

DAM SAFETY OVERVIEW

Mr. Potcharapol Brohmsubha

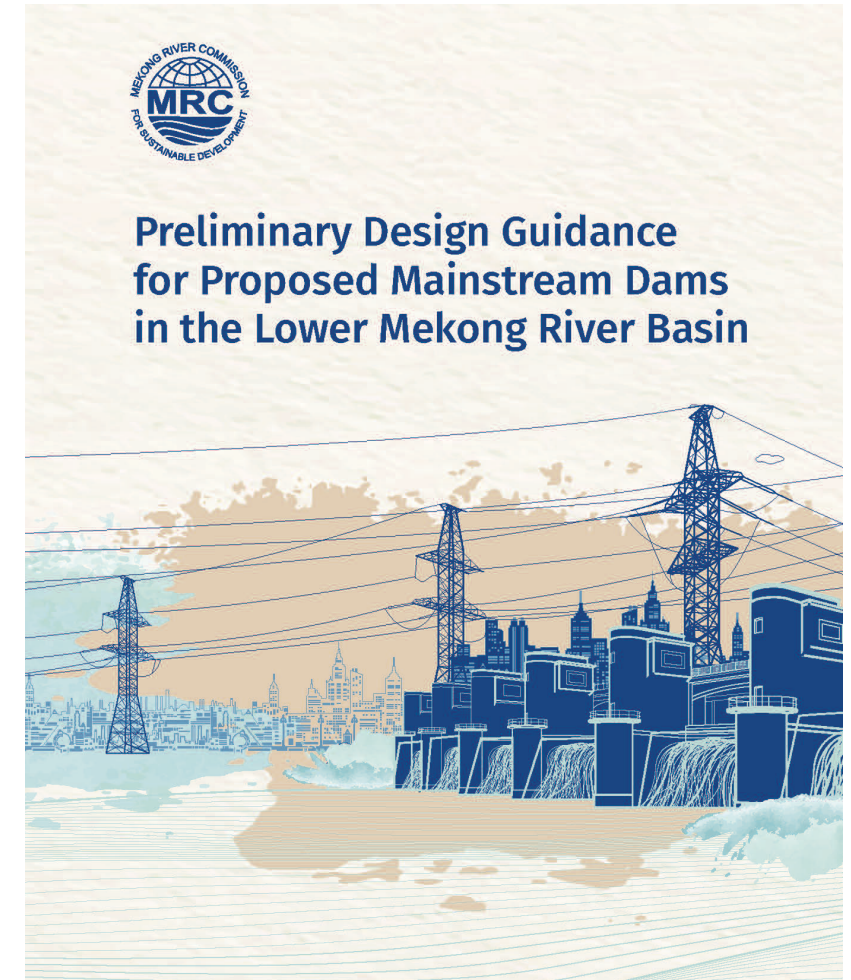
Head, Dam Safety Inspection and Evaluation Section



EGAT

Presentation Outline

- Failure Modes - Concrete Dam
- Dam Safety Overview
- Dam Inspection and Dam Instrumentation
- Conclusions

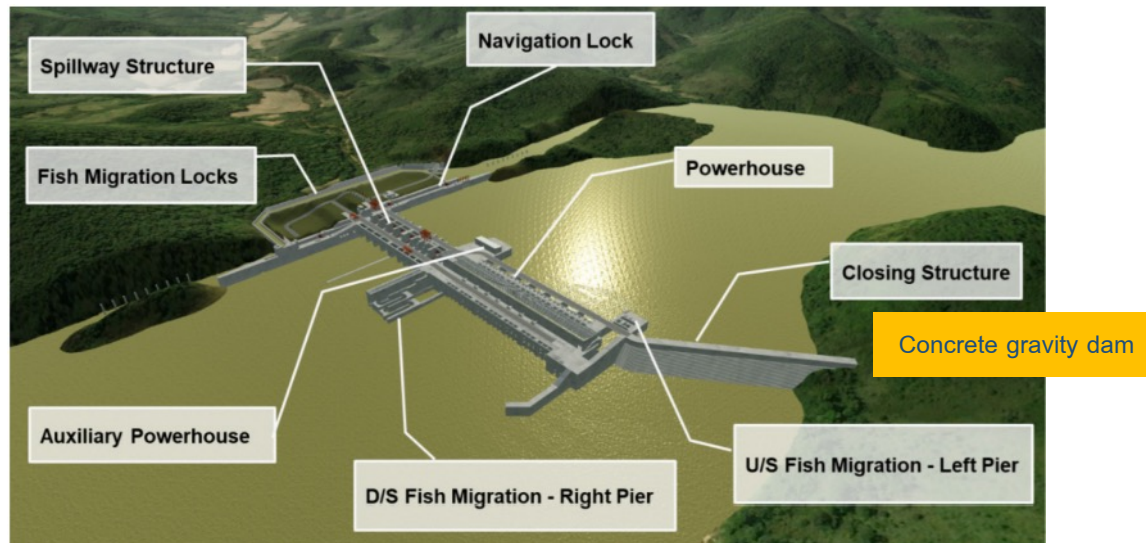


PDG2023

- Hydropower project - “run-of-river” type

Hydropower project

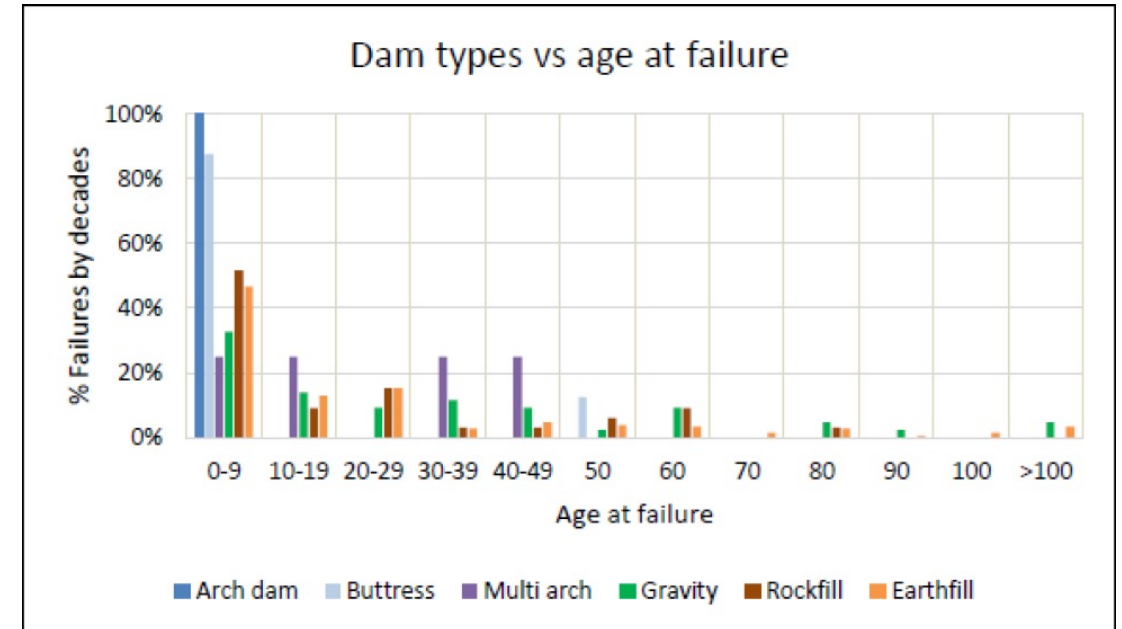
An infrastructure project that enables the generation of electricity from moving water. Different modes of operation are possible depending on the project scale and configuration, ranging from ‘run-of-river’ (hours to a few days of water retention in the impoundment) to ‘storage’ (retainment of water for a period of weeks to months for later release). This guidance is concerned primarily with the mainstream ‘run-of-river’ type.



Dam Failures in Global Context

Key Summary

- The ten first years of a dam life is still the period where 50% of the failures occur. For arch dams and buttress dams this ratio is 100%.
- Dams failures occur either during normal operation or during flood events, these two failures' contexts standing for 90% of the failures with flood context being slightly more important. Since 2000, 70% of failures have occurred during flood events.



