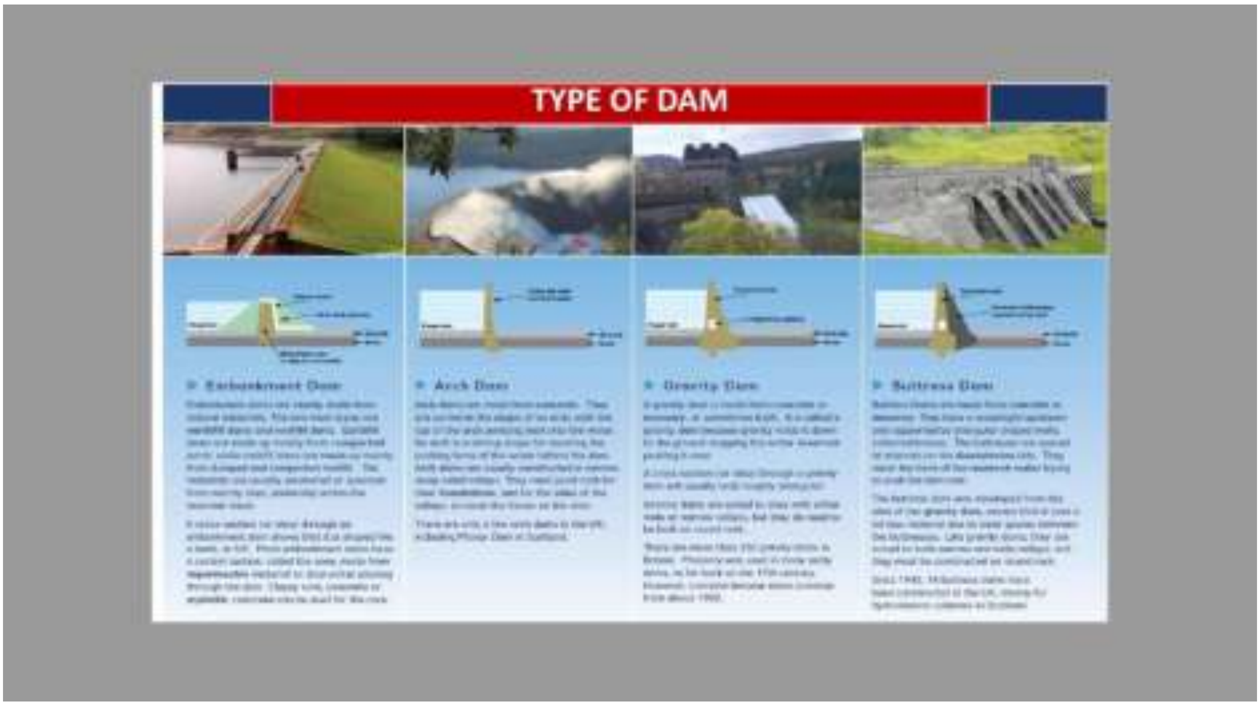
