dams and other dam owning organizations.
  - Suggest ways to bring dam safety activities in line with the latest state-of-art consistent with the Indian conditions.
  - Acts as a forum for exchange of views on techniques adopted for remedial measures to relieve distress in old dams.
  - So far, 37 meetings of NCDS have been held.
• **Central Dam Safety Organization (CDSO)**
  
  - Central Dam Safety Organization was established in CWC, in 1979
  - The objective of Central DSO was to:
    - Assist in identifying causes of potential distress;
    - Perform a coordinative and advisory role for the State Governments;
    - Lay down guidelines, compile technical literature, organize trainings, etc.; and create awareness in the states about dam safety.

• **State Dam Safety Organizations (SDSO)**-
  
  - DSO/Cell established in 18 States and 5 dam owning organizations
Safety Inspection of Dams

• Routine Periodic Inspection
  – by trained and experienced engineers from DSO
  – at least twice a year: pre monsoon and post monsoon
  – examination of general health of the dam and appurtenant works
  – Preparedness of dam and hydro mechanical structures for handling expected floods

• Comprehensive Dam Safety Evaluation
  – Once in 10 years
  – More comprehensive examination
  – Multi-disciplinary team for holistic view
  – May order additional field and laboratory investigations as well as numerical simulations
Safety Inspection of Dams-Contd.

• **Constitution of Dam Safety Review Panel (DSRP)**
  • One of the essential pre-requisites of DRIP was to constitute the DSRP by each State and get the dam safety inspection of their dams by the DSRP.
<table>
<thead>
<tr>
<th>State/Dam Owning Organizations having DSRPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
</tr>
<tr>
<td>Bihar</td>
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<tr>
<td>Chhattisgarh</td>
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<tr>
<td>Karnataka</td>
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<tr>
<td>Kerala</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
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<tr>
<td>Maharashtra</td>
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<tr>
<td>Odisha</td>
</tr>
</tbody>
</table>
Dam Rehabilitation and Improvement Project (DRIP)

- **Objective:** to improve the safety and operational performance of selected existing dams in the territory of the participating states.

- **Implementing Agencies:**
  - Central Water Commission (Nodal)
  - Madhya Pradesh
  - Tamil Nadu
  - Kerala
  - Karnataka
  - Odisha
  - Uttarakhand
  - Damodar Valley Corporation

**Total No. of Dams Covered = 242**
Background Information of DRIP

- **Project Duration:** 6 Years. Granted two years time extension (June 2020)
- **Financial Outlay:** 437.50 M US$ (WB share of 80%)
Project Components

DRIP has three main components:

- **Project Management** of DRIP is led by the Dam Safety Rehabilitation Directorate of the Central Water Commission as CPMU.
- **Rehabilitation and Improvement** of dams and associated appurtenances, focusing on structural and non-structural measures at around 242 project sites across 7 states.
- **Institutional Strengthening**, focusing on regulatory and technical frameworks for dam safety assurance and including targeted national and international training.
No. of DRIP Dams IA Wise

- TNWRD: 69
- TANGEDCO: 38
- KWRD: 16
- KSEB: 12
- KAWRD: 22
- UJVNL: 5
- DVC: 3
- MPWRD: 26
- OWRD: 26
DRIP Cost and Funding

- Project Cost:
  - Rupees: 2100 crore (US$: 437.50 M)
- Cost Component:
- Project Funding:
- WB Share (80%):
  - US$(Initial): 350 M
  - US$(Rev.): 279.3 M
- (US$M 70.7 surrendered in Feb/Mar 2014)
Workflow of DRIP dams

**Design Flood Review** → **DSRP Inspection** → **[Project Screening Template]** → **Tender Document(s)** → **Award of Work** → **Project Completion Report**

*Project Screening Template* is as per World Bank approved format (in line with Detailed Project Report) and includes:
- Project details
- Dam Specific details
- Health Status of dam
- Rehabilitation proposal
- ESMF compliance
- Implementation arrangement

**Non Structural Measures**
(e.g. Inflow Forecasting system, Reservoir Operation Manual, Emergency Action Plan, Public Warning System, Public Awareness Campaign etc.)
Common Observed Problems