Source: ICOLD Incident database Bulletin 99 update (2019): from <=1900 to 2018 (as of May 2018)

- For rigid dams, foundation failure and internal erosion in foundation are the dominant modes. Structural failure mainly occurs at gravity dams made of masonry.
- ICOLD Bulletin 188 PrePrint

Dam Failures - Concrete Dam

Concrete Dam Failures, after ICOLD 1995+

Failure Type	Concrete Dams
Overtopping	5 (9%)
Foundation*	29 (53%)
Uplift	4 (7%)
Materials	5 (9%)
Structural	6 (11%)
Spillway	5 (9%)
Seismic Deformation**	1 (2%)
Total	55

*Includes Camara Dam, 2004

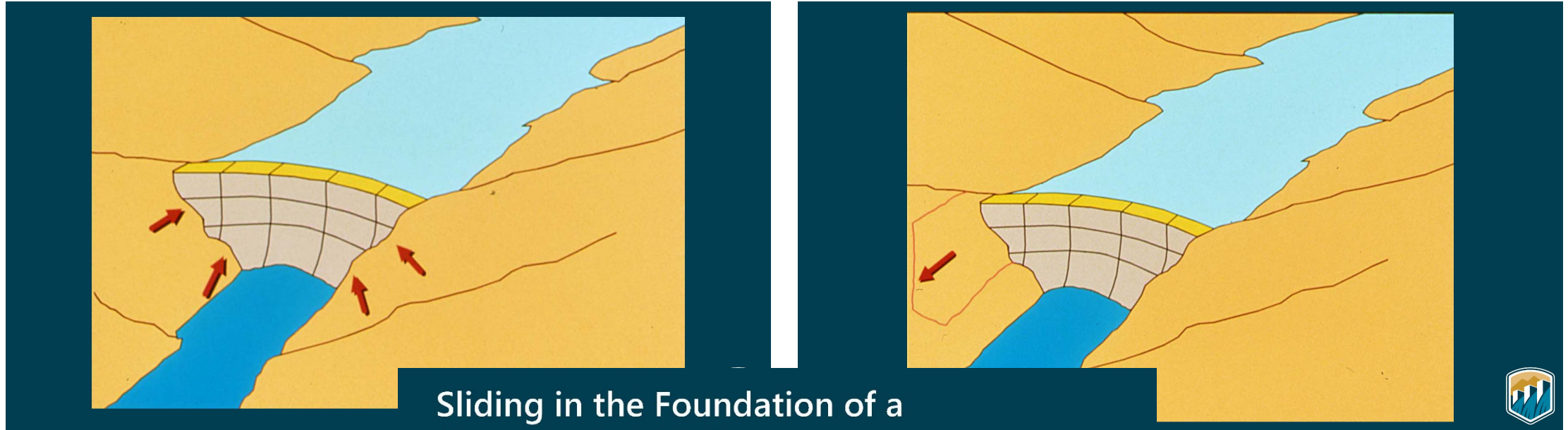
**Shi Kang Dam, 1999 Chi Taiwan E.Q.



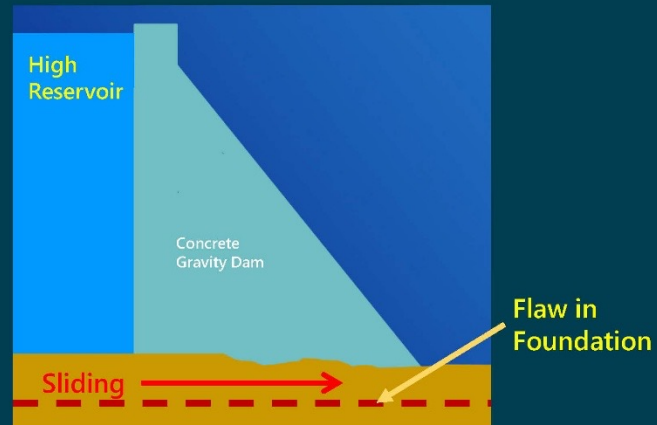
Failure Modes - Concrete Dam

- **Static (Normal Loading, Normal Operation)**
 - Foundation-Related Failure
 - Gate Failure
- **Hydrologic (Flood Loading)**
 - Flood-Related Failure
- **Seismic**
 - Earthquake-Related Failure
 - Gate Failure

Failure Modes - Static - Foundation-Related Failure



Sliding in the Foundation of a Concrete Gravity Dam



Source: USBR (2025)

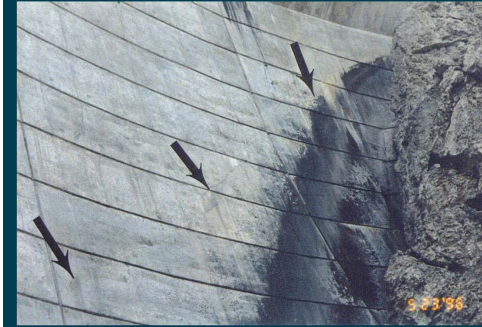
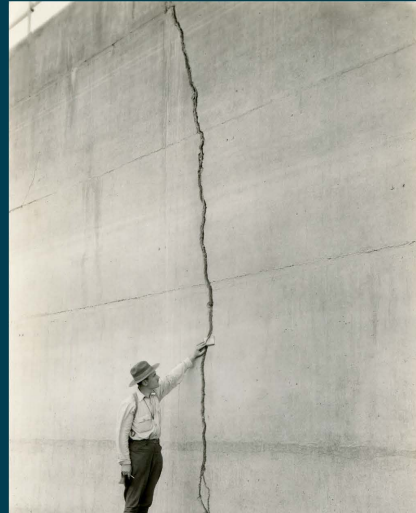
25/09/69

Failure Modes - Static - Foundation-Related Failure

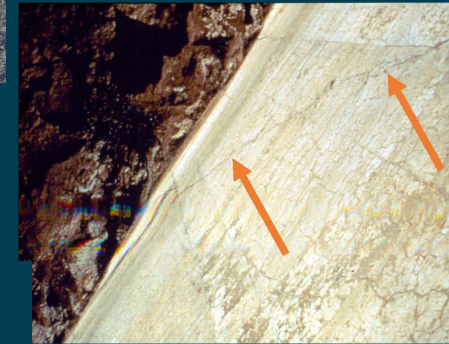
What and How to Monitor



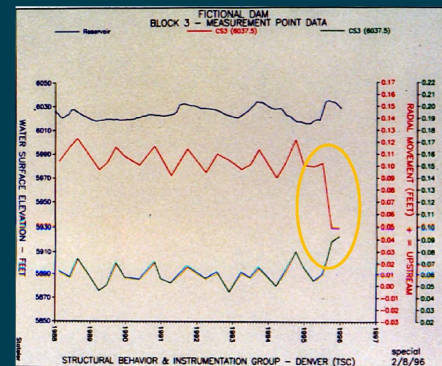
Evidence of DS movement



Diagonal Cracks



Evidence of Structural Distress

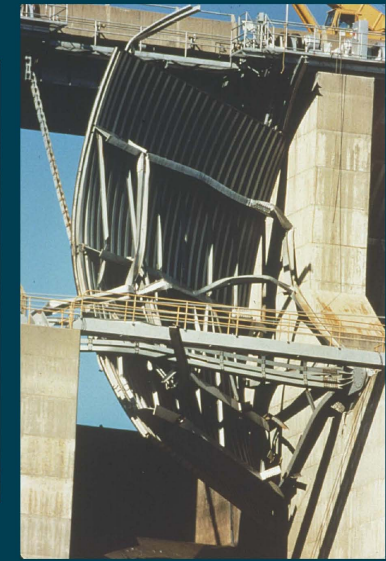
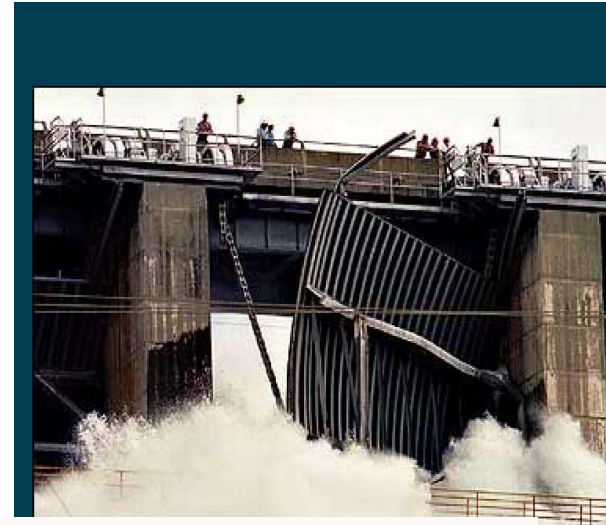


Source: USBR (2025)

