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OVERVIEW OF DAM SAFETY MANAGEMENT IN INDIA

Dr. R.K. Gupta

Chairman

Central Water Commission

GLOBAL PERSPECTIVE

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LARGE DAMS WITH ECONOMY SIZE WORLDWIDE (TOP 8)

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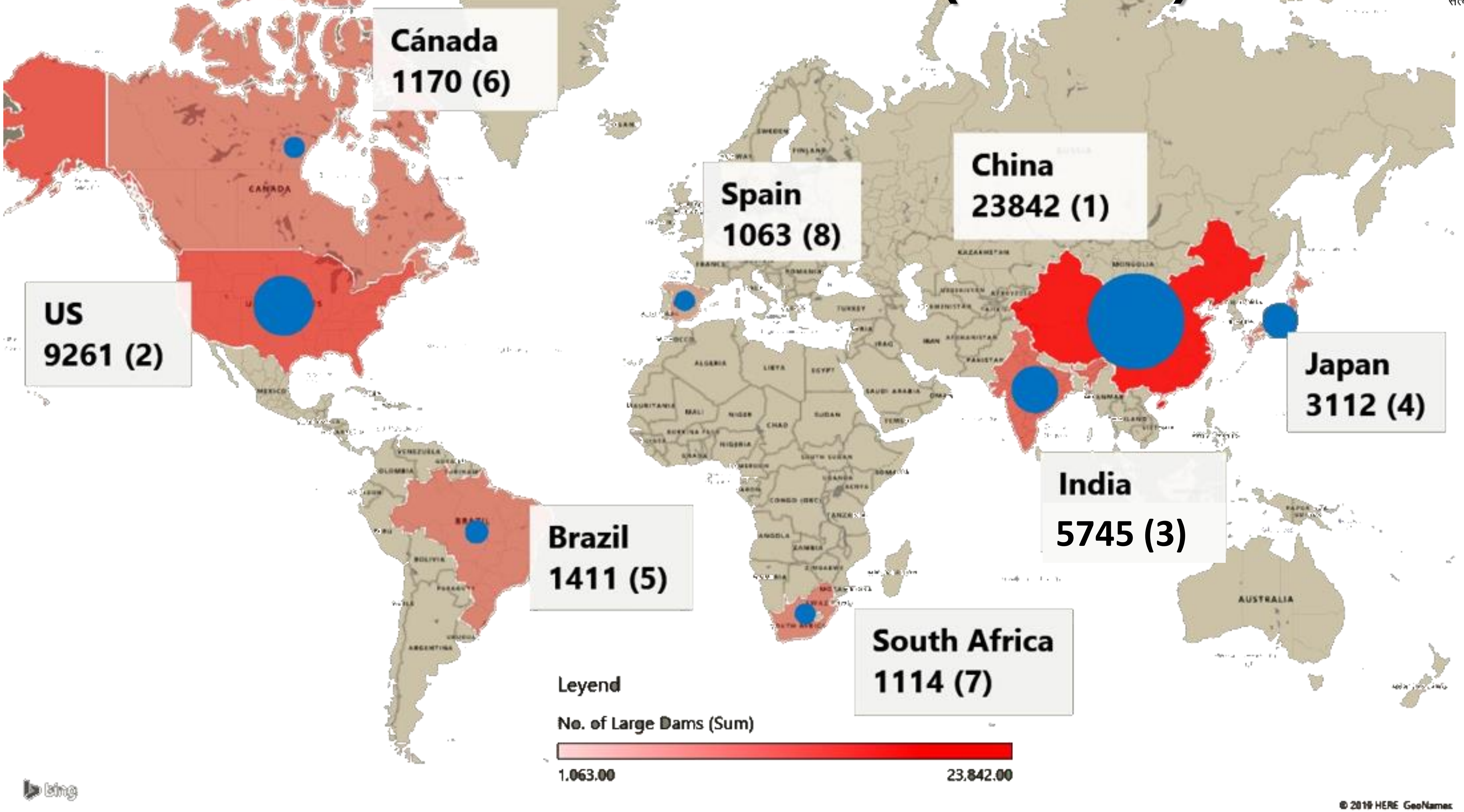

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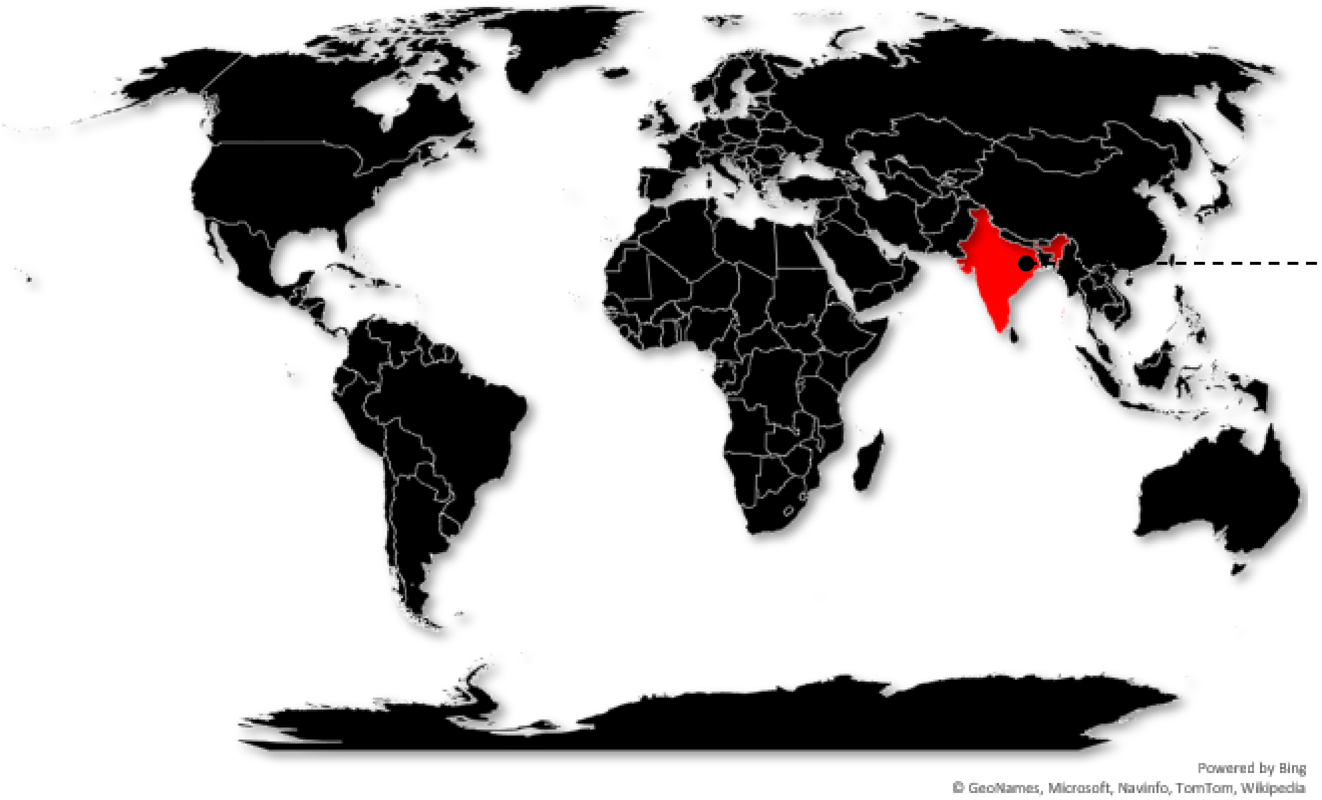
INDIA GLOBAL PERSPECTIVE



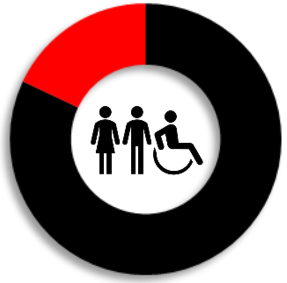
2%

Land Resources

4%

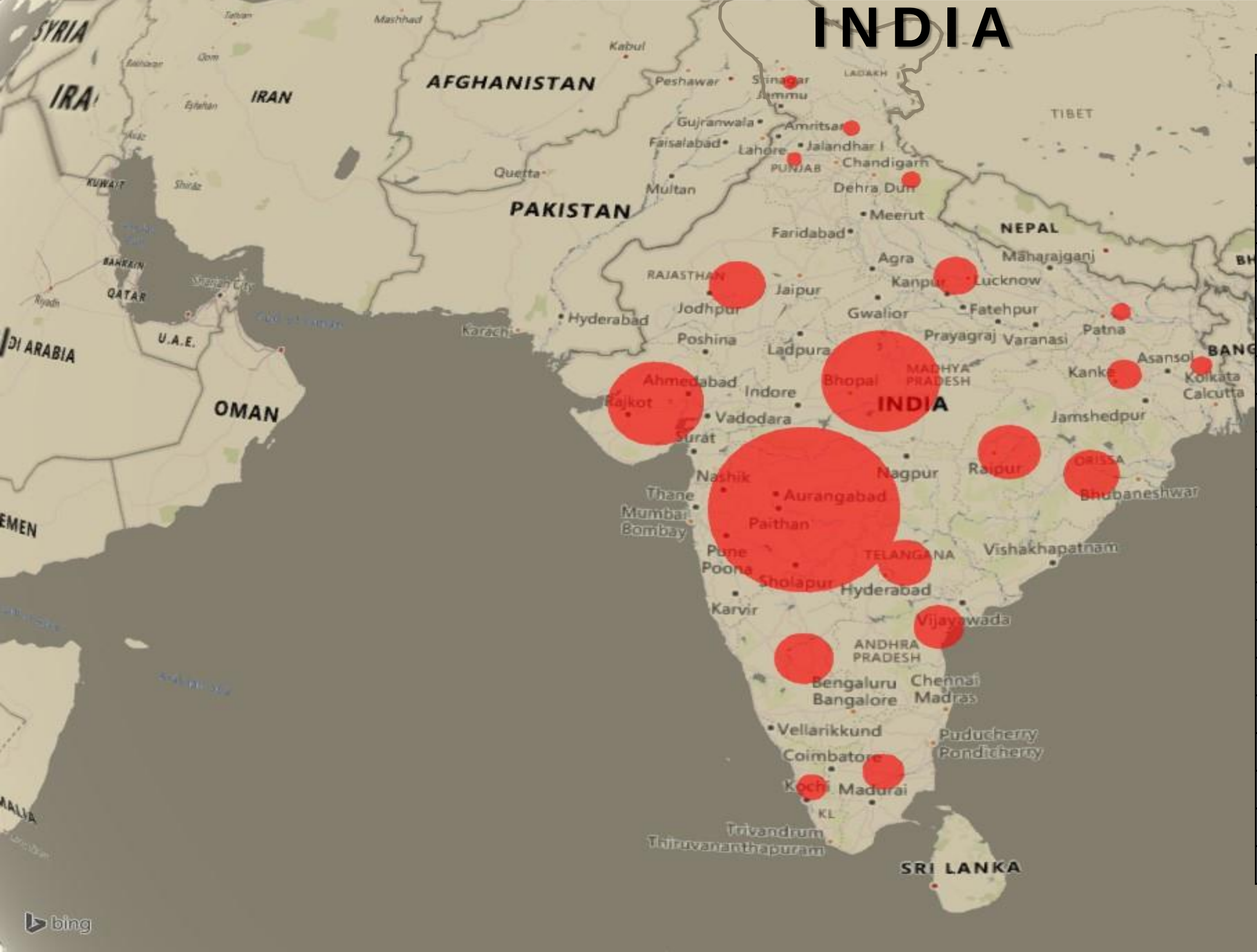
Water Resources

18%



World Population

LARGE DAMS IN INDIA



STATE	No. Dams
Maharashta	2394
Madya Pradesh	906
Gujarat	632
Chhattisgarth	258
Karnataka	232
Rajastan	212
Odisha	204
Telengana	184
Andra Pradesh	166
Uttar Pradesh	130
Tamil Nadu	118
Jharkand	79
Kerala	61
West Bengal	30
Bihar	26
Uttarakhand	25
Himachal Pradesh	20
Jammu & Kashimir	17
Punjab	16
Other States	35
TOTAL	**5745**

