Track 1: Appropriate Return Periods for Design Ground Motions for Dams

1. Summary of Current Practice for Selecting Return Periods of design ground motions ……Kofi Addo

2. Ground Motions for Dams in Active Regions …. ……...Ivan Wong

3. Developing the Technical Basis for Selection of Appropriate Return Periods for Dams in Active Regions: Status of the DRP Project ……Jennie Watson-Lamprey

4. Discussion …… ……Norm Abrahamson

Summary of Current Practice for Selecting Return Periods of Design Ground Motions

Kofi O. Addo
BC Hydro

Western Dam Safety Forum
January 15-16, 2009

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Introduction

- General Audience
  - Dam Owner
  - Regulator
  - Consultant
  - Others
- Focus
  - RESERVOIR:
    - **An asset**
    - **A potential liability**
    - Can’t be switched off instantaneously

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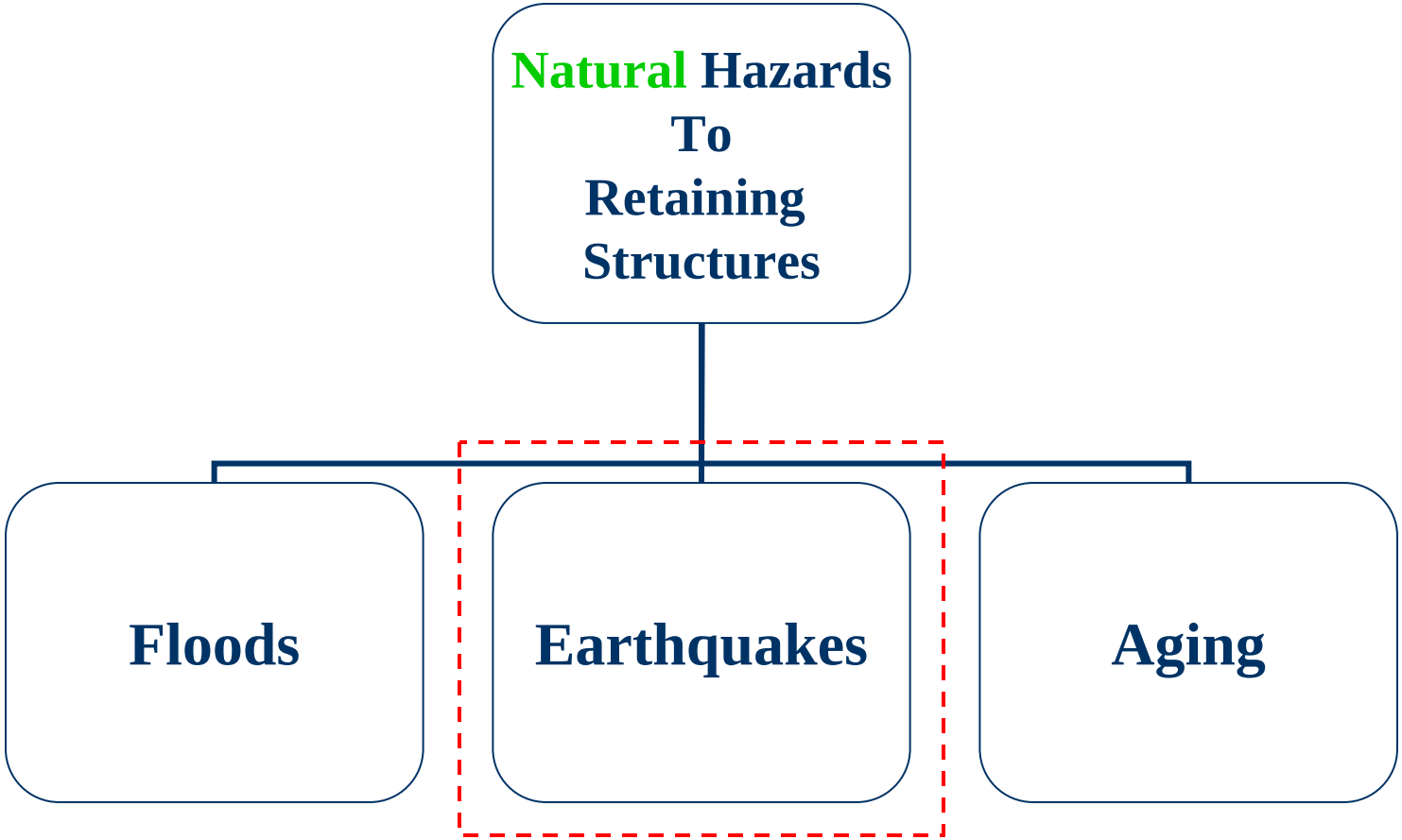
Hazards to Reservoir Retention Structures



