

**GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES
CENTRAL WATER COMMISSION
DAM SAFETY ORGANISATION**

**REPORT
ON
DAM SAFETY PROCEDURES**



BHATSA DAM

NEW DELHI

Government of India
Central Water Commission

Sewa Bhavan, R.K.Puram,
New Delhi 110066

Dated the 10th July 1986

To

The Hon'ble Minister,
Ministry of Water Resources,
Government of India,
Shram Shakti Bhavan,
Rafi Marg,
New Delhi 110001

Subject: Report of Standing committee to review the existing and to evolve unified procedure of the dam safety for all the dams in India.

Sir,

The Government of India vide their Office Memorandum No.18/18/80-I.T. dated the 17th August 1982 constituted a Standing Committee to review the existing practices of inspection / maintenance of dams and allied structures in various States and to evolve standard guidelines for the same. In pursuance of the above memorandum, the Standing Committee went through the task assigned to it and I have now the pleasure to submit its report on "Dam Safety Procedure" for the country.

The procedures outlined in this report have been suggested after taking into account the experience available in the dam safety activities in India as well as abroad. The recommendations of the Committee on Dam Safety of the International Commission on Large Dams have also been kept in view.

The Committee had a very difficult task while framing the criteria for safety, because it had to steer clear of what

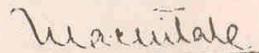
is ideal against what is practicable in the context of existing conditions in the country. The Committee has suggested that the criteria for evaluating the safety of the existing dams may not necessarily be in conformity with the current provisions for designs of new dams so long as the basic safety is not being sacrificed. Safety status of each existing dam will have to be decided separately on its own merits.

'Dam Engineering' is a discipline subject to rapid evolution. Consequently, the safety procedures will have also to be reviewed regularly by the Standing Committee. It has been suggested in the report to reconstitute the Standing Committee to make it broad based.

While submitting this report, I would also like to place on record the very pioneering work done by Shri G.S. Narayana, Chief Engineer (DSO), Central Water Commission, in his capacity as Member-Secretary of the Standing Committee. He was assisted by Shri K.D. Thite, Director(Dam Safety Service), Central Water Commission and Shri S.K. Das, the young Deputy Director from Central Water Commission. But for their devotion and hard work, the Committee would not have been able to finalise the report in time as planned.

With kind regards,

Yours faithfully,



(M.A. Chitale)

Chairman,

Central Water Commission &
Ex-Officio Secretary to
Government of India.

REPORT ON DAM SAFETY PROCEDURES

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P R E A M B L E

The growth of civilization is inextricably woven around the availability of water the world over. Dams are human device for exploitation of water for irrigation, flood control and hydro-power development etc, and thus occupy a pivotal role in the development activities of the human race. Dams, however, are not unmixed blessings. They do pose a major hazard in the unlikely event of a failure.

There have been about 200 notable reservoir failures in 20th century in the world so far. It is estimated that more than 8000 people lost their lives in these disasters. The following tabulation published by ICOLD indicates the number of major dam failures in the historical period through 1965:

| Year | Approximate No.of significant failure |
|----------------|--|
| Period to 1900 | 38 |
| 1900 to 1909 | 15 |
| 1910 to 1919 | 25 |
| 1920 to 1929 | 33 |
| 1930 to 1939 | 15 |
| 1940 to 1949 | 11 |
| 1950 to 1959 | 30 |
| 1960 to 1965 | 10 |
| Date unknown | <u>25</u> |
| | <u>202</u> |

The toll of human lives resulting from some of the major disasters throughout the world has been estimated as follows:

| Sl. No. | Dam | Country | Year of disasters | Lives lost |
|---------|---|-----------|-------------------|------------|
| 1 | Machuu II (Gujarat : 26 m masonry & earthfill) | India | 1979 | 2000+ |
| 2 | Vaiont (265 m : world's highest thin arch) | Italy | 1963 | 2600 |
| 3 | South Fork (Johnstown) (21.9 m : earthfill) | USA | 1889 | 2209 |
| 4 | Teton | USA | 1976 | 11 |
| 5 | Tailings | Italy | 1985 | 200 |
| 6 | Malpasset | France | 1959 | 421 |
| 7 | Kantle | Sri Lanka | 1986 | 100 |

Failures have not only occurred in dams built without application of engineering principles; but also in dams built to accepted state of art of "dam engineering." The failure of Malpasset dam is an example. In this connection, the observations of Karl Terzaghi in a letter addressed by him to Andr Coyne immediately after the failure of Malpasset dam are relevant.

"In situations of this kind it is at the outset impossible to divorce the technical aspects of the event from the human tragedies involved. Yet every fair-minded engineer will remember that failures of this kind are, unfortunately, essential and inevitable links in the chain of progress in the realm of engineering, because there are no other means for detecting the limit to the validity of our concepts and procedures."

"Having known you well for many years, I feel confident that the failure was not a consequence of an error in your design. Therefore, it will serve the vital purpose of disclosing a factor which in the past has not received the attention which it requires. The fact that its implications became manifest on one of your jobs is not your fault, because the occurrence of failures at the borderline of our knowledge is governed by the laws of statistics, and these laws hit at random. None of us is immune. You as an individual, and the equally innocent victims of the failure have paid one of the many fees which nature has stipulated for the advancement in the real of dam construction."

The International Congress on Large Dams has been the pioneer in projecting various aspects of dam engineering since its inception to ensure proper design and construction of safe dams. However, it was during the International Conference on Large Dams in New Delhi in 1979 a more direct and forceful action by the international body in the field of dam safety was suggested. In 1980 an adhoc committee was established. The adhoc committee recommended in the executive committee meeting during 1982 at Rio De Janeiro a new technical committee on dam safety for the following reasons:

Several dam incidents with severe consequences during recent years had given rise to general concern about the safety of dams, and indicate the necessity for the introduction of a formal safety approach.

The height of new dams and the volume of new reservoirs are increasing, while more older dams are approaching an age at which material deterioration and decreasing operational reliability may dictate some repair and upgrading. Certainly both the growing dimensions of new dams and the aging of older dams suggest a somewhat more rigid approach to safety aspects.

An ever increasing number of dams are being built in countries with little or no tradition and experience in dam engineering. The formalization of safety considerations and the issuance of summarized safety requirements would be part of the necessary transfer of technological know-how to these countries.

There was an International Conference of Safety of Dams at Portugal, Coimbra in April 1984 to highlight the importance of dam safety. Dam safety has enjoyed varying degree of attention in inverse proportion to the time and distance from the most recent catastrophic event. Engineers have been understanding and continue to understand the hazards associated with dam safety.

Dam building activity got impetus and first priority after India became independent. The total number of dams already constructed / under construction upto 1986 is of the order of 2123.

The dams built in the country by and large have performed well, but there have been a few failures. The notable ones are:

| Sl. No. | Name of the dam | Height Metres | Year of completion | Year of failure |
|----------------|------------------------|----------------------|---------------------------|------------------------|
| 1 | Kaddam | 22.5 | 1957 | 1958 |
| 2 | Panshet | 53.0 | 1961 | 1961 |
| 3 | Khadakwasla | 20.0 | 1875 | 1961 |
| 4 | Chikkhole | 36.7 | 1968 | 1972 |
| 5 | Machhu II | 24.1 | 1975 | 1979 |

The Machhu II disaster took a toll of more than 2000 lives.

Realizing the importance of dam safety, many countries in the world have initiated action to review the safety of dams in their countries and United States of America can be considered a pioneer in this field. The review conducted recently by US Army Corps of Engineers revealed that out of 8819 review inspection completed, 2925 dams were evaluated as unsafe. Of the various causes, inadequate spillway capacity was the primary deficiency found in 81% of the unsafe dams.

Keeping in view the importance of dam safety in our country, a Dam Safety Organization was established in May 1979 in Central Water Commission to assist the State Governments in various activities in dam safety. The Dam Safety Organization also initiated action for reviewing the existing procedures of dam safety in the country and also evolves appropriate dam safety practices.

Chapter I

INTRODUCTION

1.1 Background

1.1.1 The safety of dams in our country is the principal concern of the State agencies that are involved in the various aspects of their investigation, planning, design, construction, operation and maintenance. While most of the dams have performed well, there have been a few failures. These failures, either partial or complete, highlight the need to review the procedures and the criteria that are being adopted by the various States with the object of establishing the best assurance of dam safety within the limitation of the present state-of-art.

1.1.2 All State agencies who own the dams and have responsibility or are involved with any of the aspects of the project, carry-out the maintenance of the structures in some prescribed manner of their own. The practices of dam safety-operation-maintenance and surveillance, etc., being adopted by the various agencies differ from State to State and also from agency to agency within the State.

1.1.3 The broad objective is to provide a comprehensive review and to recommend means of assuring the effectiveness of existing State agencies, their practices and procedures affecting various aspects of dam safety.

1.1.4 The ultimate objective of this review would be to assure that the dam safety is given proper consideration by the State agencies in the discharge of their responsibilities, providing the greatest possible dam safety consistent with the current state of knowledge available. A unified practice would then be evolved based on what is best available at present.

1.2 Formation of Standing Committee

The Government of India, Ministry of Irrigation constituted a Standing Committee to review the existing practices and to evolve unified procedures of dam safety for all dams in India, under the chairmanship of the Chairman, Central Water Commission, vide Government of India, Ministry of Irrigation Office Memo No.18/18/80-I.T. dated 17th August 1982. A copy of the same is enclosed as Appendix I.

1.3 Terms of Reference

1.3.1 As mentioned in the Office Memorandum of the Government of India constituting this Standing Committee, the Standing Committee is to review the existing practices of inspection / maintenance of dam and allied structure in various States and to evolve standard guidelines for the same. The terms of reference to the Committee are as under:

- (a) Review practices of various agencies in the country responsible for or involved with site selection, design, construction, regulation, inspection, maintenance and operation, repairs and ultimate disposition of dams which could affect the safety and integrity of the structures.
- (b) To suggest means of improving the effectiveness of each agency, engaged in its dam safety efforts.

The Committee as constituted comprised of:

- Chairman, Central Water Commission .. Chairman
- Member (D&R), Central Water Commission .. Member
- Member (WR), Central Water Commission .. Member
- Commissioner for Indus Waters,
Ministry of Irrigation .. Member
- Director General, Geological Survey of India
(or his representative) .. Member
- Director General, India Meteorological
Department (or his representative) .. Member
- Member (Irrigation), Bhakra Beas
Management Board, Chandigarh .. Member
- * Shri J.F.Mistry, Chief Engineer, Irrigation
Department, Government of Gujarat .. Member
- Chief Engineer (DSO), Central Water Commission Member Secretary

* now Secretary (Irrigation), Government of Gujarat

The term (a) can be grouped into two parts.

- 1.3.2 The first part relating to review of practices of site selection, design construction and regulation are essentially connected with new dams which have yet to come up through information on this aspect of old dams would also be relevant.
- 1.3.3 The other part consisting of review of operation, maintenance, inspection and surveillance practices essentially relate to existing dams.
- 1.3.4 This term of reference highlights the fact that safety of the dam has to be tackled at all stages from the stage of investigation till the concept is translated to reality and subsequently during its life time. There are various Indian Standards and procedures which deal with the first part quite exhaustively. The main object of the Committee is to fill in the gap in the procedure adopted for surveillance of existing dams and, therefore, the Committee would address itself to this aspect in greater detail though incidentally; it may touch upon other aspects connected with dam building.

1.4 Stages in dam building

- 1.4.1 New dams can be made safe; if at all stages mentioned below, the existing guidelines, procedures and IS Codes are followed:

1.4.2 Investigation stage

- 1.4.2.1 The quality of data collected from field investigation would determine the adequacy of the design provisions made in the structure. Detailed geological and foundation investigations are a vital input in design.
- 1.4.2.2 The correct assessment of design inflow flood is one of the basic factors that would decide the safety of the structure. Here again, the hydrological data collected should be true and correct. There are various publications by Central Water Commission IS Codes providing necessary guidelines for ensuring accurate and detailed investigation that would form the basis for project preparation. A list of guidelines and IS Codes that are relevant for investigation stage is given in Appendix II.

1.4.3 Design stage

Provision for ensuring safety made in the design would depend upon the correctness of the data in respect of geological, hydrological, construction materials and foundation investigation,

etc. Designs of dams (masonry / earth) are governed by ISI criteria in the country. The various IS Codes relevant for design of masonry / concrete and earth core rockfill dam are given in Appendix III.

1.4.4 Construction stage

The safety of the dam would depend very much on the engineer at site who has to get the geological conditions of the foundation, the competency of reservoir rim, construction material and their properties properly evaluated vis-à-vis the design assumptions and send in time, related data back to the designers, should there be any variation in respect of the properties noticed during construction vis-à-vis design assumptions; to effect modification called for in designs.

1.4.5 Post-construction stage

The Committee would address themselves for formulating guidelines for the following:

- Administrative set up for the dam safety cell in the State and its functions.
- Fixing priorities for review of dams.
- Hydrological safety of existing dams.
- Structural review.
- Seismological review.
- Assessment of seepage in dams.
- Operation & maintenance.
- Inspection.
- Emergency preparedness plans.
- Need for legislation.

Chapter II

EXISTING PROCEDURES OF DAM SAFETY IN VARIOUS States

2.1 General

2.1.1 The Standing Committee in their first meeting decided that in order to review the present practices of various agencies involved in site selection, design, construction, regulation, inspection, maintenance and operations, repairs, etc., of dams, the relevant information has to be obtained from all concerned.

2.1.2 The Committee evolved a questionnaire and the same was sent to sixteen States, Bhakra Beas Management Board (BBMB) and Damodar Valley Corporation.

2.1.3 Replies to the questionnaire have been received from Gujarat, Maharashtra, Tamil Nadu, Uttar Pradesh, Orissa, Bhakra Beas Management Board, Damodar Valley Corporation, Kerala Irrigation Department & Kerala State Electricity Board. The information received from Karnataka is incomplete and pertains to one project only.

2.1.4 The information received from the following States / Agencies has been summarized:

- (a) Gujarat
- (b) Maharashtra
- (c) Uttar Pradesh
- (d) Kerala (Irrigation Department)
- (e) Kerala (State Electricity Board)
- (f) Orissa
- (g) Tamil Nadu (Irrigation Department)
- (h) Damodar Valley Corporation
- (i) Bhakra Beas Management Board
- (j) West Bengal
- (k) Karnataka Power Corporation
- (l) Karnataka (Irrigation)

2.2 Gujarat

2.2.1 Organization

2.2.1.1 All dams in the State are owned by the State Government and are maintained by the staff kept for operation. A separate Dam Safety

Organization is functioning in the State since September 1981 and has been attached to the Central Design Organization, Gandhi Nagar. The entire Central Design Organization is under the control of the Chief Engineer and Director, Gujarat Engineering Research Institute (GERI), Vadodra, who in turn report to the Special Secretary and Chief Engineer (Irrigation Project), Sachivalaya, Gandhi Nagar.

2.2.1.2 A Superintending Engineer (Dam Safety & Gates), along with two Executive Engineers (Civil) and one Executive Engineer (Mech) and five Deputy Executive Engineers carry out the main functions of documentation, monitoring and also inspection of dams and appurtenant structures.

2.2.1.3 A Superintending Engineer (Hydrology) with two Executive Engineers and other supporting staff review the design floods for the existing and on-going projects and suggest suitable modifications. This Cell can also be considered to be a part of the Dam Safety Organization.

2.2.2 Periodic Inspection Programme

2.2.2.1 Pre-monsoon and post-monsoon inspections are conducted by the project officers as per instructions issued in this regard. In 1981 the Government have issued detailed instructions which also include checks to be exercised during the inspections.

2.2.2.2 The inspection reports are sent to higher officers and presently also to the Dam Safety Organization.

2.2.3 Dam Safety Inspections

2.2.3.1 One of the functions of the Dam Safety Organization is to carry out phased inspection of head works of major and medium schemes and seven dams of Gujarat Water Supply and Sewerage Board (GWSSB) and to point out deficiencies noticed during the inspections, to suggest remedial measures and to watch for timely action.

2.2.3.2 The inspections of the dams is carried out as per "Checklists" and the "Guidelines for Safety Inspection of Dams" prepared by the Dam Safety Organization of the Central Water Commission.

2.2.3.3 The activities of Dam Safety Organization are restricted to major and medium dams, catering to irrigation of more than 10000 and

2000 hectares respectively, irrespective of height of dam or its storage.

2.2.3.4 Phase I inspections of all the completed major and medium dams has been done.

2.2.3.5 Training the officers in charge of dams and their inspection is imparted by Staff Training College, Gandhi Nagar and by conducting seminars on relevant subjects.

2.2.4 Geological Aspects

2.2.4.1 There is a Superintending Engineer (Geology) attached to the CDO, Gandhi Nagar. Under his guidance, the Engineering Geology Divisions under Irrigation Department of the State Government are carrying out geological investigations and subsurface exploration. Moreover, certain projects are also referred to Geological Survey of India.

2.2.5 Hydrological Aspects

2.2.5.1 At present the flood estimation is done by the unit hydrograph method and as outlined in the publication of CWC (1972) "Estimation of Design Flood – Recommended Procedures." The PMP and design storm details are obtained from India Meteorological Department.

2.2.5.2 For the purpose of deciding the spillway capacity, the dams are classified as major and medium according to their gross storage capacities. The schemes having their gross storage capacity exceeding 50000 acre ft. (6250 ha.m.) are termed as major schemes and those having their gross capacities less than 50000 acre ft. (6250 ha.m.) are termed as medium schemes. The spillway capacities for medium schemes are provided for Standard Project Flood (SPF) and that for major schemes are provided for Maximum Probable Flood (PMF).

2.2.5.3 Hydrological reviews are generally made when either observed flood surpasses the previous highest observed flood or one day/two day storm depth occurring over the basin is more severe than the design storm depth considered earlier.

2.2.6 Emergency Action Plan

2.2.6.1 There is no regular practice to prepare a dam failure inundation map for each dam.

2.2.6.2 However, during June 1983 floods in Saurashtra region, emergency preparedness plans were prepared for certain dams. The State also issues flood memorandum for various rivers every year. Setting up of flood fighting units on regional levels has been contemplated. The "Guidelines for Emergency Action Plans" as prepared by the Dam Safety Organization of the Central Water Commission is presently being adopted.

2.2.7 Quality Control

2.2.7.1 For major and medium dams under construction normally there is a quality control sub-division placed under an Executive Engineer who is not in charge of construction. The Executive Engineer or the Deputy Executive Engineer in charge of quality control reports directly to the Superintending Engineer. The quality control sub-division ensures that work is carried out according to specifications and they are empowered to stop the work if specifications are not adhered to and get the sub standard work removed.

2.2.7.2 The quality control sub-division acts as an independent agency. They collect sample from the field and test them either at the project laboratory or the samples are sent to GERI for carrying out control tests.

2.2.7.3 Training courses are frequently held at project site, at GERI, at the Staff Training College for the quality control staff to bring them up to date with the latest technological advances and practices.

2.2.8 Instrumentation

2.2.8.1 Usually instruments are provided in important earth dams having height more than 15 metres and on concrete and masonry dams more than 30 metres in height.

2.2.8.2 In earth dam hydraulic type and mechanical type, devices are provided to measure pore pressures and settlements.

2.2.8.3 In masonry and concrete dams the following instruments of the vibrating wire type are provided:

- Strain Transmitter
- Thermometers
- Stress meters
- Uplift Pressure
- Inclination Transmitter

In general, instruments provided in earth dams are functioning satisfactorily with scattered mortality. In case of masonry and concrete dams, the instruments provided in Ukai dam are reported to be functioning. The CDO and GERI analyse the observations and make use of the results for taking remedial measures, if necessary. Designs are also reviewed, if required.