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Sources: NRLD (2019)

FEW OLD DAMS OF INDIA

Kallanai Dam | Thanjavur, Tamil Nadu
2nd Century AD oldest dam
Dam Type- Masonry weir
Height above foundation- 5.4 m
Length of dam- 329 m
Width of dam- 20m
Design Spillway capacity- 5094 cumecs

Tonnur Kere Dam | Mysore, Karnataka
10th Century AD
Dam Type Earth fill (TE)
Foundation Level- 24.38 m
Dam Length- 118.8 m
Gross Storage Capacity- 13.66 MCM
Reservoir Area- 12.42 MCM

Mir Alam Dam | Hyderabad, Telangana
19th Century | 1804
Multiple Arch Buttress Dam
Height above Lowest Foundation Level- 10.06 m
Dam Length- 914.4 m
21 no. of arches

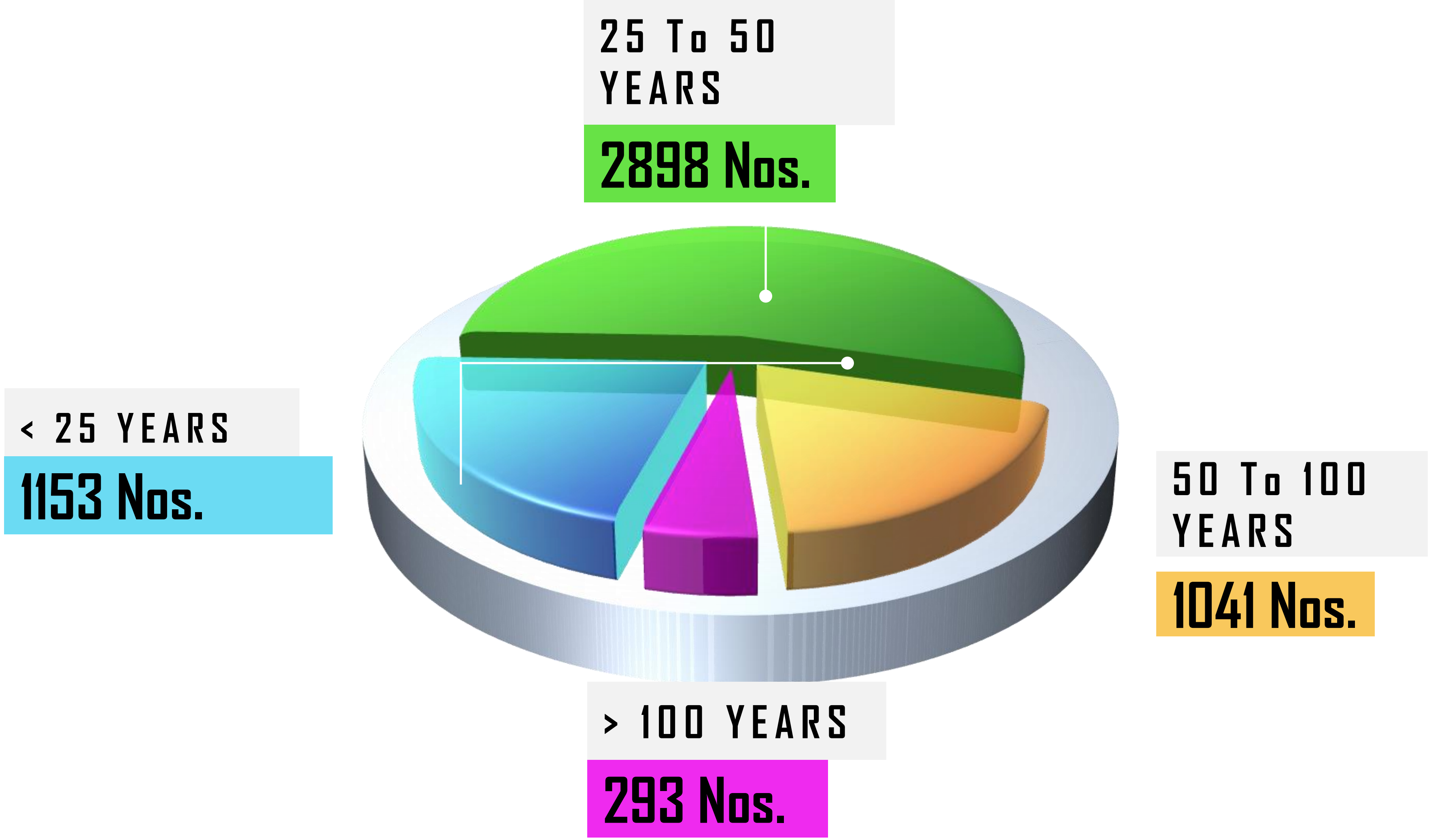
FEW OLD DAMS OF INDIA

Tansa Dam | Mumbai, Maharashtra
1892
Dam Type- Earth (TE) / Gravity Masonry Height Above foundation- 41m
Length of dam- 2804m
Gross storage capacity- 184.60 MCM
Effective storage capacity- 172.52 MCM
Reservoir area 19.15 km2

Vanivilasa Sagar Dam | Hiriyur, Karnataka
1907
Dam Type- Gravity/Masonry (PG) / Earth (TE) Height above foundation- 43 m
Length of dam- 405.40 m
Gross storage capacity- 850.30 MCM
Effective storage capacity- 802.50 MCM
Reservoir area- 87.63 km 2

Mettur Dam | Salem, Tamil Nadu
1934
Dam Type- Gravity/Masonry (PG)
Height above foundation- 65 m
Length of dam- 1615.40 m
Installed Capacity- 250MW
Gross storage capacity- 2708 MCM
Effective storage capacity- 2647 MCM
Reservoir area- 153.46 km 2

AGE OF LARGE DAM IN INDIA



EXAMPLES OF DAM FAILURES IN INDIA

1917, Tigra dam
26m, Masonry

1979, Machhu II Dam
23m, Emb. Dam with Masonry Spillway

2010, Garada Dam
33m, Embankment

2019, Tivare dam
28m, Embankment

2021, Annamayya dam
25m, Embankment

2022, Karam dam
52m, Embankment

DAM FAILURES IN INDIA

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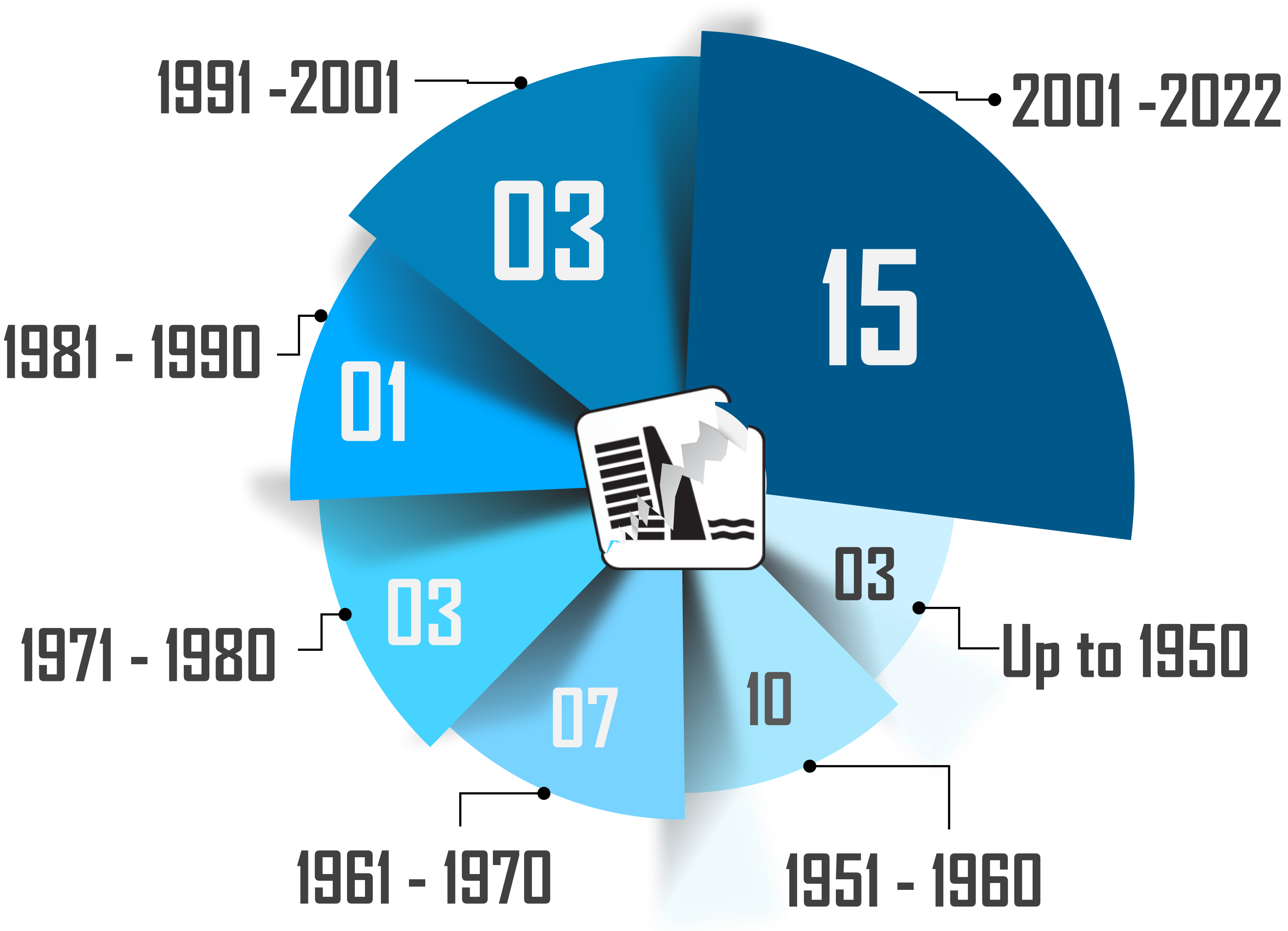
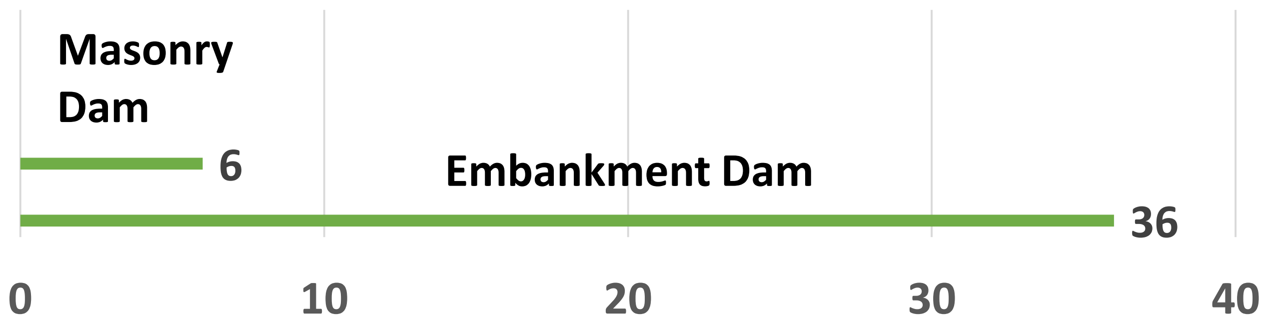
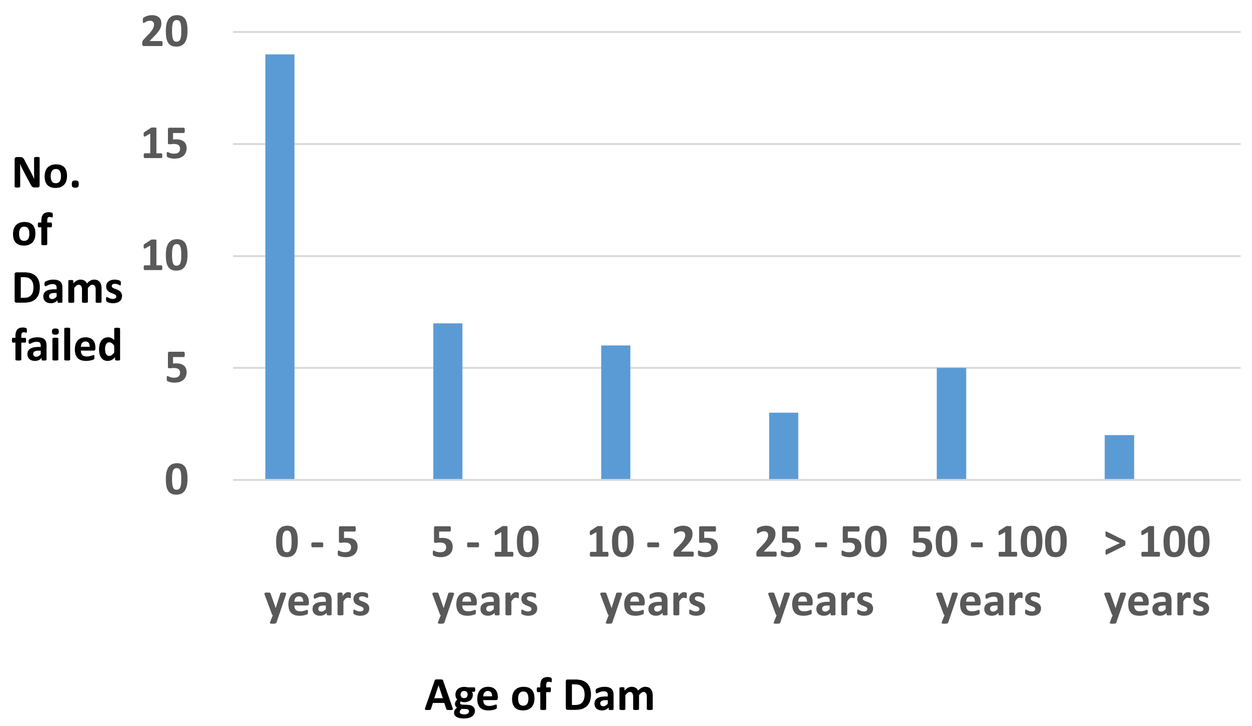