25/09/69

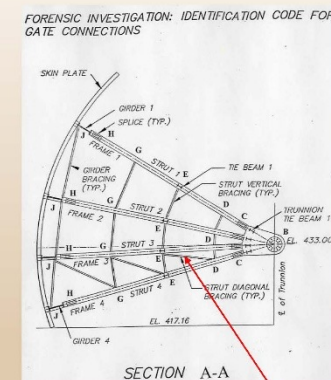


Failure Modes - Static - Gate Failure



Folsom Dam Gate Failure

- Spillway has eight spillway Tainter gates (5 service, 3 emergency)
- Gate No. 3 failed suddenly on 7/17/95 with reservoir full
- Uncontrolled release peak – 40,000 ft³/s
- Failure started at lower strut brace, proceeded to adjacent braces and then arms buckled (determined to be trunnion pin friction)
- Contributing factors
 - Spillway gates weren't designed for trunnion friction loads
 - Large, hollow pin (32" diameter)
 - Reduced frequency of lubrication and lack of weather protection at ends of pin resulted in corrosion and increased friction over time
 - Struts 3 & 4 post failure evaluation led to conclusion about failure sequence



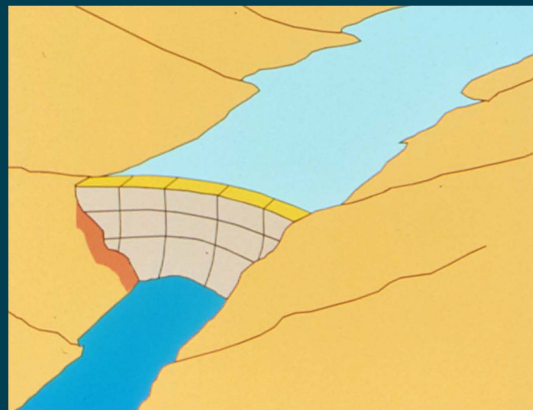
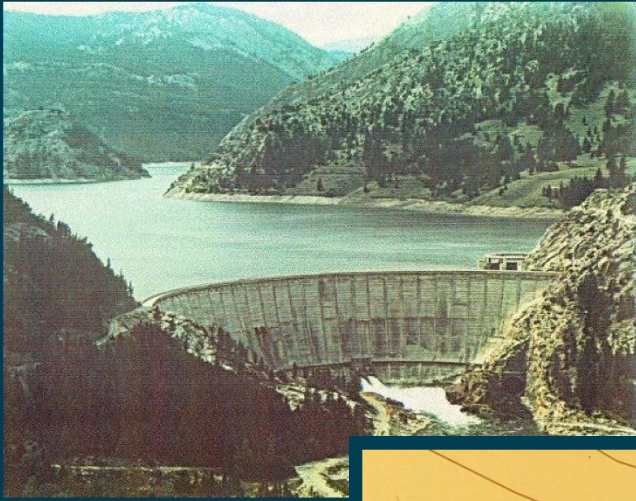
Initial Failure

Source: USBR (2025)

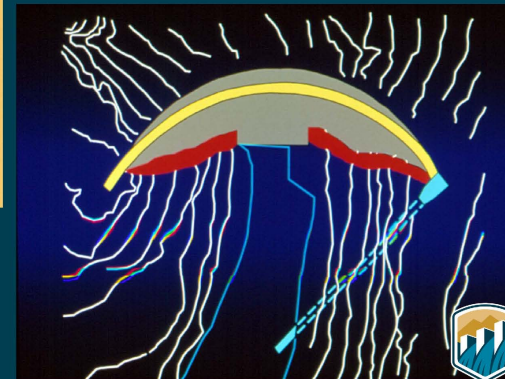
25/09/69

Failure Modes - Hydrologic - Flood-Related Failure

Gibson Dam



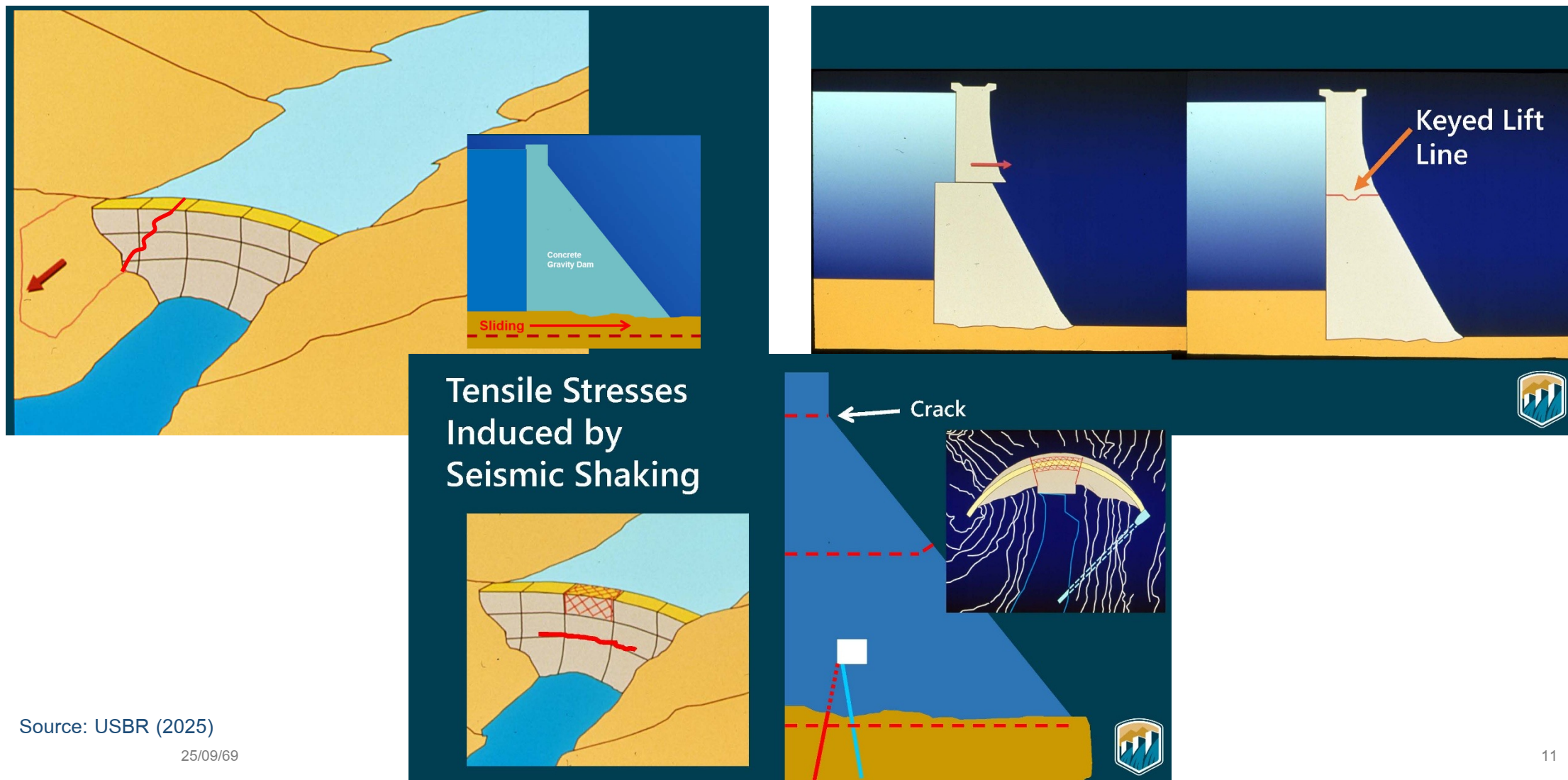
Overtopping flow erodes foundation material



Source: USBR (2025)

25/09/69

Failure Modes - Seismic - Earthquake-Related Failure



Source: USBR (2025)

25/09/69

Failure Modes - Seismic - Gate Failure

- Overtopping of run-of-river power plant due to failure of gate operation (left) and mud deposited on crest of overtopped run-of-river power plant (right) (Wenchuan earthquake in China)



Source: Martin Wieland, Sanaz Ahlehagh (2017)