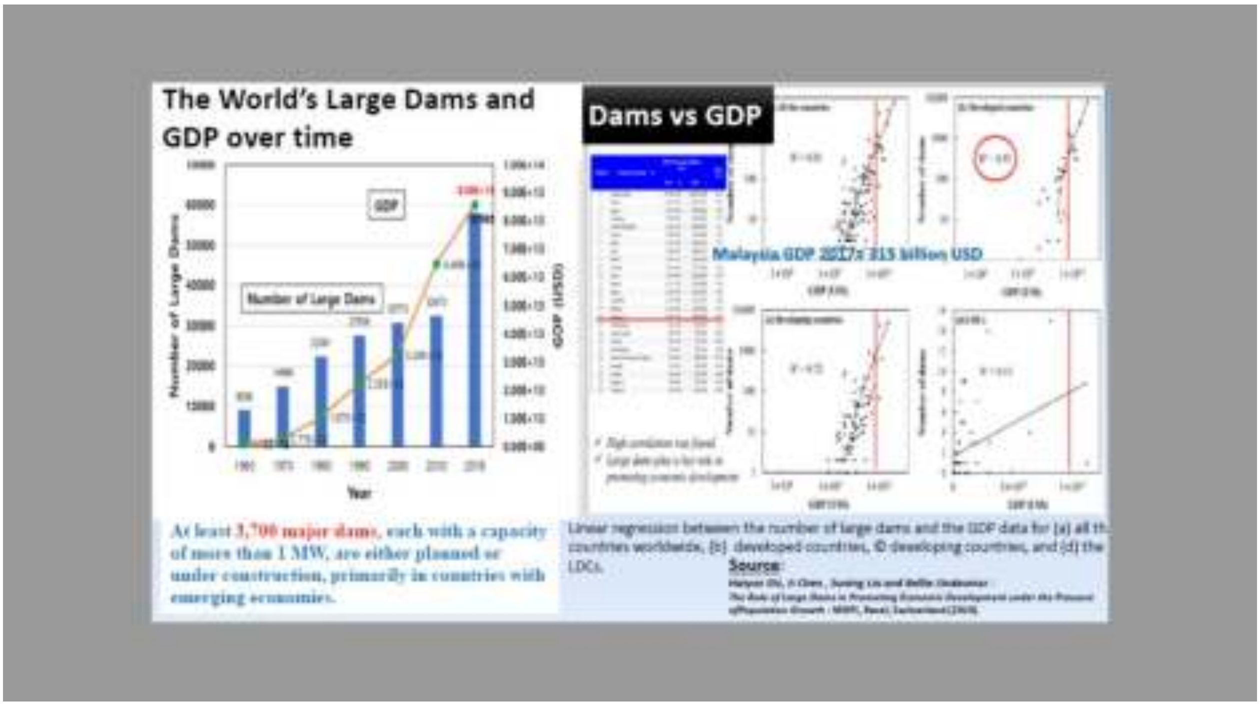