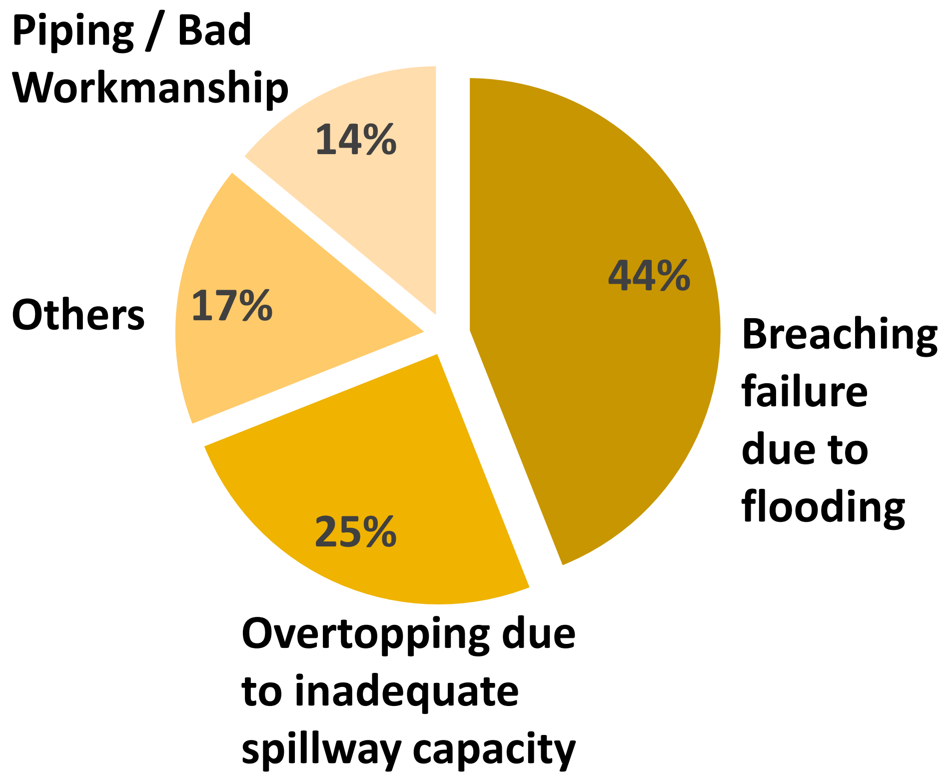
- ✓ **42 dam failures reported.**
- ✓ **Machchu II dam failure (Gujarat) in 1979 killed 2,000 people.**

DAM FAILURES IN INDIA



- ✓ 42 No. of reported dam failures
- ✓ 26 dams were of height less than 25 m
- ✓ 5 dams were of height > 50 m





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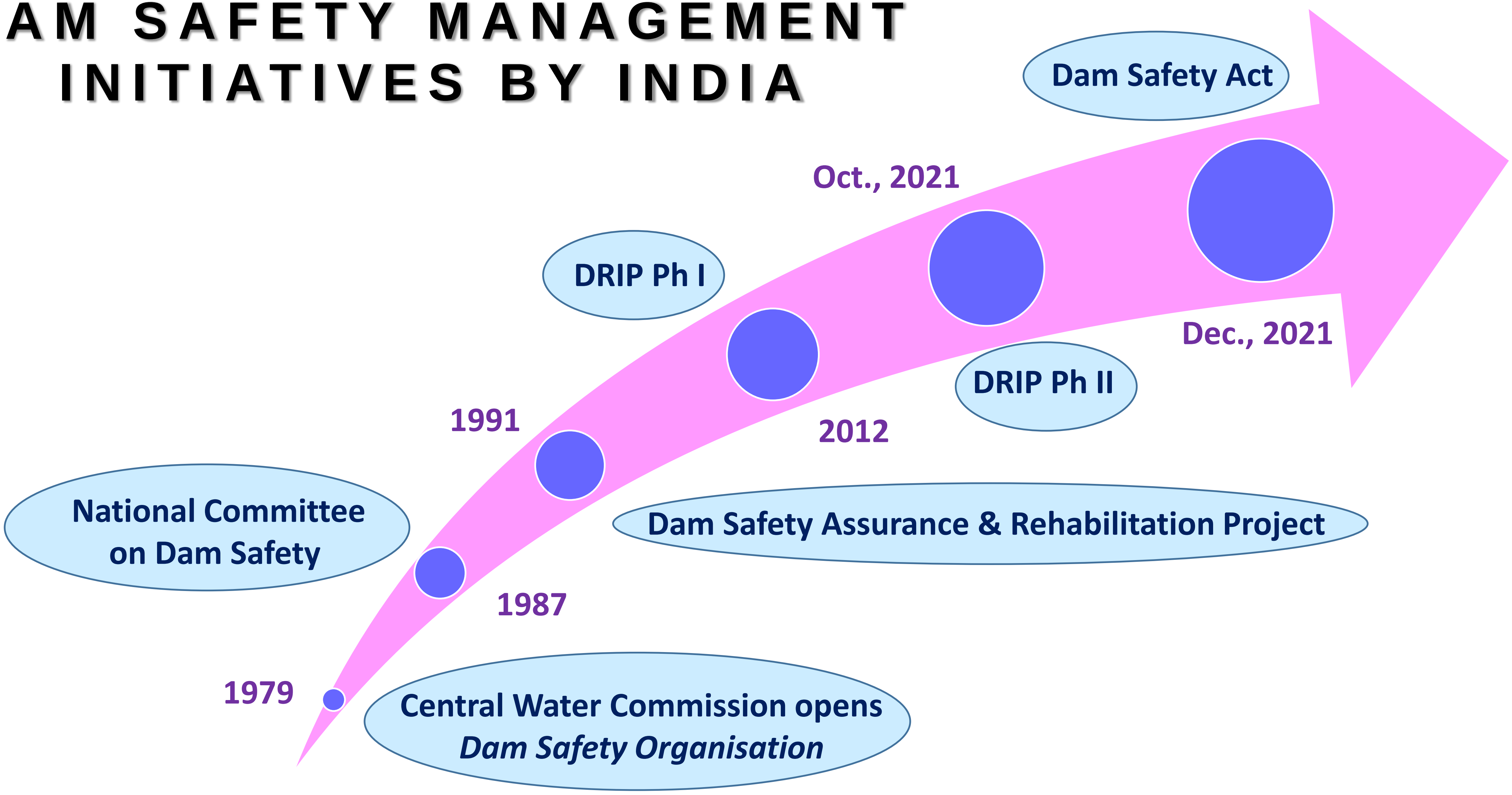
DAM SAFETY MANAGEMENT INITIATIVES

DAM SAFETY MANAGEMENT INITIATIVES BY INDIA



KEY ACHIEVEMENTS OF DAM SAFETY PROGRAMS

- Joint efforts of Central & State Governments
- Institutional Strengthening
- Rehabilitation of 33 + 223 dams; Structural & Non-structural measures
- Development of EAP and O&M Manuals
- Capacity Building through Trainings & Workshops
- Development of 11 Guidelines related to Dam Safety Aspects
- Long term Asset management through web based tool Dam Health and Rehabilitation Monitoring Application(DHARMA).
- Initiation of M.Tech courses by IISc Bengaluru & IIT Roorkee for long term sustainability through trained manpower
- Enhancing seismic preparedness through Seismic Hazard Assessment Information System(SHAIS)

DRIP Phase II & III SCHEME OVERVIEW

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OBJECTIVE

Improve safety and operational performance of selected dams, along with institutional strengthening with system wide management approach