Failure Modes - Seismic - Gate Failure

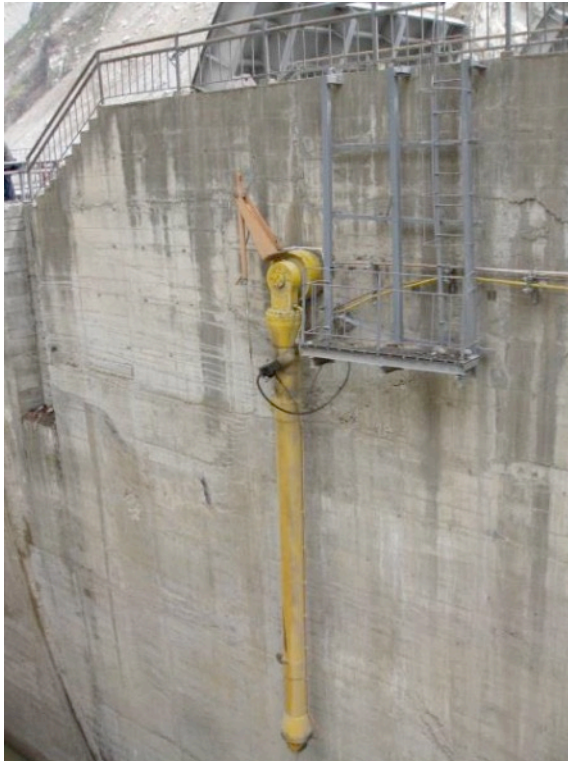
- Failure of two bays of the Shih-Kang weir caused by (mainly vertical) fault movements during the 1999 Chi-Chi earthquake in Taiwan



Source: Martin Wieland, Sanaz Ahlehagh (2017)

Failure Modes - Seismic - Gate Failure

- Left-over of radial gate destroyed by rockfall during Wenchuan earthquake in China



Source: Martin Wieland, Sanaz Ahlehagh (2017)

Failure Modes - Operational-Related Failure

- The various ways improper or accidental operation can lead to failure
- Operator error
- Inadvertent operation
- Gate misoperation or malfunction
- SCADA and remote operation
- Access
- Barge impact and towboat misadventures
- Etc.

“Things Just Don’t Go As Planned”

- Gates do not operate or fail
- Power for operating the gates is lost
 - Due to outage in the area due to storm and auxiliary power does not exist or function as planned
- Access to site is lost
- Procedures break down

Source: USBR (2017)

25/09/69

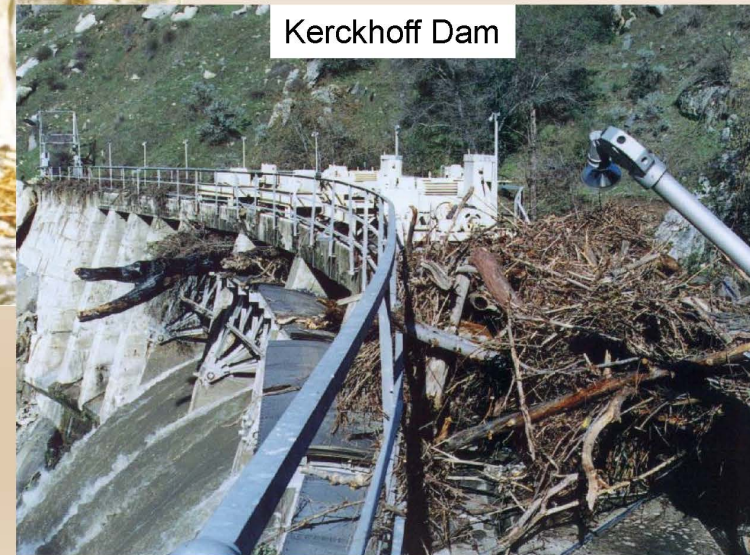
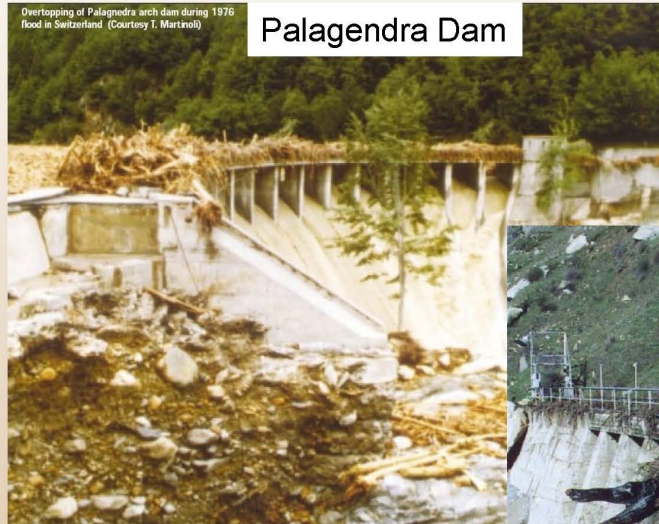
Civil Maintenance Division

15



Failure Modes - Operational-Related Failure

Dams with Debris



10



Source: USBR (2017)

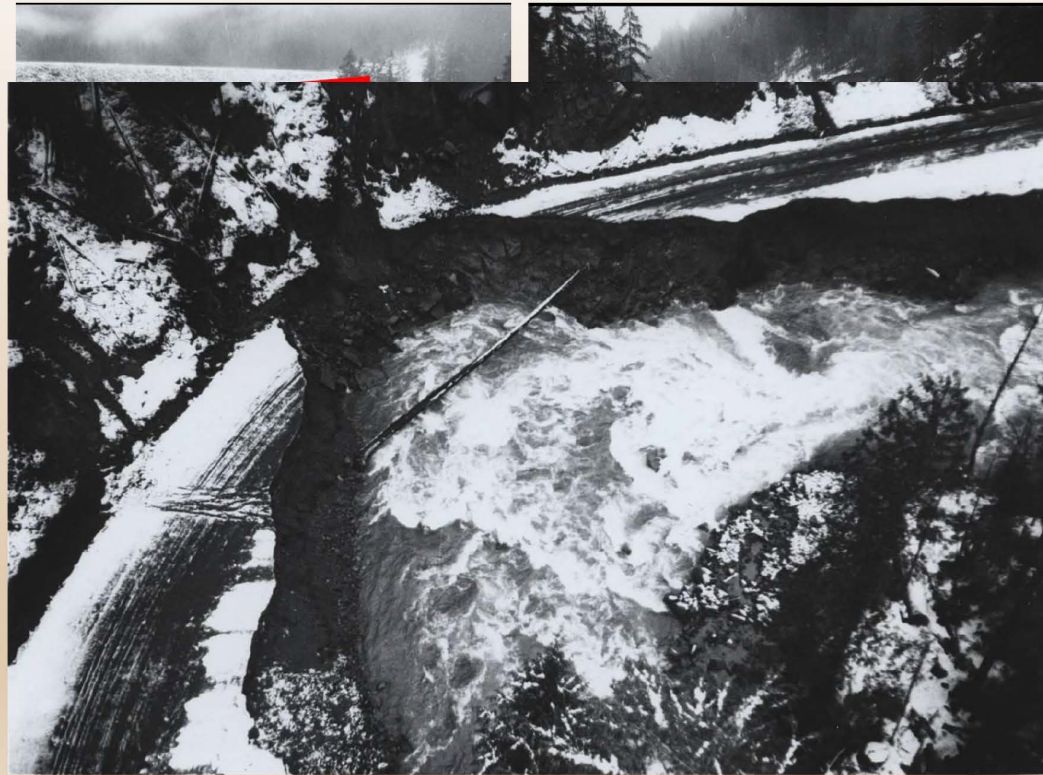
25/09/69

Civil Maintenance Division

16

Failure Modes - Operational-Related Failure

Project Access



Source: USBR (2017)

25/09/69

Civil Maintenance Division

17

Failure Modes - Operational-Related Failure

Spillway Operating Deck and Generator Floods



Emergency generator room
same elevation as catwalk



Catwalk almost inundated
during flood – gates must be
operated from catwalk



14



Failure Modes - Operational-Related Failure

Switchyard Floods – Loss of Power Release Capacity



Source: USBR (2017)