- Seepage boils & leakage d/s of earth dams;
- Deformity & erosion of u/s and d/s slopes, erosion of abutments and settlement & cracks along dam crests;
- Excessive seepage through masonry/conc. dams;
- Cracks and pitting in spillways and outlet gate structures, erosion of energy dissipation systems;
- Deficiencies in gates and hoisting system;
- Malfunctioning of dam monitoring instruments.
- Under-designed spillways.
Progress of Activities

**Rehabilitation Progress:**
- Design Flood Review completed for all dam projects to check the adequacy of Flood handling capabilities.
- Formation of Dam Safety Review Panels consisting of independent experts by each States. DSRP inspected all the DRIP dams.
- Geophysical investigation for 5 dams.
- De-siltation study for 3 dams.
- Idukky Arch Dam – Study of *unusual dam Behavior and distress Completed*.
- Rehabilitation Works Completed for 20 dams.
Typical Rehabilitation Works in DRIP Dams

• Pointing of upstream face of masonry dams with special UV resistant mortar to control seepage.
• Treatment of dam contraction joints for damaged seals using hydrophilic materials.
• Grouting of Masonry dams to control seepage.
• Reaming of porous drains and re-drilling of foundation drains.
• Replacement of rubber seals of the spillway and sluice gates and periodic overhauling of gate hoisting systems.
• Repairs and replacement of gates.
• Provision of automation of gates and control room structures.
• Bringing the earth dam section to design section.
• Improvement of rip-rap, chute drains, toe drains, rock toe and general drainage system for earthen dams.

• Improvement of access roads to different components of the dam project.
• Providing security system to guard dam / project area.
• Improving dam instrumentation and monitoring system of dams.
• Providing additional spillway structures / fuse plugs / flush bars to take care of increased flood.
• Raising of height of dams to cater for increased design flood.
• Repair of spillway glacis and energy dissipation arrangements.
• Survey and mapping of cracks and its remedial measures.
• Desiltation of dam reservoirs on selective basis.
• Provision of standby DG Sets, dewatering pumps.
Progress of Activities

Institutional Strengthening

• 78 National training programmes have been conducted for over 2,700 officials.
• Four International Trainings on Dam Safety held at Deltares, Netherlands and USBR, USA.
• 6 technical exposure visits to Japan involving 50 participants for seismic, desiltation, and instrumentation.
• Collaboration with Japan Water Agency to develop the O&M Manual for Seismic Events.
• Organization of Three National Dam Safety conferences in Chennai (March 2015), Bengaluru (January 2016) and Roorkee (February 2017).
Progress of Activities

Institutional Strengthening

• Development of DRIP Website.
• Preparation of 16 Guidelines on different aspects of dam safety.
• QMS Documents completed.
• ISO 9001:2008 to CDSO
• Involvement of 9 Academic & Research Institutes in DRIP
**What is DHARMA?**

**Web-based Software**

**Data Collection**

**Asset Management**

**Data Management**

**DARMA — Dam Health and Rehabilitation Monitoring Application** is a web-based asset management software to support the effective collection and management of asset and health data for all large dams in India.
EAP and Inundation Mapping

• EAP to be prepared for each DRIP Dam
• Inundation maps for 81 dams completed
• Inundation maps for 7 further dams in various states under finalisation
• EAPs prepared using DRIP inundation mapping for 15 dams.
Lessons Learnt

• Lack of systematic assessment and monitoring coupled with inadequate resources is the primary cause of poor maintenance of dams and appurtenant works.
• A review of the hydrology necessitated by factors like updated meteorological knowledge has concluded that some of the existing spillways cannot cater to the revised design floods.
• Review of Design Flood estimates of DRIP dams have indicated that in more than 58% cases, the design floods have undergone substantial upward revisions. Such revisions underline the issue of hydrological safety of these dams.
• Revision study of dam hydrology needs to be completed much in advance of any rehabilitation exercise; and this not being the case has led to delays in DRIP implementation.
• Institutional Capacity building needed in design flood estimation and flood routing for most of the states.
Lessons Learnt