NB – Other man-made hazards

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Target Ground Motions

Ground motions are required for design or evaluation of dams and appurtenant structures. Three ground motion target levels are identified probabilistically by a **RETURN PERIOD** or deterministically by an earthquake 'magnitude-distance' scenario.

Target Level	Functional Requirements
Safety	Some structural damage allowable No uncontrolled release of the reservoir
Operational (100-200 yr)	No structural damage; Minor non-structural damage allowed; Dam remains operable after event
Design (2500 yr)	No damage to load bearing members No loss of life

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Selecting the Return Period (RP)

1. Decision Makers
2. Process and Typical Values
3. What are commonly cited values?
4. Guiding principles for selection
5. Concluding Comments

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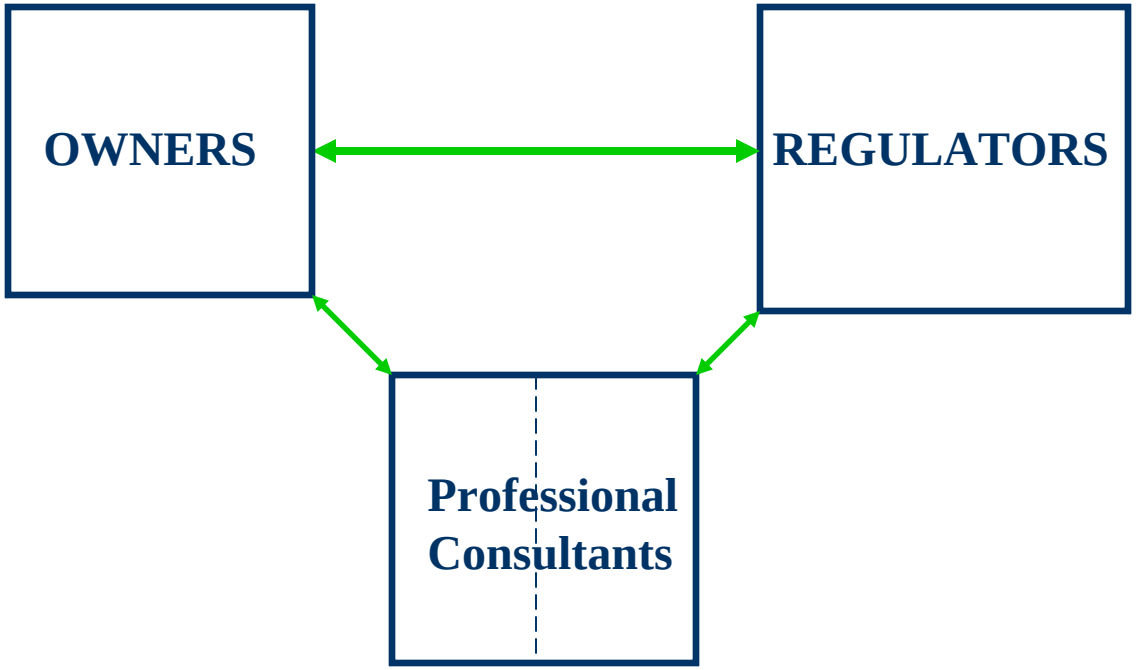
Who Selects the Return Period?