VALUING WATER - RESILIENT WATER INFRASTRUCTURE FOR SAFE COMMUNITIES
Prof Datin Ir Dr Lariyah Mohd Sidek
Professor, Institute of Energy Infrastructure & Department of Civil Engineering, Universiti Tenaga Nasional, MALAYSIA
Co-President MYCOLD
27th April 2021
Resilient Dams for Safe Communities


Contents
1. Introduction
2. CONSEQUENCES Understanding the Unique NATURE of our Water Infrastructures
3. Current Issues in Ageing Water Infrastructure
4. State-of-the-art Technologies related to Water Infrastructure
5. Conclusions
Resilient Dams for Safe Communities

e-ISSN : 2621-7469

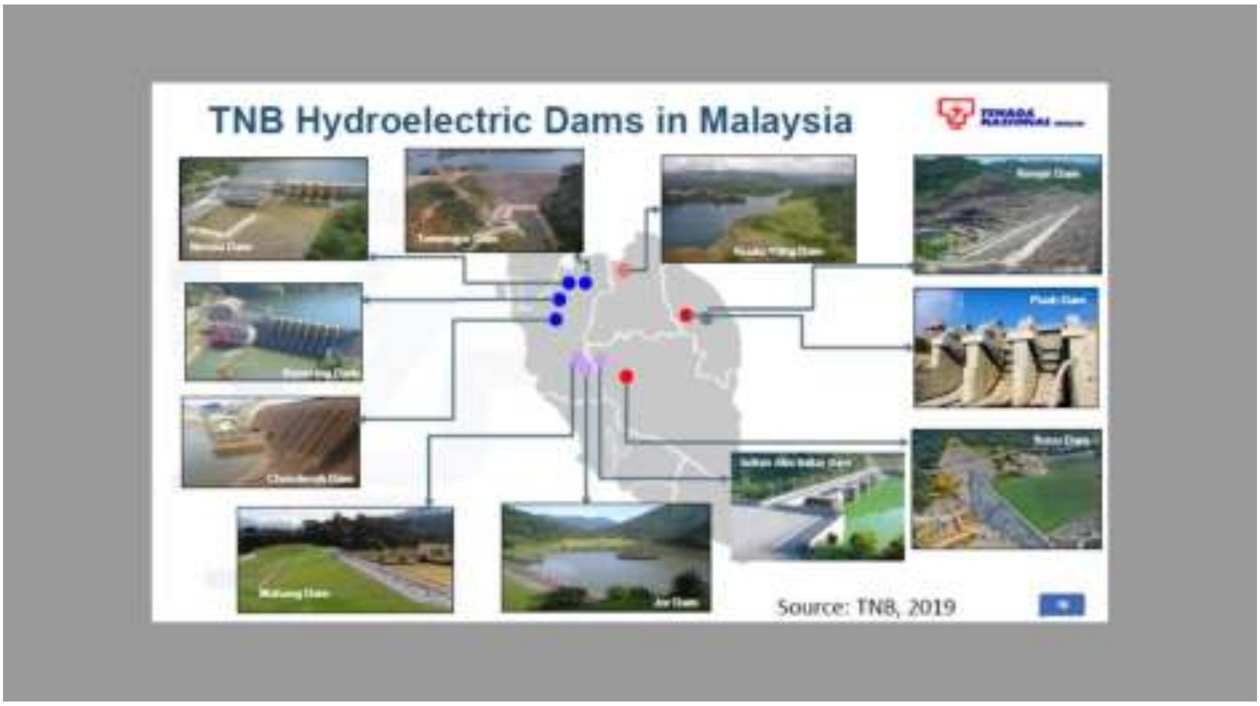

TYPE OF DAM
Embankment Dam
Arch Dam
Gravity Dam
Buttress Dam


The World's Large Dams and GDP over time
Dams vs GDP
GDP
Number of Large Dams
Number of Large Dams
GDP (USD)
Year
Malaysia GDP 2017: 315 billion USD
At least 3,700 major dams, each with a capacity of more than 1 MW, are either planned or under construction, primarily in countries with emerging economies.
Linear regression between the number of large dams and the GDP data for (a) all th countries worldwide, (b) developed countries, © developing countries, and (d) the LDCs.
Source:


Dam Sustainability - Alignment with UN SDGs
"Managing our business to minimise any negative impact of our operations and maximise the positive impact of what we do for our community."
Five Main Goals related to Dam Infrastructure
United Nations Sustainable Development Goals


Function of Dam Infrastructure
Flood Mitigation
Water supply for domestic consumption
Water supply for agriculture irrigation
Eco tourism (income for state government)
Commercial inland fishing and aquaculture
Hydroelectric power generation (renewable energy)
Source: TNB, 2019