• In many of the cases, structural interventions for mitigation of enhanced flood estimates are not found viable owing to topographical constraints. In such cases, non-structural measures including modification of dam operational parameters needs to be implemented.
• Real time inflow forecasting systems are not in place even in important reservoirs. Such systems can add to dam safety measures besides improving operational efficiencies.
• Rehabilitation of old dams using the latest materials and technologies can enhance the life of a dam for many more decades.
• Dam design drawings or drawings as constructed are not available with project authorities in many cases.
• A well planned monitoring system based on data collection and evaluation using modern instrumentation is the key to early detection of defects and ageing scenarios.
Lessons Learnt

• Lack of institutional capacities noticed in most cases to generate adequate design drawings for proposed works.
• Dam Safety Organizations (DSO) in states are short of adequate man power and need to be strengthened.
• Training of dam engineers for inspection & monitoring, operation & maintenance, construction supervision, and emergency action planning & latest know-how, both in India and abroad, can ensure competence building in dam safety.
• Key premier Institutions brought under DRIP by facilitating acquiring state-of-the-art technologies, hardware & software programs will meet the future requirements of dam owners across the country.
• Dam Break Analysis leading to preparation of inundation maps for DRIP dams is helping in preparation of Emergency. Action Plans to meet the challenges in case of catastrophe.
Lessons Learnt

• Prevention and mitigation of ageing dams can be achieved best through carefully thought-out designs, and implementation of well-managed operation and maintenance programs.

• Siltation of reservoir is a serious issue, though in most cases the extent of siltation continues to remain unknown.

• Appropriate Interventions for Sediment Management is not available in most cases. In few cases river sluices are available in dams, but they have not been operated for long periods, and are no more functional.

• Desiltation of reservoir is difficult in many a cases owing to environmental concerns related to sediment disposal

• Lessons learnt from DRIP have contributed for the finalization of Central Dam Safety Bill 2016, to be passed by the Parliament.
Proposal for DRIP -II

Pre-Requisites for participation in the DRIP-II:

- Early Submission of proposal consisting of name of the proposed dams, their deficiency along with the cost estimates to CWC.
- Formation of Dam Safety Review Panel by each participating States.
- Formation of State Dam Safety Organisation in the States.
- Immediate initiation of the review of design flood of the proposed dams. Review of Design Flood has to be carried out by the State themselves either through their department or consultancy or through academic institutes and requires the CWC’s approval.
- Formation of a dedicated cell (Project Management Unit) in each of the participating States for day-to-day liasoning.
- Preparation of Project Screening Templates (Rehabilitation proposals) for each proposed dam by undertaking geo-technical, geophysical investigation and under water inspection by ROV, wherever required etc.
- Disclosure of the ESMF framework to the general stakeholders.
- Preparation of Tender Documents, approval of the same from the competent level, and start of tendering process and award of works.
Proposal for DRIP -II

Pre-Requisites for participation in the DRIP-II:

• Sufficient estimates to cover all proposed rehabilitation measures – *estimates should be prepared on latest SOR to avoid large variations*.

• Need to investigate the exact leaking dam blocks, the quantity of leakage with respect to reservoir water level – *it is essential to know levels, locations of exit and probable entry points of water in the dam body etc., for planning the appropriate rehabilitation measures. If any remedial measures were taken by the department in the past to mitigate the problem, the same should be recorded along with the outcome of rehabilitation.*

• Need to have centralized system for procurement of goods as well as the preparation of the EAP, dam breach study, and flood forecasting and warning system so as to have uniformity in system which may result in economic maintenance in future

• Need of expert advice (*in case DSRP does not include hydromechanical expert*) for major hydro-mechanical issues.
Proposal for DRIP -II

• Pre-Requisites for participation in the DRIP-II:
  – Sufficient Estimates for comprehensive rehabilitation work along with the provision for basic dam safety facilities works.
  – Sufficient provision for the dam instrumentation, trainings (both national as well as international), potential tourism sites at the dam, investigation works, preparation of Emergency action plan for each of the proposed dams, Desiltation study, bathymetric survey work, inflow forecasting of reservoir, flood warning system, if required.
  – Project funds shall not be used to increase the design storage capacity of a reservoir.
  – Rehabilitation cost of the dam – varies from dam to dam. Under DRIP, average rehabilitation cost of one dam comes as about Rs. 10.0 Crores.
### Original / Updated Project Cost (Rs. In Cr.)