2.2.9 Operation and Maintenance

The officers in charge of the various dams are required to inspect the head works from time to time and guide the resident staff in properly operating and maintaining the works. Procedures have also been laid down for detailed pre-monsoon inspection of the head works. One constraint in proper operation and maintenance appears to be the lack of adequate financial provision. Though these provisions are being increased from time to time, it appears that they are required to be substantially increased to ensure safe and proper maintenance of the project. For careful operation and maintenance during the rainy season, the State makes necessary arrangements to set up flood control cells and install wireless and warning stations, etc., at the dam sites, and the catchment areas and in the vulnerable areas downstream of the reservoir as well as at the administrative headquarters. It is, however, often noticed that general lines of communications like power, telephones & roads, etc., get disrupted during high floods or storms and it appears that a much more comprehensive arrangement is required in this respect and the State is making necessary arrangements.

2.3 Maharashtra

2.3.1 Organization

2.3.1.1 There are about 1200 large dams in Maharashtra State including 940 completed large dams and 260 dams under construction. Most of the dams in Maharashtra State are under the jurisdiction of the Irrigation Department of the State. There are some dams owned by Semi Government and private bodies like Environmental Engineering Board, Maharashtra State Electricity Board, Maharashtra Industrial Development Corporation, Bombay Municipal Corporation and Tata Hydro Electric Company. All such dams are expected to be under the State supervision of the Irrigation Department for safety aspects. The pre- and post-monsoon inspections of dams owned by Tata Hydro Electric Company are already being conducted by the officers of Irrigation Department since their commissioning.

2.3.1.2 A separate Dam Safety Organization is functioning in the State since 20th October 1980. Since 1st May 1985, the set up of the Organization has been modified and it consists of a circle level unit headed by a Superintending Engineer, with three Dam Safety Divisions as under:

- (a) Dam Safety Division No.1, Nasik with five cells (including one mathematical cell)
- (b) Dam Safety Division No.2, Nasik with four cells
- (c) Dam Safety Division No.3, Nasik with four cells.

2.3.1.3 The Dam Safety Organization and its Divisions are working as an integral part of the CDO, Nasik and are located in the same premises.

2.3.1.4 The Dam Safety Organization in Maharashtra does not have any independent hydrology unit for flood studies for the work of review of spillway capacities of existing dams in the State. However, the Government has constituted a Committee comprising the Superintending Engineer, Dam Safety Organization, Nasik, as the Chairman and six Executive Engineers from Water Resources Investigation Divisions and Irrigation Projects Investigations, including the Executive Engineer, Water Planning, CDO, Nasik, as members. One Meteorologist from India Meteorological Department is also a member of this Committee.

2.3.2 Periodic Inspection Programme

2.3.2.1 There is a schedule for regular inspection of all dams in the State which indicates the different types of dams and the categories into which they could be classified and also the levels of officers at which close vigilance is maintained by camping at the dam site and the levels at which periodic inspections are done and inspection reports sent to higher authorities. This schedule is given in Appendix IV.

2.3.2.2 For inspection reports, there are various proforma and even for inspection of minor irrigation dams, specific proforma have been evolved. The inspections are carried out as pre-monsoon and post-monsoon inspection. Special inspections are carried out during and after heavy floods, earthquake and if any signs of peculiar behaviour are noted.

- 2.3.2.3 The pre- and post-monsoon inspection reports are submitted to the concerned Superintending Engineer, the Regional Chief Engineers and also to the Superintending Engineer, DSO. The inspection reports are scrutinized in the DSO and a periodical status report (Health Report) of the dams is prepared and submitted to the Government in August and February for pre- and post-monsoon inspections respectively. Copies of these status reports are also sent to the Regional Chief Engineers and the concerned Superintending Engineers. Further compliance about the deficiencies reported and the remedial measures is watched in the DSO.
- 2.3.2.4 The DSO has now prepared a revised checklist for inspection of dams which is brought in use on trial basis on some selected projects. The State Government has also prescribed a proforma for watching progress and position in respect of completion of installation and operation capabilities of gates and control structures on outlets and spillways in dams. This information is also required to be sent to the Superintending Engineer, DSO along with the pre- and post-monsoon inspection reports.
- 2.3.2.5 The DSO has also taken up the preparation of a Dam Safety Manual. Chapter No.7 on Flood Forecasting, Reservoir Operation and Gate Operation and Chapter No.8 on Preparedness for Dealing with Emergency Situation in Dams are already published.
- 2.3.2.6 Administrative and technical methods pertaining to Dam Safety are also being reviewed for improving their effectiveness.
- 2.3.2.7 With a view to train the field officers in dam safety aspects, seminar-cum-training courses are conducted by the Engineering Staff College, Nasik-4. It is also proposed to have regular region-wise programmes of short term workshops for training the field staff working on dams on maintenance and safety aspects of dams and reservoirs.

2.3.3 Status Reports on Health of Dams

- 2.3.3.1 The Dam Safety Organization oversees the timely completion of pre- and post-monsoon inspections of all large dams in the State by the concerned field officers. The inspection reports received by the DSO are scrutinized and a periodic status report of health of dams based on these inspections is prepared and submitted to State Government in August and February, each year. The report consists of:

- (i) Statement – I: Large dams having capacity more than 60 mm³ whose health and performance is required to be carefully observed.
- (ii) Statement – II: Dams with major deficiencies (storage capacity less than 60 mm³)
- (iii) Statement – III: Dams with minor rectifiable defects (storage capacity less than 60 mm³)
- (iv) Statement – IV: Dams reported to be without signs of deficient performance.
- (v) Statement – V: List of the dams having capacity 60 mm³ and more for which pre- and post-monsoon inspection reports are not received in the DSO.

2.3.4 Geological Aspects

There is a geological unit under the Superintending Engineer (Masonry Dams), CDO, Nasik. This unit, along with the Engineering Geology Division of Geological Survey of India (GSI), Nagpur, advises on the initial geological investigations and interpretation of the results. The geological reports prepared by the GSI and the State Geologists are examined in the CDO, Nasik for preparing detailed designs about foundation treatment, etc.

2.3.5 Emergency Action Plan

2.3.5.1 In Maharashtra State there is a practice to prepare a probable dam failure inundation map for each dam. Emergency preparedness plans in appropriate details are prepared at the time of first filling.

2.3.5.2 Government of Maharashtra have issued Code of Instructions about precautions to be taken in case of imminent danger to dams as early as 1965. Even prior to this there were instructions on the subject.

2.3.5.3 The Code of Instructions mainly for earth dams, specified preparation of maps showing approximate flood level downside of the dam on the assumption that the dam may breach at the most vulnerable location. This map showing the likely flood zone as well as inhabited localities, public properties and special installations coming in the flood zone is supplied to the collector of the District, Commissioner of the Division, the officers of the various concerned

departments and District Superintendent of Police in addition to the Department officers.

- 2.3.5.4 It also specified formation of flood committees, fixing the safe places by the Mamlatdar in consultation with villages and local bodies, communication arrangements and even listing of 100 able bodied persons from nearby villages, for rescue operations.
- 2.3.5.5 The Code also provides instructions and formats of 'Alert Signal', 'Action Warning' & 'De-alert Signal' and actions to be taken by the police and administrative authorities on receiving the 'Alert Signals.'
- 2.3.5.6 The Government of Maharashtra have taken up the preparation of a Dam Safety Manual and the Chapter 8 of this Manual titled 'Preparedness for dealing with emergency situations on dams' which has already been prepared is quite exhaustive. This Manual specified that it is obligatory on the part of every agency that owns a dam which is under construction or operation to fulfill the following requirements.
- 2.3.5.7 "To formulate and implement an Emergency Action Plan for each dam to minimize to the greatest extent possible the probable loss of life and damage to the property in the event of failure of the dams."

Some other aspects covered in the Manual are:

- (a) The Regional Chief Engineers and Superintending Engineers must also ensure that the Emergency Action Plan of the dam is completed before permission of gorge filling work is granted for creation of any storage.
- (b) Guidelines for inundation map under dam-break floods.
- (c) Constitution of Emergency Action Committees.
- (d) Actions in dealing with problems of public safety during emergency on dams.
- (e) Preparation of zoning maps and land use regulation for dam-break flood zones.

2.3.6 Technical Aspects

The State has got independent organization for investigation, designs, research, quality control, staff training and dam safety. These organizations are expected to provide specialized services to

the Irrigation Department in their respective fields as per the latest state-of-art.

2.3.7 Hydrological Aspects

2.3.7.1 At present the flood estimate is done by unit hydrograph method. The design storm and relevant data for design flood are being obtained from the India Meteorological Department (IMD).

2.3.7.2 Review of spillway capacity of all existing dams has been taken up by the DSO and 33 dams have been identified for such a review. The adequacy of spillway capacity is checked tentatively for 12 dams. Latest designs flood criteria based on PMP and PMF or SPF and the up-to-date hydrological data is being followed for such reviews.

2.3.8 Structural Aspects

For actual designs, various IS Codes are followed. Wherever necessary, the USBR and US Army Corps of Engineers practice is also referred to.

2.3.9 Quality Control

2.3.9.1 Field laboratories are established at all major projects for testing the construction materials and quality control during construction. The norms of the laboratory equipments for such field laboratories are prescribed by the MERI, Nasik depending upon the size of the project and the quantities of various important items of work involved. There are also regional laboratories at several places in addition to the field laboratories to meet the requirements of any special testing work. Confirmation testing work is also done at the fully equipped laboratories at Maharashtra Engineering Research Institute, Nasik.

2.3.9.2 Responsibility of maintaining quality of work is entrusted to the field organizations in charge of construction. Normally quality control is exercised by an independent field unit which is in charge of the field laboratory and works under the project organization. In case of World Bank aided projects, there is a separate quality control circle at Pune headed by a Superintending Engineer with divisional and sub-divisional level units which assist the field organizations for maintaining proper quality control.

2.3.9.3 The Irrigation Department of Maharashtra has published Hand Books on Quality Control which are intended to serve as practical

guides on quality control on the construction of earth – embankments and concrete and masonry works.

2.3.10 Instrumentation

2.3.10.1 Instruments are provided on almost all the important dams in the State, to monitor their behaviour. Several agencies are involved in the preparation of proposals, layout and designs of instrumentation, procurement and field installation of instruments, maintenance and taking observations and analysis of the data, etc.

2.3.10.2 Regular observations of the various instruments are being taken by the field officers and these are submitted to DSO for further process.

2.3.10.3 The Irrigation Department of Maharashtra has published a Hand Book on “Instrumentation” which is intended to serve as a practical guide on instrumentation regarding installation, maintenance, upkeep and operation of instruments and collection & analysis of the data, etc.

2.3.11 Operation and Maintenance

The dams are being operated and maintained by the field officers.

2.3.12 General Aspects

In addition to the above, the Dam Safety Organization of the State also deals with the following works:

- (a) Conducting check inspections of dams.
- (b) Preparation of upto date registers of dams in the State.
 - (i) Register of large dams.
 - (ii) District-wise registers of small dams.
- (c) Compilation of record of dams (major & medium dams)
 - (i) Design reports of dams and ancillary works, including instrumentation.
 - (ii) Record drawings.
 - (iii) Completion reports.
 - (iv) Data Books
- (d) Compilation and scrutiny of operation manuals of dams.

- (i) Gate operation schedules and flood inundation maps of gated dams.
 - (ii) Emergency Action Plans of all high and medium hazard potential dams.
- (e) Compilation of miscellaneous information.
- (i) New gorge filling works.
 - (ii) Installation of wireless stations on all major projects during monsoon.

2.4 Uttar Pradesh

2.4.1 Organization

2.4.1.1 There are 80 dams in the State which are 15 metres or more in height or which impound 6000 ha.metre or more of water under the jurisdiction of the Irrigation Department. A Dam Safety Cell has been created by the Government and is functioning since August 1982. The Organization consists of one Director, one Hydrologist, two Executive Engineers and six Assistant Engineers. The main functions of the Cell are maintenance of an inventory of dams and compilation of the history of the dams to bring out areas requiring special attention for their safety. The Cell also monitors the administrative and technical procedures being adopted on all aspects of dam safety and recommends improvement where any deficiency is noticed.

2.4.2 Periodic Inspection Programme

2.4.2.1 The officer in charge of the dam inspects the dam at least once before monsoon. The Executive Engineer inspects the dam once before monsoon and thereafter as per requirements. The Superintending Engineer inspects the dam once before the monsoon. In respect of major, important and potentially more hazardous dam, inspections are done more frequently and in greater detail and also at a higher level. A maintenance manual for earth dams has been published by the Uttar Pradesh Irrigation in 1970. There is a Uttar Pradesh State Engineers Academy at Kalagarh, which also organizes refresher courses on various subjects including dam safety.

2.4.2.2 The inspection reports are sent to the next higher officers for further suitable action.

2.4.2.3 Guidelines for safety inspection of dams compiled by the Central Water Commission has been provided to field engineers for guidance in carrying out the inspection by dam safety cell. Field engineers have been asked to furnish certificate in respect of safety of dams before monsoon season.

2.4.3 Dam Safety Inspection

Checklists for maintenance and repairs of earth dams is given in the maintenance manual. The inspection is done by the field engineers directly and no such reports and follow-up action is sent to the Cell.

2.4.4 Geological Aspects

One post of Geologist has been sanctioned by the Uttar Pradesh Government in the Dam Safety Cell.

2.4.5 Emergency Action Plans

At present there are no detailed dam failure inundation maps for any dams. There is also no practice to prepare emergency preparedness plans for existing dams.

2.4.6 Technical Aspects

These are examined in the Central Designs Organization at Lucknow and Roorkee. The detailed technical designs are done as per IS Code and other standards on the subject.

2.4.7 Quality Control

At every project site quality control is set up with field laboratories to collect samples and carry out tests on smaller works. Samples are taken by the field staff and sent to outside laboratories at Roorkee and Lucknow, etc.

2.4.8 Instrumentation

Instrumentations are being provided in dams under construction as prescribed in standards and codes. Instrumentation has been done in a few important major dams only. The collected instrumentation data is being analyzed.

2.4.9 Operation and Maintenance

2.4.9.1 The operation and maintenance of the dam is done according to the standing regulation orders of the Chief Engineers. A common

maintenance manual for the earth dam published by the Uttar Pradesh Irrigation in 1970 is available for guidance. This manual specifies the duties and checklists. Pre- and post-monsoon inspections and repairs are generally carried out by the field engineers.

2.4.9.2 Uttar Pradesh Irrigation Department has brought out a “Maintenance Manual for Earth Dams” for guidance of field engineers. It specifies the important maintenance features and duties of various officers responsible for the maintenance of the dams. The common causes of failures and remedial measures have also been outlined for guidance of field officers. As per the manual, it is applicable for earth dams upto 30 metres in height as higher dams would require special study and more detailed maintenance instructions.

2.4.9.3 The manual contains detailed instructions on maintenance during monsoon and non-monsoon period. It also specifies in Chapter 6 by way of guidelines, the duties and responsibilities of various officers concerned with the safety of earth dams.

The manual also lists out the following:

- (a) Records to be maintained at dam site.
- (b) Lists of drawings and data to be maintained at dam site.
- (c) Proforma for statement of inspection data for the previous year (which includes action taken).
- (d) Daily report proforma
- (e) Checklist for maintenance and repairs of earth dams.
- (f) Proformae for record of seepage, piezometers, piezometer inspection, etc.

2.4.10 Typical Regulation Order

2.4.10.1 The manual contains a typical regulation order (Pili Reservoir) for guidance.

2.4.10.2 It specifies the regulation points and staff to be stationed. Proformae for daily gauge, rainfall, river discharge and filling of the reservoir are also given.

2.4.10.3 A schedule for filling and emptying the reservoir has been specified which indicates the dates on which particular reservoir levels should be attained. Instructions for observations for determining silting pattern, performance of relief wells and drainage systems, materials to be kept in reserve – their quantity and locations are

also specified. T&P articles to be provided to maintenance and patrolling gauges are also indicated.

2.5 Kerala (Irrigation)

2.5.1 Organization

The Kerala Public Works Department have 11 projects under their jurisdiction. A Dam Safety Cell has been created and is functioning in the office of the Chief Engineer, PIDO, Trivandrum. The Organization consists of one Executive Engineer, one Design Assistant and one Junior Designer who have been deployed for this work from the Design Organization to do this work in addition to their allotted duties. The main functions of this Cell are to document the data pertaining to dams.

2.5.2 Periodic Inspection Programme

The State does not have any periodic inspection programme. If any field officer notices some unusual or potentially dangerous situation, the matter is brought to the notice of higher authorities for instructions.

2.5.3 Dam Safety Inspections

The Department has issued a checklist for maintenance guidelines which is the same as thus circulated by the Central Water Commission. In addition, there are departmental instructions regarding inspection of irrigation structures and their maintenance which comprises of a checklist / questionnaire. The inspections are conducted by the field officers and the reports are not received in the Dam Safety Cell.

2.5.4 Emergency Action Plan

There is no practice to prepare a dam failure inundation map or emergency preparedness plans.

2.5.5 Technical Aspects

2.5.5.1 Unit Hydrograph method is used for determining the maximum flood and for providing suitable spillway. Model studies are also conducted.

2.5.5.2 There are no special manuals but the designs are prepared based on the guidelines and the relevant Indian Standards.

2.5.6 Quality Control

Some of the projects under execution are equipped with laboratories for quality control with an Executive Engineer in charge of the unit. This unit is answerable directly to the Chief Engineer.

2.5.7 Instrumentation

The old dams are instrumented to the bare minimum but these are not functioning properly. Instrumentation data has not yet been analyzed.

2.5.8 Operation and Maintenance

Maintenance is being done as per guidelines given in Kerala PWD Manual which contains checklist / questionnaire.

2.6 Kerala (State Electricity Board)

2.6.1 Organization

The Kerala State Electricity Board have 19 dams under their jurisdiction. There is no dam safety organization as such but there is an organization to look after the safety of the dams under Idukki Project. This organization consists of one Director with one Deputy Director and three Assistant Executive Engineers. The organization is known as the Research Organization, Kothamangalam.

2.6.2 Periodic Inspection Programme

No periodic inspection programme except for dams in Idukki Project. Dam monitoring unit of research organization under Kerala State Electricity Board is responsible for inspection of dams in Idukki Project. Checklists / manuals are available only for dams of Idukki Project.

2.6.3 Technical Aspects

Efforts are made to see that all the dams owned by Kerala State Electricity Board are maintained to the latest requirements in the field of design, construction and maintenance. But proper and sufficient personnel still remains to be mustered for this job.

2.6.4 Quality Control

Kerala State Electricity Board maintains quality control laboratories in all the projects under construction which though attached to the Construction Wing, performs independently and is under the Chief-in-Charge of the Project.

2.6.5 Instrumentation

Instruments are provided only in Idukki, Cheruthoni, Kulamanu and Idamalayar dams. Regular observations are taken and analysis of data are being carried out.

2.6.6 Operation and Maintenance

At present in Kerala State Electricity Board, Deputy Director, Research Organization is attending to maintenance and operation of dams in Idukki Project. There are no separate organizations for other dams. Operation manual, maintenance manual and checklists are available for Idukki dam.