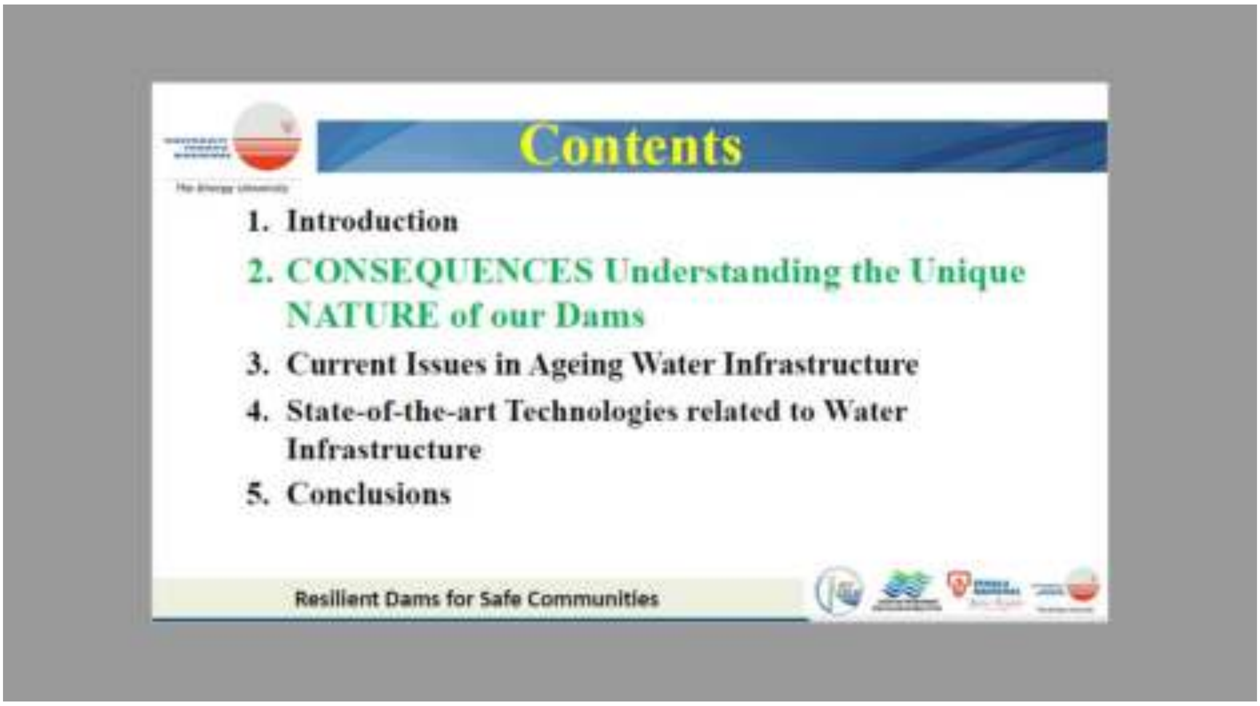
e-ISSN : 2621-7469



e-ISSN : 2621-7469

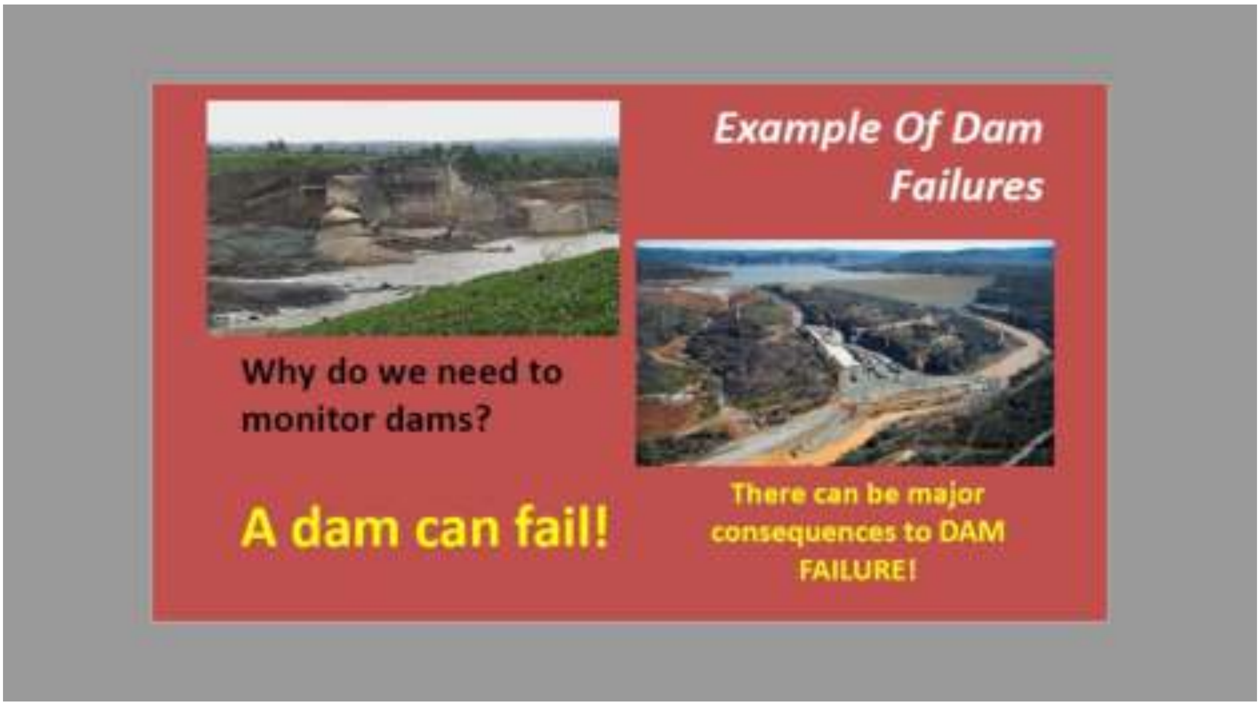
e-ISSN : 2621-7469

e-ISSN : 2621-7469