25/09/69

Civil Maintenance Division

19

Failure Mode Identification Processes

1. Most Likely Failure Modes

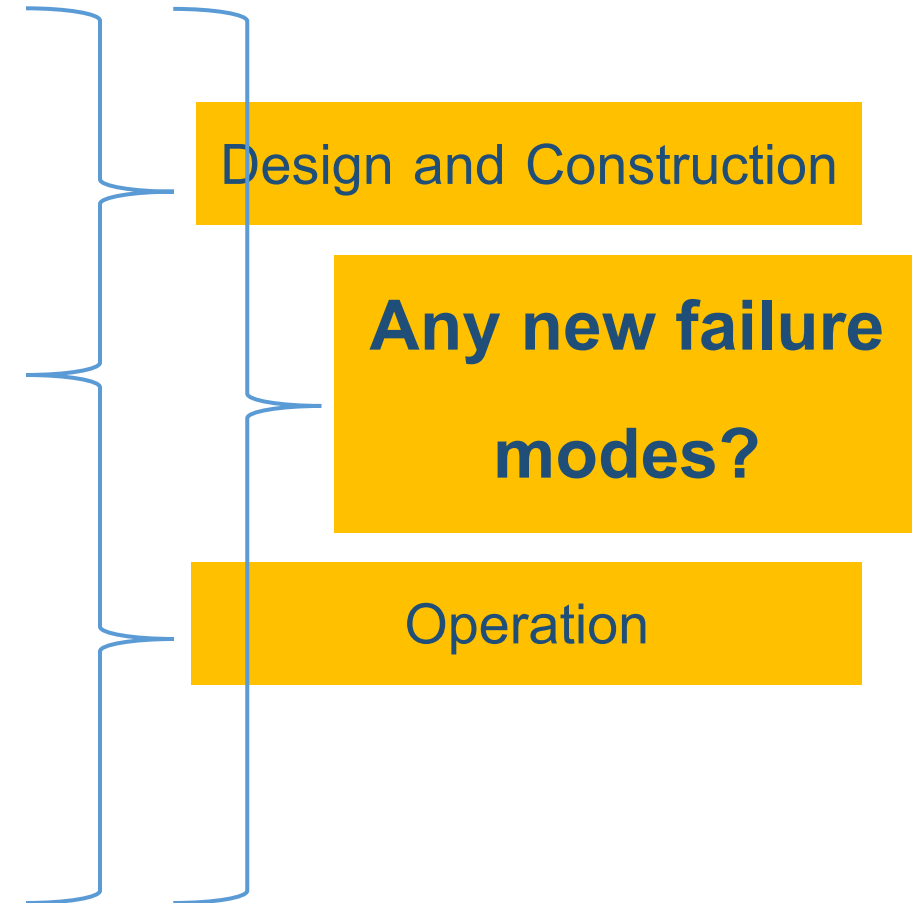
Important Information for Evaluating Failure Modes

- 1) Site geology
- 2) Design of dam
- 3) Construction methods and records
- 4) Performance history (instrumented and visual)
- 5) Current earthquake and flood loadings

2. Key Parameters to Monitor

- 1) Visual Inspections and Expected Performance
- 2) Instrumented Monitoring & Expected Performance

3. Ranges of Expected Performance



PDG2023 CI 274 - Design and Operational Guidance

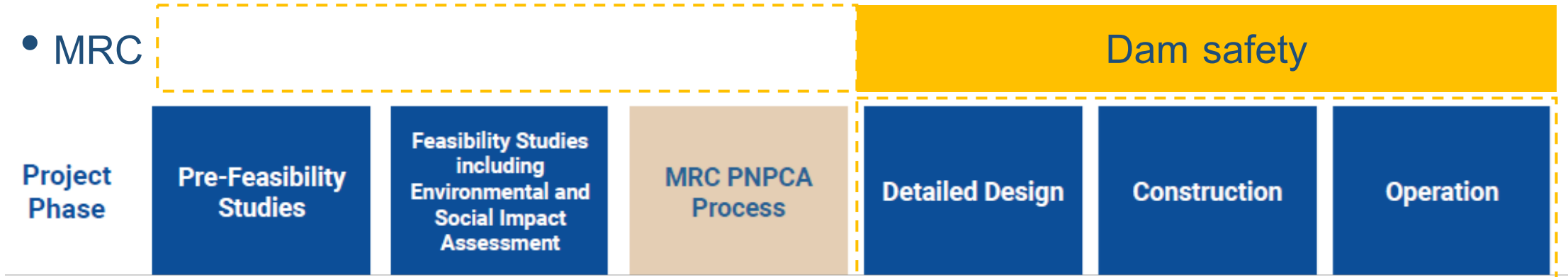
	Risk	Mitigation measures
Design	Failure of upstream dams	Hydraulic modelling of the impact of failure of the upstream dams should be carried out and the dam designed to prevent catastrophic failure due to overtopping by an upstream dam failure
	Uncertainties in flood loading	Existing dams on the mainstream have been designed to safely pass the probable maximum flood (PMF). All new dams should use the PMF as the check flood. ICOLD Bulletins
	Uncertainties in the geological and geotechnical investigations	Detailed geological and geotechnical investigations of the dam site should be carried out before and during the construction phase.
	Below-standard design of dam and structures	Experienced designers should be hired. Adequate quality assurance systems should be included in the design. <u>Dam Safety Review Panel</u> should be actively involved at all stages of the project.
	Uncertainties in seismic loading	Detailed seismic hazard assessment should be carried out as recommended by ICOLD Bulletins 120 and 148 (ICOLD, 2014, 2011).

	Risk	Mitigation measures
Construction	Below-standard construction control and quality	Detailed specifications should be prepared by the designers and then strictly applied during construction. The design and construction should be carried out by experienced dam engineers and contractors with all stages independently reviewed by a competent party from a dam safety perspective.
	Failure of the dam during construction due to undersized or blocked diversion works causing overtopping of the partially completed dam	The diversion works should be adequately sized. The debris should be actively managed. Flood forecasting systems should be implemented during construction. Emergency planning and dam safety monitoring should be carried out during construction.
Operation	Inadequate operation, maintenance and dam safety surveillance	Detailed dam safety management plans, operational and maintenance plans, and emergency preparedness plans based on potential failure mode assessments should be prepared by the designers and implemented by the developer and owners. Operating rules covering extreme flood events should be prepared and include all actions required to ensure that dam safety risks are mitigated and that potentially affected communities are consulted. ICOLD Dam Safety Program

Source: Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong River Basin (2023)