SCHEME

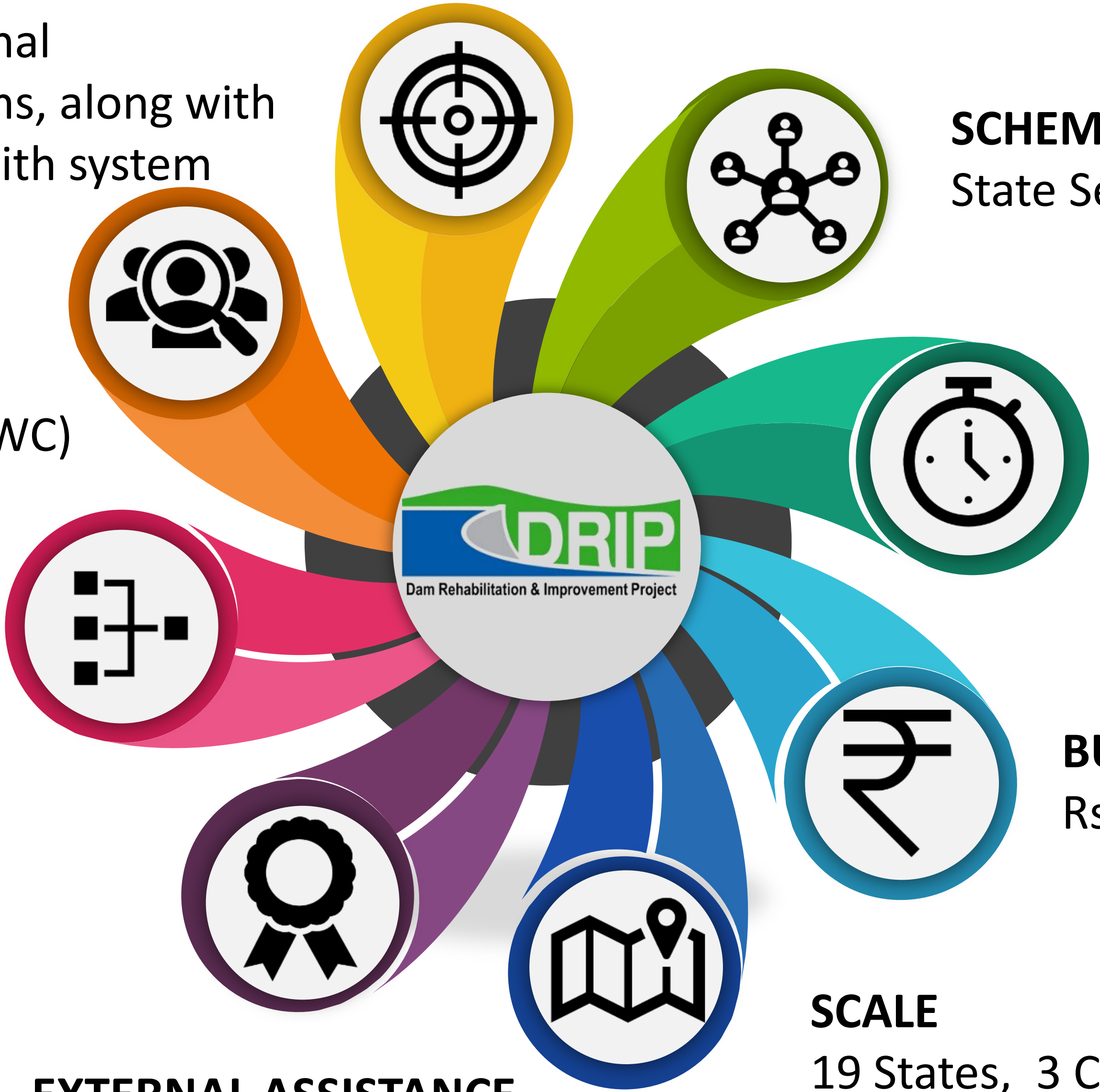
State Sector with Central Component

TIMELINE

10 years, two Phases , each of 6 years duration with 2 years overlap.

OVERALL SUPERVISION

Central Water Commission (CWC)



PROJECT COMPONENTS

I: Rehabilitation of dams and associated appurtenances

II: Dan safety Institutional Strengthening

III: Incidental Revenue Generation for sustainable operation and maintenance of dams

IV: Project Management

BUDGET & FUNDING PATTERN

Rs. 10211 Cr (US $ 1.46 billion)

SCALE

19 States, 3 Central Agencies, 736 dams.

EXTERNAL ASSISTANCE

INR 7000 Cr (US $ 1 billion)

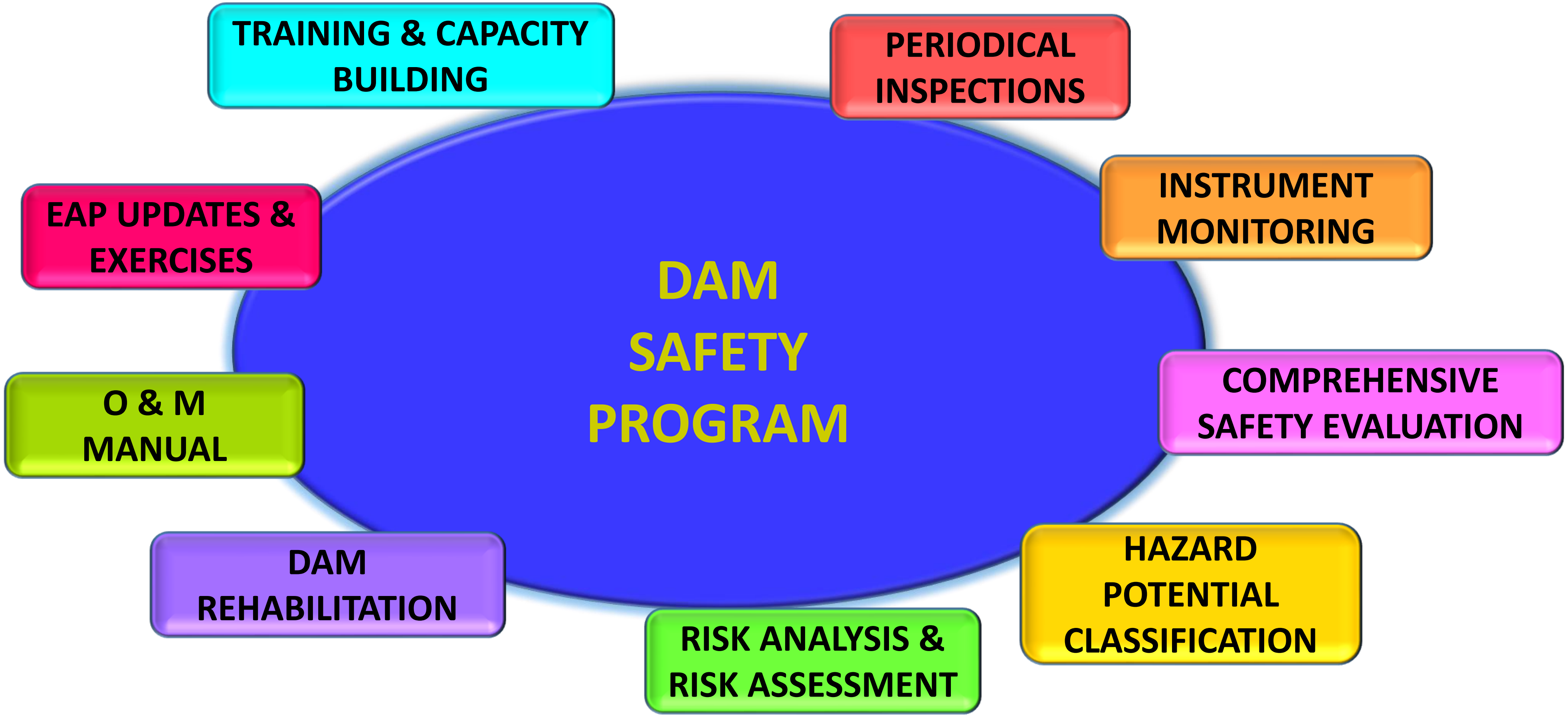
DAM SAFETY ACT 2021

"To provide for surveillance, inspection, operation and maintenance of the specified dam for prevention of dam failure related disaster and to provide for institutional mechanism to ensure their safe functioning and for matters connected therewith or incidental thereto "

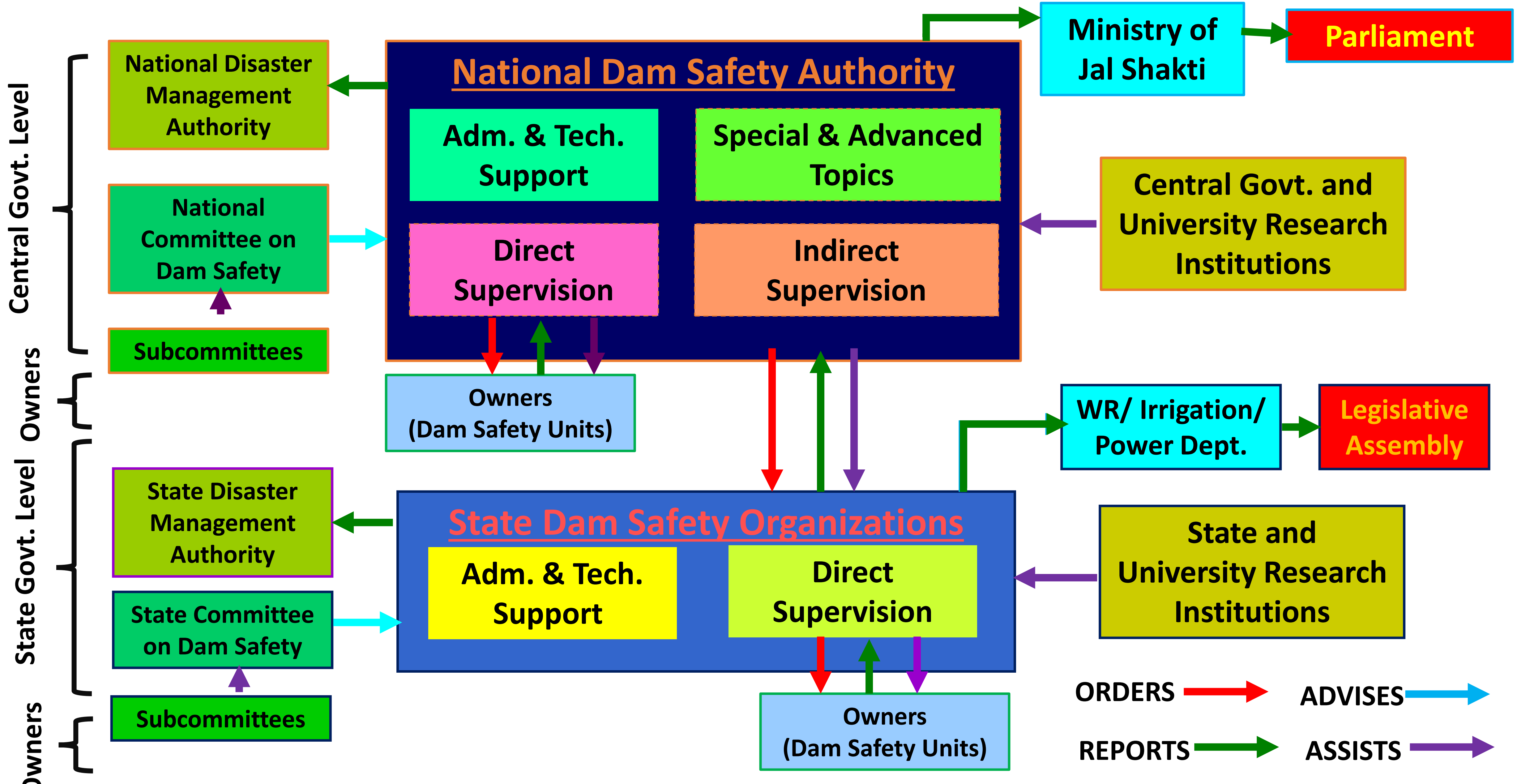
11 Chapters, 56 Clauses, 3 Schedules

- Uniform dam Safety Procedures across the Country
- Institutional Mechanisms at Central & State Government Levels
- Provisions to make Dam Owners Accountable
- Mandatory for Dam Owners to keep Funds for Maintenance
- Mandatory Dam Inspections & Safety Evaluations
- Provisions for EAP, O&M Manuals, Instrumentation & Monitoring