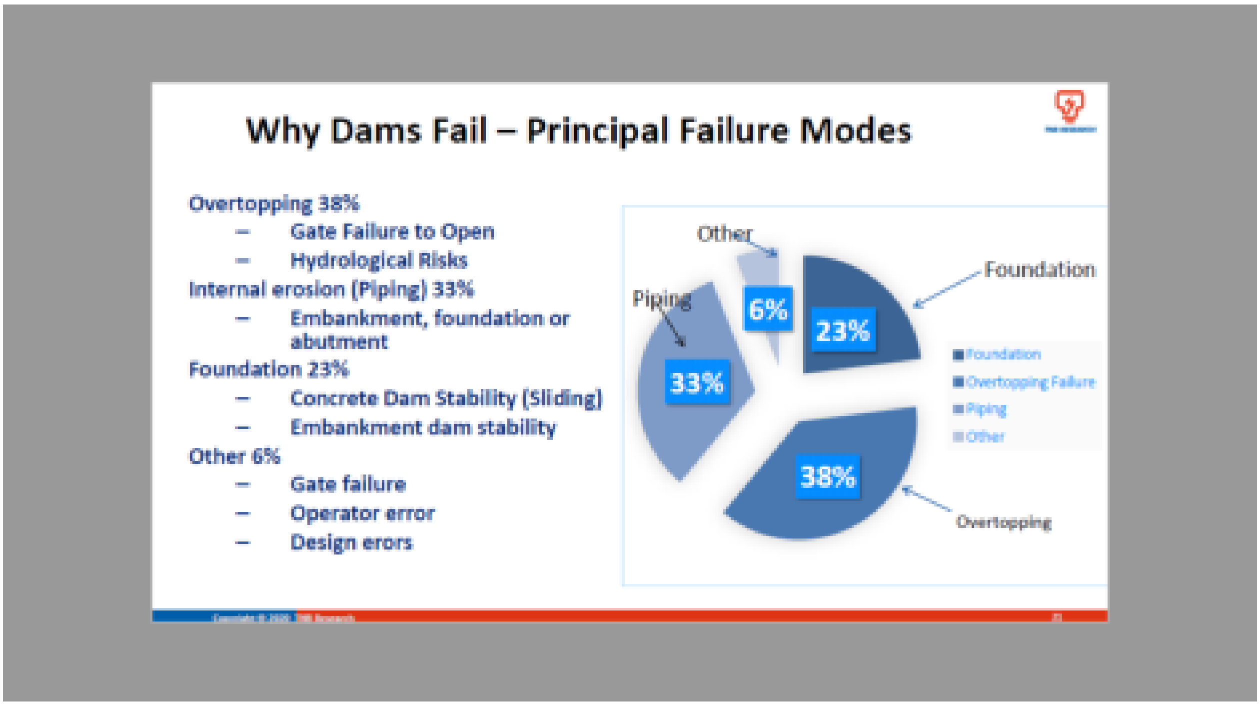


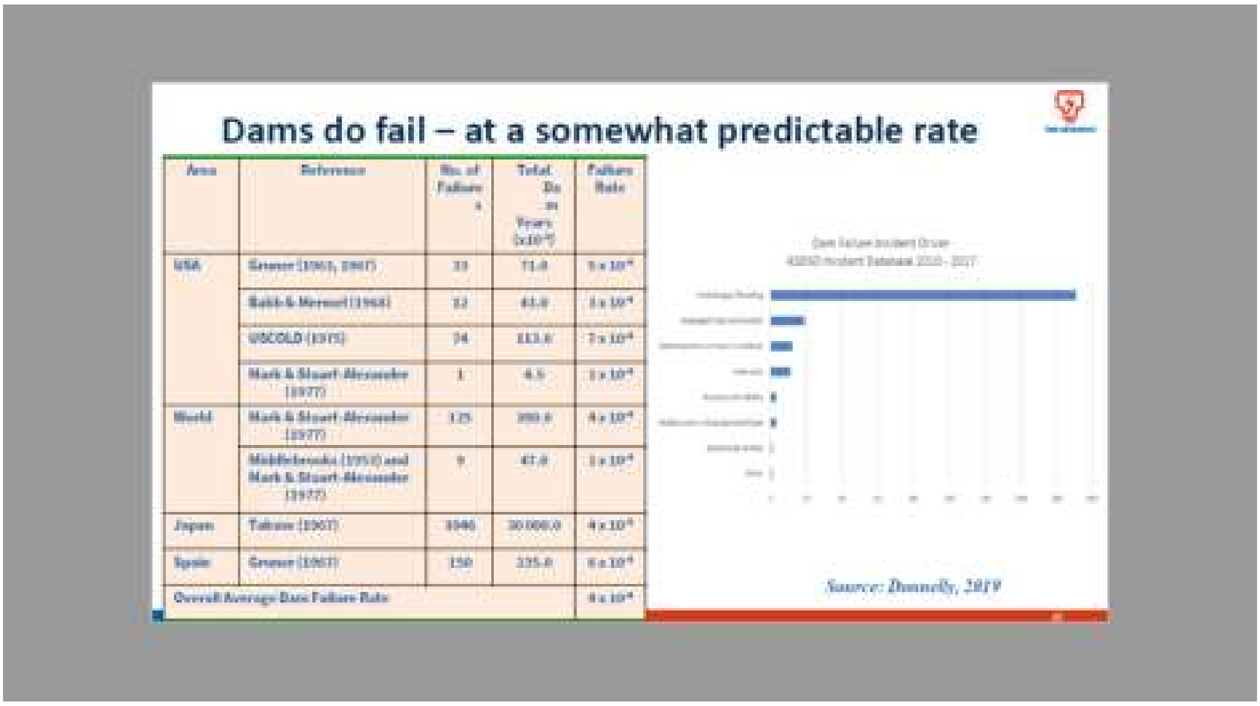
e-ISSN : 2621-7469


ISSUES RELATED TO DAM INFRASTRUCTURE