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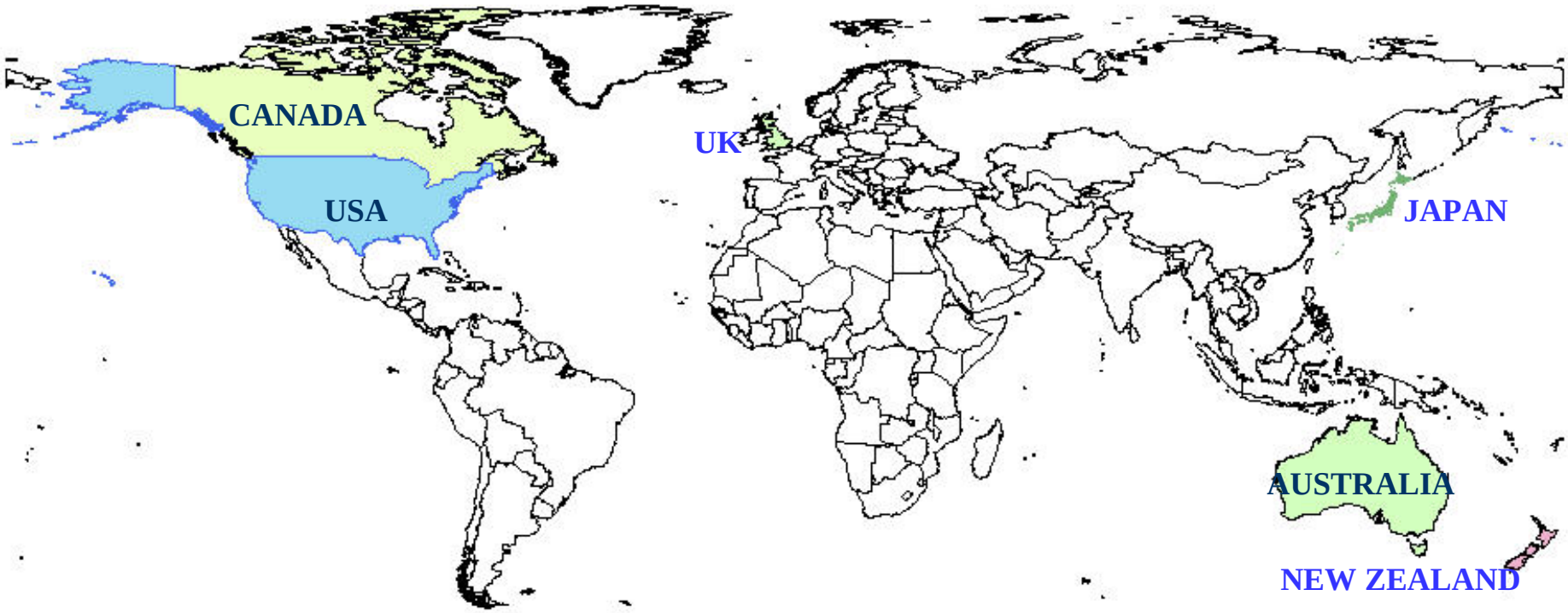
How is the Return Period Selected?



- Tectonic Region (Active, Stable Continental)
- Socio-environmental standards
- State of Geo-science & Engineering Practice
- Language

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Professional Associations

Country	Organization	
	International Committee on Large Dams	ICOLD
Canada	Canadian Dam Association	CDA
USA	United States Committee on Large Dams Federal Emergency Management Agency Federal Energy Regulatory Committee United States Bureau of Reclamation United States Army Corps of Engineers National Research Council California Dept. of Water Resources Division of Safety of Dams Etc …..	USCOLD FEMA FERC USBR USACE NRC DSOD
Japan	Ministry of Construction	
New Zealand	New Zealand Society on Large Dams	NZSOLD
United Kingdom	Department of the Environment	DOE
Australia	Australian National Committee on Large Dams	ANCOLD

ICOLD (1989/2009) Guidelines

Risk Factor	Extreme	High	Moderate	Low
	Contribution to Risk (Weighting Points)			
Capacity (hm^3)	>120 (6)	120–1 (4)	1–0.1 (2)	<0.1 (0)
Height (m)	>45 (6)	45-30 (4)	30-15 (2)	<15 (0)
Evacuation Requirements (# Persons)	>1000 (12)	1000-100 (8)	100-1 (4)	None (0)
Potential D/S Damage	High (12)	Moderate (8)	Low (4)	None (0)

Total Risk Factor	Risk Class (Risk Rating)	Return Period (yr)
0 - 6	I (Low)	~1,000
7 -18	II (Moderate)	1,000 – 3,000
19 - 30	III (High)	3,000-10,000
31 - 36	IV (Extreme)	~10,000