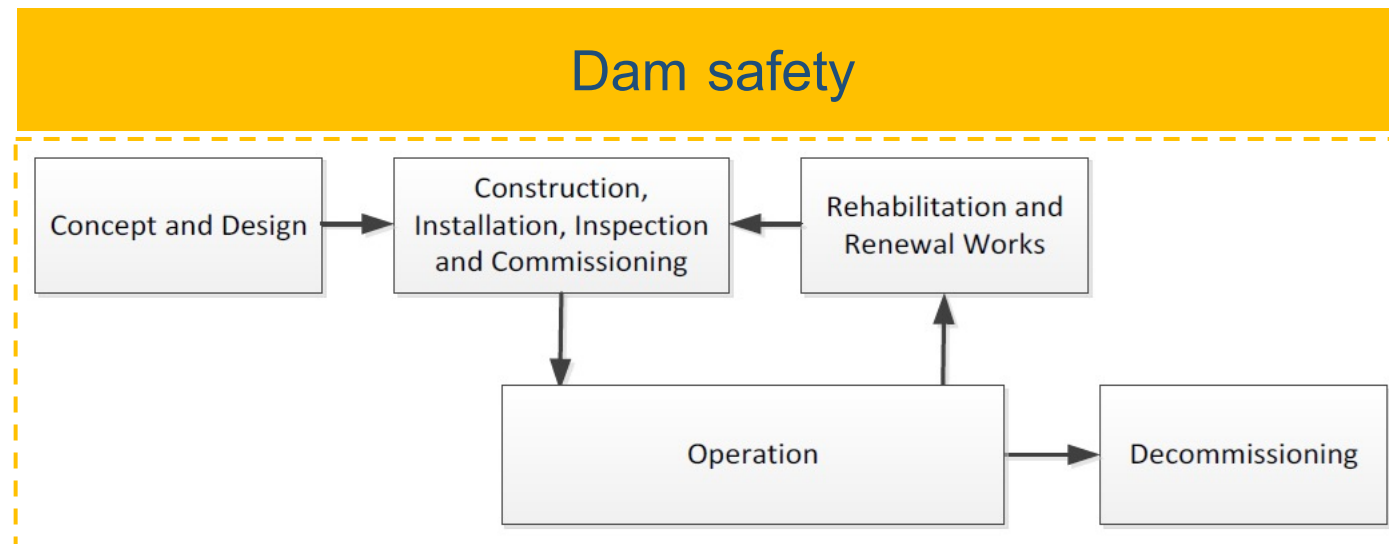
Dam Safety in Hydropower Project Phase

- MRC



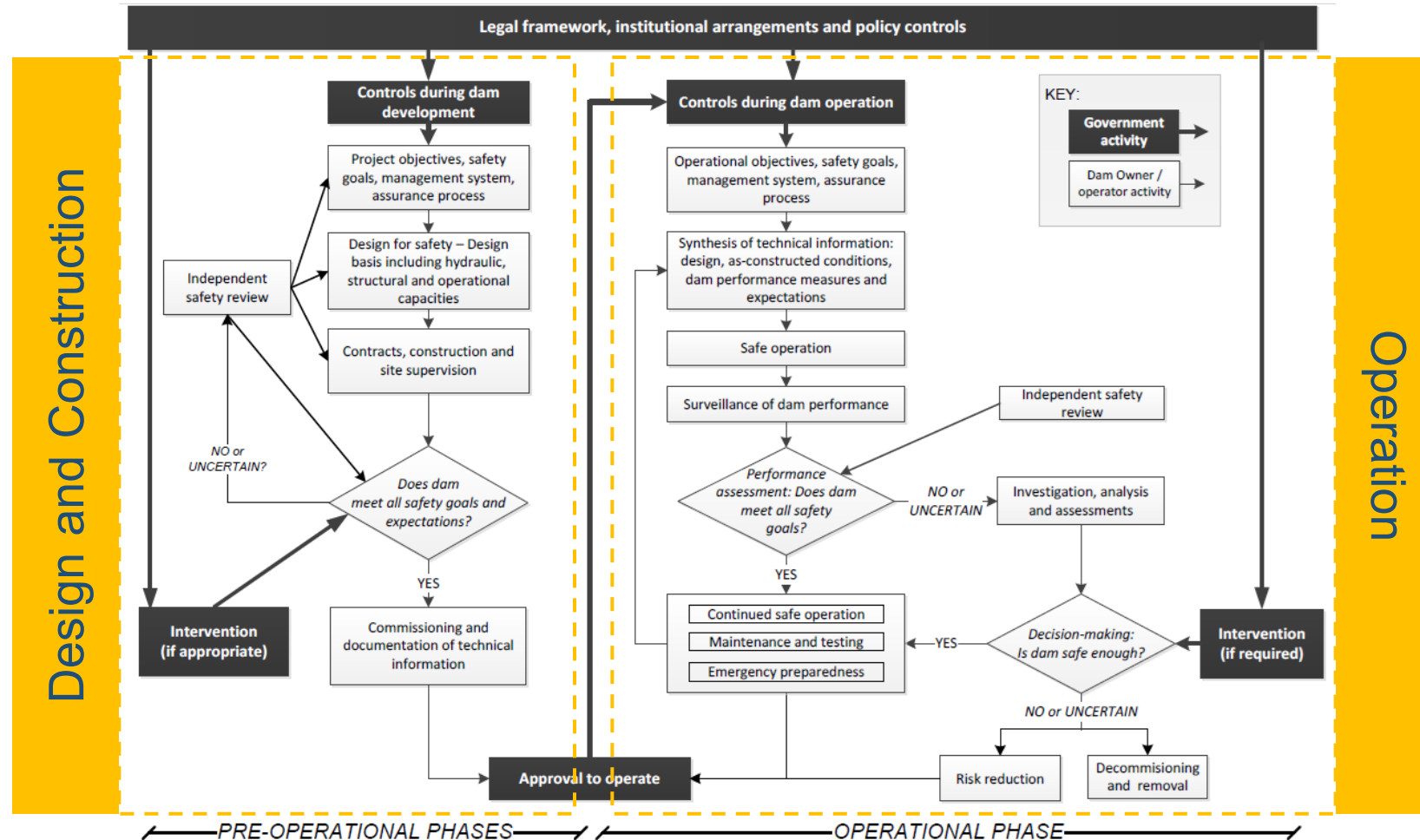
Source: Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong River Basin (2023)