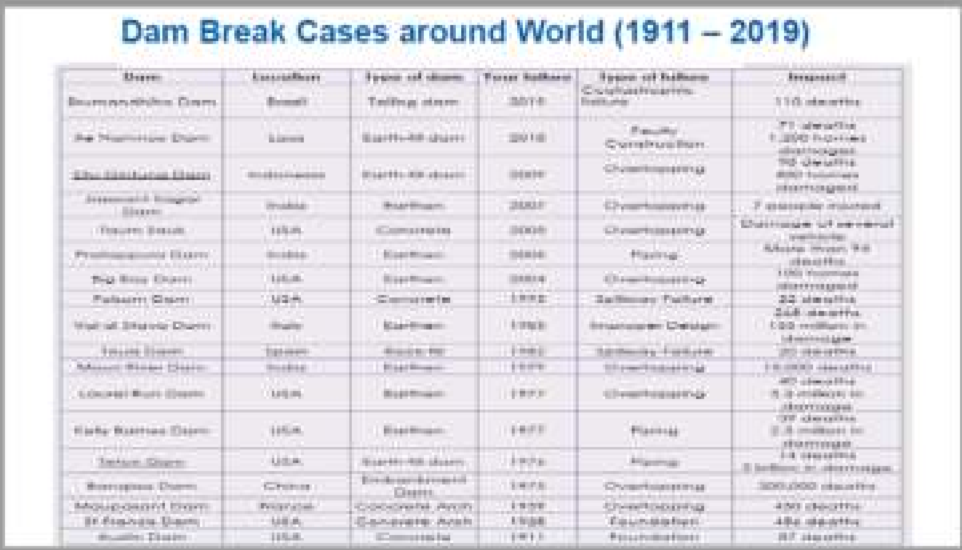

Example Of Dam Failures
Why do we need to monitor dams?
A dam can fail!
There can be major consequences to DAM FAILURE!