<table>
<thead>
<tr>
<th>Implementing Agency</th>
<th>As Per PAD</th>
<th>Original Project Cost</th>
<th>Revised Project Cost Submitted By SPMU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>MPWRD</td>
<td>315</td>
<td>293</td>
<td>6</td>
</tr>
<tr>
<td>OWRD</td>
<td>148</td>
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<td>CWC</td>
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<td>KAWRD</td>
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</tr>
<tr>
<td>UJVNL</td>
<td>-</td>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>DVC</td>
<td>-</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td>Unallocated Resource</td>
<td>480</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2100</strong></td>
<td><strong>1610</strong></td>
<td><strong>157</strong></td>
</tr>
</tbody>
</table>

- **86.22%**
- **6.20%**
- **6.64%**
- **0.95%**
## Cost of Rehabilitation of American dams

<table>
<thead>
<tr>
<th>Size-Based Category</th>
<th>Percent of Dams in Need of Rehab</th>
<th>Cost Estimate Per Rehab Project</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category #1 1 &lt;= 15’</td>
<td>42% = 7,635</td>
<td>$276,098/project</td>
<td>$2.273 Billion</td>
</tr>
<tr>
<td>Category #2 1 &lt;= 25’</td>
<td>44.2% = 11,900</td>
<td>$649,821/project</td>
<td>$8.13 Billion</td>
</tr>
<tr>
<td>Category #3 1 &lt;= 50’</td>
<td>43% = 13005</td>
<td>$1,685,834/project</td>
<td>$22.569 Billion</td>
</tr>
<tr>
<td>Category #4 greater than 50’</td>
<td>38% = 2,068</td>
<td>$8,851,025/project</td>
<td>$18.484 Billion</td>
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</tbody>
</table>

Total cost for all projects (23800 Dams) Avg. cost Rs. 14.48 Cr. | $51.456 Billion (344755.2 Cr)

Source: ASDSO 2009
Project Screening Template

• FORM-I: PROJECT DETAILS
• FORM-II: DAM SPECIFIC DETAILS
• FORM-III: HEALTH STATUS OF DAMS
• FORM-IV: REHABILITATION PROPOSALS
• FORM-V: ENVIRONMENTAL AND SOCIAL MANAGEMENT FRAMEWORK (ESMF) COMPLIANCE
• FORM-VI: IMPLEMENTATION ARRANGEMENT
• FORM-VII: ADDITIONAL INFORMATION
• PRACTICAL APPLICATION
Some of the Tools for Developing a Good Project Screening Template

- Salient features
- Hydrology reports including peak flood
- Instrumentation data
- Pre- and post-monsoon inspection reports
- Periodic inspection reports
- Incident reports
- Input from dam operators
- Mechanical-electrical reports
- Environmental impact report
Failure of Machu-II Dam 1979
Machu-II Dam Failure

• Machu-II Dam is located on river Machu, 9 km u/s of Morbi town in Gujarat.

• Completed in 1972, the 24.7 m high dam has a central masonry spillway and 2.3 & 1.4 km long earthen flanks on either side.

• On Aug. 10, 1979, witnessed a flood of 14000 cusecs against designed spillway capacity of 6180. Dam overtopped and 700 & 1000m stretch of flanks washed out.

• 2000 people died in Morbi and 12700 houses were destroyed.

• Now, dam height raised by 2.7m, spillway capacity enhanced to 26650 cmecs.
Sarathi Dam, Madhya Pradesh
Durgawati Dam, Bihar
Approach Road issue at Ashok Nalla Dam of Odisha
Kuttiyadi Dam, Kerala
Maudha Dam, Uttar Pradesh
Baglihar Dam, Jammu & Kashmir
Dhuti Weir and Ari Dam, Madhya Pradesh
Konar Dam, Jharkhand
Temghar Dam, Maharashtra
Regulation of the flood in October 2009 at the Srisailam project in Andhra Pradesh
Introduction