2.6.7 Emergency Action Plan

No emergency action plans to cover any possible failures of dams constructed and maintained by Kerala State Electricity Board have been evolved so far.

2.7 Orissa

2.7.1 Organization

2.7.1.1 In Orissa, the operation and maintenance of all large, medium and small dams is being done by the Irrigation and Power Department. Mandira dam on river Sankh is operated and maintained by M/s Hindustan Steel Limited, Rourkela and Jalaput dam on Machkunda river operated and maintained by Andhra Pradesh State Electricity Board.

2.7.1.2 The Dam Safety Organization in Orissa is headed by Superintending Engineer, Dam Safety and Hydraulic Research Circle. Two Executive Engineers are attached for dam safety functions.

2.7.2 Periodic Inspection Programme

2.7.2.1 Dam safety inspections are conducted by Superintending Engineer, Dam Safety & Hydraulic Research Circle, Burla and Executive

Engineer, Dam Safety (Major Projects) Division and Dam Safety (Medium Projects) Division in accordance with the framework of designated duty and based on the guidelines and safety inspection of dams issued by Dam Safety Organization of Central Water Commission. The Phase I investigation for all completed and on-going medium and major projects has been completed and the inspection reports have been submitted to Engineer-in-Chief, Irrigation, Orissa. The Phase II investigation of dam safety inspection has not yet been started.

2.7.2.2 The Superintending Engineer, Safety Circle submits suggestions to the Engineer-in-Chief in respect of improvements in the administration and technical methods required to ensure dam safety as and when such necessities are needed in the course of inspection.

2.7.3 Geological Aspects

A Superintending Engineer (Geophysics) is functioning under the Engineer-in-Chief and he generally conducts geophysical exploration during inspection stages. Geophysical inspections during the pre-construction stages are done by the Engineering Geology Division of the Geological Survey of India.

2.7.4 Technical Aspects

- (a) The State is following the guidelines issued by the CWC.
- (b) The IS Code of practices is followed in the design of the dam.

2.7.5 Quality Control

The quality control organization at the State level and at project level controls the quality of work.

2.7.6 Instrumentation

Generally instrumentation is being done only in respect of major projects and this is done by the respective projects. A proposal is being made to entrust all instrumentation work to the Dam Safety Circle.

2.7.7 Operation and Maintenance

The operation and maintenance is being done by senior engineers, stationed at head works. Superintending Engineers have been stationed at major dams.

2.7.8 Emergency Action Plan

Emergency Action Planning has not yet been developed.

2.8 Tamil Nadu

2.8.1 Organization

2.8.1.1 There are 43 (forty three) dams under the jurisdiction of Tamil Nadu PWD (Irrigation Department) and 44 (forty four) dams under the control of Tamil Nadu Electricity Board.

2.8.1.2 The Dam Safety Cell in PWD in Tamil Nadu is attached to the Chief Engineer (Irrigation). The Cell comprises of one Assistant Executive Engineer, one Assistant Engineer, one Assistant D'man, one Assistant and one Office Assistant and is functioning under the control of Deputy Chief Engineer (Inter State Waters). The Cell is entrusted with the task of ensuring safety of dams in PWD, Tamil Nadu. The main functions of the Cell are documentation of details in specific formats, continuous monitoring and review of inspection reports and seepage flows and taking necessary follow-up action.

2.8.2 Periodic Inspection Programme

The field Superintending Engineers and Executive Engineers have been instructed from Chief Engineer's (Irrigation) office during April 1982 to follow the guidelines for safety inspection of dams based on the checklists furnished by the DSO and submit the inspection reports. After review of the inspection reports, the final decision regarding the remedial measures, if found necessary, is taken by the Chief Engineer (Irrigation). The guidelines issued already to the field officers in connection with the safety inspection of dams have been further amplified during 11/84 and 1/86.

2.8.3 Technical Aspects

- (a) Generally the design flood is estimated using Ryve's formula. For some recent dams, unit hydrograph method has been adopted.
- (b) (i) For the projects which are 30 m or more in height, the seismic coefficient recommended by the "Standing Committee constituted by the Government of India to advise on the seismic coefficient to be adopted in the design of River Valley Projects" is being followed.

(ii) For the projects which are less than 30 m in height, the seismic coefficient as per I.S.Code is adopted.

(c) Structural designs are as per I.S.Code.

2.8.4 Dam Safety Inspections

Dam Safety Evaluation Inspections have not yet been taken up.

2.8.5 Quality Control

In large projects, separate staff for quality control is established. This unit works directly under the control of the Chief Engineer of the Project. In case of other projects, the field officers themselves control the quality of the work. The quality of work is also ensured by frequent inspection by the higher officers.

2.8.6 Instrumentation

Instrumentation in dams are provided where essentially required and their working monitored.

2.8.7 Operation and Maintenance

Maintenance guidelines have been issued by the Chief Engineer (Irrigation) in April 1982.

2.8.8 Emergency Action Plan

There is no practice of preparing Emergency Action Plan. This will be taken up and details worked out in due course.

2.9 Damodar Valley Corporation

2.9.1 Organization

2.9.1.1 There are four dams owned and operated by Damodar Valley Corporation. These are Tilaiya, Konar, Maithon and Panchet.

2.9.1.2 A Dam Safety Cell is functioning in Damodar Valley Corporation. This Cell is headed by the Chief Engineer (Civil) with Deputy Chief Engineer (Civil), Superintending Engineer (Engineering Circle), Superintending Engineer (Circle I & II), Manager, Reservoir Operation and respective Maintenance Senior Divisional Engineers of the Dam.

2.9.2 Periodic Inspection Programme

2.9.2.1 Pre- and Post-monsoon inspections are being carried out by Level I (Superintending Engineers) and Level II (Sr.Divisional Engineers / Executive Engineers) officers. Items of inspection are generally as per the instructions of the Dam Safety Organization of the Central Water Commission issued from time to time. Special inspections are also being carried out by the two levels of engineers from time to time as the situation warrants.

2.9.2.2 There is no regular system for imparting training to the officers engaged in dam safety. The officers are sent to attend workshop or seminars.

2.9.2.3 Inspection reports are compiled and monitored by the Sr.Divisional Engineer, under the guidance of Manager, Reservoir Operation. Special items requiring remedial measures are placed before the dam safety cell which are discussed in various meetings and finally placed before the Chief Engineer (Civil) for advice.

2.9.3 Dam Safety Inspections

Dam safety inspections are carried out as per the checklists prepared by Dam Safety Organization of the Central Water Commission with minor changes.

2.9.4 Geological Aspects

The services of Geological Survey of India are requisitioned for geological and surface exploration and for interpretation of data whenever required.

2.9.5 Emergency Action Plan

There is no practice to prepare a dam failure inundation map. Emergency preparedness plan have also not been prepared so far.

2.9.6 Technical Aspects

Design floods are reviewed from time to time and spillway capacities, freeboard are being assessed accordingly. In re-assessing, latest relevant code of ISI are followed.

2.9.7 Structural Aspects

The relevant IS Codes are being followed.

2.9.8 Instrumentation

Piezometer settlement pipes are provided in earth dams. Some instruments have been installed at Konar dam after its distress. Regular observations are being taken and the data is being analyzed.

2.9.9 Operation and Maintenance

2.9.9.1 The existing practice for operation of the reservoir in Damodar Valley Corporation is incorporated in Damodar Valley Corporation reservoir manual.

2.9.9.2 There is a committee known as "Damodar Valley Reservoir Regulation Committee" with Member (Floods) of Central Water Commission as its Chairman. This Committee meets periodically to review the reservoir operation of DVC reservoirs.

2.9.9.3 Maintenance is carried out by the Maintenance Division as per CWC guidelines.

2.10 Bhakra Beas Management Board

2.10.1 Organization

2.10.1.1 Bhakra Beas Management Board is looking after the administration, maintenance and operation of a big irrigation and power complex consisting of three major hydro-electric projects, namely Bhakra dam, Beas dam, BSL Project, including Pandoh dam.

2.10.1.2 A Chief Engineer stationed at each of the three project sites looks after the safety of the dam under his charge and is assisted by the field and design engineers.

2.10.2 Periodic Inspection Programme

2.10.2.1 Periodic inspection of work of all the three dams is being done regularly by field engineers as stipulated in the publication entitled "Criteria for operation, maintenance and observations published by each project and necessary reports are sent to the Chief Engineer and Director (Designs) through their respective Superintending Engineer. As a result of field inspection, discussions and study of the problem in detail, necessary remedial measures, if required, are adopted. Annual observation memorandum for each project is

prepared on the basis of the observed, field data, and these are put up to the Board of Consultants for review and advice.

- 2.10.2.2 Detailed checklists work-wise for dry testing before initial filling, during initial filling, de-watering, etc., have been prepared and supplied to field engineers. Checks required to be done before the onset of monsoons, during monsoon and during routine and other maintenance have also been incorporated in the operating instructions issued to the field engineers.

2.10.3 Emergency Action Plan

Dam failure inundation map and Emergency Action Plans have not been prepared.

2.10.4 Hydrological Aspects

- 2.10.4.1 A network of snow gauges, rain gauges, automatic rain gauges, discharge sites with reliable communication system, etc., was created to determine the soundness of the previous available data and for collecting further data which is necessary for deciding the regulation of supplies from the reservoir from time to time.
- 2.10.4.2 A separate Regulation Directorate has been created to regulate the flow of water judiciously for maximum benefit of the water for the partner States. A separate Hydrological Cell has been created under this Directorate for comprehensive observation of hydrological data. This Hydrology Cell is also in constant touch with other related agencies for rain forecasts, glacier / avalanche studies, snowfall studies, etc., and also for deciding regulation of supplies from the reservoir.
- 2.10.4.3 The silt survey and sedimentation studies were carried out annually in the first few years of the commissioning of the project and on alternate years thereafter to know the pattern of silting in the reservoir and the loss of reservoir storage capacity.
- 2.10.4.4 The design flood for both Beas and Pandoh dams have been estimated as per USBR criteria. Estimation of flood for Bhakra dam designed nearly 40 years ago was based on various empirical formula and probable flood frequency studies. Recently, studies were carried out for Pandoh dam by CWC to work out the SPF and PMF. Similar studies for Bhakra and Beas dams have also been initiated.

2.10.5 Technical Aspects

- 2.10.5.1 A separate Design Directorate was created for the design of permanent works of Bhakra Beas project to deal with the design of various works and also to maintain a record of construction activities. The relevant Indian Standards and design criteria adopted for other similar works in India and abroad were consulted for evolving the requisite designs. For problems concerning designs of the important works, technical memos were prepared and presented to the Board of Consultants for advice.
- 2.10.5.2 A network of seismological observatories around the dams and their appurtenant works were installed to assess and monitor the seismic behaviour of the structures and also to find out the effect of impounding of water in the reservoirs on the seismicity of the area. The School of Earthquake Engineering, Roorkee was consulted for fixing up the seismic coefficient for the design of various structures and these were also got approved by the Board of Consultants.
- 2.10.5.3 The BBMB has a data bank which gives complete details of drawings, computation, model tests reports, specifications memos work-wise along with the source from where taken and are kept for ready reference.

2.10.6 Operation and Maintenance

Guidelines for maintenance staff have been laid down in the publication of "Guidelines for Operation, Maintenance and Observations" prepared separately for each dam and its appurtenant works. In addition, detailed instructions for operation, maintenance and checklists, etc., important do's and don'ts along with instructions are displayed at conspicuous places.

2.10.7 Instrumentation

- 2.10.7.1 A Design Directorate to monitor the structural behaviour of the three dams under the charge of BBMB and to process the instrument data has been created.
- 2.10.7.2 Instruments have been provided for all the three dams. Regular observations of various instruments are being taken by field engineers. The annual observation reports for individual projects giving complete details of the structural behaviour of works as obtained from the instrument data are being prepared and is being put up to a special committee of technical experts headed by the Chairman, Central Water Commission.

2.11 West Bengal

The dams in West Bengal are mostly owned and operated by Irrigation and Waterways Directorate.

2.11.1 Organization

A Dam Safety Cell has been created for monitoring the activities in connection with dam safety. The functions and composition are not finalized. At present it is engaged in documentation of existing dams and in checking safety of large dams. The Cell is headed by one Assistant Engineer.

2.11.2 Period Inspection Programme

The periodic inspection programme consists of inspection by Executive Engineer twice a year and by Superintending Engineer once a year.

2.11.3 Training

There is no facility for imparting training to staff in dam safety.

2.11.4 Dam Safety Inspection

The "Guidelines for Safety Inspection of Dams" prepared by the Dam Safety Organization of CWC are adopted. Checklists and instructions issued by CWC for inspection of dams are followed.

2.11.5 Emergency Action Plan

There is no practice of preparing Emergency Action Plans. On the basis of flood forecasting system there is a procedure for alerting the area likely to be inundated wherever danger is apprehended.

2.11.6 Technical Aspects

Detailed investigations and designs are done on the basis of standards adopted by I.S.I., CWC, etc. Designs done are reviewed if design criteria are revised. There is no system for review at fixed intervals.

2.11.7 Hydrological Aspects

As per standards laid down by I.S.I. and guidelines for preparation of projects, works of re-evaluation of adequacy of spillway of existing large dams is under progress.

2.11.8 Quality Control

For major projects separate Quality Control Wing is set up. In other cases necessary arrangement is made under the engineer in-charge of construction. In case of separate quality control unit this is also responsible to the project in-charge of construction.

2.11.9 Instrumentation

Instrumentation is provided in all large dams. Not all the instruments are functioning properly. Analysis of observations are made during dam safety inspections.

2.11.10 Operation and Maintenance

Superintending Engineers and Executive Engineers are in charge to guide operation especially during floods. Operation manual has been prepared for one large dam.

2.12 Karnataka Power Corporation

2.12.1 Organization

2.12.1.1 There are six dams under the jurisdiction of Karnataka Power Corporation, viz. Talakalale, Linganamakki, Bommananahalli Pickup dam, Chakra dam, Savehakklu dam and Tattihalla dam.

2.12.1.2 There is a Dam Safety Cell in Karnataka, which reviews the safety of dams under the Irrigation Department and also the Karnataka Power Corporation. The Secretary to PWD, Government of Karnataka is the Chairman and Chief Engineers of major projects are Members. The Director, Karnataka Engineering Research Station, Shri Krishnarajasagara is the Member-Secretary.

2.12.1.3 The Chief Engineer (Civil Designs), Karnataka Power Corporation is also a member of the Dam Safety Cell.

2.12.1.4 The main functions of the Dam Safety Cell is to review the inspection checklists furnished by the various projects to the Dam Safety Cell and suggest measures regarding safety of the dam, etc.

A sub-Committee has been constituted by the Dam Safety Cell for review of the reports and placing them before the Dam Safety Cell.

2.12.2 Periodic Inspection Programme

The inspection programme consists of an inspection by the Chief Engineer in charge of the dam twice in a year, one before monsoon and the other after monsoon, the Project Engineer in charge of the dam twice in a year, one before monsoon and the other after monsoon, independent of Chief Engineer's inspection. The Divisional Engineer has to inspect the dam once in a month. The inspection of the dams are carried out as per the guidelines issued by the Dam Safety Organization of the CWC.

2.12.3 Dam Safety Inspection

The inspection checklists issued by the Dam Safety Organization of the CWC are being followed. There is no regular training programme.

2.12.4 Geological Aspects

A Divisional Geologist is in charge for carrying out geological and sub-surface exploration, interpretation of data and day to day problems. Assistance of Geological Survey of India is also taken.

2.12.5 Structural Aspects

Panel of experts are consulted. The panel consists of Shri N.G.K.Murty, Shri P.M.Mane, Shri K.C.Thomas, Shri M.S.Balsundram and Member (D&R), CWC.

2.12.6 Quality Control

Independent quality control unit is set up at the project locations which are technically and administratively under the control of Chief Engineer (Designs), independent of the Construction Wing.

2.12.7 Instrumentation

Instrumentation is provided in all the dams. Most of the instruments are in working condition and the data is being analyzed.

2.12.8 Operation & Maintenance

The manuals issued by the Dam Safety Organization of the CWC are being followed.

2.13 Karnataka (Irrigation)

2.13.1 The Government of Karnataka created a Dam Safety Cell in July 1981 comprising Additional Secretary, PWD, Irrigation as Chairman, Chief Engineer, Upper Krishna Project (Canals) and Chief Engineer (Logistics), Karnataka Power Corporation as Members and Deputy Secretary, PWD (Irrigation) as Secretary.

2.13.2 With a view to involving the expertise available with both Irrigation Department and Power Corporation, the Dam Safety Cell was expanded in August 1981 with five Chief Engineers as Additional Members and Director / Chief Engineer, Karnataka Engineering Research Station, Krishnarajasagar as Member Secretary. The Chief Engineer (DSO), CWC is a member of this Cell.

2.13.3 The terms of reference of the Dam Safety Cell are as under:

- (a) To prepare and update checklists for the preparation of inventory of dams and to compile the history of each dam.
- (b) To review the particulars furnished by the Chief Engineer on the checklist and to identify such of the areas which require special attention of the Cell and offer advise thereon.
- (c) To inspect such of the identified areas and to forward its findings and recommendations to the Government for taking further action.
- (d) To suggest remedial measures, follow-up actions subsequent to the inspection by the Cell and to forward its report to the Government.
- (e) The final recommendations of the Cell with probable financial implications of such recommendations will be placed before the State Cabinet for its decision.

2.13.4 The members of the Dam Safety Cells felt that there should be a sub-Committee for review of the data documented for the dam. Accordingly the Government of Karnataka has set up a sub-Committee with the following members:

Chapter III

EVALUATION OF EXISTING PROCEDURES

3.1 General

3.1.1 As per the directive of the first State Irrigation Ministers' Conference, a Dam Safety Organization was created in the Central Water Commission in May 1979. Within a short period of its existence, this Organization has been called upon to advise on a number of problems.

3.1.2 In India, by and large, storage dams were owned, constructed and maintained by the respective State Governments. The responsibility for ensuring their safety rests with the owner.

3.1.3 The Dam Safety Organization in the Central Water Commission consisting of one Chief Engineer with one Director initially was intended to assist the State Governments to identify causes of distress and to recommend measures for restoring the integrity of the structure. The services rendered by this organization are only on specific request from the State Governments.

3.1.4 It was realized that it would not be possible to cater to simultaneous requests from different States on problems encountered in respect of dam safety by the single agency located at the Centre with the staff initially sanctioned. This was considered in the Fifth Conference of State Ministers of Irrigation who resolved that the State Governments should also constitute their own Dam Cells / Organizations with a view to build up appropriate expertise at the State level to cater to the requirement of the States. These Cells of the States inter-alia were required to maintain an inventory of dams, compile history of each dam to bring out areas requiring special attention to review and monitor administrative and technical procedures adopted in respect of dam safety. In pursuance of the above resolution, the following States have created Dam Safety Cells / organizations:

Andhra Pradesh, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and Uttar Pradesh & West Bengal.