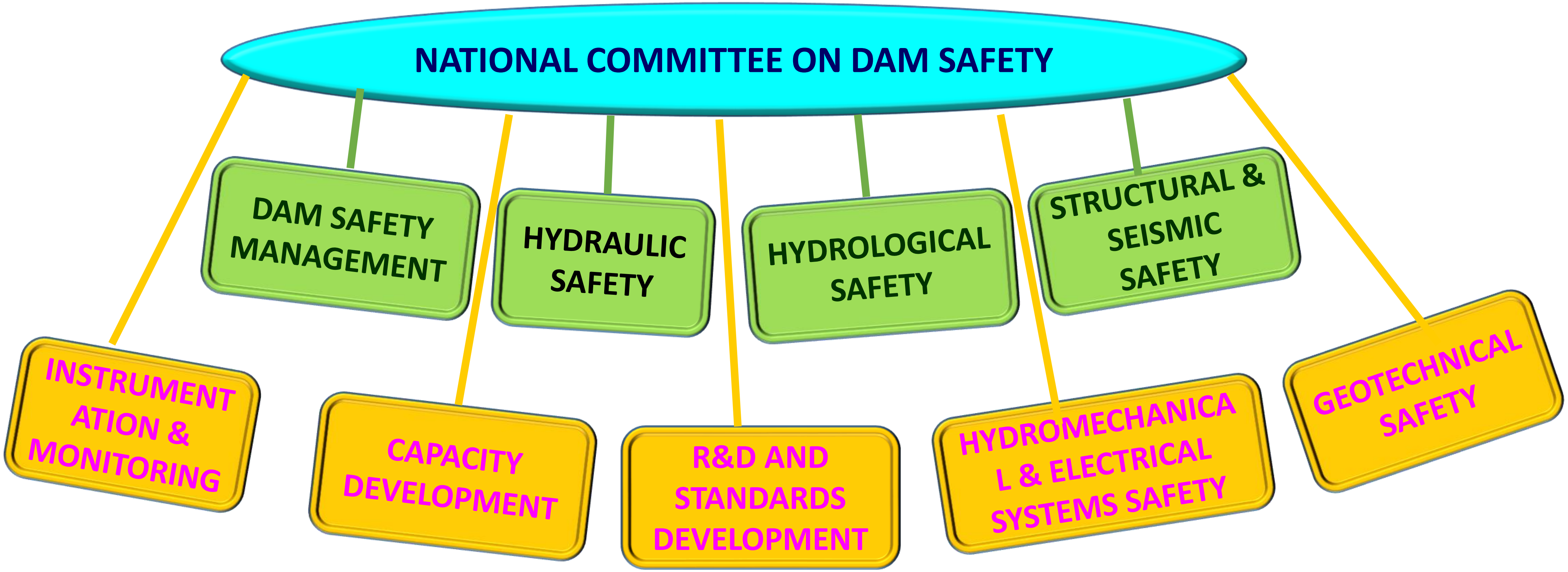
PILLARS OF DAM SAFETY MANAGEMENT



DAM SAFETY ACT-INSTITUTIONAL ARRANGEMENT



TECHNICAL SUB-COMMITTEES OF NCDS



MOVING TOWARDS RISK INFORMED DAM SAFETY MANAGEMENT

HAZARD POTENTIAL CLASSIFICATION

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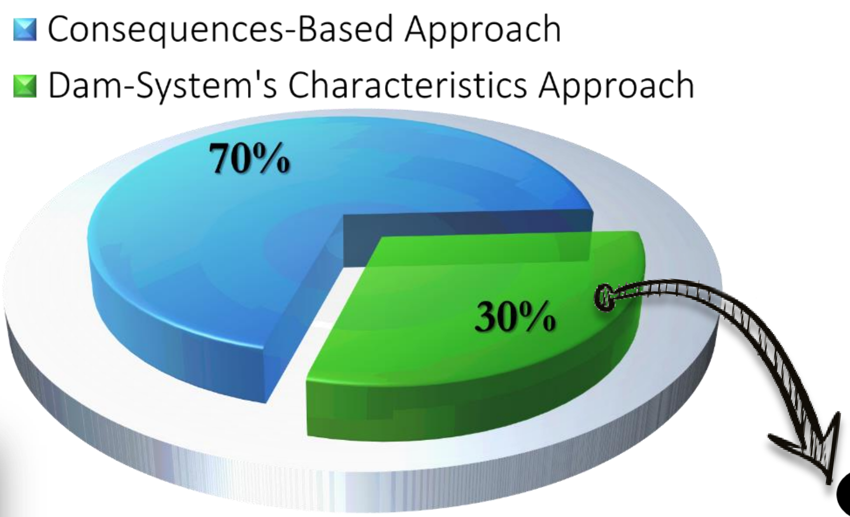
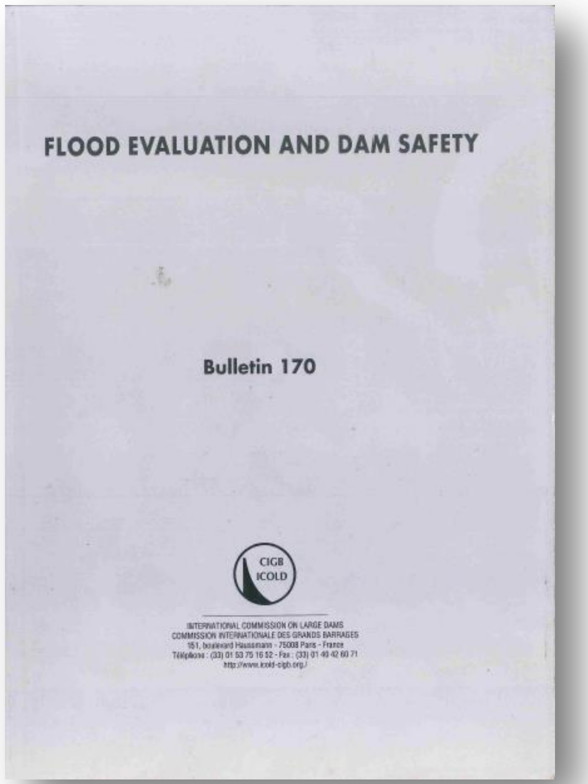
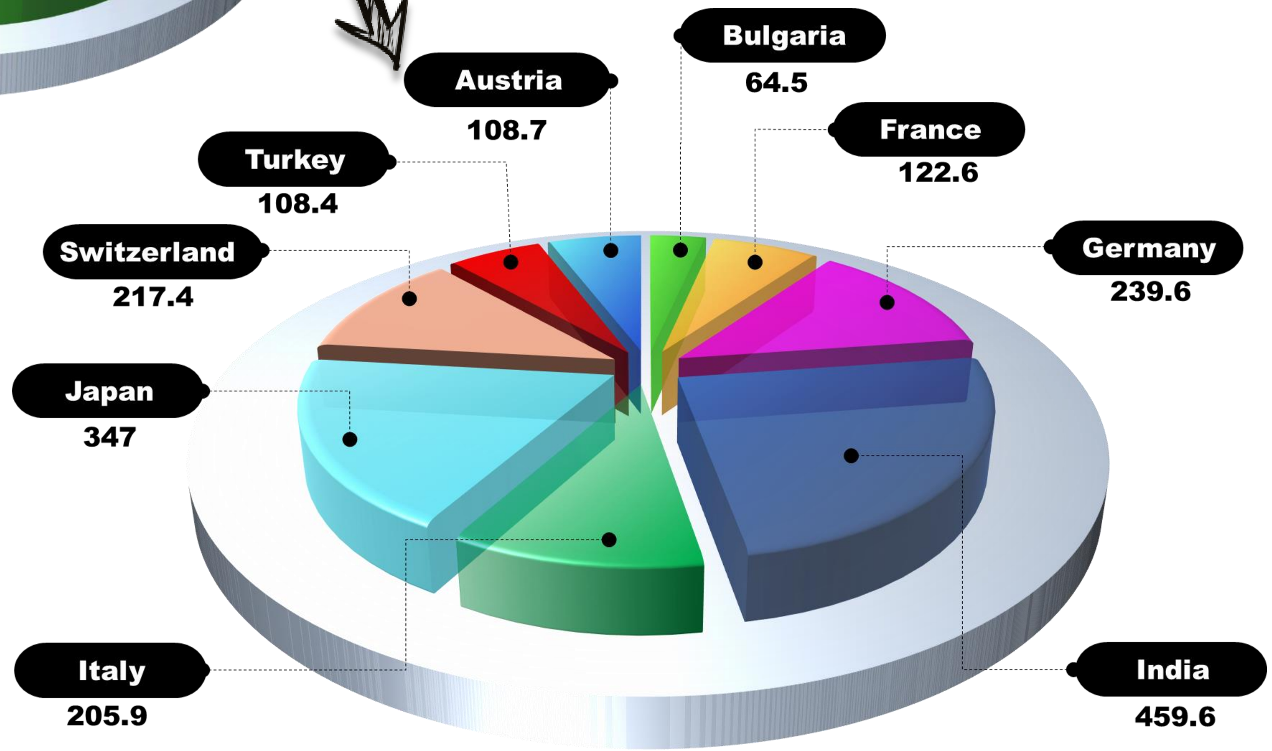
Global trend for Dam's Hazard Classification approach
(as per Bulletin 170, ICOLD)





Population Density in Countries using only Dam-System's characteristics to classify their dams



HAZARD POTENTIAL CLASSIFICATION

New dam's hazard potential classification approach is consequences-based, it is scalable and could be effectively implemented at different portfolio levels (dam managing organisation, state, and national level).

Hazard Potential Class	Potential Consequences Index (P_{CI})	Consequences Categories			
		Capital Value of Project	Potential for Loss of Life	Potential for Property Damage	Potential for Environmental and Cultural Impact
Class I	< 300	Low	None. Temporal or no incremental population at risk, no potential loss of life is expected. No inhabited structures.	Minimal. Limited economic and agricultural development.	None
Class II	< 300	Average	Minimal or low population at risk. No potential loss of life is expected even during the worst-case scenario of emergency management	Notable agriculture or economic activities. States highways and/or rail lines.	Minimal incremental damage. Short-Term or reversible impact (less than 2 years)
Class III	$300 < P_{CI} < 600$	Significant	Considerable. several inhabited developments. Potential for loss of life highly dependent of the adequacy of warning and rescue operations.	Significant industry, commercial and economic developments. National and state highways and rail lines.	Limited. Impact have a mid-term duration (less than 10 years) with high probability of total recovery after mitigation measures
Class IV	> 600	Critical	Extreme. High density populated areas. Potential for loss of life is too high even during the best scenario of emergency management	Highly developed area in terms of industry, property, transportation and lifeline features	Severe. long-term impact/effects in the protected areas or cultural heritage sites with low probability of recovery.

New approach is based on a **consequences index** which considers all elements that could influence the assessment of potential consequences of dam failure or mis-operation (**i.e. Capital value of the project, project's benefits, potential for loss of life, loss of properties and environmental impact**)

HAZARD POTENTIAL CLASSIFICATION

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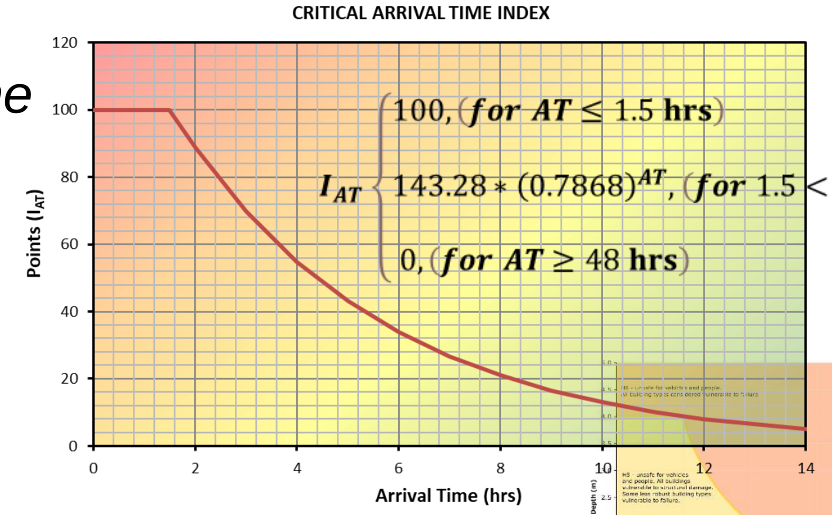
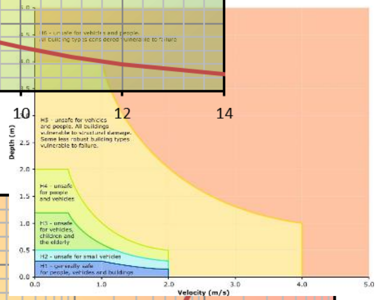
An additive weighting and point index scheme was developed using the principles of decision theory to estimate potential consequences due to dam failure or its mis-operation