• Neelam Sanjeeva Reddy Sagar (NSRS) Srisailam Project, constructed across river Krishna, is a multi-purpose hydro electric project with an installed capacity of 1670 MW.
• The dam is one of the largest concrete dams in India, with a maximum height of 470 feet over the deepest foundation.
• There are two powerhouses, viz; the left bank powerhouse with an installed capacity of 900 MW (6 X 150MW) and the right bank powerhouse with an installed capacity of 770 MW (7 X 110 MW).
• The spillway of the dam is designed for a discharge of 1,10,300 cusec (cubic feet per second) at Full Reservoir Level (FRL) of +885.00 feet and 13.20 lakh cusec at Maximum Water Level (MWL) of +892.00 feet.
• The capacity of the reservoir at FRL is 263.63 TMC.
• Spillway has 12 vents (of 60 feet x 50 feet) with radial crest gates.
• A restriction has been imposed that the end gates of no.1 and no.12 be operated during extreme floods only.
• Top level of dam is +904 feet. Length of dam is 1680 feet.
• Dam is designed for a thousand year return flood of 20.20 lakh cusec. In such a scenario, the magnitude of the present flood of 25.50 lakh cusec is even more than the thousand year return flood and is likely to occur once in 10,000 years.
IN OVERFLOW SECTION

![Diagram of Instrumentation in Overflow Section]

**NOTATION** | **INSTRUMENTS** |
---|---|
G | GROUP OF FIVE STRAIN METERS, ONE NO. STRESS STRAIN METER AND ONE STRESS METER |
J | GROUP OF FIVE STRAIN METERS AND ONE NO. STRESS STRAIN METER |
D | STRESS METERS |
O | ROCK COMPRESSION DISPLACEMENT METERS |
P | PORE PRESSURE CELLS |
L | LONG GAUGE STRAIN METERS |
S | NO STRESS STRAIN METERS |
T | THERMOMETERS |

**No. Of Instruments**

| | B9 | B18 |
---|---|---|
G | 5 |
J | 2 |
D | 6 |
O | 3 |
P | 4 |
L | 4 |
S | 2 |
T | 22 |

---

IN NON-OVERFLOW SECTION

![Diagram of Instrumentation in Non-Overflow Section]

**NOTATION** | **INSTRUMENTS** |
---|---|
G | GROUP OF FIVE STRAIN METERS, ONE NO. STRESS STRAIN METER AND ONE STRESS METER |
J | GROUP OF FIVE STRAIN METERS AND ONE NO. STRESS STRAIN METER |
D | STRESS METERS |
O | ROCK COMPRESSION DISPLACEMENT METERS |
P | PORE PRESSURE CELLS |
L | LONG GAUGE STRAIN METERS |
S | NO STRESS STRAIN METERS |
T | THERMOMETERS |

**No. Of Instruments**

| | B9 | B18 |
---|---|---|
G | 5 |
J | 2 |
D | 6 |
O | 3 |
P | 4 |
L | 4 |
S | 2 |
T | 22 |
• An unprecedented heavy rainfall was received in the areas around Mantralayam on the border of Karnataka State and Andhra Pradesh State (both in Kurnool District and Mahbubnagar District) in Krishna river basin during the period from September 29th to 2nd October, 2009 particularly.

• The rainfall ranged from 344mm to 560 mm.

• This rainfall caused extremely unprecedented and unrecorded level of peak inflow of the order of 25.50 lakh cusec on 2.10.2009 at Srisailam reservoir against an earlier highest recorded flow of 10.60 lakh cusec that had occurred on 7.10.1903.

• Bulk of rainfall occurred below the major storage reservoirs of upper riparian States without giving any scope for flood moderation.

• The unprecedented floods occurred between 2.10.2009 to 6.10.2009.
• The Srisailam reservoir received unprecedented floods of high intensity in the first week of October 2009.

• The maximum flood received is 25, 50,000 cusec at the dam site (against the design flood of 19.55 lakh cusec) and the maximum upstream water level recorded at an all time high of + 896.50 feet against the designed MWL and the FRL.

• The maximum discharge through spillway was 14, 80,400 cusecs as against the designed discharge of 13.20 lakh cusecs at MWL.

• The duration of high inflows and outflows lasted for nearly 78 hours.

• The end gates in vents 1 and 12 were also opened to pass the record outflows.

• The coordination among various agencies led to successful routing of more than 600 TMC of flood over 600 kilometers of river length.
Earlier, high floods had occurred during 1998 and the right side powerhouse was completely inundated under the tail water of the dam due to opening of 12th gate, causing loss of crores of rupees to the power plant.