3.1.5 Only the State of Bihar which owns significant number of dams is yet to create a Dam Safety Cell.

- 3.1.6 The staffing pattern in the various State Cells is given in Appendix V.
- 3.1.7 All dams in this country are by and large owned by the State Governments through their various departments like Irrigation Department, State Electricity Board, Corporation, Municipal Corporation, Public Undertakings who are semi-Government organizations. In fact the dams were owned originally by Irrigation Department in most of the States. With the formation of State Electricity Board, the ownership of hydro dams has gone over to the Electricity Boards. This has become a regular feature for hydro-electric projects in most of the States. For example in Uttar Pradesh, the owner of Rihand dam is the State Electricity Board while the maintenance is being looked after by Irrigation Department and the funds are made available to the Irrigation Department by the State Electricity Board. In Gujarat, all dams are owned and maintained by the State Government through the Irrigation Department and come under the purview of Dam Safety Organization. Maharashtra is the only State wherein a few dams are owned by private agency, i.e. TATAS, Zilla Parishad and Bombay Municipality. A question arises whether all these Governments, Semi-Governments / Departments should create a Cell and which would be the right organization to undertake this task. The departments who own maximum number of dams in the State shall take the burden of building an expertise in dam safety and to this effect the Cells may be constituted. The other departments who own the dams in the State, i.e. State Electricity Board, Municipal Corporation, Public Undertakings shall seek the assistance of these Cells for getting their dams reviewed and also shall send review reports to them. If any Executive Order or orders / legislations are required in this behalf, the same shall be enacted at the State level. From consideration of background and available infrastructure and expertise it appears desirable that these Cells shall be created by the Irrigation Department in the State who incidentally owns maximum number of dams.
- 3.1.8 Among the States, Maharashtra and Gujarat have gone in a systematic way to evolve appropriate machinery to take care of dam safety aspects. In Gujarat, the Dam Safety Cells are charged with the responsibility of conducting safety inspection in respect of all dams, major and medium in their States. As against this in Maharashtra, the Dam Safety Cell has an advisory role. On the administrative side, Gujarat has a Chief Engineer who has under him design organization and GERI and the Cell itself is manned by two Superintending Engineers, one exclusively for dam safety and gates and the other reviewing hydrological aspects of all existing

dams. The organizations set up in the other States are not as elaborate as has been in existence in Gujarat and Maharashtra.

- 3.1.9 In Andhra Pradesh which has significant number of dams, the existing Executive Engineer has been asked to look after the dam safety aspects also. Obviously such a situation appears to be inadequate to the task involved in dam safety.
- 3.1.10 It would be observed from the details given in Chapter II that there is no uniformity either in the administrative set up or functions of the Dam Safety Organization in the State. While the administrative set up may have relation with the number of dams, it would be necessary to have very clear cut demarcation of its functions vis-à-vis the functions of the existing departments who are in charge of the dams, lest we introduce complacency. Maharashtra Government have gone to the extent that it may be useful to finalize the Emergency Action Planning even at the stage of sanctioning of the project. They have stipulated in their manual that Emergency Action Plan should be prepared before gorge filling work is taken up. Such stipulations are not indicated by the other States. Further, the size of the dams that come under the purview of the Cell also differ from State to State. For example, in Gujarat the activities of the Cell are confined to major and medium dams which cater to irrigation for more than 10000 and 2000 hectares respectively, irrespective of the height of the dam or its storage. From the point of view of risk and hazard, height and quantum of water stored behind the dam are significant parameters to be reckoned for their falling under the care of Dam Safety Cell. As against this, in Maharashtra, all large dams fall under the purview of Dam Safety Cell. The Government of Maharashtra have also in their scheme, an advisory dam inspection and safety service comprising 4 to 5 retired Chief Engineers of Maharashtra State to advise the Government regarding safety aspects of the dam in the State.
- 3.1.11 On the technical side also variations are noticed both in Gujarat and Maharashtra and perhaps Karnataka also.
- 3.1.12 The procedures and practices adopted from the conceptual stage of Bhakra, Beas and Pong dams till they are translated to reality and in their subsequent maintenance, have been highly systematic and thorough.
- 3.1.13 In Gujarat particularly, there is a Superintending Engineer (Geology) attached to the Central Design Organization. Under his guidance, the Engineering Geology Divisions of the State

Government are carrying out geological investigation and sub-surface investigation, etc. However, certain projects are also referred to GSI whereas in Maharashtra there is a geological unit under Superintending Engineer (CDO) and the investigations are planned and executed in consultation with the GSI. Kerala has not furnished any information as to the machinery available for geological investigation. It is presumed that GSI is consulted. The Kerala State Electricity Board has a Superintending Engineer (Geophysical) who conducts geophysical exploration during inspection stage and detailed investigations are done by GSI. In Tamil Nadu, GSI is consultant for geological and surface exploration.

3.1.14 In other States also, GSI is consulted. As regards computing design flood, practices vary from State to State and many States have designed their inflow design flood on the basis of empirical formula.

3.1.15 Designs are based on ISI standards though in some States the criteria are indicated but ISI have not been strictly adhered to. However, USBR practices are also followed. On the construction side, there has been a separate quality control organization in most of the major and medium projects and the administrative set up is in keeping with the size of the project. Rules for operation and maintenance did exist in most of the States even though they did not have the brand name of the dam safety. In pursuance of the resolution adopted in the Irrigation Ministers' Conference, Dam Safety Cells have been created in 12 States. These are now charged with the responsibility of bringing out adequate manuals on operation and maintenance of hydraulic structures throughout the State. For example, many people were not aware of the existence of a manual, viz. 'Maintenance Manual of Earth Dams' published by Uttar Pradesh Irrigation in 1970. The Maharashtra Government have recently taken up preparation of a Dam Safety Manual, particularly for operation and maintenance. For the rest of the States, there appears to be a need for filling up the gap in the existing machinery to ensure effective dam safety surveillance.

3.1.16 On the instrumentation side, which is vital for monitoring of dam safety, there appears to be a communication gap between the officer-in-charge of design / construction and officers who take over maintenance. There are many instances where the officers in charge of maintenance are not aware of the instrumentation proposal that has gone into the dam and there exist many missing links. The initial readings of the instrument are rarely available for

an instrument embedded in the dam, the absence of which has made subsequent analysis difficult.

3.2 Technical report of design and construction.

3.2.1 Prior to independence, the dam building activity was not as intense as it became after independence. In our urge to catch up with all round development in the world, a large number of irrigation and hydro-electric projects were taken up. In the process, only the basic necessities required in the activities of the project were carried out, since time was at a premium. The record preparation and its management was relegated to the background. This is borne out by the fact that whereas completion report for old dams like Periyar and Rihand are available, no such well-compiled documents are available for many dams constructed after independence. Such records at a later date will assume great importance was not thought of for dams constructed after independence. The importance of such records, however, has been day-lighted as the necessity has now arisen to review the various aspects of design and construction with a view to determine its safety, vis-à-vis the present standards.

3.2.1 Each River Valley Project is unique and presents many complicated problems peculiar to that particular project. In spite of detailed investigations, surprises are met within the foundation and modifications from the original design need to be made in the light of feedback received from the field during construction. Many challenging problems are encountered during construction which could not be solved on the conventional methods and solution of the same might have resulted in new method of construction technique and innovations. Unless these experiences are properly recorded they would be lost for posterity. It is, therefore, necessary that completion report of all important and major projects shall be undertaken by the Chief Engineer of the project when the project is in 50% completion stage.

3.2.2 He should take advance action to identify the various chapters that need to go with the completion report. The quantum of data that need to be presented in the completion report with regard to quality control exercised during construction, the extent of geological features that need to be incorporated in the report need to be decided by him, in consultation with the Engineering Geologist. He should also identify engineers who would write chapters and those identified officers shall be responsible for preparation of the chapter assigned to them. It would be desirable if they are kept in the same project till these final chapters are written by them.

However, due to administrative exigencies, if engineers are transferred to some other project, they should still be responsible for completion of the chapter assigned to them. These officers shall be given suitable financial incentive to motivate them to take up this work in right earnest and complete them on time.

3.2.3 A separate financial provision in the project report shall be provided for preparing the completion report including its printing etc. It shall also cover the cost of micro filming important technical and quality control data that need to be kept for posterity.

3.2.4 As regards fixing of priorities in writing completion report of projects, first priority will be accorded to on-going projects for which immediate data is available and the personnel involved in design and construction are there within the project area to take up the task of writing the completion report chapter by chapter. Second priority will be accorded to those projects which have been completed recently and for which completion reports are not available. In writing the completion reports for such dams, the records will have to be searched and the personnel involved in the various phases of design and construction will have to be located before commencing writing of the completion report. The third and last priority will be given to those projects that have been constructed long back and for which much efforts are required to locate the data for compiling the completion report. It is likely that the personnel involved in the various activities of the project might have retired from service. Fixation of the above priorities are essential to ensure that some progress is achieved within a reasonable time in writing the completion reports and valuable time and energy are not dissipated in searching old records.

3.3 Design Memoranda

3.3.1 The preparation of memorandum on all aspects of design is a good practice which has been followed in many major projects like Bhakra, Beas, Ramganga and presently in Sardar Sarovar and Navagam projects. The practice should be extended to all medium sized projects also. The memoranda should be put up to the dam safety panel for the projects and their views / recommendations obtained. A copy of the memo should be sent to the Dam Safety Cell of the State. By this process, the collective wisdom of the top experts in the field is brought to bear in the planning stage of the project and this will go a long way for strengthening of design cell of the State as well as Central Water Commission.

- 3.3.2 A copy of the memorandum together with the report of the panel should be sent to Dam Safety Cell in the State and Chief Engineer (DSO), Central Water Commission.
- 3.3.3 The personnel manning the design cell in the State should be a chosen one, who have the required aptitude for original work and design. Provision to give special design allowance shall be made to attract the best talent in the department.

3.4 Preservation of records

- 3.4.1 All technical data from planning to completion and relating to subsequent operation, i.e. hydrological data, drawings, memos, specifications, design computations, model test reports, geological reports, survey reports, seismological reports, special studies, construction drawings, operating instructions from suppliers of equipments, structural analysis report, foundation conditions and remedial measures taken and field reports should be preserved for future reference. The photo negatives, photostats of all drawings, completion plans, survey sheets & geological plans be prepared for future references.
- 3.4.2 A data bank complete with the above details along with the source from where these can be located be prepared work-wise. The micro-filming of the important drawings, reports and computations may also be done. These shall be preserved for the entire life of the project.

3.5 Dam Safety Organization in the Central Water Commission

- 3.5.1 Coming to the organization at the Centre, it is seen that the organization as sanctioned provides for one Chief Engineer and one Director with complementary staff. Realizing that this is too inadequate, the Commission on its own attached two more Directorates, viz. Special Analysis & Instrumentation Directorate and Foundation Engineering Design Directorate to give the necessary support to the Organization.
- 3.5.2 This Organization has done commendable work in bringing out guidelines for safety inspection checklists, etc., and has also been instrumental in setting up Dam Safety Cells for effective surveillance and monitoring of dams in the States. It has also developed the following computer programmes:

- Conventional stability analysis for Gravity Dams.
- Simplified method of dynamic analysis of Gravity Dams by Chopra's method.
- Dynamic analysis of Gravity Dams by FEM.
- Programme for rehabilitation of existing dam by backing on the downstream face.

3.5.3 With a view to up-dating technical know-how of instrumentation and dam safety surveillance, a UNDP proposal has been framed and the proposal is in advanced stage of being taken up for implementation. The proposal envisages training of CWC and State officers in instrumentation as well as dam surveillance programme. It also provides for workshop to be organized on instrumentation and underwater investigations of dams and the necessary equipment required for these investigations are also proposed to be obtained through UNDP aid.

3.5.4 States are advised to utilize the facilities developed at the Centre and arrange to depute senior / middle level officers to these workshops.

3.5.5 Out of 22 States and 9 Union Territories in this country, only 12 States have constituted Dam Safety Cell. The following States / Union Territories in the country have yet to create Dam Safety Cells and develop dam safety expertise.

- | | | |
|----------------------|--------------|----------------------|
| 1. Assam | 2. Bihar | 3. Jammu & Kashmir |
| 4. Manipur | 5. Meghalaya | 6. Sikkim |
| 7. Andaman & Nicobar | 8. Tripura | 9. Arunachal Pradesh |
| 10. Delhi | | |

3.5.6 For some more years to come, the Centre will have to provide necessary support both in respect of design of hydraulic structures and also for their surveillance to these States. The number of dams in all the above States is of the order of 50. It is recommended that the safety review of these dams shall be initiated by the Centre. This would call for strengthening Dam Safety Organization in the Central Water Commission for effective implementation of the dam safety programme in the country.

3.5.7 The Dam Safety Organization in the Central Water Commission should also oversee the safety status of such dams, the failure of which would have inter-State repercussions. They shall also assist in developing appropriate mechanism for coordinated activity for such dams.

3.5.8 The Dam Safety Organization need to be strengthened in the following disciplines:

- (a) Development of computer programme, Numerical studies, including Finite element techniques.
- (b) Dam Safety Surveillance.
- (c) Hydrology.

3.5.9 In respect of (a) & (b) the existing directorates need to be strengthened. Separate staff will have to be provided for hydrological review. Such strengthening of the Dam Safety Organization in the Centre is essential for taking up the additional responsibility as suggested in para 3.4.6, and also for effective dam safety programme in the country.

3.6 The Standing Committee

3.6.1 In the Standing Committee only one State is represented, i.e. Gujarat. Since many States have significant number of dams, it is essential that they are represented on the Standing Committee. The Committee, therefore, recommends that all States having significant number of dams be represented on the Committee. Such broad-based Committee would help in the follow up action on the recommendations of this report of the Standing Committee. The Standing Committee should meet at least once a year to review the dam safety programme in the country.

Chapter IV

SUGGESTED ADMINISTRATIVE SET UP FOR THE DAM SAFETY CELL IN THE STATE, ITS FUNCTIONS AND PRIORITISATION FOR SAFETY REVIEW

4.1 Introduction

4.1.1 A well planned administrative machinery is essential to achieve the objective of ensuring the safety of dams. The administrative set up in each State will have to be governed by the number of major dams in the State. Some of the States which have hardly a few dams, the administrative set up need not be as elaborate as has been suggested for States having significant number of dams. The assistance of the Dam Safety Organization of CWC may be availed in such cases.

4.1.2 The Government of Gujarat and Maharashtra have gone a systematic way in developing infrastructure required for dam safety surveillance. The Bhakra Beas Management Board have a very well manned dam safety surveillance and monitoring procedures. In Maharashtra State dam inspection and dam safety services are constituted with advisory capacity as its main function. As against this, Gujarat State have attempted to involve Dam Safety Cell in a more effective way for implementation of dam surveillance programme. There is a school of thought which holds the view that a Dam Safety Cell should be made responsible for the safety of the dam. In the context of Indian condition and administrative set up, the owners invariably being Government agencies, barring a few exceptions, an independent authority either in the Centre or at the State would bring in dual responsibility leading to responsibility with none. In view of this, the Committee recommends the responsibility for the safety of the dam shall rest with the owner of the dam. A similar concept is in existence in the Railway Act. This is also reflected in the Dam Safety Procedures in other countries like USA, UK, Switzerland, Finland, etc.

4.2 Administrative set up

4.2.1 Each State which has more number of major dams (more than twenty) should have a post of Chief Engineer under whom the following departments may be attached:

- (a) State Engineering Research Laboratory,
- (b) Design and Investigation Wing,
- (c) Dam Safety Cell

4.2.2 If separate Chief Engineers are existing in respect of the above discipline, then the Dam Safety Cell should be placed under the Chief Engineer, Design & Investigation Wing. The Dam Safety Cell shall include one Hydrology Unit which would undertake the review of the inflow design flood after fixing priorities.

4.2.3 The Cell may be headed by an officer not below the rank of Superintending Engineer initially, and may consist of one expert on the design of concrete and masonry dams and another expert on earth and rockfill dams with supporting technical staff. One of them should have a good geotechnical background. An identified officer from GSI should be associated with the Cell.

4.3 Functions

4.3.1 Existing Dams

4.3.1.1 Only large dams as defined by the ICOLD may be considered for identification by the Cell / Organization in their dam safety programme. Tailings dam should also be included. A large dam has been defined by the ICOLD as either:

A dam above 15 m in height measured from the lowest portion of the general foundation area to the crest; or

A dam between 10 and 15 m in height provided it complies with at least one of the following conditions:

- (a) the length of crest of the dam to be not less than 500 metres;
- (b) the capacity of the reservoir formed by the dam to be not less than one million cubic metres;
- (c) the maximum flood discharge dealt with by the dam to be not less than 2000 cubic metres per second;
- (d) the dam has specially difficult foundation problems; or
- (e) the dam is of unusual design.

4.3.1.2 The technical documentation of all identified projects should be compiled and kept for record by the Cell. The latest techniques of microfilming and keeping data in the computer is suggested.

- 4.3.1.3 Each State should issue executive order for inspection, maintenance and surveillance of dams.
- 4.3.1.4 The responsibility for the safety of the dam rests with the engineer in-charge.
- 4.3.1.5 The follow up action on the executive order, the implementation and monitoring aspect will be taken care of by the Cells constituted in the State.
- 4.3.1.6 The State Cell shall arrange safety review of dam which are more than 15 metres in height or which store 50,000 acre feet or more of water by an independent panel of experts once in 10 years. The State Cell shall develop its own mechanism for safety review of the balance dams in their State. The Dam Safety Cell / Organization of the State shall submit an annual report of the review done to the State with copy to Dam Safety Organization of CWC.
- 4.3.1.7 The State should also arrange for review of spillway capacity of the existing dams after assigning priorities and convey the recommendation for provision of additional spillway / modification of operation if called for or any other alternative means by which it could be accommodated, to the Secretary to the Government who in turn will pass it on to the concerned Chief Engineer for implementation. A copy of that letter shall also be endorsed to the Dam Safety Cell for monitoring.
- 4.3.1.8 Pre- and post-monsoon inspection of the dam shall be done by an engineer not below the rank of an Executive Engineer. A responsible engineer should be stationed at the dam site throughout the monsoon period and he should send periodical reports about the behaviour and health of the dam.
- 4.3.1.9 His report should be forwarded to the Superintending Engineer who in turn will forward it to Chief Engineer with copy to Dam Safety Cell for information.
- 4.3.1.10 If there are no problems, the Dam Safety Cell should record the report for future reference.
- 4.3.1.11 If there is / are any follow action(s) to be taken, a letter may be addressed by the Cell to the Chief Engineer requesting him to let the Cell know whether he would require any special assistance from the Dam Safety Cell or he is himself in a position to undertake repairs indicated in the inspection report(s).

- 4.3.1.12 If the request from the Chief Engineer comes for assistance then the senior officers of the Dam Safety Cell along with the expert in the discipline in the design office of the State / Centre as the case may be should visit and find out whether they are in a position to offer appropriate remedial measures. If the problem is complicated, they should immediately write to the Secretary to the Government through appropriate channel to constitute a panel to go into the problem to identify the cause / causes and suggest remedial measures.
- 4.3.1.13 The Dam Safety Cell should be responsible for speedy formation of the panel and it should act as secretariat to the panel. The coordination of various studies / investigations suggested by the panel should be done by the State's Cell.
- 4.3.1.14 The panel should consist of the following:
- (a) Chairman – an experienced dam engineer who has background of design and construction.
 - (b) Chief Engineer (DSO) of Central Water Commission or his representative.
 - (c) Chief Engineer of the concerned project.
 - (d) Head of the Dam Safety Cell as Member-Secretary.
- The panel should have the powers to co-opt any expert whose advice is considered essential for assessing the problems.
- 4.3.1.15 Dam Safety Cell should be responsible for monitoring the studies / investigations and for arranging the panel's inspection, investigation suggested by them, etc. They should also be responsible for preparation of the panel's report.
- 4.3.1.16 One copy of the panel's report should go to the Secretary of the Department who in turn should forward it to the concerned Chief Engineer for speedy implementation. An advance copy of the report may also be sent by the Cell to the Chief Engineer concerned.
- 4.3.1.17 The monitoring of implementation of the proposal and expediting the same should be the responsibility of the Chief Engineer of the project.