e-ISSN : 2621-7469



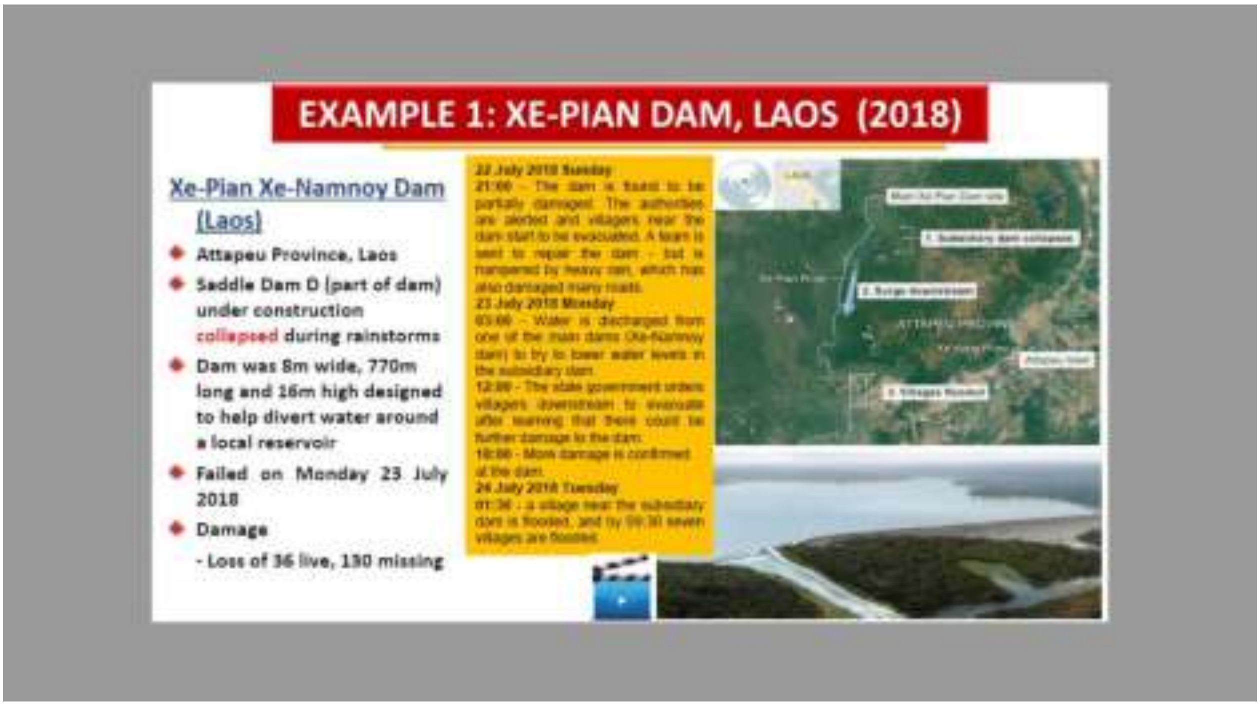


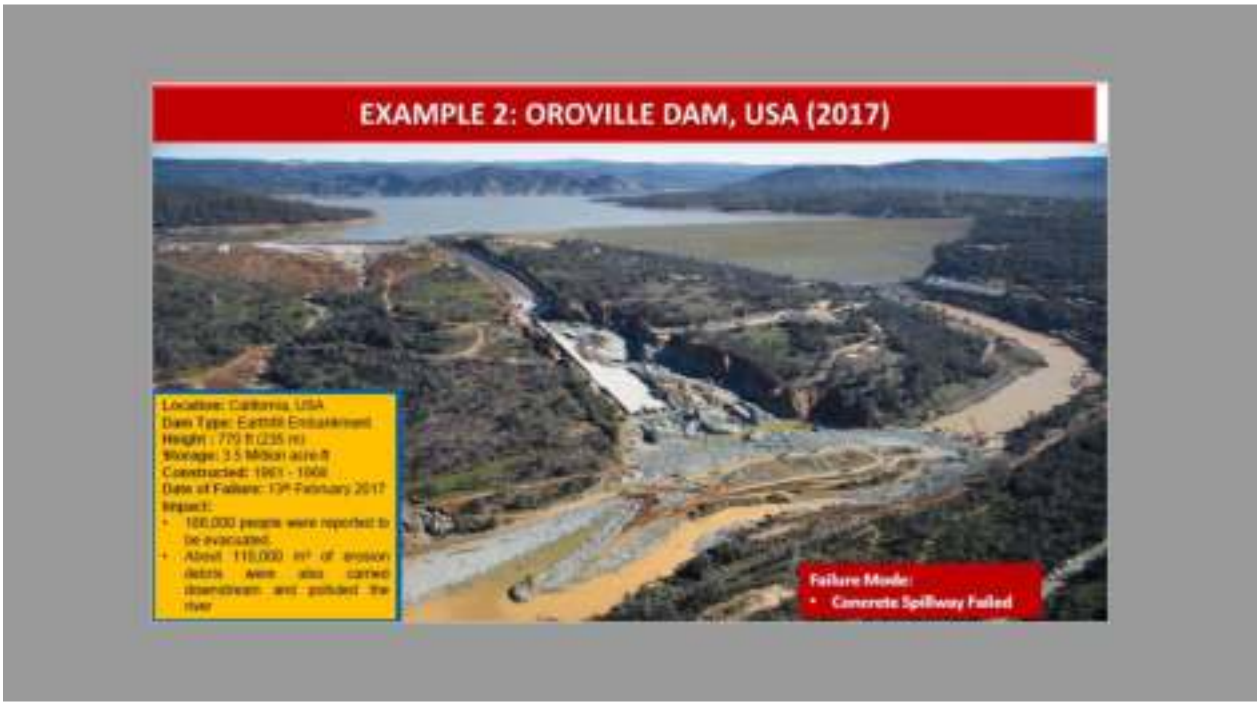