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USCOLD (1999) Guidelines

Risk Factor	Extreme	High	Moderate	Low
	Contribution to Risk (Weighting Points)			
Capacity (acre-feet)	$>10^5$ (6)	10^5–10^3 (4)	10^3–10^2 (2)	<100 (0)
Height (ft)	>150 (6)	150 -100 (4)	100-50 (2)	<50 (0)
Evacuation Requirements (# Persons)	$>10^3$ (12)	10^3 -10^2 (8)	100 - 1 (4)	None (0)
Potential D/S Damage	High (12)	Moderate 8)	Low (4)	None (0)

Total Risk Factor	Risk Class (Risk Rating)	PGA (g)
0 - 6	I (Low)	< 0.1
7 -18	II (Moderate)	0.1-0.25
19 - 30	III (High)	> 0.25; (R>10 km)
31 - 36	IV (Extreme)	>0.25; (R<10 km)

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DOE (UK) Guidelines

Total Risk Factor	Dam Category	Return Period (yr)
0 - 6	I	1,000
7 -18	II	3,000
19 - 30	III	10,000
31 - 36	IV	30,000

	Contributing Risk Factor			
Capacity (10^6 m^3)	>120 **(6)**	120–1 **(4)**	1–0.1 **(2)**	<0.1 **(0)**
Height (m)	>45 **(6)**	45-30 **(4)**	30-15 **(2)**	<15 **(0)**
Evacuation Requirements	>1000 **(12)**	1000-100 **(8)**	100-1 **(4)**	None **(0)**
Potential D/S Damage	High **(12)**	Moderate **(8)**	Low **(4)**	None **(0)**

CDA (CANADA) Guidelines

Dam Class	Population At Risk	Loss of Life	Socio-economic	Environmental	Return period (yr)
Extreme	Permanent	≥ 100	Extreme economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)	Major loss of critical fish or wildlife habitat. Restoration or compensation in kind impossible	**10,000**
Very High	Permanent	≤ 100	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)	Significant loss or deterioration of critical fish or wildlife habitat Restoration or compensation in kind possible but impractical	**5000**
High	Permanent	≤10	High economic losses affecting infrastructure, public transportation, and commercial facilities	Significant loss or deterioration of important fish or wildlife habitat Restoration or compensation in kind highly possible	**2500**
Significant	Temporary Only	Unspe - cified	Losses to recreational facilities, seasonal workplaces, and infrequently used transpiration routes	No significant loss or deterioration of fish or wildlife habit Loss of marginal habitat only Restoration or compensation in kind highly possible	**1000**
Low	None	0	Low economic losses, area contains limited infrastructure or services	Minimal short-term loss No long-term loss	**500**

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NZSOLD (2000)

Potential Impact Category	Potential Incremental Consequences of Failure	
	Life	**Socio-economic, financial, environmental**
High	Fatalities	Catastrophic Damages
Medium	A few fatalities possible	Major Damages
Low	No fatalities expected	Moderate Damages
Very Low	No fatalities	Minimal Damages