- 4.3.1.18 Chief Engineer of the project should keep the Cell informed of the performance of the remedial measures.
- 4.3.1.19 Instrumentation data of the dam should be collected by the Chief Engineer of the project and forwarded to the Design Wing for review.
- A copy of the performance report prepared by the Design Wing should be sent to Dam Safety Cell for information.
- 4.3.1.20 If the feedback from the instrumentation data warrants a review at short intervals, the same should be done by the Design Wing.
- 4.3.1.21 The structural behaviour report based on instrumentation data should be sent to the Chief Engineer / owner of the project.
- 4.3.1.22 The Dam Safety Cell should compile statistics concerning failures and should have the burden of preparing the FIR report of any failure / accident in their State.
- 4.3.1.23 The Cell should be responsible for initiating action for constitution of a Committee to go into the causes of failure with a view to increase knowledge in the field.
- 4.3.1.24 The Dam Safety Cell should act as a data bank in respect of dam safety.
- 4.3.1.25 The establishment of Dam Safety Cell and safety review of existing dams by independent panel suggested by the Committee would throw additional financial burden on the State exchequer. Since dams are national assets and dam failure would become national disaster, the Committee suggests that financial assistance in the form of matching grants may be provided by the Centre towards the expenditure for establishment of the Cells and safety review. The cost of repair proposal as a result of safety review should be borne by the owner.

4.3.2 New Dams

- 4.3.2.1 All dams defined as large dams by this Committee should be designed by a competent Design Organization. Necessary orders should be issued to this effect. For all major dams in the State, it would be desirable to constitute an independent Dam Safety Panel to advise the project authorities in all phases of dam building activity. This would ensure the availability of collective wisdom for ensuring building safe dams. They should be constituted on the

lines of World Bank Dam Safety Panels and the implementation of their recommendations should rest with the Chief Engineer of the project. The monitoring of compliance of the recommendations should rest with the Cell.

- 4.3.2.2 During the course of the construction, the Cell should review quality control data for new projects for which the Chief Engineer is required to send the data to the Cell. The review report should be sent to the Chief Engineer of the project by the Cell for his comments with a copy to the Secretary to the Government. The object of this is to ensure that the quality of the work is reviewed periodically and any corrective measures if called for can be undertaken before it is too late. This procedure will assist the Cell in its inspection of the dam prior to first impoundment. In case of dams where exclusively a Dam Safety Panel has been constituted, the review of the quality control aspect need not be done by the Dam Safety Cell of the State. This job preferably should be left to the Dam Safety Panel who should also advise on the soundness and readiness of the dam prior to its first impoundment.
- 4.3.2.3 However, for projects where Dam Safety Panels are not in existence, the Dam Safety Cell along with the expert in the State shall inspect the new dams prior to their first impoundment and give its assessment regarding soundness and readiness of the dam for its maiden filling.
- 4.3.2.4 In addition to the routine instrumentation that are planned, seismological instrumentation to assess the seismic status of the project site and the response of the structure should be planned for all dams lying in Zone IV and above, and also for major dams in other zones.
- 4.3.2.5 The Cell should ensure close surveillance on the performance of the dam for the first consecutive three years and compile a report on the same.
- 4.3.2.6 The Cell should also ensure preparation of completion report relating to the dam by the project authorities.
- 4.3.2.7 The Cell should be responsible for collection and compilation of the salient technical details of design and construction of each new project.
- 4.3.2.8 The Cell should also ensure assistance in the preparation of reservoir operation schedule including detailed standing operating procedures for the dam.

- 4.3.2.9 The Cell should ensure that the project engineers frame a disaster preparedness plan.
- 4.3.2.10 The Cell should arrange for training courses for quality control staff and other engineers involved in design construction and maintenance of dams.
- 4.3.2.11 The Cell also should bring out manuals on operation and maintenance of hydraulic structures throughout the State in consultation with design and construction engineers.
- 4.3.2.12 After about an initial period of three years, the dam shall be classified as an existing dam and the functions of the Cell as detailed under existing dams will apply.

4.4 Prioritisation of safety review

- 4.4.1 The Cell should identify all dams, as indicated in para 4.3.1.1.
- 4.4.2 Engineering data should be collected in respect of the dams identified above. Such data should be furnished by the engineer in-charge of the project.
- 4.4.3 The Dam Safety Cell should make random checking of the technical data received; by site visit, to ensure the correctness of the data.
- 4.4.4 Of the dams in the above category, they should identify dams with distress / inadequate spillway capacity / age factors.
- 4.4.5 The Dam Safety Cell should prepare a programme of review of safety of dams in the State from
 - (a) Hydrological consideration; and
 - (b) Structural consideration.
- 4.4.6 The following guidelines are suggested to fix priorities for reviewing the safety of dams. While fixing interse priority, the hazard potential of the dam in question shall also be taken into account as the hazard rating offers a very useful tool for the establishment of priorities for examining and rehabilitation of older dams. In addition, the following considerations shall apply:
 - (a) Dams showing extreme distress with significant danger potential.
 - (b) Dams having grossly inadequate spillway capacity.

(c) Dams where deficiencies have been noticed in the design criteria followed.

- 4.4.7 Hydrological review of all projects defined by the Committee should be arranged by the Cell. A separate hydrology wing may be established for this purpose, if warranted. The guidelines determining hydrological safety of existing dams elaborated in Chapter V may be followed.
- 4.4.8 Adequate rain gauge stations, including automatic recording rain gauges, with mechanism for transmission of data by wireless should be established in the catchment area of all dams. Wherever the safety of the dam is threatened due to inadequate capacity of spillway, their installation becomes all the more vital and therefore the project authorities / owner should ensure establishment of automatic rain gauge in the catchment area, arrange for the transmission of rainfall data through wireless to the dam site and also work out the likely inflow based on the rainfall data so obtained. In such places, they should also exhibit at the site the reservoir operation rules governing. These operation rules shall be mounted on a photo frame and exhibited in the office of the engineer in charge at site so that they are not lot in the files.
- 4.4.9 The responsibilities for preparation of operation table for dams where inadequate spillway have been identified rests with that of the Dam Safety Cell. These rules of operation shall be prepared by the Cell and forwarded to the Chief Engineer in charge of the project for his comments, if any. If he has no comments, he should forward the same for the strict compliance by the site in-charge.
- 4.4.10 Keeping in view the considerations mentioned in para 4.4.6, structural safety of the existing dams shall be reviewed as per ISI Code (modification thereof, if any) and the stresses obtained / factor of safety attained on the basis of ISI Code shall be reviewed from safety angle, taking into account points indicated under structural safety review.
- 4.4.11 For dams showing extreme distress with significant danger potential, the Cell shall initiate action for the formation of a panel referred under the functions of the Cell. The Cell shall ensure speedy implementation of the submission of the Panel's report and subsequent follow-up action on its recommendation followed by monitoring the performance.

Chapter V

GUIDELINES FOR DETERMINING HYDROLOGICAL SAFETY OF EXISTING DAMS

5.1 Introduction

- 5.1.1 Every artificial storage can be a potential hazard to downstream life and property. All storage dams are provided with spillways, the primary purpose of which is to reduce this artificial hazard to negligible or acceptable level.
- 5.1.2 The decision on spillway capacity of a dam, including the decision on its surcharge storage, freeboard, etc., constitutes an important hydrologic and engineering decision affecting the safety of the dams. These decisions were being taken on the basis of "empirical" formulae based on regional experience and not adequately supported by systematical data and analysis. The Central Water Commission for the first time formulated a design flood criteria for hydraulic structures in the early sixties. This criteria was circulated to various States and was finalized in 1968.
- 5.1.3 In regard to the major projects under the Plans, CWC utilized these design criteria for ensuring, within workable limits that this criteria is followed in all new projects. However, in minor and medium projects which were either not examined, or not examined in detail, conformity with the criteria would not be adequately ensured. Also the various existing projects and projects under construction were not necessarily conforming to the criteria.
- 5.1.4 Even where projects are designed as per the CWC criteria, with the increase in data base in particular in regard to storms some times the inflow design flood estimates may be revised upwards. In such a case also, the existing structure may not come up to the norms.
- 5.1.5 The dam safety service was initiated in CWC in around 1980. This service brought to the notice of all State Governments, the need to review design floods to ensure the safety of the dams in general, in the light of the existing criteria for new dams.
- 5.1.6 In 1985, the Indian Standards Institute finalized the draft of a standard entitled 'Guidelines for fixing spillway capacity of dams.' This is somewhat more comprehensive than the existing CWC criteria in regard to storage dams. These guidelines are under printing and would replace the existing CWC design criteria.

5.1.7 In its part 1.1 of scope, the ISI guidelines state that the standard is for constructing new spillways and are not for deciding the adequacy of old structures. Thus, there seems to be a need for separate guidelines for deciding adequacy of old structures.

5.2 **Need for Separate Guidelines**

5.2.1 The question of whether guidelines for fixing spillway capacity consistent with the safety of dam should be of a general nature covering both new and existing structures or whether these should be separate for the two types of structures, is debatable. An important view is that social equity would demand the same standards of safety for the population in the country, irrespective of whether they are likely to be affected by new or old structures in case of hydrological failure. However, new guidelines, which generally are more stringent, can easily be accommodated while planning new projects which are tagged on with a package of costs and benefits. Another view, therefore, is that it would be more pragmatic and practicable to have separate guidelines for review of the old dams.

5.2.2 The fact that a particular dam is not having adequate safety from hydrologic angle may or may not necessitate immediate remodeling to ensure the safety. This again is debatable and different views as indicated above could be taken.

5.2.3 In this situation, the present suggestion is to proceed as follows:

- ◆ There shall be two separate guidelines, one for existing dams and another for new dams. However, the two guidelines would not differ in the choice of inflow design floods. They may differ marginally in regard to the freeboard, clearances and safety factors. Thus, although two guidelines would exist, these would not differ radically.
- ◆ A separate guideline for fixing priority amongst the existing dams in regard to their modification for greater safety under floods would be formulated. While it would be desirable to improve the status of each dam which does not conform to the guidelines for existing dams, these guidelines would allow differing action on some dams, in preference to some others in view of constraints on funds and organizations capabilities as they may exist.

- ◆ The prioritization of the dams not coming upto the norms for interse priority of action could be done on two considerations as follows:
 - (a) On the basis of the largest flood that can be safely negotiated as compared to the appropriate inflow design flood; or
 - (b) On the basis of the likely structural status (say, factor of safety) which the dam would have in case the inflow design is encountered (with relaxed ambient conditions, etc.) as appropriate to the case, as compared to the desirable structural status.

For the purpose of the present draft, the scheme at (a) above is followed.

5.3 Review of adequacy of spillway and allied provisions in existing dams.

5.3.1 It is proposed that these guidelines would be the same as the guidelines for new dams which have already been discussed above and which has been reflected in the latest Indian Standards. However, while reviewing adequacy of spillway capacity, relaxation of the following ambient conditions may be considered on the merits of each case.

- (a) For existing dams, impingement level to be considered can be lower than that for new dams, after taking into account a practicable schedule of filling.
- (b) For existing dams, where a flood forecasting possibilities exist and have been proved in the field, a reasonable pre-depletion may also be allowed, although this is not allowable for new dams.
- (c) For existing dams, where the gate maintenance is very satisfactory, and after making sure of standby arrangements, the design condition I of gate failure may not be considered.
- (d) Relaxation of freeboard and clearance.

For new dams, as per clause 4.1, freeboard and clearance above MWL of design condition II are necessary as per the relevant ISI. For existing dams, these could be relaxed on

case to case basis. A properly designed solid parapet wall may be considered for the freeboard.

5.4 Prioritisation for modification of existing dams for greater safety.

5.4.1 Since at any time funds for this purpose would be limited, and also there could be constraints on organizational capabilities etc., it would be necessary to have a guideline for deciding the priorities in tackling existing dams for greater safety under floods.

5.4.2 These could be arrived at as follows:

- (i) Consider an existing project and its spillway and other allied provisions.
- (ii) Work out the inflow design flood as per the ISI standards for the new dams.
- (iii) Route the flood with ambient conditions as per new dam and check if it is successful. If it is successful, no action is required. If not, consider if ambient conditions and freeboard and clearances can be relaxed as mentioned above. If after such relaxation the dam is successful in negotiating the inflow design flood, no action is required. If the dam is unsuccessful, the behaviour of the dam under the design flood, such as reduction of freeboard and clearances, physical overtopping, likelihood of development of tension, likelihood of water hitting the deck bridge, etc., may be brought out.
- (iv) By trial studies through proportionate reduction of inflow design flood, the percentage of the inflow design flood which can be successfully negotiated by the dam under the relaxed conditions may be worked out.
- (v) The inflow design flood type depends upon the hazard potential in the eventuality of a failure. In some projects it may be possible to relocate the downstream habitation at a safe level in such a way that after such reallocation, the standard project flood may become the relevant inflow design flood for this dam. Such possibilities may be examined with some cost estimate of the relocation, if found feasible. In such cases, the safety of the dam against reduced inflow design flood may be worked out, repeating the steps one onward above mentioned.

- (vi) After completing such studies for all dams within a State, the extent of inadequacy of the spillway capacity may be classified according to the following:
 - (i) The maximum inflow flood that can be passed through the dam with the relaxed ambient conditions, expressed as a proportion of the inflow design flood.
 - (ii) The likely effect of the inflow design flood on the safety of the dam, i.e. whether the dam has reasonable chance of not failing under such a flood.
- (vii) Where an existing dam is found to have inadequate hydrologic safety in the review, immediate action would also be initiated to frame an emergency action plan as a disaster prevention measure. Such an action plan would be kept active until the permanent corrective measures are evolved and implemented.

Chapter VI

STRUCTURAL REVIEW

6.1 Methodology

This would involve the following:

- (a) Study of design criteria that went into the design / construction of dam.
- (b) Fixation of review criteria.
- (c) Geological considerations.

6.2 Study of design criteria

The study of design criteria that went into the design / construction of the dam would call for elaborate efforts to find out the criteria that were used at the time of design / construction of the dam in question. In some of the major project in the country, design memoranda for each component of the project have been prepared and these have to be studied to locate the criteria that have gone into the dam. Where such detailed design memoranda are not available, this work would become laborious and time-consuming as it would involve digging up of old records looking to articles published in various journals, etc. It is in this context, the Committee would recommend that in respect of major projects, design memoranda in respect of each component of the project should be prepared by the organization as these would facilitate quick appraisal of structural safety of dams.

It is more vital that the details of reports on foundation geology as revealed during construction, the treatment for the foundation, departures made from design during execution, drawings of the structure as constructed and the standard of quality control exercised during construction needs to be studied in depth. The importance of preparation of technical reports on design and construction after completion of the project becomes relevant about which specific recommendation has been made in Chapter III of the report.

6.3 Review of design criteria

6.3.1 Fixing of review criteria for assessing structural safety of the existing dam is indeed a complex affair. The Committee has the following alternatives to choose:

(viii) Should the criteria conform to the present standards. Or

(ix) Alternatively can relaxation be allowed.

6.3.2 If we opt for the second, we are posed with the following technical, legal and moral problems:

How to ignore the performance of the dam which has been standing for all these years? How can you fix a lower level of safety for an existing dam?

What moral right one has got to subject the people below the existing dam to a lower level of safety when compared to people who come under new dams?

Legally it would amount to discrimination / negligence. If we opt for the first, we are faced with:

Undertaking an engineering decision which may not be economically viable.

There may be instances where appropriate remedial measures have yet to be developed like alkali silica reaction.

In the context of financial constraints, do we bring them to the present standards immediately, or alternatively use the available resources to provide additional benefits elsewhere?

Taking a decision on this aspect of safety review would call for an inter-disciplinary effort. It would be better if the existing dam can conform to the present ISI Code with modifications thereof, if any. However, more often than not, it is found that they do not conform strictly to the codal provisions. The structural safety of the dam shall be assessed taking into account the latest state-of-art. Each case has, therefore, to be decided on its own merit and precedents shall have no place in such a review.

6.3.3 In a situation where safety review indicates that the existing dams do not conform to the present standards, it would be obligatory on the part of the owner to plan disaster preparedness, including dam

break model studies to meet the unlikely event of a failure indicating therein the possible inundation downstream of the reservoir consequent to dam break. Such dam break model studies shall take into account the deficiencies noticed in the review of the structure.

6.4 Seismic considerations

6.4.1 The current procedure adopted for earthquake resistance design of dams is based on the conventional pseudo-static method outlined in IS 1893-1975. In case of concrete and masonry dams falling in seismic zones of high intensity and / or high dams over 50 to 60 m in height, further detailed dynamic analysis using Finite Element Method or by any other simplified method has now come into vogue.

6.4.2 After the Koyna earthquake, the seismic zoning map of India has been revised and the Government of India constituted a Standing Committee under the Chairmanship of Member (D&R), CWC to recommend the design seismic coefficient for River Valley Projects. On this Committee, GSI, IMD, School of Earthquake Engineering, Roorkee, and NGI, Hyderabad are represented. The data received by the Committee are examined and seismic parameters are recommended for design of dams. For evaluation of existing dams, the recommendation of the Standing Committee should be sought, only in such cases where it had not been before the Standing Committee at the design stage.

6.4.3 A two-tier basis indicated below for design of hydraulic structure is now an accepted practice:

Design Basis Earthquake (DBE)

Maximum Credible Earthquake (MCE)

The dam structure is checked by applying both the criteria to ensure that the separate stipulations made in each criteria is satisfied. In the event of maximum credible earthquake, the dam should be safe and some repairable damages are accepted.

6.4.4 As per the existing ISI Code, gravity dams have to be designed for no tension at the heel. However, in the revised ISI Code, a tension of the magnitude 1.5 kg/cm^2 has been permitted at the heel of the dam under full reservoir conditions when pseudo-static method of analysis for earthquake forces are adopted. Where dynamic stress

analysis is used for DBE, tension upto 6.25% and for MCE, upto 12.5% of the allowable compressive stress is permitted.

6.4.5 Embankment dams are also affected by earthquake. The particle readjustment capacity and the non-rigidity of the material forming the earth and rockfill dams reduce the impact of seismic forces on the structure to a great extent. The embankment dams, therefore, appear to have an edge over rigid dams provided there are no liquefaction hazards associated with the material forming the dam foundation system.

6.4.6 It is well known that prior to the occurrence of the Koyna earthquake, the entire Deccan Zone was considered to be safe from earthquakes and the design of dams within this zone did not cater for resistance to earthquakes. In general, for dams designed within this country prior to the Koyna earthquake, the criteria adopted for earthquake resistance design was not as rigid as was followed after this event. The crux of the problem is whether the existing criteria is to be applied to existing dams. It would be rational to presume that in an ideal case, the present criteria should be applied to existing dams. If those dams are still found to be safe under the present earthquake resistant design criteria, then there is no problem. In practice, more often than not, it will be seen that some of the existing dams do not measure upto the present standard of earthquake resistant design criteria. In such cases, it is not possible to spell out any general guidelines for safety review. Each dam has to be treated on its own merit and certain aspects have to be examined to undertake engineering solutions to make the structure safe against earthquake.