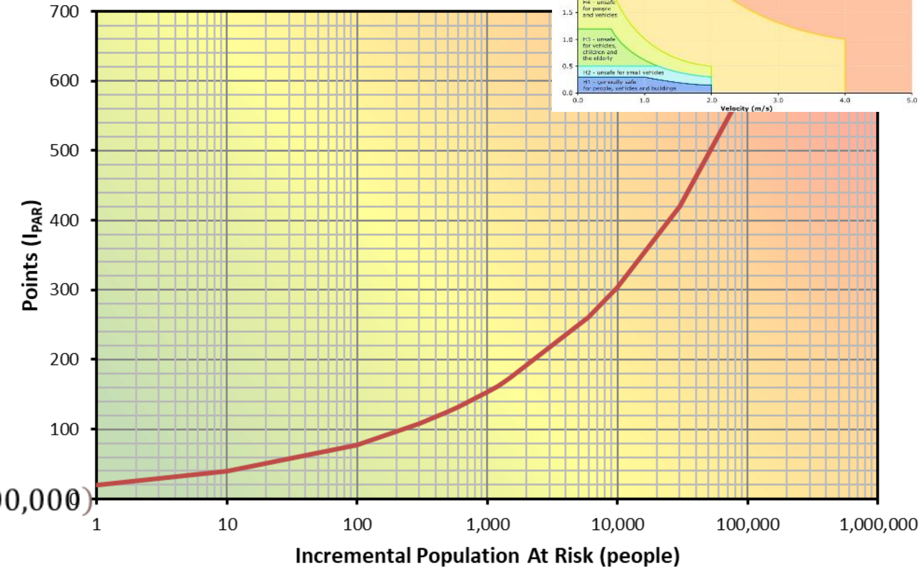
Critical Arrival Time Index(I_{AT})

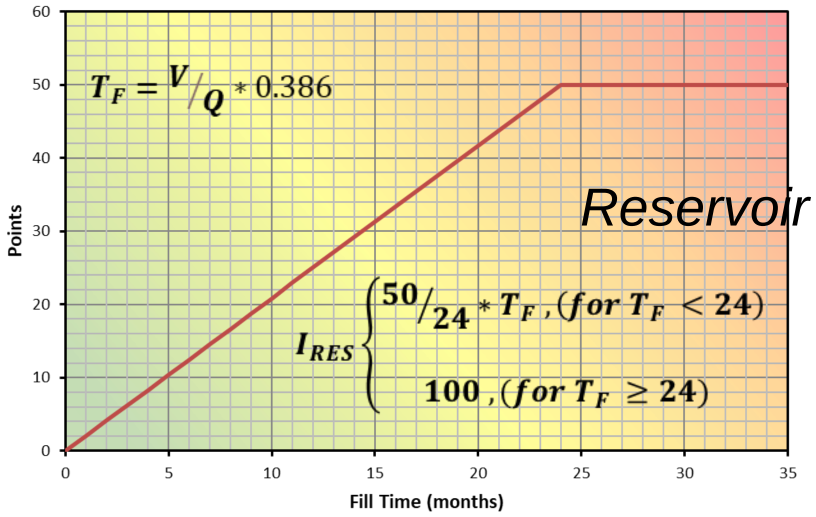
AT = critical arrival time in hours
I_{AT} = critical arrival time index



$$I_{AT}\begin{cases}100, (\boldsymbol{for\ AT} \le 1.5\ \mathbf{hrs}) \\ 143.28 * (0.7868)^{AT}, (\boldsymbol{for}\ 1.5 < AT < 48) \\ 0, (\boldsymbol{for\ AT} \ge 48\ \mathbf{hrs})\end{cases}$$







$$T_F = {}^{V}\!/_{Q} * 0.386$$

$$I_{RES}\begin{cases}{}^{50}\!/_{24} * T_F, (\boldsymbol{for}\ T_F < 24) \\ 100, (\boldsymbol{for}\ T_F \ge 24)\end{cases}$$

T_F = Time to fill the reservoir in months
V = Volume of the reservoir in Mm^3
Q = Average river flow in m^3/s

Reservoir Content Index (I_{res})

$$I_{PAR}\begin{cases}20 * \boldsymbol{PAR}^{0.2954}, (\boldsymbol{for\ PAR} < 100{,}000) \\ 600, (for\ PAR \ge 100{,}000)\end{cases}$$

PAR = incremental population at risk

Population at Risk Index (I_{PAR})

HAZARD POTENTIAL CLASSIFICATION

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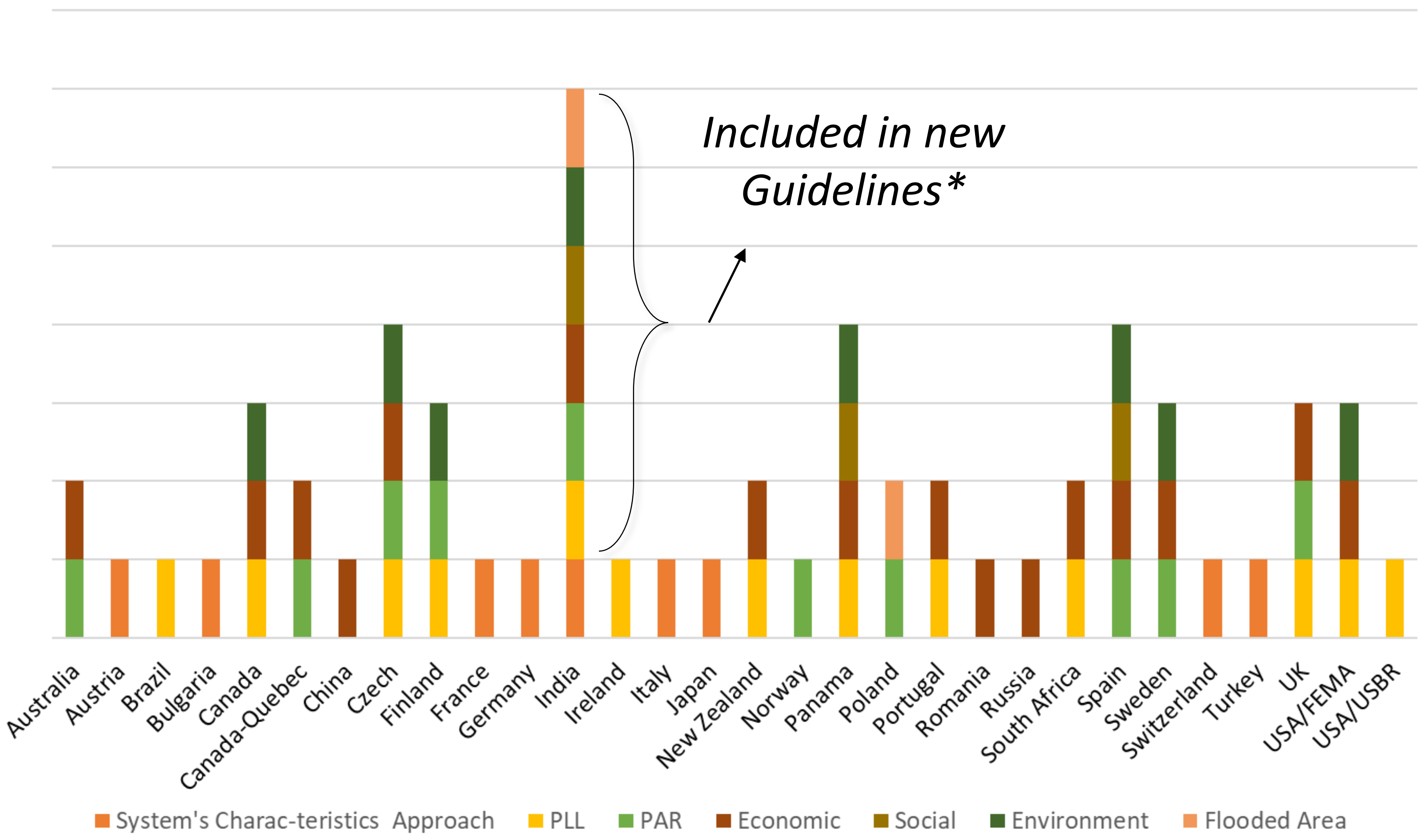


PLL = Potential Loss of Life

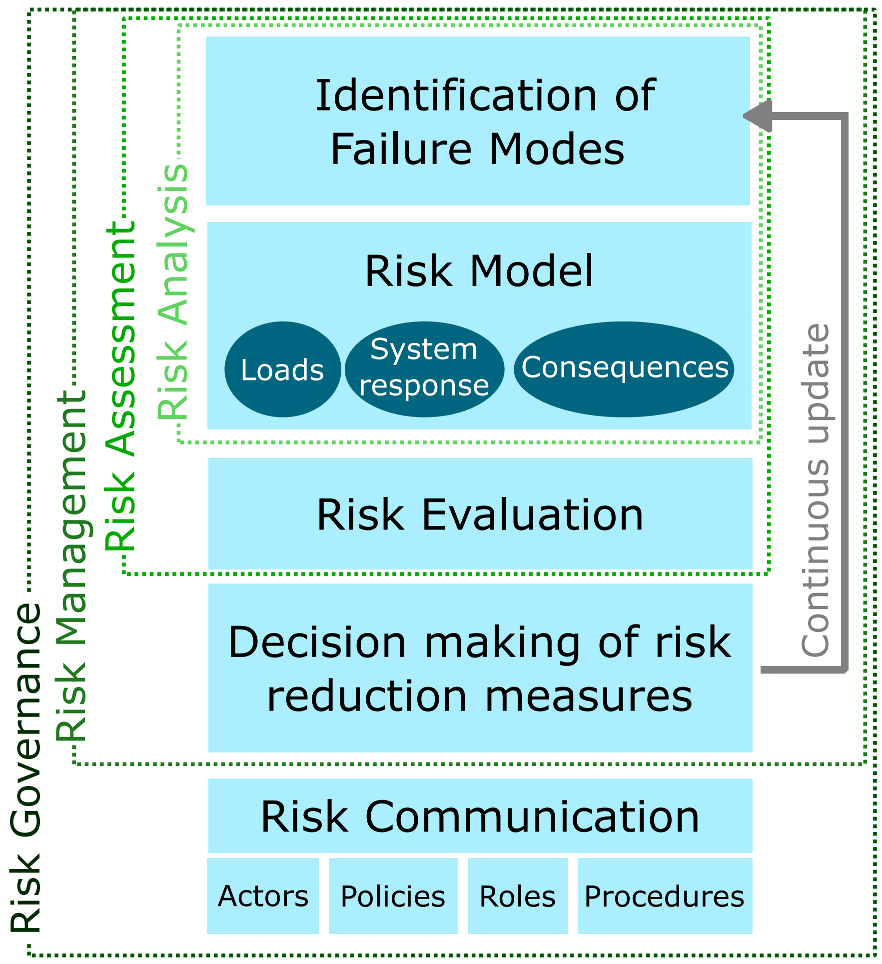
PAR = Population at Risk

****Potential Loss of life considered indirectly with PAR and Flood Wave Arrival time***

International Comparison of the criteria considered to evaluate the potential hazard (based on ICOLD bulletin 170)

RISK-INFORMED DAM SAFETY MANAGEMENT

Some justifications for a risk-inform decision-making in India



- The **ageing of the existing dams** (most of the structures are over 50 years old), and, current engineering knowledge versus the knowledge at the time when they were designed and built has im-proved.
- The need to **evaluate available information** in each dam and **prioritize** new studies and instrumentation.
- **Water availability** is crucial for human development in India. For this reason, water resources system management should be **optimized and increased** in their regulatory capacity to respond to important challenges such as Climate Change and its manifestation for severe droughts or severe floods.
- The increasing **social demand for higher safety levels and justification for the use of public funds**.
- India is a country with a high urban density, so first **priority funding** must be dedicated to improving the **resilience of communities** via more effective evacuation plans and exercises.