The occurrence of a flood of such high intensity of 25, 50,000 cusec at the dam site was without precedent.

The sudden surge in the inflows was as a result of record rainfall in the un-intercepted catchment area downstream of Tungabhadra dam and Jurala project but upstream of the Srisailam dam.

As the run off on account of the heavy rainfall was in the area not covered by the gauging stations of Central Water Commission (CWC), the magnitude of the inflows received at the Srisailam dam could not be anticipated well in advance.

As a result, pre depletion of the Srisailam reservoir was not possible to such an extent that the upstream water levels could be limited to the designed level of +892.00 feet.

However, it is seen that the reservoir level was brought down from + 884.90 feet at 19.00 hrs on 30.09.09 to a level of +880.60 feet by 23.00 hrs on 01.10.2009, depleting to an extent of 27.289 TMC.
Imagine a situation where one is faced with the task of managing a reservoir holding about 350 TMC of water and watching about 25.5 lakh cusec of inflow and 14.8 lakh cusec of water being discharged from a height of 250 feet.

It can be beyond the imagination for many, but the staff of Srisailam reservoir, particularly those engaged in operating the radial crest gates of the project, encountered such a situation.

Giving an account of the moments when the reservoir reached its highest recorded level ever, 896.5 feet, officials of the reservoir recollected that there was massive vibration of the dam when about 25.5 lakh cusec of water was being received and 14.8 lakh cusec discharged on Oct 3.

“We stayed on at the site in spite of the awesome spectacle as otherwise no worker would have dared to stay there” Mr Y Abdul Basheer, who was present at the site on the fateful day, said.

Asked what was going in their minds at that time, the engineer said that “though the situation was frightening, never in my mind was there any apprehension that the dam would give in.”

The quality of construction and the rigorous standards enforced by the engineers those days was beyond any question.
UPSTREAM SIDE OF SRISAILAM DAM
AT WATER LEVEL +896.50 FEET
Design Flood - Extent of Revision

- One third of dam failures are the direct result of flood exceeding the capacity of spillways.
- In India, overtopping accounts for 25% failures. Machu-II failure (1979) was due to overtopping, on account of inadequate spillway capacity.
- Checking and upgrading the DF estimates is a key technical priority in national dam safety program.
- DF revisions is also the prime requirement under Dam Rehabilitation & Improvement Project (DRIP).
- Review of DFs completed for 217 DRIP dam projects.
- For DRIP dams, there is an upward revision of over 50% for 58% of dams and an upward revision of over 100% for 36% of dams.
- For many dams, revised DF is exceeding the original estimates by substantial orders:
  - Kharadi dam (MP): 929%,
  - Sher tank (MP): 503%,
  - Manimukhanadhi Dam (TN): 384%,
  - Mangalam dam (Kerala): 525%.
Design Flood - Extent of Revision

- DVC
- UJVNL
- Karnataka
- Kerala
- TN
- OWRD
- MPWRD

No. of Dams

- 0-25%: 59
  - DVC: 3
  - UJVNL: 23
  - Karnataka: 22
  - Kerala: 7
  - TN: 5
  - OWRD: 5
  - MPWRD: 4

- 25-50%: 33
  - DVC: 3
  - UJVNL: 14
  - Karnataka: 5
  - Kerala: 2
  - TN: 2
  - OWRD: 3
  - MPWRD: 1

- 50-75%: 29
  - DVC: 2
  - UJVNL: 13
  - Karnataka: 2
  - Kerala: 4
  - TN: 2
  - OWRD: 5
  - MPWRD: 1

- 75-100%: 18
  - DVC: 1
  - UJVNL: 12
  - Karnataka: 3
  - Kerala: 2
  - TN: 1
  - OWRD: 5
  - MPWRD: 1

- >100%: 78
  - DVC: 8
  - UJVNL: 21
  - Karnataka: 32
  - Kerala: 12
  - TN: 5
  - OWRD: 3
  - MPWRD: 1

Total: 217

125
Dam Safety Procedures in India

CWC Guidelines for Safety Inspection of Dams, June 1987

- Hydrological Safety
- Structural Safety
- Operational Adequacy

Visual inspection
  - Pre Monsoon
  - Post Monsoon

PHASE – II INSPECTION

• Supplementary to Phase – I inspections

• Includes all additional studies, investigations and analyses
PERFORMANCE MONITORING THROUGH INSTRUMENTATION

**INSTRUMENTATION – KEY TO MONITORING**

- Instrumentation of a dam furnishes data to determine if the completed structure is functioning as intended and provides a continuing surveillance of the structure to warn of any unsafe developments.