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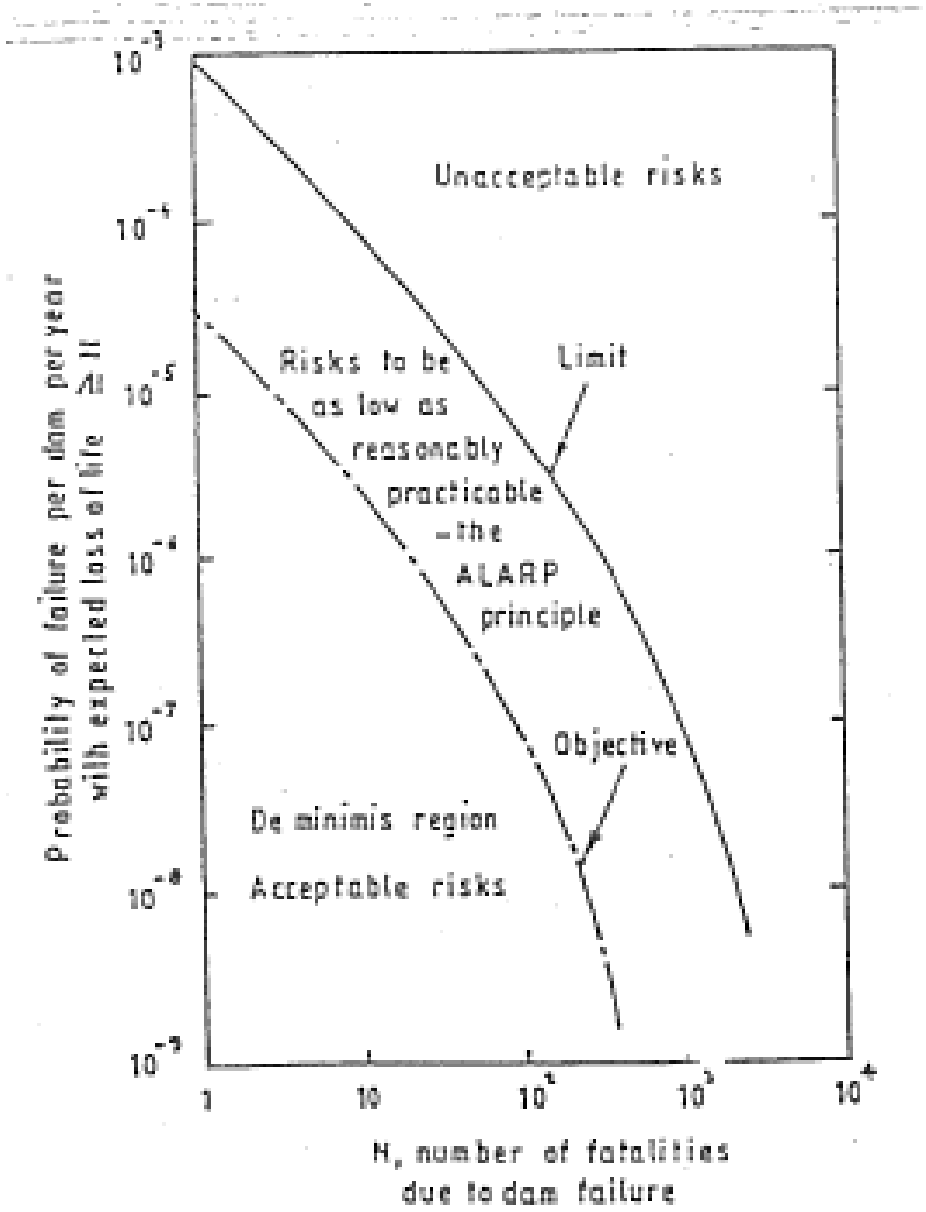
Safety Evaluation

CRITERIA ELEMENT	Potential Impact Category		
	High	**Medium**	**Low**
Earthquake Definition	CME (<CES) ≤10,000 yr motions	CME (<CES) ≤ 2500 yr motions	CME (< CES) ≤ 500 yr motions
Ground Motion Definition	84th ≤ 10,000 yr motions	50th - 84th ≤ 2500 yr motions	50th ≤ 500 yr motions
Foundation Displacement	84th ≤ 10,000 yr displ	50th - 84th ≤ 2500-yr displ.	50th ≤ 500 yr displ.

Risk-Based (ANCOLD, USBR)



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Practice Summary

- General Approaches
  - Standards-based
    - - which standard?
      - -similar tectonic regime (active, stable continental)
      - - similar socio-economic, environmental, legal, etc
      - - intended downstream design methodology
  - Risk-based
    - Performance-criteria (Potential Failure Modes)
      - -spillway & intake gates open
      - - core thickness > fault displacement
      - - freeboard > crest displacements
      - - liquefaction
      - - slope stability

Some Guiding Principles for Selection

- **R**ationale (defensibility)
- **R**ank (different criteria for different dams)
- **R**eference (how others do it in similar situations, CAUTION!!)
- **R**obustness (reduce frequency of downtime)
- **R**eliability (dependable power)
- **R**edundancy (alternatives)
- **R**eplacement (ready acquisition of spares)
- **R**ecovery (minimal outage times)
- **R**ealistic (not too rare, not too costly)

Discussion Points

- Should loss of life (rather than ability to draw down the reservoir) be directly cited as a basis for selecting a given return period?
- Should owners and regulators focus on performance criteria and let the engineers and scientists determine the appropriate return periods?
- How does the intended design methodology impact the selection of the return period?

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END

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