6.4.7 The fact that no masonry or concrete gravity dam has failed due to earthquake is a pointer to the effect that the present standard may not be applied in toto to the existing masonry / concrete structures. However, certain factors may be taken into account before deciding on the engineering solutions to be applied to make the existing dams safe from earthquake forces. The main factors that should be taken into consideration could be as under:

- ◆ Seismicity of the area;
- ◆ Age of the dam
- ◆ Location of the dam
- ◆ Degree of maintenance

- ◆ Past history of occurrence of disaster in the area at which the dam is situated;
- ◆ Disaster potential in case of the failure of the dam.

6.4.8 For earth and rockfill dams of course, the fail safe criteria will be more appropriate. For earth and rockfill dams, an engineering solution may not be sufficient and disaster preparedness will have to be resorted to in such cases.

6.4.9 While undertaking engineering solution for the existing dams, it would be pertinent to note that dams built earlier were founded on good foundations and in areas which are geologically favourable.

6.4.10 Taking into consideration the number of small dams in the country, the Committee addressed itself to the problem arising in reviewing all the dams in the country from seismic considerations. Keeping this in view the Committee suggests the following guidelines:

- (a) The safety of all dams identified in high seismic zones (Zone IV & V) shall be reviewed from seismic considerations.
- (b) For dams located in other seismic zones, the priority shall be based on the height of the structure and the hazard involved thereof in the event of its failure.
- (c) Pre- and post-construction monitoring of the seismic status of dams should be carried out for dams located in high seismic zones.

6.5 Assessment of seepage in masonry dams

6.5.1 All hydraulic structures without exception are required to serve the purpose of retaining huge mass of water of the reservoir formed by the very existence of the structures and to release the water stored in a well defined and controlled manner for the purpose of irrigation, power, flood control, etc. whereas huge quantities of water may be released through various outlets for the purposes mentioned above, it often happens that a minute quantity gets released through the body of the dam which is a function of the material properties of the dam, size of the structure and the water head stored. The release of this minute quantum of water is termed as seepage. A distinction need to be made here between seepage and leakage. The water that gets released due to imperfections in the construction joints or due to imperfect compaction of materials or through piping are not functions of the

permeability of the materials of the structure and are termed as leakage. Release of water in small quantities over a long period of time through the pores of the material constituting the dam where the quantum of flow has a specific relation with the permeability of the dam material, the lake level and on the area exposed to the water mass is known as seepage.

6.5.2 A well constructed dam using appropriate materials of construction should be ideally watertight allowing for very low quantum of seepage through its body. From the point of view of imperviousness of the construction material, concrete dams should be considered the least pervious followed by masonry dams, earth and rockfill dams which have a comparatively high perviousness as compared to the other two. An excessive seepage can endanger the safety of the dam and can often lead to undesirable conditions.

6.5.3 Measurements of seepage are often indicators of the functioning of a dam and the state of safety of a dam can be approximated once the permissible seepage through a particular dam can be specified. The crux of the problem lies in the fact that whereas the permeability limits of various materials constituting the dam is known, the permeability limits of the completed dam does not yield itself to easy measurement. Inferences on the safe magnitude of seepage for the dam as a whole cannot also be worked out based on the permeability values of the constituent materials. It is here that we have to resort to in-situ measurements and determine the limits of permissible seepage based on simple mathematical calculations.

6.5.4 A simple mathematical relation can be derived for seepage through a concrete / masonry dam by the application of Darcy's law and assuming a slit type drainage provision wherein all the seepage water from the upstream face of the dam gets drained through the porous drains and no water escapes to the downstream portion past the porous drains. It is also assumed that concrete / masonry are permeable in nature, having higher coefficient of permeability in the horizontal direction. The second assumption of course is a logical outcome of the hydrostatic head of water acting on the upstream face of concrete / masonry dams which are either vertical at the bottom portion or are steeply inclined to the base resulting in the hydrostatic pressure to act either in a horizontal or near horizontal direction.

6.5.5 By applying Darcy's law to the dam area exposed to the reservoir, we obtain an expression in the following functional form:

$$Q = f(k, L, d, H^2, h^2)$$

where

Q = Seepage quantity

k = permeability as defined in Darcy's equation

L = characteristic length of the structure

d = distance of the drain hole from the upstream face of the structure

H = characteristic height of the structure

h = lake level

For a particular dam, the above function reduces to

$$Q = \emptyset (k, h^2)$$

The discharge and the reservoir level being measurable quantities permeability of the concrete / masonry dam as a whole can be evaluated for varying reservoir heads. In fact, the two end points would be permeability coefficients at MDDL and FRL.

6.5.6 In practice, the process would consist of measurement of seepage (as distinct from leakage) for varying reservoir levels for a few well constructed concrete / masonry dams and determine the coefficient of permeability. Having obtained these values, it would be possible to fix approximately the permeability limits that would be considered appropriate for a specific dam in question. By this process it would be possible to specify the upper limit of seepage for a specific dam and also the average seepage quantum.

6.6 Assessment of seepage in embankment dams

6.6.1 Seepage in embankment dams is a vital parameter to assess the behaviour of embankment dam.

6.6.2 The seepage measurement can be used to assess the behaviour of the embankment by adopting the following rough procedure:

- (i) Compute seepage discharge with reservoir at FRL from flownet.

- (ii) Separate the discharge for the zone below minimum drawdown level (say Q1) and above minimum drawdown level (say Q2) with $Q1 + Q2 = 'X'$.
- (iii) Let the observed discharge be 'Y'.
- (iv) If 'Y' is equal to 'X' it appears to indicate the attainment of steady seepage for continuous FRL condition which is not likely with reservoir fluctuations. The cause for this need to be investigated.
- (v) If 'Y' is greater than 'X' there is an urgent need for detailed inspection / investigation.
- (vi) If 'Y' is less than 'X' then a comparison of $(Y - Q1)$ with Q2 gives indication of saturation in zone above minimum drawdown level which can be corroborated with pore pressure observations in the section, if possible.

6.6.3 In fact this method can be used as a rough guide in cases where no pore pressure measurement facilities are existing.

6.6.4 The data of seepage at the toe of the dam, and its turbidity is of extreme importance for evaluating the safety. Dam should be divided into convenient reaches and seepage monitored reach-wise. Most of the Indian rivers carry a significant amount of silt and as years to by earth dams are in a better position with regard to their performance provided they are not overtaken by a high flood and their upkeep is properly maintained. Reduction of seepage is a good parameter with regard to behaviour aspect of the dam.

6.7 Geological considerations

6.7.1 The foundation problems may be related to the weak rock zones, structural discontinuities and permeable zones.

6.7.2 The engineering geologist need to orient the geotechnical investigations covering the following subjects:

Regional geology and geo-environment.

Identification of foundation problem.

Meaningful sub-surface exploration with justification.

Analysis of data for design consideration.

Chapter VII

GUIDELINES FOR INSPECTION, OPERATION AND MAINTENANCE

7.1 Inspection

- 7.1.1 The Dam Safety Organization of the Central Water Commission has prepared "Guidelines for Safety Inspection of Dams." The guidelines were presented during the workshop on dam safety organized by Central Board of Irrigation and Power in October 1983. The CBIP have sent copies of these guidelines to all the States.
- 7.1.2 The guidelines cover all types of water resources structure in a comprehensive way, to include the gamut of all things that need to be looked into while doing safety inspection. Modifications may be required to meet specific types of structures / site conditions prevailing in the States. The States are advised to follow these guidelines as closely as possible.
- 7.1.3 The Earthquakes Committee of the United States Committee on Large Dams (USCOLD) has prepared a publication titled "Guidelines for inspection of dams following earthquakes." These guidelines may be followed during inspection of dams following an earthquake.

7.2 Operation and Maintenance

- 7.2.1 Even a well constructed dam may face problems and difficulties if it is not properly maintained. The maintenance budget of most of the structures, it is noticed, hardly covers the establishment charges leaving very little funds for carrying out actual maintenance. The budget provisions for maintenance of hydraulic structure need to be upgraded and this should be on the basis of the present cost of the structure instead of the original cost. This should be upgraded once in ten years.
- 7.2.2 In case of remedial works, necessary as a result of review for existing dams, a detailed estimate has to be prepared and got sanctioned before the commencement of work. If such repairs are to be undertaken as a consequence of the panel's recommendation, the Dam Safety Cell shall act as a catalyst to arrange for speedy sanction of the estimate. The estimate, however, shall be prepared by the Chief Engineer in charge of the project. In case of emergency repairs, the work will be commenced and the estimate submitted for ex-post-facto sanction.

- 7.2.3 Each river valley project / dam should have an operation and maintenance manual which should contain detailed instructions, procedures and rules for operation and maintenance of the dam and its appurtenant works. It should also include instructions regarding operation, maintenance and record of observations in respect of working of various facilities as well as the equipment / instruments embedded within the body of the dam and its appurtenant works.
- 7.2.4 A copy of the operation and maintenance manual should always be handed over to any new officer who joins the project and is charged with the responsibility of maintenance of dams.
- 7.2.5 Operation and maintenance manuals should be prepared by the design office in consultation with the construction and maintenance organization / Dam Safety Cell of the State. The procedure formulation should also involve administrative authorities and requirement of downstream riparian rights. Any modifications considered necessary as a result of field experience in following the instructions contained in the operation and maintenance manual, shall be proposed by the field engineers to the design office. All amendments considered necessary by the design office shall be done after getting the approval from the competent authority in consultation with the Dam Safety Cell.
- 7.2.6 An adequate flood forecasting system with wireless communications needs to be established for reservoirs wherever such a system is likely to provide enough advance information of incoming flood volumes useful for reservoir operation.
- 7.2.7 In respect of major projects, the State Government may consider the formation of an Expert Committee consisting of experienced design and construction engineers of dams to advise on the various problems encountered during operation and maintenance stage. Annual memos may be prepared regarding the performance of dams and other important components of the project and see the advise of the experts. Copies of these memos may be sent to Dam Safety Cell in the State as well as Chief Engineer, Dam Safety Organization.
- 7.2.8 It would be necessary that before shifting the operation and maintenance staff from one project to another, it should be ensured that the staff posted in their place are properly trained and at no time all the staff is new at a project.

7.3 Principles of Reservoir Operation

- 7.3.1 The aim of reservoir operation is to reduce the risk of man-made floods to the area on the downstream through carefully prepared reservoir regulation schedules, release procedure and gate operation schedules aided by an accurate & reliable flood forecasting and warning system.
- 7.3.2 In case of ungated reservoirs the only fact that needs to be carefully decided is the design flood, the adequacy of spillway and the freeboard. These need to be periodically reviewed with the help of continuous short term data built up during the course of operation.
- 7.3.3 In case of gated reservoirs, while it is desirable to fill the reservoir early, it should not be brought to near F.R.L. if late monsoon inflows are adequate to fill the reservoir.
- 7.3.4 In case of the gated reservoir having flood control storage space, the operation could be flexible keeping the requirements of both conservation and flood control in view. The reservoir operation should be carefully coordinated between flood disposal and the building up of the conservation storage. This is achieved by preparing guide curves and gate operation schedules and efficient system of flood forecasting.
- 7.3.5 The Regulation Manual for Damodar Valley Reservoirs was prepared by CWPC in April 1969, and this deals with integrated regulation of the four DVC multipurpose reservoirs at Panchet, Maithon, Konar and Tilaiya for the principal benefits of flood control, irrigation, industrial, domestic water supply and power. This can be referred to with benefit for developing integrated regulation manual for a system of reservoirs in a basin.
- 7.3.6 The Government of Maharashtra has brought out a Dam Safety Manual Chapter 7, entitled "Flood Forecasting, Reservoir Operation and Gate Operation" for general guidance of field staff engaged on the operation and maintenance of dams in the State. The Manual contains guidelines relating to principles and techniques of flood forecasting, operation of flood forecasting systems, principles of reservoir operation, preparation of guide curves for reservoir filling and regulation, gate operation schedules for gated dams and flood disposal, flood fighting, constitution of flood coordination committees, flood plain zoning and details of various data to be collected and registers to be maintained relating to reservoir operation and floods. The Manual is quite exhaustive and other States may develop similar documents to meet the specific

requirements of the State relating to reservoir operation, flood disposal and safety of dams and downstream property.

7.4 Gate Operation Schedules

- 7.4.1 The gate operation schedules must be based on the site conditions, the results of model studies and the regulation schedule of the reservoir. The gate operation schedule should clearly indicate the complete sequence and stages of operation of various gates corresponding to various lake levels and flood situations.
- 7.4.2 Operating instructions for important structures should be displayed near associated equipment. Each operating device should permanently and clearly marked for easy identification of equipment, and proper security arrangements should be made to ensure that unauthorized persons cannot operate or tamper with the equipment.
- 7.4.3 All mechanical and electrical equipments should be maintained properly and inspected at regular intervals to avoid any mishap in case of emergency. The working of spillway gates, outlet gates and undersluices and low level outlets should be specially checked before the onset of monsoon every year so as to ensure that these are not jammed and become inoperative.
- 7.4.4 Proper measurement of short period water levels during floods, short duration rainfall measurement in the catchment, outflow rating calculations and maintenance of gate operation records, etc., is very essential for all existing reservoirs. Automatic water level recorders in the reservoir, to monitor drawdown effect caused by outflow, should be installed in all reservoirs at suitable places.
- 7.4.5 An efficient and reliable flood forecasting system should be established to formulate accurate forecasts of inflow and volume of floods and regulation of gates for efficient flood disposal.

7.5 Silt Surveys

- 7.5.1 Reservoir silt survey should be done at regular intervals and the area capacity curve of the reservoir should be accordingly revised. If some major slides / mishaps take place in the reservoir which considerably affects its capacity, silt surveys will be conducted

immediately thereafter. These surveys should be more frequent in the initial years so as to know the trend of silting.

- 7.5.2 Flood carrying capacity of the river channels downstream of the dam shall be reviewed at intervals of five years.

7.6 Record of Operation

- 7.6.1 Proper measurement of water levels at short intervals during floods, short duration rainfall measurement in the catchment, outflow rating calculations and maintenance of gate operation record, etc., are very essential for existing reservoirs. Automatic water level recorders in the reservoir should be installed in all reservoirs at suitable places.

- 7.6.2 In Maharashtra State, regular workshops are conducted every year before the monsoon for training of dam operating staff in reservoir operation. The workshops are of a short duration of 4 to 5 days and are conducted at the regional training centre at Paithan dam through the Engineering Staff College, Nasik. The workshops are intended to acquaint the staff engaged on actual operation of reservoirs in the State with the techniques and methodology of reservoir operation and related aspects. The trainees include mostly Assistant Engineers and Junior Engineers posted on maintenance and operation of important dams in the State.

- 7.6.3 The training syllabus of the workshop includes lake filling schedules, flood hydrology (a broad appraisal), flood forecasting, flood disposal, flood moderation and upstream & downstream safety, collection of hydrological data at the dam sites, maintenance of records, maintenance and operational aspects of spillway gates, and vigilance of dams during monsoon. In addition to the lectures, the trainees are taken round the existing facilities at Paithan dam for practical demonstrations and drills in various related aspects of the course.

- 7.6.4 The Committee recommends that such training programmes should be organized in other States.

Chapter VIII

EMERGENCY PREPAREDNESS

- 8.1 Nature of disaster and its effects.**

8.1.1 A situation of emergency arises in case of an impending disaster. The disaster itself may be natural or man-made. While natural disasters run through a definite known cycle of events and follow certain norms of localized scale, man-made disaster neither have known cycle of events nor are they necessarily spatially and temporarily restricted. In other words, natural disaster barring earthquake, may be considered to be structured events while man-made disasters are unstructured.

8.1.2 Floods are one of the natural events, which often spell disaster. The existence of a dam upstream of the flood plain may either mitigate the extent of the calamity or accentuate it. As such, the disaster due to the existence of a dam may have the quality of a natural disaster or qualities of both natural and man-made disaster. The disaster would be considered natural if the quantum of outflow from the dam is equal to the inflow flood. If, however, due to the very existence of a dam the outflow exceeds the inflow, the disaster can be logically classified as man-made. In the event of dam break also, it will then be purely man-made.

8.2 Planning for emergency

8.2.1 The emergency preparedness plan should, however, be applicable for both natural and man-made disaster. The man-made disaster arising out of an outflow in excess of the inflow can be taken care of by developing operation rules with built-in factor of safety and adequate and efficient warning system. Our greater concern is to evaluate the disaster, consequent to dam break.

8.2.2 The aim of management cannot be the handling of the natural phenomena itself, but rather to lessen or mitigate its impact upon human beings and natural environment. In order to carry out such measures it is necessary to have a proper plan and well-defined measures which would help reduce the risk of disaster. Assessment of a country's vulnerability to disaster should be regarded as an essential element in the planning and implementation of measures which are designed to prevent or mitigate the disaster. If this basic element is ignored, disasters will keep occurring and take its toll and a great deal of avoidable damage will continue to occur which will ultimately have a disastrous effect on the economy of the country.

8.2.3 An integrated disaster plan would encompass the disaster prevention and disaster preparedness and these two aspects are like the two faces of the same coin. One part cannot be dealt exclusively without the other.

8.2.4 Disaster preparedness can minimize loss of life and property by proper planning in advance so that measures are available to counteract the disaster. Visualizing challenges in advance and equip yourself to meet it effectively is the hallmark of rational human being. Such planning would call for correct assessment of the following items:

- ❖ Evaluation of the disaster – advance knowledge of the likely occurrence of flood or cyclone.
- ❖ To identify the likely effects on property and human beings with a view to assess the damage potential of the disaster.
- ❖ Vulnerability analysis and hazard area mapping to identify the most common area prone to such type of disaster.
- ❖ Review of organization and machinery for proper upkeep and maintenance of flood control works like dams, embankments, etc.
- ❖ Review of the provision of anti-disaster shelter – adequacy of medical aid facility, transportation, food, etc.
- ❖ Review of existing method of flood and cyclone warning system with a view to rectify the missing links and gaps and modernizing the system in accordance with the latest state-of-art, if necessary.

8.3 Prioritisation of the projects for emergency preparedness

8.3.1 It would be ideal if emergency preparedness plans can be developed for all dams whose failure would endanger human life and property. However, due to financial and other constraints it may not be possible to prepare emergency preparedness plan in a single stage for all projects in one go. In fact, emergency preparedness plans shall be prepared for certain priority situations to be decided on the basis of the following considerations.

- (i) Dams in distress (dams whose level of safety has been adjudged low after review).
- (ii) Projects with an earth dam component for which inadequacy of spillway has been identified during review and which even after adoption of engineering solutions, there exists a remote

possibility of overtopping while managing the reviewed design inflow flood.

- (iii) Projects with an earth dam component for which the inadequacy of spillway has been identified, but engineering solution to manage the design inflow flood without overtopping would need considerable time and funds.
- (iv) Dams constructed from masonry or concrete without an element of an earth dam. Here again, disaster preparedness shall be done for a possible outflow beyond the capacity of the downstream channel, but the dam is saved in the process.
- (v) For dams having a nuclear power plant on the downstream, studies will be conducted in consultation with the Atomic Energy Commission.
- (vi) While fixing interse priority, the hazard potential of the dam in question shall also be taken into account.

8.4 Inputs for preparation of emergency plan

8.4.1 Planning of emergency preparedness plan would get facilitated if the “flood plain zoning bill” has been enacted and is given effect to for the basin under consideration. Such an approach would lessen the effect of the disaster at a later stage.

8.4.2 Release of large amount of water due to combination of flood coupled with dam break, disaster preparedness shall be done for the dams listed above in the same order of priority.