- Warning or timely detection of a problem
- Definition and analysis of a problem
- Proof that behavior is as expected
- Remedial action performance evaluation
- Main objectives:
  1. Diagnostic,
  2. Predictive, and
  3. Research and Development.

- Main criteria:
  1. Reliability (accuracy, resolution, precision and drift)
  2. Durability
  3. Ease of readout automation
INSTRUMENTATION IN DAMS

ARCH DAMS

Key

- SP - Survey point
- TS - VW Temperature sensor
- W - V-Notch Weir
- PC - VW Pressure Cell
- PZ - Piezometer (single or string)
- WL - Water Level Meter
- SM - Strong Motion Accelerograph
- J - Jointmeter
- P - Pendulum system
- ST - Strain Gauge
INSTRUMENTATION IN DAMS

GRAVITY DAMS

Key

SP - Survey point
TS - VW Temperature sensor
W - V-Notch Weir
PC - VW Pressure Cell
PZ - Piezometer (single or string)
EX - Extensometer
WL - Water Level Meter
SM - Strong Motion Accelerograph
J - Jointmeter
P - Pendulum system
ST - Strain Gauge
INSTRUMENTATION IN DAMS

EMBANKMENT DAMS

Key

- **SP** - Survey point
- **TS** - VW Temperature sensor
- **I** - Inclinometer
- **W** - V-Notch Weir
- **PC** - VW Pressure Cell
- **PZ** - Piezometer (single or string)
- **EX** - Extensometer
- **WL** - Water Level Meter
- **SC** - Settlement Cell
- **SM** - Strong Motion Accelerograph
Dam Instrumentation:

- Status of dam instrumentation in most of the dams is very poor. Hardly 4 to 5% of dams are having some meaningful and operational dam instrumentation to monitor the behavior of the dam.
- Even in cases where instrumentation measures like Vnotches or plumb-lines are available, not sufficient care is being given to the data collection and achieving.
- States have very limited technical capabilities for analyzing instrumentation data for investigation and detection of dam distress.
- Seismic instruments are either not there, or if available are not functional. The dam operator urgently requires seismic instrumentation networks for ensuring prompt response to earthquake events.
Investment made in Dams and the related Infrastructures by the Central/State Govts.

• Over the past 11 five year plan periods, development of major and medium irrigation sector alone has absorbed over 3,50,418 crores of rupees.

• Some of the early plan periods taking away lion’s share (11 to 22%) perhaps constraining developing of other equally crucial sectors.

• (Source: Report of the Working Group’s on MMI and CAD for 12th Plan).
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of state</th>
<th>Status of Dam Safety Organisation /Cell / setup overseeing dam safety activities etc. of states</th>
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<tbody>
<tr>
<td>1</td>
<td>Andhra Pradesh</td>
<td>Dam Safety Organisation</td>
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<tr>
<td>2</td>
<td>Bihar</td>
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<td>Dam Safety Committee / Dam Safety Cell</td>
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<tr>
<td>8</td>
<td>Kerala</td>
<td>Dam Safety Organisation</td>
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<tr>
<td>9</td>
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<td>--------</td>
<td>-----------------------------</td>
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<tr>
<td>12</td>
<td>Punjab</td>
<td>Dam Safety Committee</td>
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<tr>
<td>13</td>
<td>Rajasthan</td>
<td>No separate Organisation for dam safety. Director (Dam) in the Water Resources Department oversees the activities for safety of Dams.</td>
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# Pre & Post monsoon Inspection Report - 2016

<table>
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<th>Sr No.</th>
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<td><strong>461</strong></td>
<td><strong>4</strong></td>
<td><strong>63</strong></td>
</tr>
</tbody>
</table>

*Category I* - Deficiencies which may lead to failure of dam

*Category II* - Major deficiencies requiring prompt remedial measures

*Category III* - Minor deficiencies which are rectifiable during the year
Thanks for your attention