- ICOLD



Source: ICOLD Bulletin 191 (2021) PrePrint

Process for Management of Dam Safety over All Life Phases



Source: ICOLD Bulletin 191 (2021) PrePrint

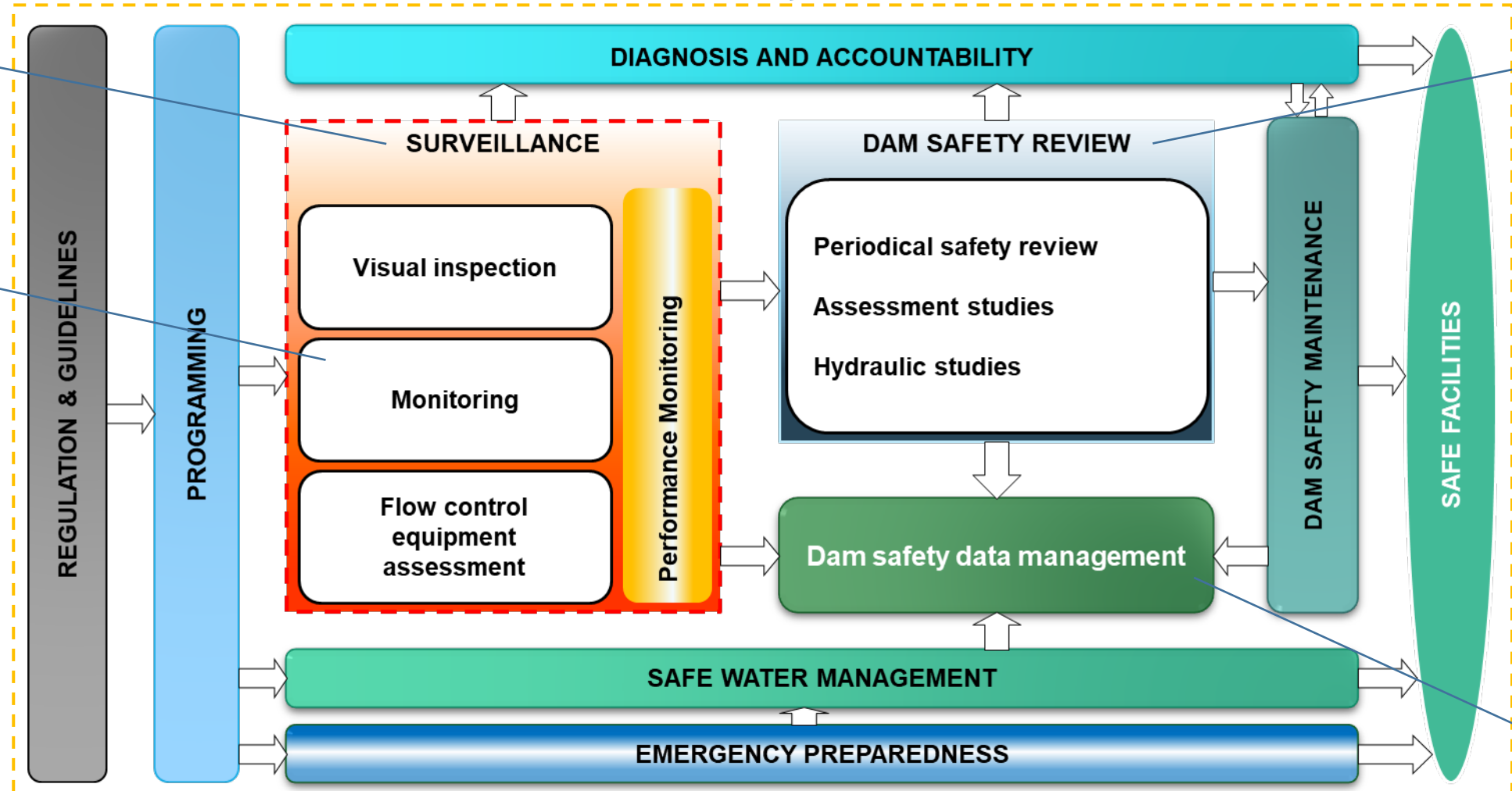
Dam Safety Program and PDG2023



CI 293

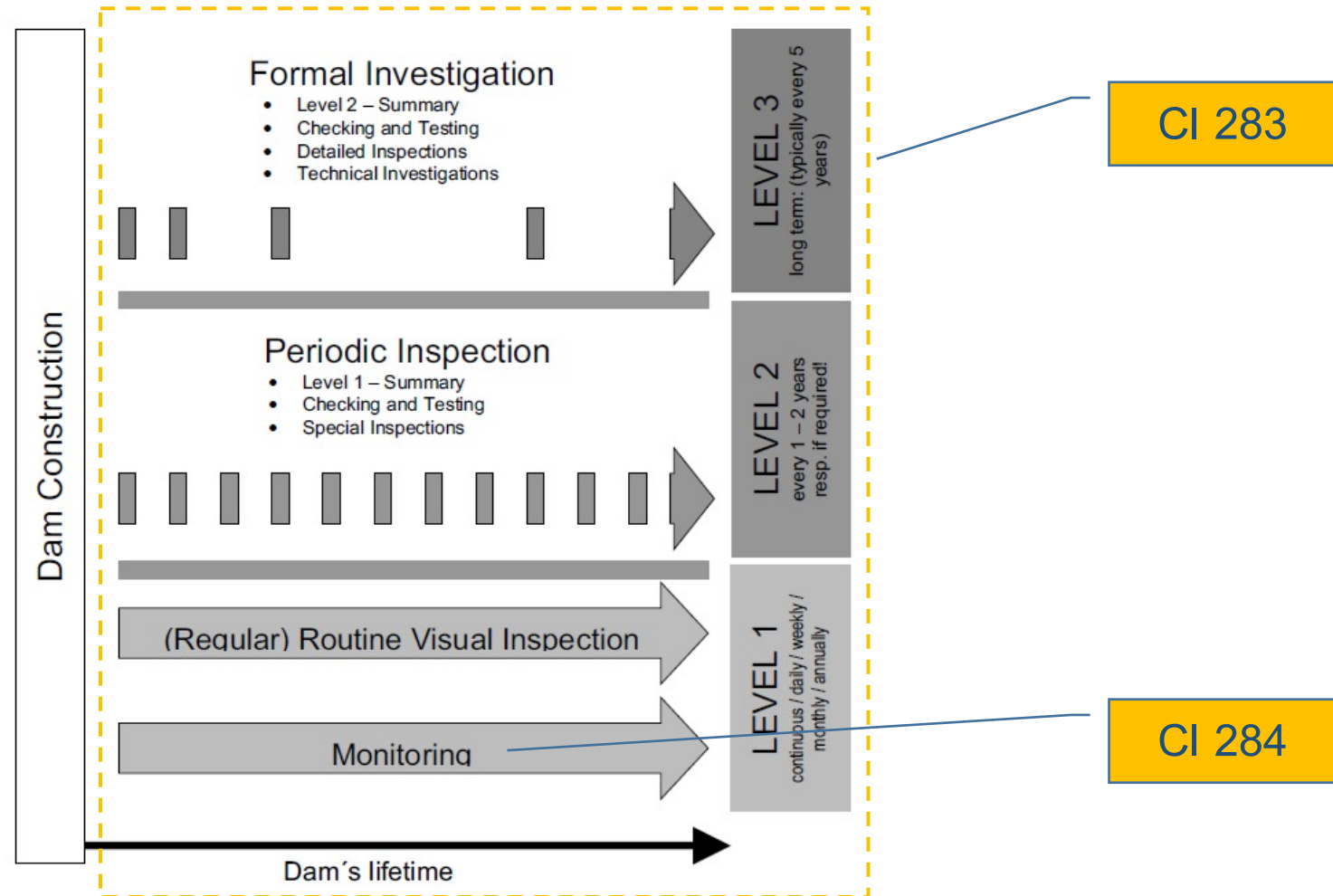
CI 283

CI 283



Source: ICOLD Bulletin 138 (2009)

Dam Inspection



Source: ICOLD Bulletin 158 (2018)



EGAT Dam Safety Activities in EGAT

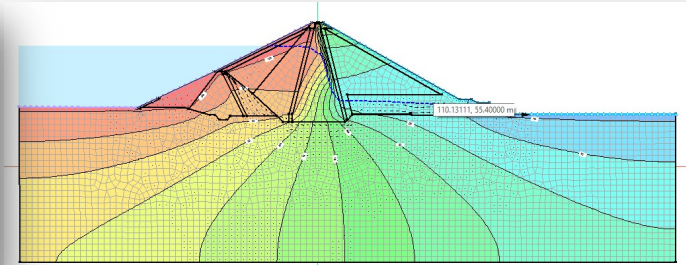
Dam Visual Inspection



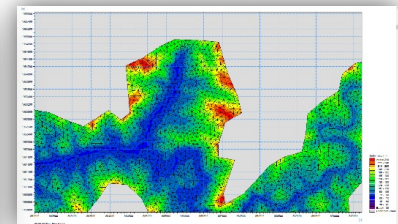
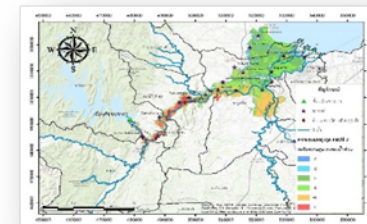
Appurtenant Structures Inspection



Monitoring dam behavior by Instrument data and Perform **Dam Safety Review** to recheck dam safety criteria



Emergency Action Plan



Dam Safety Remote

Monitoring System (DS-RMS)





EGAT Surveillance - Visual Inspection and Monitoring

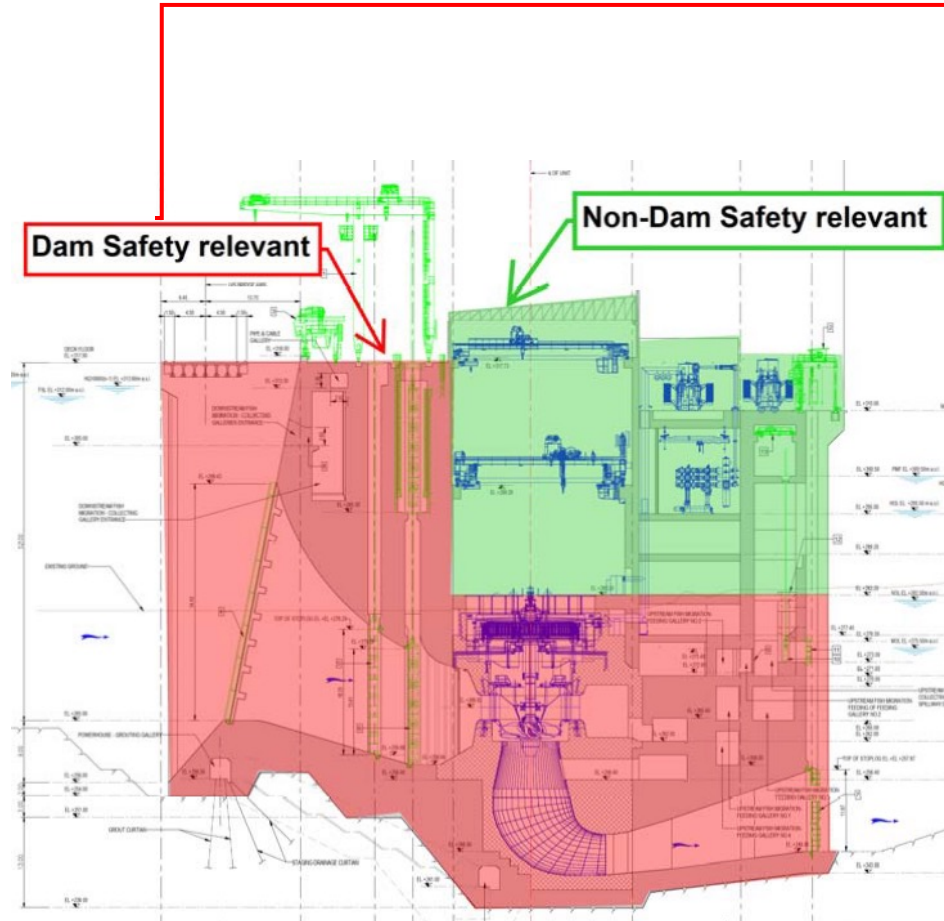
**Visual Inspection of
dam and appurtenant
structures**



**Monitoring
e.g. settlement and
displacement of dam
crest, seepage through
dam and foundation**



Surveillance - Monitoring



DAM SAFETY

Monitoring Program

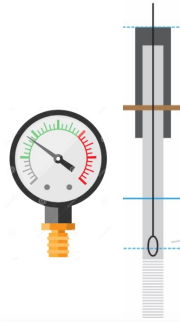
- Relevant during impounding and operation
- General
 - **Visual Inspections:** Regular inspections by O&M staff
 - **Survey Monitoring:** Measurement of surface displacements and deformations
 - **Monitoring Instruments:** Deformation, water pressure, etc.
- Dam Instrumentation
 - Parameters and Instruments as below:

Parameter	Monitoring Instruments
Displacement, movement, settlement	Jointmeter, Rocmeter, Inclinometer, Levelling bolt, Stationary light reflector
Water level, water pressure	Gauge, Observation well, Piezometer
Leakage/ seepage	Flowmeter, Piezometer
Climate	Weather station
Dynamic response (seismicity)	Strong Motion Accelerator

Monitoring Instrument	Behaviour	Reading	No
El. Piezometer (EP)	Water Level Uplift Pressure	Automatic	40
Flowmeter (FM)	Water Leakage	Automatic	10
3D-Jointmeter (TJM)	Movement Displacement Settlement	Automatic	75
Rocmeter (RM)	Movement Displacement Settlement	Automatic	20
Inclinometer (IM)	Movement Displacement Settlement	Manual	3
Groundwater Observation Well (OW)	Water Level Uplift Pressure	Manual	10
Strong Motion Accelerometer (SMA)	Dynamic Response	Automatic	2
Leveling Bolt (LB)	Movement Displacement Settlement	Manual	50
Stationary Light Reflector (SR)	Movement Displacement Settlement	Manual	30
Weather Station	Rainfall Intensity Temperature Relative Humidity Barometer Wind Velocity Evaporation Pyranometer	Automatic	1



EGAT Dam Safety Remote Monitoring System (DS-RMS)



Dam Instrument Data (Auto & Manual)

- Knowledge and experience from dam safety experts
- Guideline in Dam Safety by International Committee of Large Dams (ICOLD)

ระบบผู้เชี่ยวชาญ

พฤติกรรมเขื่อนในสภาวะใช้งานปกติ

ปกติ	เสถียร	ไม่ทราบสาเหตุ	ปกติ	ปกติ
การไหลซึมผ่านสันเขื่อน	การไหลซึมผ่านตัวเขื่อน	การไหลซึมผ่านตัวเขื่อนไม่ปรากฏ	การไหลซึมผ่านตัวเขื่อน	การไหลซึมผ่านตัวเขื่อน

พฤติกรรมเขื่อนในสภาวะแผ่นดินไหว

ปกติ	ปกติ	ปกติ	ปกติ
การไหลซึมผ่านตัวเขื่อน	การไหลซึมผ่านตัวเขื่อน	การไหลซึมผ่านตัวเขื่อน	การไหลซึมผ่านตัวเขื่อน

พฤติกรรมเขื่อนในสภาวะน้ำหลาก

ปกติ	ปกติ	ปกติ
ระดับน้ำจะสูงกว่าระดับเขื่อน	ระดับน้ำจะสูงกว่าระดับเขื่อน	ระดับน้ำจะสูงกว่าระดับเขื่อน

Expert System

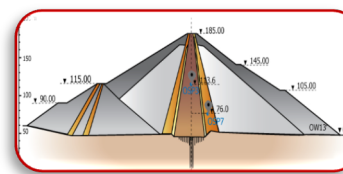
Earthquake Data



Water Information (EGAT-WIC)



Design Criteria



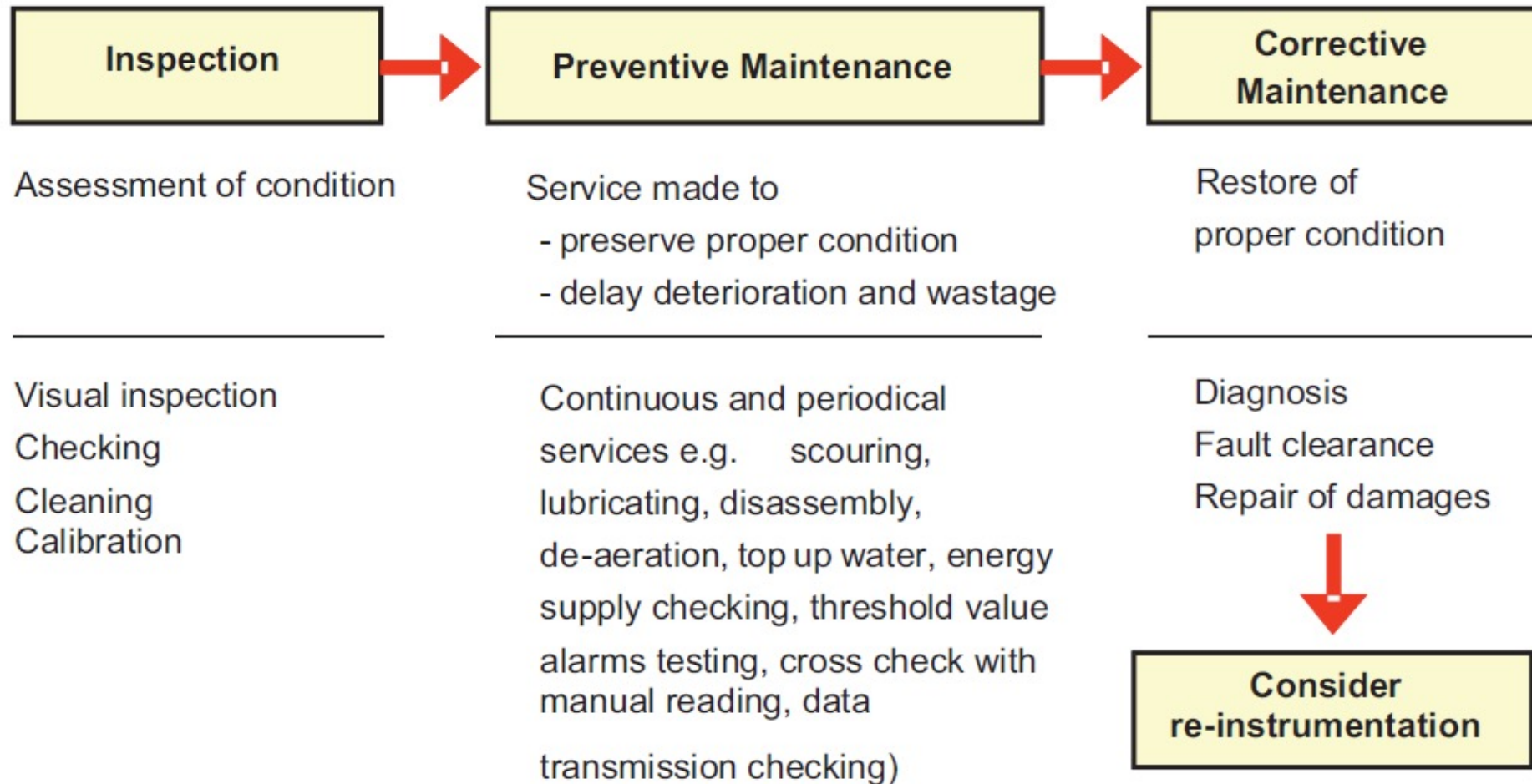
As-Built Drawing



Reference Documents



Dam Instrumentation



Capacity Building for Dam Safety

- Domestic training - Universities, etc
- International training - ICOLD, USBR, ASDSO, etc.
- Research projects in collaboration with universities and national center
- International collaboration in dam safety
- **Regional (Lower Mekong Basin) training and collaboration in dam safety**
- ICOLD Bulletin 174 Action Plan on Capacity Building

Dam Safety Challenges

- Climate change - Risk of flooding
 - Emerging public awareness - Dam safety
 - **Integrated operation of Mainstream Dams in the Lower Mekong Basin - Advantage**
 - Etc.
-
- ICOLD Bulletin 185 CHALLENGES AND NEEDS FOR DAMS IN THE 21ST CENTURY
 - ICOLD Bulletin 186 INTEGRATED OPTIMAL OPERATION OF CASCADE HYDROPOWER STATIONS AND RESERVOIRS

References - ICOLD Bulletins

- National Standards
- ICOLD Bulletins - Example

	Dam Safety Management	
192	Dam Safety: Governance Considerations	PrePrint
191	Dam Safety: Concepts, Principle and Framework	PrePrint
175	Dam Safety Management: Pre Operational Phases of the Dam Life Cycle	2021
154	Dam Safety Management: Operational Phase of the Dam Life Cycle	2017
203	Best practices for achieving reliability of flood discharge gates	PrePrint
	Etc.	

Conclusions

- Dam safety is of paramount importance for the individual dams
- Ensure that up-to-date national and international standards/requirements/best practices in dam safety aspects are used through every phase of the project (design, construction, and operation)





EGAT

THANK YOU