RISK-INFORMED DAM SAFETY MANAGEMENT

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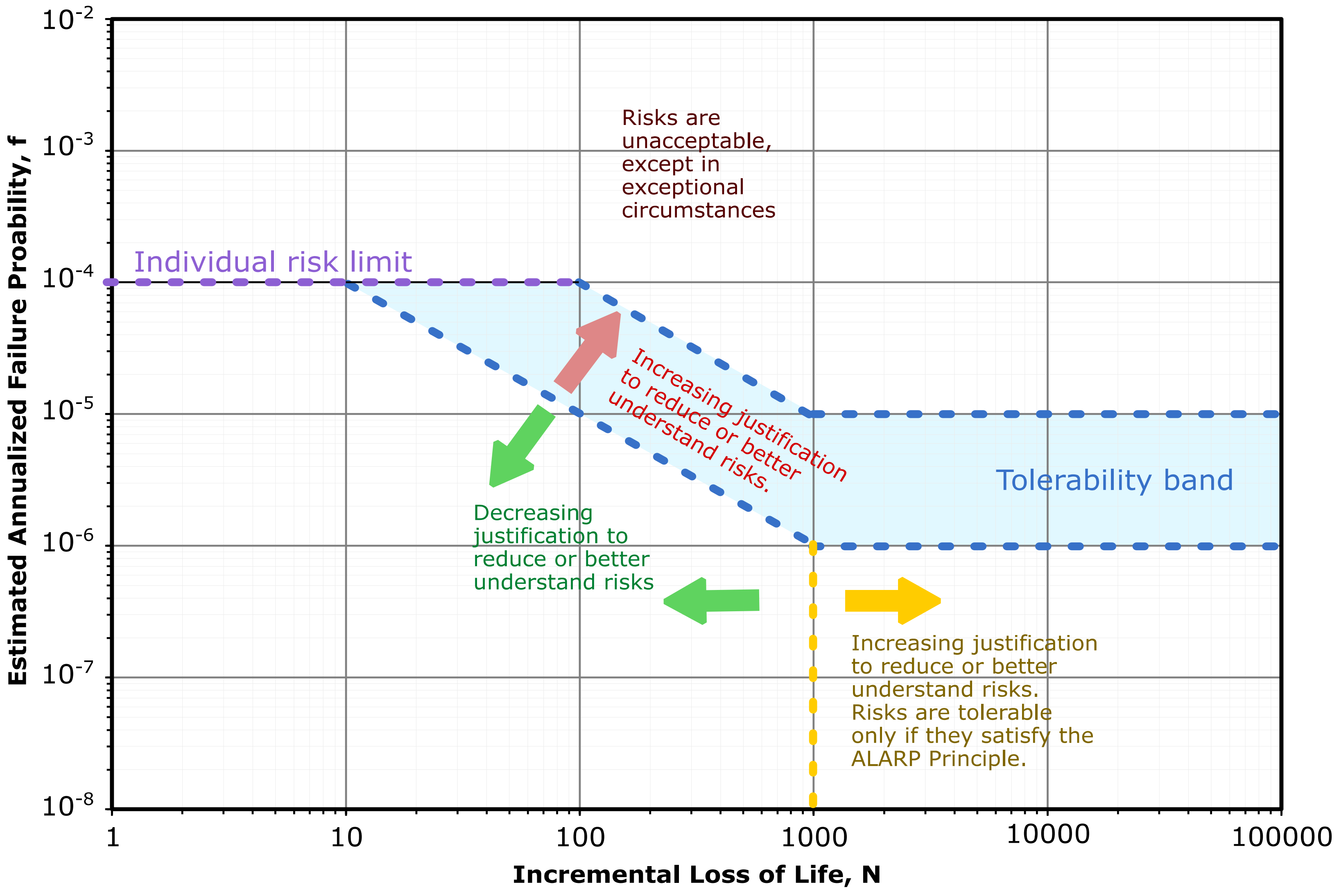
Proposal of Risk Tolerability Guidelines for India



RAPID RISK INDEXING

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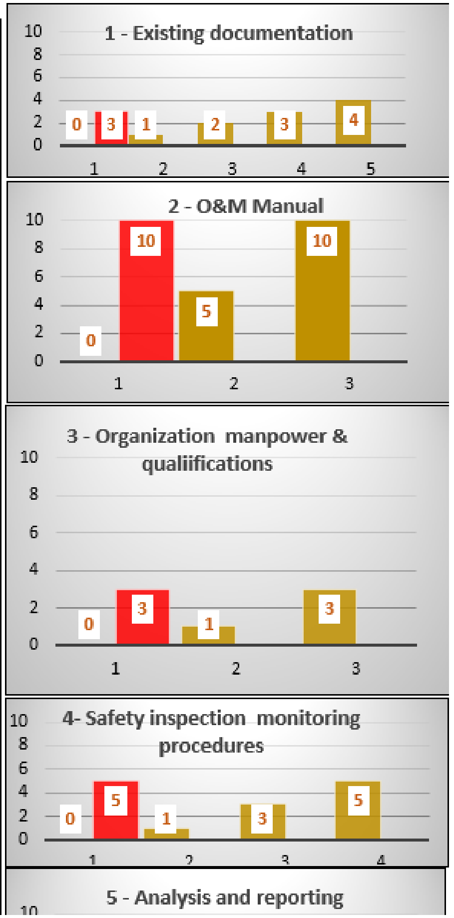
- TC = Technical Characteristics
- EC = Existing Conditions
- SP = Safety Plan
- RC = Risk Category
- PH = Potential Hazard

Final scores					
TC	EC	SP	RC	PH	Risk Index
19	72	30	121	145	17,545
Percentage of RC score					
16%	60%	25%			

Input scores into red-shaded cells

	Possible scores	Selected score	Comments
1-Design documentation			
Plans/specs as-built and construction records	0	3	The dam was constructed in 1957. It is in operation for the past seven decades. Hence we are not able to trace out the specification and design records. Some of the drawings are available.
Only design and construction records	1		
Only basic design drawings and specs	2		
Only a feasibility study and conceptual design documentation	3		
No or partial and very limited records	4		
2-Operations & Maintenance (O&M) Manual			
Comprehensive O&M Manual developed, implemented and followed. The manual contains: • definition of roles and distribution of responsibilities • detailed instructions for normal, abnormal and emergency operation • rule curves for reservoir management • flood management • debris handling • dam safety operational restrictions • schedule of surveillance, maintenance and testing activities and their associated frequency for each structure and piece of equipment that is dam safety related.	0	10	O&M Manual is under review at CWC. Debris handling and flood management are not insisted in O&M Manuals and hence not included.
Only some of the elements listed above are present in the O&M Manual.	5		
O&M Manual not developed or implemented.	10		
3-Emergency Preparedness Plan			
The plan is in place and is regularly exercised and the public is aware	0	5	EAP under development process.
Not all elements listed above are present	2		
EPP not developed or implemented	5		
4-Organization, manpower and technical qualifications			
Complete organizational structure led by dam safety engineer with sufficient and fully competent staff with appropriate training and experience.	0	3	Dam safety Engineers as well as Dam Safety Technicians are in place.
Organizational structure in place led by dam safety technician with most of the required knowledgable staff with appropriate training and experience.	1		
• structure inadequate and			

Charts below display possible scores and selected score



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KEY CHALLENGES

KEY CHALLENGES

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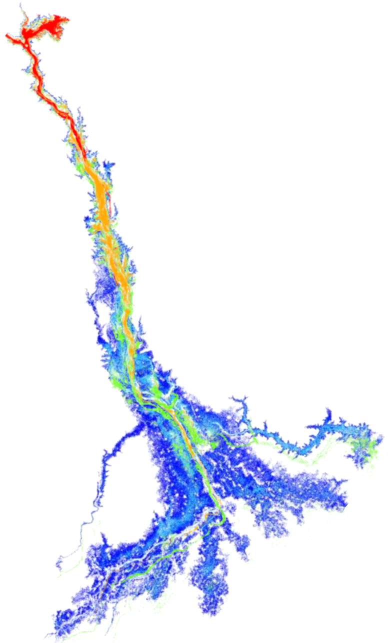
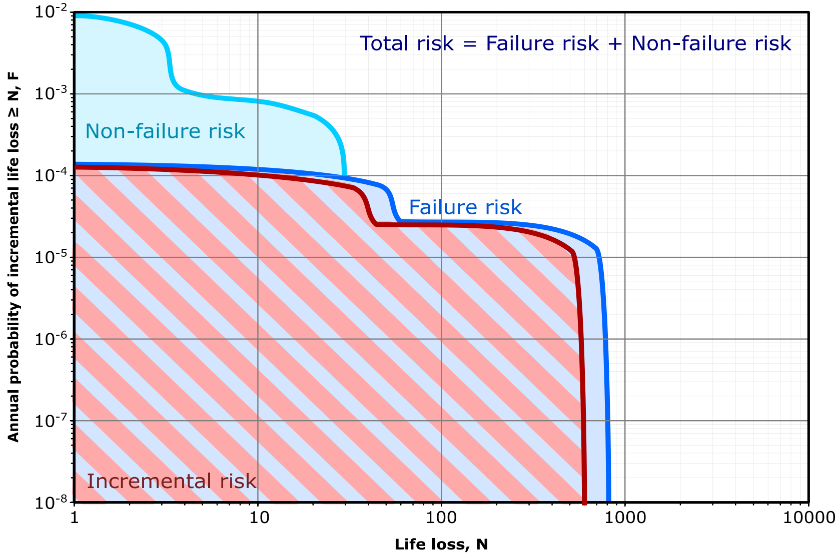
1

CAPACITY BUILDING

- Lack of expertise in dam owner’s agencies in areas such as flood hazard mapping, advanced hydraulic simulations, and quantitative risk assessment
- Trainings required to have long term sustainability of intended objectives for optimum benefits from existing assets





2

STRENGTHENING OF SDSO

- Thin manpower in SDSOs is a natter of concern. State Governments have to deploy dedicated more manpower to da, safety organisations.

KEY CHALLENGES

3 RESERVOIR SILTATION

- Increasing reservoir sedimentation, and loss of a dam's functionality and effectiveness represents a current challenge in India. Currently, India have a sedimentation rate of about 0.72% per year. Till date a loos of gross storage capacity of about 32 billion m3 is estimated

4 INSTRUMENTATION & MONITORING

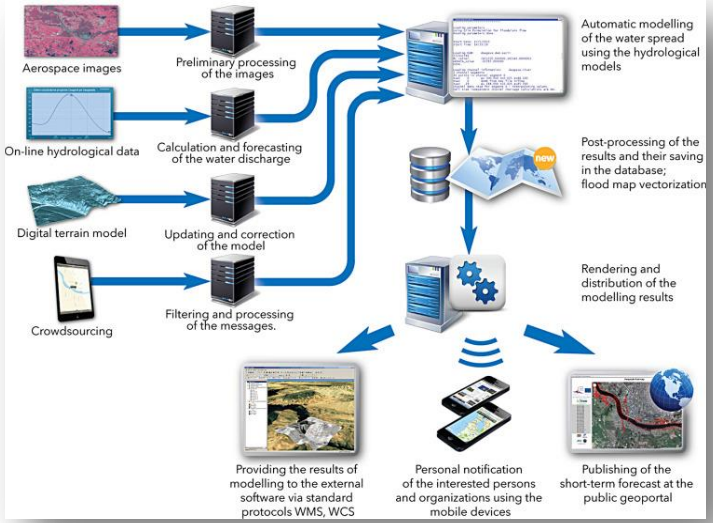
- Limited number of dams have desired level of instrumentation in the country

KEY CHALLENGES

5

FLOOD AND RISK MANAGEMENT

- Establishment of control centres for inter-state and integrated reservoir operations is still a paramount in India
- Implementation of expert decision-support systems along with real time flood forecasting systems for reservoir operations rather than traditional operation rule curves