8.4.3 Inundation map is the first input for planning an effective emergency preparedness plan. The following guidelines are suggested:

- ✓ Assess the safe carrying capacity of the downstream channel and the safe levels.
- ✓ Assess the inundation area for
 - ❖ 25 years flood;
 - ❖ 50 years flood
 - ❖ For routed design flood

- ❖ For PMF + dam break

8.4.4 Inundation map may be prepared for 25 years flood, 50 years flood and routed PMF in the order in which they are indicated above. The inundation map for floods coupled with dam break shall be prepared subsequently after conducting studies on dam break and collecting additional data, etc.

8.4.5 Dam break studies

8.4.5.1 There are computer programme packages to evaluate inundation area due to dam break floods:

| Model Solution | Technique | Remarks |
|---|--|--|
| HEC I DB | Modified Pulse Kinematic Wave | Well documented, easily applied, incorporates variation in breach geometry and time rate of breach formation. Presently limited to single dam application with dry downstream channels. |
| USTFLO (Corps of Engineers) | Explicit, Staggered Grid | Requires usage of separate programme to calculate geometric elements (GEDA), designed for river routing, usage for dam break flood difficult. Requires relatively small time steps and fixed distance steps. |
| DAMBRK (National Weather Service) | Four point, weighted difference implicit. | Designed specifically for dam break floods, is easily applied and extremely versatile. Handles variable breach and time rate of breach formation, using storage or dynamic routing in reservoir. Will handle multiple (domino type) failures and will route super-critical or sub-critical flow. |
| MOC-LIF (United States Geological Survey) | MOC explicit method of characteristics, LIF - Four or Six point linear implicit. | Not widely used. Treats dam as internal node, propagates a single bore, sub-critical flow only. Limited to single dams. Requires trapezoidal cross sections, evenly spaced distance steps, small time steps, relatively expensive computational cost. |

8.4.5.2 The DAMBRK model is more versatile compared to other models. This model is available in the Dam Safety Organization, Nashik. The following minimum data is required for this model:

- ❖ Breach geometry (simplified to rectangular or trapezoidal shape parameters).
- ❖ Time rate of breach formation.
- ❖ Reservoir elevation – surface area points.

- ❖ Two or three valley cross sections. The cross sections should be chosen to accurately describe valley storage and conveyance. More sections generally improve the accuracy of computed peak stages.
- ❖ Valley roughness coefficients.
- ❖ Boundary inflow hydrograph and lateral inflow hydrograph.
- ❖ Reservoir elevation at start of failure and initial water surface elevation at the downstream end of the channel.
- ❖ Description of downstream channel flow conditions, i.e. sub-critical or super-critical.

8.5 Preparation of Inundation Maps

- 8.5.1 The population and property situated within the area prone to inundation and damage must be surveyed to identify the emergency potential.
- 8.5.2 Based on this survey, the index maps and detailed maps of likely inundation area due to dam break floods to be prepared by the Executive Engineer. The index maps and detailed maps of the dam break inundation area should ordinarily be prepared and handled as secret documents. These maps should also indicate location of safe high ground which can be used for evacuation and shelter purposes.
- 8.5.3 The inundation maps should be prepared to the scale of 2 cms = 1 km or 1 : 50,000 or the scale of available topographical maps. A list of towns and villages, important public buildings and installations, railway lines, railway stations, post and telegraph offices and roads which may come under the flood line, should be prepared on the index map itself.
- 8.5.4 In respect of cities or towns and the villages falling in the likely inundation area of dam break floods, the detailed contour maps of the entire area showing contours at 0.5 m. intervals should be prepared. The hypothetical dam break flood line, the 25 years return period outflow and the maximum spillway design discharge flood line (wherever relevant), the various populated sectors, streets and roads, public buildings, important installations and all prominent places must be marked on these plans. The detailed maps should be prepared on the available town planning or city survey or land record plans or village maps.

8.5.5 Normally such maps are available for the command area of irrigation projects having direct canals. These maps with additional surveys covering the likely inundation area will also serve the purpose in majority of the cases.

8.6 Arrangement for public safety

8.6.1 The Revenue Officers should be informed to select suitable higher locations where the people from flood prone area should be shifted in case of necessity. Details of such locations to be used for evacuation and shelters should be worked out and clearly marked on these detailed maps. The particulars of the railways and road bridges in the flood zone should be obtained and likely flood levels to which they might be subjected should be intimated to the revenue authorities and the authorities in charge of the bridges.

8.6.2 The above maps and details should be scrutinized and approved by competent officers of Irrigation Department as under:

| Sl.No. | Category of Hazard Potential | Competent Authority |
|--------|------------------------------|-------------------------|
| 1 | High | Regional Chief Engineer |
| 2 | Medium | Superintending Engineer |
| 3 | Low | Executive Engineer |

8.6.3 The approved plans of inundation area should be supplied to the following authorities:

- ❖ Chief Engineer (Irrigation Department)
- ❖ Commissioner of Revenue Division
- ❖ Superintending Engineer
- ❖ Executive Engineer
- ❖ Collector of the District

8.6.4 Sufficient spare copies of the approved plans should also be kept ready to be supplied to any other officials concerned at short notice.

8.6.5 Location of readily available equipment material, labour and engineering expertise which can be commandeered need to be identified and properly planned. All emergency preparedness plans

shall be reviewed after a period of 5 to 10 years depending upon its operation.

8.7 Public participation

8.7.1 Public participation to make emergency preparedness plan a success is an absolute must. Consequently, the MLAs, MPs in the disaster prone area, and all responsible persons of the locality shall be involved in the emergency preparedness plan. The help of voluntary organizations like Ramakrishna Mission and others shall be utilized. To chalk out the plan of action and fixing responsibility a meeting shall be convened at the District Magistrate level before the flood season every year to assign responsibilities and indicate their duties in the unlikely event of disaster.

8.8 Efficient communication system

8.8.1 An efficient communication system to achieve success of emergency preparedness plan is absolutely essential and this has to be worked out in consultation with local authorities and administrative set up. More often than not, the entire communication facility gets disrupted in a disaster situation. The wireless facility which is slightly free from the general encumbrances of the communication system shall invariably be a part of the emergency preparedness plan. Department of Police invariably has wireless sets and there are standing instructions with them that they should convey disaster messages effectively and in time.

8.8.2 All departments who are to deal with the emergency preparedness plan shall be identified and the officer who is to be the nodal officer in each department shall be identified and such officers will be provided residential telephone in addition to their office telephones. It is evident that the emergency preparedness plan is an integrated matter and requires technical expertise and specific administrative procedures if it is to be made practical, pragmatic and successful.

8.8.3 The Government of Maharashtra has brought out a Dam Safety Manual Chapter 8 entitled "Preparedness for dealing with emergency situation on dams", which is quite exhaustive and it may be used for developing similar plans to meet the specific requirement of each State.

Chapter IX

NEED FOR LEGISLATION

9.1 Introduction

In a welfare State, one of the object of legislation is to guide the behavioural pattern of individuals or groups in a society resulting in a general good to the greatest numbers. In an Utopian concept, a Government which rules the least is the best. Implied in the above, it follows that the individuals and groups have attained a degree of perfection in their behavioural pattern and their attitudes. However, the Utopian concept cannot be reached. Therefore, it follows that the Government has got to resort to legislation to bring in general good of the greatest numbers.

9.2 Importance of dam safety

The concept of dam safety as a separate discipline, even though was in existence in different form, has been a latecomer. While the dams constructed the world over have been the kingpin for the advancement of human civilization, it also poses a potential hazard in the event of failure. A failure of a dam brings in its wake loss of life and disastrous economic consequences in the basin. Hence, there is a definite urgency to regulate the monitor supervision of these dams to take timely corrective steps to prevent failure and in the unlikely event of failure shall be prepared with appropriate plans to mitigate its effects. Visualizing in advance the challenges that are likely to come up and to equip oneself to meet it is the hallmark of rational human being.

9.3 Basic contents of Dam Safety Legislation passed by in foreign countries.

9.3.1 In many advanced countries, particularly UK and Switzerland, etc., Dam Safety Legislation has been enacted for this purpose. In other countries it is still in the proposed stage. However, we have no idea how effective these have been and what difficulties they have encountered in enforcing them. The basic structure of the legislations as drafted by USCOLD are as under:

9.3.1.1 The intent of the act is to provide for the regulation and supervision of all dams and reservoirs exclusively by the State to the extent required for the protection of public safety.

9.3.1.2 Creation of a Central authority for the above.

- 9.3.1.3 Insistence of competent, licensed, experienced civil engineers in dam design assisted by qualified engineering geologists, specialists of other disciplines connected thereof to be in charge of planning, construction and operation of reservoirs.
- 9.3.1.4 Approval of the agency shall be sought for undertaking construction of new dams, enlargement of old dams or removal of existing dams and also to review and approve the design, construction, alteration, repair, maintenance and operation, etc.
- 9.3.1.5 The approval given by the agency in respect of any of the above shall not be construed to relieve the owner or operator of a dam or reservoir of his legal duties / obligations or liabilities instant to the ownership and operation of the dam or reservoir. Implied in this the responsibility for the safety of the dam rests with the owner.
- 9.3.1.6 The findings and orders of the agencies and the certificate of approval of any dam or reservoir issued by the agency are final and conclusive and binding on all owners and State agencies regular or otherwise as to the safety of the design, construction, maintenance and operation of any dam. However, there is a provision for the owner to seek legal recourse against the decision of the agency.
- 9.3.1.7 All owners are required to obtain approval of the agency with regard to safety of the dam under their control which has to be done by appropriate application and the legislation indicates also fees to be paid along with the application, the time limit for the application to be processed, etc.
- 9.3.1.8 The agency may by a consulting board of two or more consultants not previously associated with the structure to report to the agency of its proposed action with respect to this consideration. The cost of it shall be borne by the owner.

9.4 Functions of the agencies

- 9.4.1 For all dams and reservoirs under the jurisdiction of the agency, except those dams which are federally owned, the agency shall review and approve the design, construction, alteration, repair, etc.
- 9.4.2 Approval of agency is required for taking up new work, or making alteration for existing structure or to remove a structure.
- 9.4.3 Agency has power to review rules and regulations which do not conflict with the provisions of the act.

- 9.4.4 Agency has power to determine whether a proposed dam constitute a danger to life and property and shall recommend such measures to the owner as are necessary to the satisfaction of the agency to remove the resultant danger to life and property.
- 9.4.5 Agencies are required to get appropriate investigations and studies conducted before coming to any conclusion with regard to the safety or otherwise of the dam.
- 9.4.6 Agency is armed with the power for enforcement of the act.
- 9.4.7 Agency shall in times of emergency can declare repair or breach of dam or such recommendations shall be carried at owner's expenses, failing which agency shall have it repaired at owner's expenses.
- 9.4.8 Agency shall also give certificate for the initial filling of the reservoir and the owner has to put in application as soon as the dam is ready for its maiden filling. No water shall be impounded by the reservoir prior to issuance of the certificate. The agency has power to revoke a certificate or issue a certificate with terms and conditions as they deem fit.
- 9.4.9 Before revoking the decision, the agency is required to give a hearing to the owner to understand his side of the case.
- 9.4.10 The agency shall also issue instructions for alterations, enlargement and repairs of any dams which pose significant danger potential.
- 9.4.11 The agency shall also order removal of any unsafe dams. This shall be done by the agency only after site inspection and determining that all danger to life and property as a result thereafter has been eliminated.

9.5 Complaints as to the unsafe condition of dam

- 9.5.1 After receipt of complaint the agency shall cause an inspection to be made unless the proper records, inspection reports on file with it are found adequate for determination to find whether the complaint is valid. The agency shall recover from the complainant the cost of investigations required, if the complaint is found to be without merits after investigation. If it is found that a complaint was genuine, the money deposited by the complainant shall be returned and the owner requested to take appropriate action.

- 9.5.2 The agency has powers for periodic inspection at State expense for the purpose of ascertaining compliance with approved plans and specifications. During such inspection if it is found that some modifications are called for, they may get the same ordered to get them done. Owner has right to appeal through the independent consultant to review the order of the agency.
- 9.5.3 The supervision over maintenance and operation of the dams and reservoirs in the State other than those owned by the federal Government is vested in the agency. The agency shall have the dams reviewed by an independent panel for structural safety of the dam at the State expenses at regular interval, say 3 to 5 years. However, the cost involved on the recommended measures shall be borne by the owner. The agency is also authorized to declare emergency in the initial filling of the reservoir and shall have powers to take command of the situation. However, the agency take over will not operate to relieve the owner of the dam or reservoir liability for any negligent act by the owner or his agent. The cost of such emergent operation shall be recovered from the owner. The legislation also provides for fines and punishment.

9.6 Dam Safety Act – Constitution

- 9.6.1 In India, under the Constitutional dispensation of legislative powers, the States have been assigned a primary role in the development of water. Entry 17, List II of the Seventy Schedule to the Constitution reads:

Water, that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power subject to the provisions of Entry 56 of List I.

- 9.6.2 However, the Centre has been given the responsibility of “Regulation and development of inter-State rivers and river valleys to the extent of which such a regulation and development under the control of Union is declared by Parliament by law to be expedient in the public interest” under Entry 56 of List I.
- 9.6.3 Under this, the Union has power to legislate over inter-State rivers and river valleys. The Union has not acted so far to extent its control over the water resources development (beyond legislating, the River Boards Act 1956 which has not been made use of and the Betwa – River Board Act 1976 enacted when the concerned States, namely States of Uttar Pradesh and Madhya Pradesh requested the Union to enact).

9.7 Present condition in the country

- 9.7.1 In India, dams are mostly owned by State Governments. Some dams are owned by Public Sector Undertakings, Boards and Corporations, which are also Government agencies. Tatas own a few dams privately. As against this position, in foreign countries where dam legislation has been attempted, dams are owned (operated) by private agencies and they are many in number. The Tailings Dam that failed in Italy recently which took a toll of 200 lives was owned by a private concern and had exchange of ownership. This situation is non-existent in India. In fact, it is significant to note that in the model law, i.e. proposed by US COLD, the federal dams are outside the purview of the proposed act.
- 9.7.2 Dam is made safe if adequate precaution and care are exercised at every stage from the point of conception of the scheme till it is translated to reality. The various important stages are:
- Investigation;
 - Design;
 - Construction;
 - Operation & Maintenance
- 9.7.3 Dams in India are investigated, designed constructed and maintained by qualified engineers appointed by the State / Public Undertakings.
- 9.7.4 The various input data required in the preparation of a project are outlined by the Planning Commission in consultation with CWC and the proforma that are prescribed for the preparation of the project report is quite exhaustive and elaborate. Meticulous compliance on the various points raised in the proforma would certainly ensure adequate precautions even in the formative stage of the project.
- 9.7.5 All new projects to be undertaken in the Irrigation & Power Sector by the State are to be approved by the Planning Commission and the technical details of the project are scrutinized and examined by CWC, who in turn advise the Technical Advisory Committee of the Planning Commission with regard to its clearance. There are IS Codes that govern the design of water control structures and strict adherence to these would result in a safe structure.
- 9.7.6 In most of the major projects quality control during construction is watched by an independent agency other than construction agency which is also under the Chief Engineer. In fact in India, the Chief

Engineer / Executive Engineer is basically the kingpin for the safety of the dam or dams. He has got to take decisions keeping the exigencies of work and the need for quality control to ensure safety of the dam.

- 9.7.7 Before foundation is laid the foundation has to be cleared by the Resident Geologist of the project. The importance of this stipulation can be gauged by the fact that nearly 40% of the failures of dam have been attributed to foundation failure. Before a concrete or masonry block is raised, the OK signal of the quality control has to be obtained. Of late the major projects aided by World Bank are assisted by Dam Safety Panel which comprises of experts from various disciplines where collective wisdom of the experts are brought to bear on the project problems at all stages. When work is executed through contract, payments are made only after a certificate is given in the M.B. "Certified that the work has been done as per specifications and drawings" approved by the competent authority.
- 9.7.8 Coming to the operation and maintenance of the reservoir, there are existing departmental rules and manuals and these are obligatory. In some of the advanced States like Maharashtra, they are bringing out dam safety manual which is quite exhaustive and elaborate.
- 9.7.9 The manual has gone to the extent of making obligatory, preparation of Emergency Action Plans for all dams before taking up the work of closure of river channel or building up any storage. The manual goes to the extent of indicating that it may be useful to finalize the Emergency Action Plan for any storage project even at the stage of finalizing the technical sanction so that the hazard potential of the project can be known beforehand and the same can be fully considered while finalizing the relevant technical details and designs. Such Emergency Action Plan also suggests dam break model studies to be conducted for formulating emergency planning. The Uttar Pradesh Government has also brought out a manual regarding operating instructions for maintenance of dams.
- 9.7.10 In 1979, realizing the importance of dam safety, a Dam Safety Organization was created in Central Water Commission. This Organization has been instrumental for setting up Dam Safety Cell in various States by a resolution adopted in the State Ministers' Conference. Dam Safety Cells have been set up in 12 States. The awareness about implication of dam hazard and the consequence of failure thereof are being disseminated by holding workshops and discussions with State level officers and lectures by Directors of

Central Water Commission. A Workshop on Dam Safety was organized under CBI&P in October 1983, wherein Chief Engineers and Engineers of the State associated with dam safety participated. The following documents which have significant importance for monitoring the safety of the dams have been prepared and circulated:

- Guidelines for Dam Safety Inspection.
- Literature relating to mode and causes of failure.

9.7.11 In the year 1981, the Dam Safety Organization initiated action for review of design flood of dams in the country and a letter was addressed by the then Union Minister for Agriculture and Irrigation to the Chief Ministers of all States to take up review of design flood of all existing dams in their States. Gujarat Government have already reviewed quite a number of their dams and have also evolved appropriate technical modification / strategies to overcome the inadequacy. The States of Maharashtra and Uttar Pradesh have also initiated action. The BBMB which owns dams on Bhakra Beas complex has also initiated review of design flood of their dams. However, there exists a significant gap in many States with regard to maintenance and operation of their reservoirs. This is possibly due to

- Inadequate funds for maintenance;
- Inadequate appropriate technical staff for maintenance as there is an unwillingness of the staff to be on maintenance;
- Communication gap when the project is handed over to maintenance from the construction stage.

9.7.12 These aspects are dealt with by the review committee in the other chapters of the report. Thus it is seen that most of the objectives that are proposed to be covered by dam safety act are being covered in the existing rules, procedures / conventions in the country.

9.7.13 It is seen that in some of the new dams which we have constructed do have some problems. These problems are not due to lack of any deficiency in the working of any rules and codes, but concerns the implementation aspect of the same. Advocators of Dam Safety Act advance an argument that a law would help to ensure compliance of the provisions of the law when once it is put into statute. It needs to be remembered that legislation by itself cannot provide any guarantee against the risk of disaster, but what is lacking in the country is not lack of rules and procedures, but an effective

inspection and surveillance system which can reduce the probability of failure of a dam to a large degree.