6

LARGE STRUCTURAL INTERVENTIONS

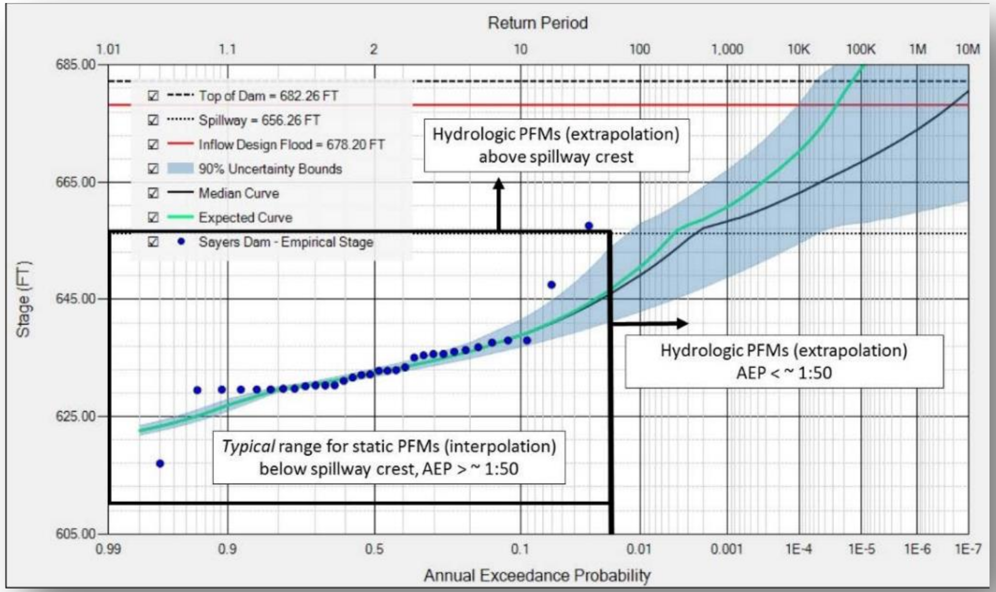
- Approval of Environmental Impact Studies, R&P Plan, EMP Plans, bid documents etc. takes considerable resources

KEY CHALLENGES

7

CLIMATE CHANGE UNCERTAINTIES

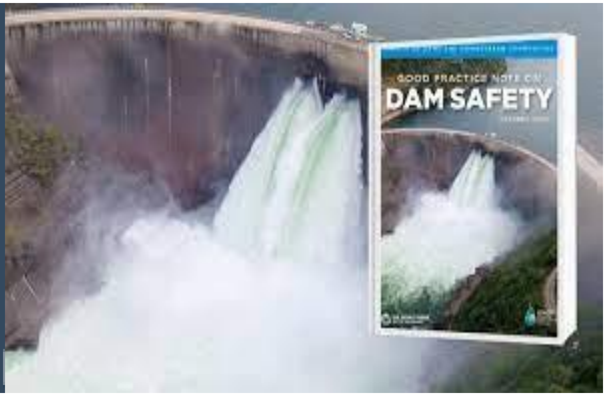
- Significant changes in seasonal and annual rainfall patterns and other factors affecting streamflow are being experienced in India



8

DEDICATED FUNDS FOR DAM SAFETY

- No or Meager fund allocation for maintenance.
- State Governments have to allocate sufficient funds for dam safety management activities.

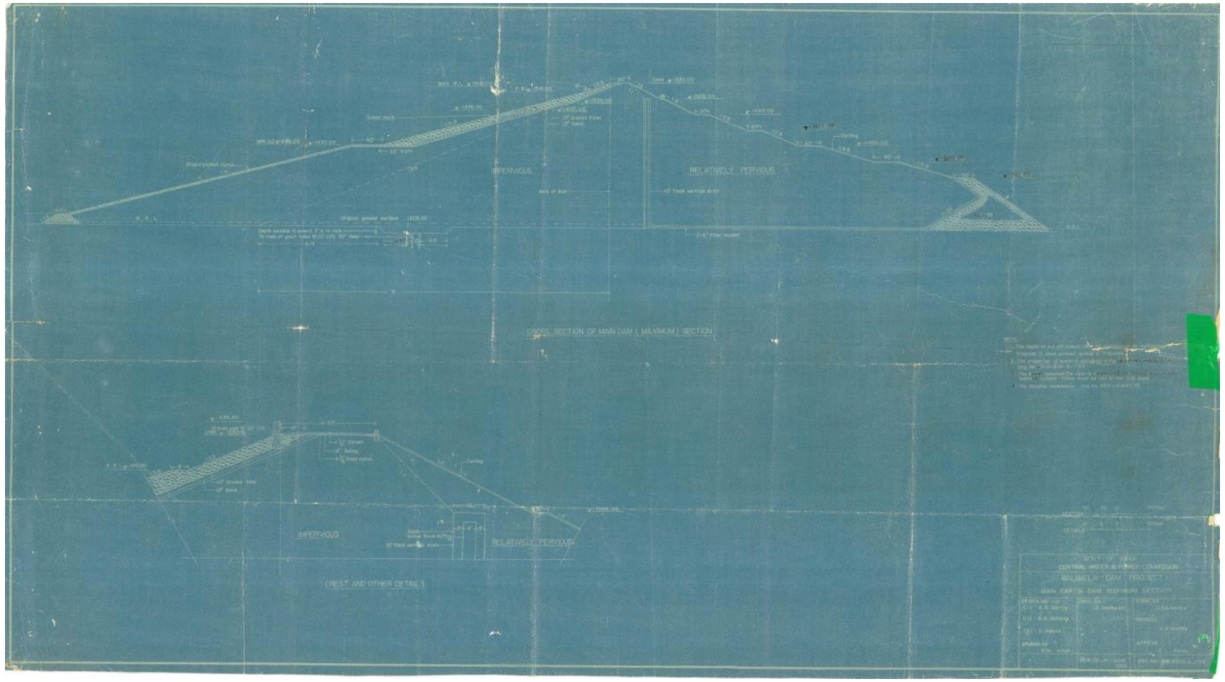


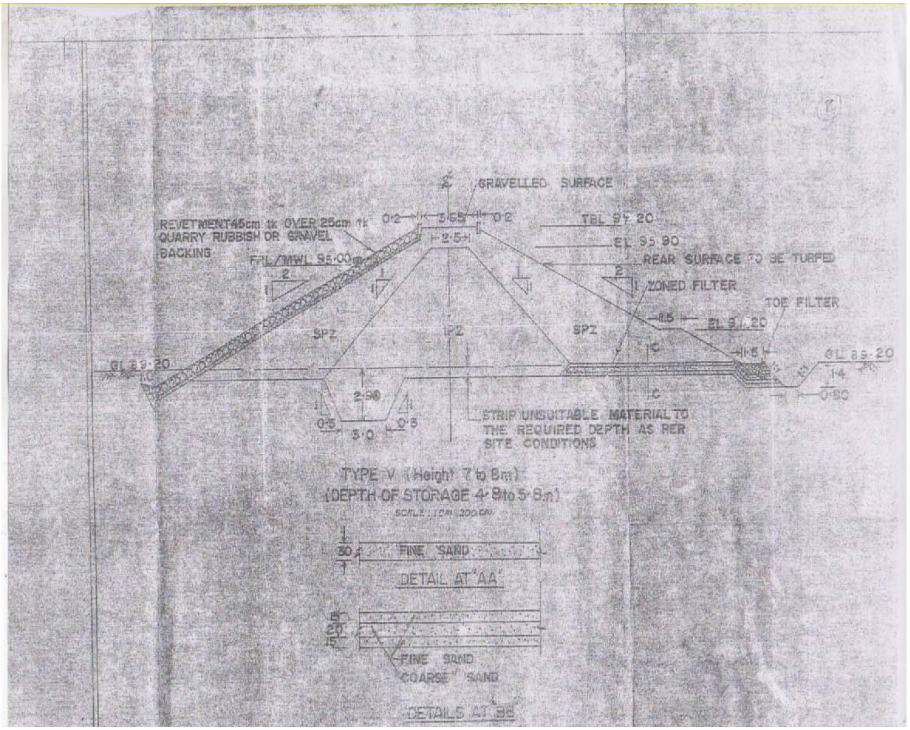
KEY CHALLENGES

9

DAM DESIGN REPORTS AND DRAWINGS

- Drawings as constructed and related design reports are not available with project authorities in many cases. In some others, existing drawings are not readable





ARE AGEING WATER STORAGE INFRASTRUCTURE REALLY A THREAT ??

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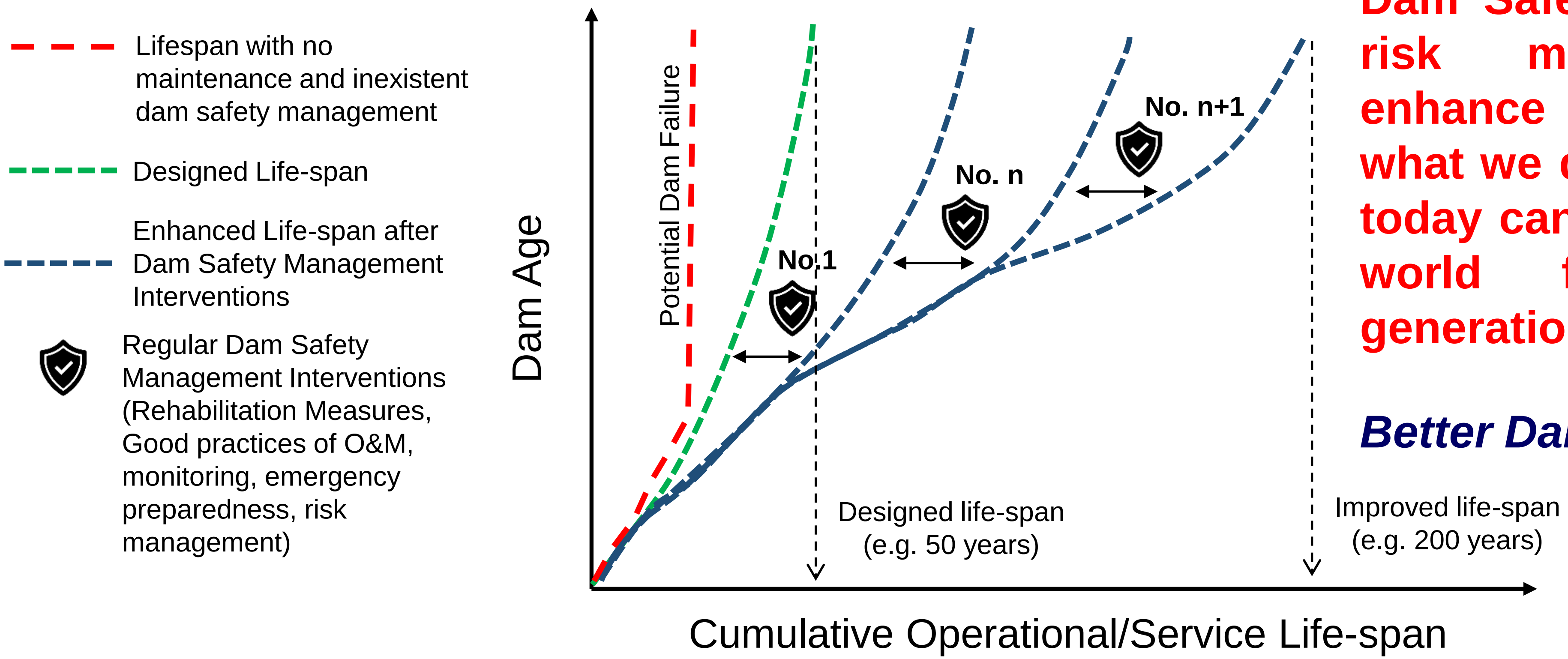
AN UN University report attempt to directly link dam risk and dam age with decommissioning and removal without considering current dam safety management and risk mitigation practices.



Dam Safety Management and risk mitigation practices enhance the life of dams – what we design and construct today can serve people of our world for many, many generations

Better Dams for Better World


Thank you