- 9.7.14 If the State Government were to approach the legislature to legislate on matters of dam safety, it would amount to the executive asking the legislature to enact a law to govern its own activities. The executive under subsidiary legislative powers can frame appropriate rules and regulations to ensure effective dam surveillance, maintenance, etc. There appears to be no need for a legislation on this behalf.
- 9.7.15 If a law is to be passed by the Centre, it would need amendment of the Constitution as to equip the authority with sufficient powers. However, it is a moot point in a large country like India with dams scattered all over the country how effective it will be.
- 9.7.16 With the present laws that are available in the country, it is possible to fix responsibility for actions or inactions which result in negligence resulting in failure of a dam. In fact, wherever a failure has taken place, an enquiry has been constituted under the existing laws and the causes identified. Law does not provide any flexibility. Water resource structures are combined efforts of various disciplines and their operation also need close cooperation of all the disciplines. The subject of dam safety is inter-disciplinary, cross sectorial and all pervasive in character. So, in assessing a particular situation it would need flexibility which would not be provided if there is a law under statute.
- 9.7.17 In this connection it would be relevant to mention that in the introduction to the model law prepared by the "Committee on the model legislation for safety of dams" prepared by US Committee on Large Dams they have observed as under:
- "Some States may prefer to put some of the requirements into administrative or technical rules or regulations rather than into the statute itself to provide more flexibility. Experience has shown that incorporation in the basic law removes the requirements from possible frequent changes by a succession of administrators."*
- 9.7.18 In our country, the Government happens to be the owner of most of the dams. The Committee, therefore, feels that the situation that exists in foreign countries does not exist in this country and there is no need for legislation on the lines as it exists in other countries. In the context of Indian condition and administrative set

up, the owners invariably being Government agencies, barring a few exceptions, an independent authority either in the Centre or at the State would bring in dual responsibility, leading to responsibility with none. In view of the above, the creation of a separate dam safety authority would also not meet the requirements. As for effective functioning, the Dam Safety Organization has to function with the assistance of the design organization and operation and maintenance authorities.

9.7.19 The Committee feels that a legislation on the following lines would serve the purpose for the present, the contents of which would be as indicated below. Procedural and technical details of the dam safety work are not proposed to be covered by the act. They will be dealt with by the States' concerned organizations.

9.8 Contents of legislation

9.8.1 All large dams shall be investigated, designed and constructed by recognized organizations consisting of qualified, experienced and competent engineers.

9.8.2 All the States which have significant number of dams shall constitute a body called "Dam Safety Organization." This Organization shall be manned by competent technical people and adequately staffed and funded.

9.8.3 The functions of the Organization shall be in accordance with the guidelines of the Standing Committee's report.

9.8.4 The Dam Safety Organization of the State shall prepare annual report of its activities, and these shall be submitted to the Government. A copy of the same shall be sent to the Central Water Commission. The Central Water Commission through its Dam Safety Organization, shall maintain liaison with the Dam Safety Organizations in the States to provide necessary technical assistance when requested.

9.8.5 The Dam Safety Organization of the State shall provide to Central Water Commission, documentation of projects, annual report of status of dams and report of enquiries into failures and such other data as required, or in such other forms or manner as it may direct.

9.8.6 The Dam Safety Organization of the Centre will prepare an annual report on the subject for consideration of the Ministry of Water Resources.

9.8.7 A technical enquiry shall always be instituted to investigate the causes of failure of any dam.

Chapter X

SUMMARY OF ACTION POINTS

- 10.1 New dams shall be investigated, designed and constructed as per guidelines / procedures and IS Codes and the state-of-art of dam engineering.
- (Chapter I)
- 10.2 Each State which has significant number of major dams shall create a Dam Safety Cell in the State.
- (Chapter III)
- 10.3 Keeping in view the infrastructure and expertise available in the State, it appears desirable that the Dam Safety Cell shall be created by the Irrigation Department in the State who incidentally owns maximum number of dams. This Cell shall be responsible for safety review of dams owned by other agencies.
- (Chapter III)
- 10.4 The technical report of design and construction of a project is a vital document for subsequent review. It is, therefore, necessary that completion report of all important and major projects shall be undertaken by the State. Action need to be initiated by the Chief Engineer of the project for drafting the completion report when the project is in 50 % completion stage. The officers who have to provide chapters need to be identified. It would be desirable if the officers are kept in the same project till final chapters are written by them. Suitable financial incentive to motivate them to take up this work in right earnest is recommended. A separate financial provision in the project report shall be made for preparing the completion report including its printing cost, etc. It shall also provide for micro filming of important drawings of the dam as constructed including geological features as revealed after excavation, technical and quality control data that need to be kept for posterity.
- (Chapter III)
- 10.5 Preparation of design memorandum of all aspects of design is a good practice and this practice should be extended to medium projects also.
- (Chapter III)

- 10.6 The Dam Safety Organization at the Centre shall be strengthened to discharge its functions effectively and also assist some of the States which have not yet developed the requisite expertise in dam engineering.
- (Chapter III)
- 10.7 The Committee recommends that all States having significant number of dams should be represented on the Standing Committee. Such broad based representation would help in the follow up action on the recommendations of the Standing Committee. The Standing Committee should meet at least once a year to review the dam safety programme in the country.
- (Chapter III)
- 10.8 The States shall arrange safety review of dams which are more than 15 metres in height or which store 50,000 acre feet or more of water by an independent panel of experts once in 10 years. Matching financial grants shall be provided by the Centre towards expenditure incurred for establishment of the Cell and safety review. The State shall, however, bear the cost of repairs, resulting from such review.
- (Chapter IV)
- 10.9 The functions and responsibility of the Dam Safety Cell so constituted at the State shall be modeled on the lines suggested in Chapter IV.
- (Chapter IV)
- 10.10 It is desirable that all major and medium projects are guided by a panel of experts, even from the stage of design if not investigation, till the project is completed.
- (Chapter IV)
- 10.11 The priorities for safety review of existing dams shall be on the lines as suggested in Chapter IV.
- (Chapter IV)
- 10.12 With a view to assist the State Cell in fixing priorities for safety review, guidelines have been indicated in Chapter IV, V and VI relating to assessment of safety in dam, hydrological, structural and

seismological assessment. It is hoped that these guidelines would provide the necessary assistance in safety review.

(Chapters IV, V & VI)

- 10.13 Even a well-constructed dam would face many problems and difficulties if it is not properly maintained. The present budget provision for hydraulic structures is too inadequate. The budget provisions for maintenance of hydraulic structures need to be increased and these should be on the basis of present cost of the structure instead of the original cost which can be reviewed once in 10 years or at such time as dictated by inflation.

(Chapter VII)

- 10.14 Each river valley project should have an operation and maintenance manual which contains detailed instructions, procedures and rules for operation and maintenance of the dam and its appurtenant works.

(Chapter VII)

- 10.15 Operation and maintenance manual should be prepared by the Cell in consultation with design and construction engineers.

(Chapter VII)

- 10.16 Adequate flood forecasting system with wireless communication need to be established for reservoirs where such system is likely to help in giving advance information about incoming flood volume useful for reservoir operation.

(Chapter VII)

- 10.17 The State Cell shall develop their own guidelines for safety inspection keeping in view their requirements. Such guidelines shall draw their basic contents from the guidelines framed by CWC.

(Chapter VII)

- 10.18 Assessment of country's vulnerability to disaster shall be regarded as an essential element in the planning and implementation of the measures which are designed to prevent or mitigate the disaster.

(Chapter VIII)

10.19 Guidelines for emergency preparedness plan have been spelt out in Chapter VIII. The States may find them useful for preparing their disaster preparedness plan.

(Chapter VIII)

10.20 Investigation, design and construction shall be done by recognized institutes manned by qualified engineers with expertise in dam technology.

(Chapter IX)

10.21 In matters of legislation, the Committee feels that the conditions prevailing in India are different from those that are prevailing in foreign countries where owners of dams are private agencies. In India dams are by and large owned by the Government Organizations. In the context of Indian conditions, the Committee does not feel the need for a legislation on the lines indicated in foreign countries. However, there are many missing links and with a view to streamline the procedure in respect of discipline of dam safety, the Committee has, therefore, spelt out the broad framework of legislation.

(Chapter IX)

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(M.A. Chitale)
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Central Water Commission and Ex-Officio
Secretary to the Govt. of India.

Chairman,
Standing Committee

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ACKNOWLEDGEMENT

Most of the State Governments have rendered us unqualified cooperation and more so the Government of Maharashtra, Gujarat and Bhakra Beas Management Board. We are grateful to the State Governments and their officers for helping us to finalize this report.

The Committee was initiated by Shri Mahesh Chand, Chief Engineer, Dam Safety Organization and the guiding spirit behind was Shri Pritam Singh, ex-Chairman, Central Water Commission, and the Committee would like to recall their contribution at this juncture.

An intellectual report of this kind could not have been finalized without whole-hearted cooperation and advice of the Members of this Committee. We had had cooperation of Ganga Brahmaputra Water Studies Organization and the Publication Branch of Central Water Commission in the typing and binding of this report. We are also grateful to the Tamil Nadu Government for sending us coloured transparencies of the Periyar Rehabilitation works.

The report has been typed by Shri Hans Raj and Shri Rajendra Babu. Their work is acknowledged.

No. 18/18/80-I.T.
Government of India
Ministry of Irrigation

New Delhi, 17 August 1982

OFFICE MEMORANDUM

Sub: Standing Committee to review the existing and to evolve unified procedure of dam safety for all the dams in India.

The practices of safety inspection of dams presently adopted varies from State to State. In order to evolve a uniform simplified procedure based on the latest 'State-of-the Art'. The Government of India is pleased to constitute a Standing Committee to review the existing practices of inspection/maintenance of dams and allied structures in various States and to evolve standard guidelines for the same.

The Standing Committee shall consist of the following: -

| | |
|--|---------------------|
| 1. Chairman, Central Water Commission | Chairman |
| 2. Member (D&R)), Central Water Commission | Member |
| 3. Member (WR), Central Water Commission | Member |
| 4. Commissioner for Indus Water, Ministry of Irrigation. | Member |
| 5. Director General, Geological Survey of India (or his representative) | Member |
| 6. Director General, India Meteorological Department (or his representative) | Member |
| 7. Member (Irrigation), Bhakra Beas Management Board, Chandigarh. | Member |
| 8. J.F.Mistry, Chief Engineer, Irrigation Department, Government of Gujarat. | Member |
| 9. Chief Engineer, (DSO), Central Water Commission | Member Secretary |

The terms of reference to the Committee are as under:

- a) Review practices of various agencies in the country responsible for or involved with site selection, design, construction, regulation, inspection, maintenance and operation, repairs and ultimate disposition of dams which could affect the safety and integrity of the structure.
- b) To suggest means of improving the effectiveness to each agency, engaged in its dam safety efforts.

The expenditure involved on TA/DA and other incidentals of the official members would be borne by the concerned controlling authorities. Expenditure on non-official members, if any, would be borne by the Central Government.

Sd/-
(C.S. HUKMANI)
Joint Secretary to Govt. of India

APPENDIX – II

| IMPORTANT REFERENCES AND CODES FOR INVESTIGATIONS | | | |
|--|-----|-----------------------|---|
| 1 | IS | 1192-1981 | Velocity - area methods for measurements of flow of water in open channels |
| 2 | IS | 1194 - 1960 | Forms for recording measurement of flow of water in open channel. |
| 3 | IS | 2912 - 1964 | Recommendation for liquid flow measurement in open channels by slope-area method (approximate method). |
| 4 | IS | 2913 - 1964 | Recommendation for determination of flow in tidal channels. |
| 5 | IS | 2914 - 1964 | Recommendation for estimation of discharge by establishing stage - discharge relation in open channels. |
| 6 | IS | 4986 - 1983 | Code of practice for installation of raingauge (non-recording type) and measurement of rain. |
| 7 | IS | 4987 - 1968 | Recommendations for establishing network of raingauge stations. |
| 8 | IS | 5542 - 1969 | Guide for storm analysis. |
| 9 | IS | 6065 - 1971 (Part I) | Geological and geotechnical maps for river valley projects - recommendations for the preparation of |
| 10 | IS | 5313 - 1969 | Guide for core drilling observations. |
| 11 | IS | 4078 - 1967 | Indexing and storage of drill cores - code of practice for |
| 12 | IS | 4464 - 1967 | Presentation of drilling information and core description in foundation investigation. |
| 13 | | | Guidelines for investigation of major irrigation and hydro electric projects (CWC Aug.1975). |
| 14 | | | Report on the Committee to decide uniform yardsticks for investigation, design and research units (Government of India, Ministry of Irrigation, June 1982). |
| 15 | IS | 5002 - 1969 | Method for determinatio of sample size to estimate the average quality of a lot of process. |
| 16 | IS | 4905 - 1968 | Method for random sampling inspectin tables. |
| 17 | IS | 2500 [Part (I) 1963] | Inspection by attributes and by count of defects. |
| | | Part (II) 1965 | Inspection by variable for percent defectives. |
| 18 | | Hiranandani & Chitale | Stream Gauging. |
| 19 | BDC | 47 | Preliminary investigation and collection of data. |
| 20 | BDC | 49 | Geological investigation and subsurface exploration. |

This list mentions only the important IS Codes and references

| IMPORTANT REFERENCES AND CODES FOR DESIGN | | | |
|--|----|-----------------|--|
| 1 | IS | 5512 - 1972 | Criteria for design of solid gravity dams. |
| 2 | IS | 7894 - 1975 | Code of practice for stability analysis of earth dams. |
| 3 | IS | 8826 - 1978 | Guidelines for design of large earth and rockfill dams. |
| 4 | IS | 4997 - 1968 | Criteria for design of hydraulic jump type stilling basins with horizontal and sloping aprons. |
| 5 | IS | 4999 - 1968 | Recommendations for grouting of pervious soil. |
| 6 | IS | 5050 - 1968 | Code of practice for design, construction and maintenance of relief wells. |
| 7 | IS | 5186 - 1969 | Criteria for design of chute and side channel spillways. |
| 8 | IS | 5477 | Methods of fixing the capacities of reservoirs. |
| | | (Part I) 1969 | General requirements |
| | | (Part II) 1969 | Dead storage |
| | | (Part III) 1969 | Live storage |
| | | (Part IV) 1971 | Flood storage |
| 9 | IS | 6066 - 1971 | Recommendations for pressure grouting of rock foundations in river valley projects. |
| 10 | IS | 6939 - 1973 | Methods of determination of evaporation from reservoirs. |
| 11 | IS | 7365 - 1974 | Criteria for hydraulic design of bucket type energy dissipators. |
| 12 | IS | 8237 - 1976 | Code of practice for protection of slope for reservoir embankments. |
| 13 | IS | 8414 - 1977 | Guidelines for design of under-seepage control measurements for earth and rockfill dams. |
| 14 | IS | 8605 - 1977 | Code of practice for construction of masonry in dams. |
| 15 | IS | 9429 - 1980 | Code of practice for drainage system for earth and rockfill dams. |
| 16 | IS | 10135 - 1982 | Code of practice for drainage system for gravity dams. |

This list mentions only the important IS Codes and references

APPENDIX – III (contd.)

| IMPORTANT REFERENCES AND CODES FOR INVESTIGATIONS | | | |
|--|----------------------|-----------------------|--|
| 17 | IS | 10137 - 1982 | Guidelines for selection of spillways and energy dissipators. |
| 18 | IS | 4967 - 1968 | Recommendations for seismic instrumentation for river valley projects. |
| 19 | IS | 6524 - 1972 | Code of practice for installation and observation of instruments for temperature measurement inside dams : Resistance type thermometers. |
| 20 | IS | 6532 - 1972 | Code of practice for design, installation, observation and maintenance of uplift pressure pipes for hydraulic structures on permeable foundations. |
| 21 | IS | 7356 | Code of practice for installation, maintenance and observation of instruments for pore pressure measurements in earth dams. |
| | | (Part I) - 1974 | Porous tube piezometers |
| | | (Part II) - 1976 | Twin tube hydraulic piezometers |
| 22 | IS | 7436 | Guide for types of measurement for structures in river valley projects and criteria for choice and location of measuring instruments. |
| | | (Part I) - 1974 | For earth and rockfill dams. |
| | | (Part II) - 1976 | Concrete and masonry dams. |
| 23 | IS | 7500 - 1974 | Code of practice for installation and observation of cross-arms for measurement of internal vertical movement in earth dams. |
| 24 | IS | 8226 - 1976 | Code of practice for installation and observation of base plates for measurement of foundation settlement in dams and embankment. |
| 25 | IS | 8282 (Part I) - 1976 | Code of practice for installation, maintenance and observations of pore pressure measuring devices in concrete and masonry dams: Part I Electrical resistance type cell. |
| 26 | IS | 9116 - 1979 | Water stage recorder (float-type) |
| 27 | IS | 10334 - 1982 | Code of practice for selection, splicing, installation and providing protection to the open ends of cables used for connecting resistance type measuring devices in concrete and masonry dams. |
| 28 | IS | 10434 (Part I) - 1982 | Guidelines for installation, maintenance and observation of deformation measuring device in concrete and masonry dams. |
| | | | Part I Resistance type joint meters. |
| 29 | IS | 1893 - 1970 | Criteria for earthquake resistant design of structure (second revision). |
| 30 | Design of small dams | | USBR |
| 31 | Concrete Manual | | USBR |
| 32 | Earth Manual | | USBR |
| 33 | BDC - 54 | | Criteria for fixing spillway capacity. |

This list mentions only the important IS Codes and references

PERIODICAL INSPECTION OF DAMS

Schedule showing size of dams and the competent inspecting authority

| Sl. No. | Type of dam | Height from deepest river bed in m. | Impounded gross storage capacity upto FRL in M Cum. | Spillway capacity in M.Cum/sec. | Inspection authority | Inspection report to be sent to | Remarks |
|---------|-------------|-------------------------------------|---|---------------------------------|--|---|---------|
| 1 | Mini | 0 to 5 | 0 to 5 | 0 to 100 | Junior Engineer | Sub Divisional Officer / Executive Engineer | |
| 2 | Small | 5 to 15 | 5 to 30 | 100 to 1000 | Sub Divisional Officer / Sub Divisional Engineer | Executive Engineer | |
| 3 | Large | 15 to 30 | 30 to 300 | 1000 to 3000 | Executive Engineer | Superintending Engineer concerned | |
| 4 | Large | 30 to 60 | 300 to 1000 | 3000 to 10000 | Superintending Engineer | Superintending Engineer, Dam Safety Organization, Chief Engineer of Region. | |
| 5 | Large | More than 60 | 1000 | 10000 | Superintending Engineer, Test Check by Regional Chief Engineer | | |

Note : Dam satisfying any one of the above criteria to fall in the reservoir higher category.

APPENDIX - V

STAFF STRENGTH IN THE STATE DAM SAFETY CELLS

| State | Dy.CE | Supr.Engr. Director | Exe.Engr. Dy.Dir. | A.E.E. A.E. | Supr. J.E. | Hydro- logist | Geo- logist | Remarks |
|-------------------------|-------|------------------------|----------------------|----------------|---------------|------------------|----------------|---|
| Gujarat | - | 2 | 5 | 6 | - | - | - | |
| Maharashtra | - | 1 | 3 | - | - | - | - | |
| Uttar Pradesh | - | 1 | 2 | 6 | - | 1 | 1 | |
| Kerala (Irrg) | - | - | 1 | - | 2 | - | - | |
| Kerala (SEB) | - | 1 | 1 | 3 | - | - | - | |
| Orissa | - | 1 | 2 | 2 | - | - | - | |
| Tamil Nadu | - | - | - | 2 | - | - | - | |
| DVC | 2 | 7 | 7 | - | - | - | - | |
| BBMB | - | - | - | - | - | - | - | Respective CE responsible for dam safety job. |
| West Bengal | - | - | - | 1 | - | - | - | |
| Karnataka (Power Corpn) | - | - | - | - | - | - | - | Review Unit only |
| Karnataka (Irrg.) | - | - | - | - | - | - | - | Review Unit only |



Back cover: 100 year old Periyar Dam:
Strengthened by buttressing