e-ISSN : 2621-7469



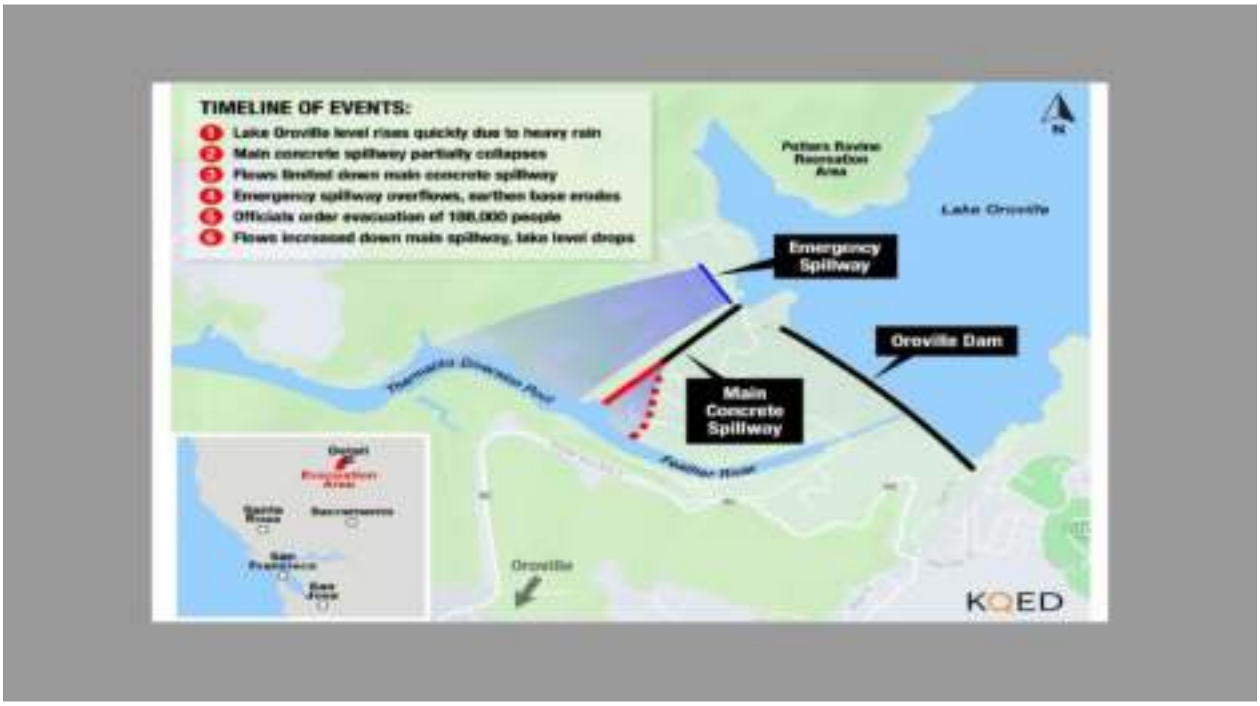
Dam Break Cases around World (1911 – 2019)

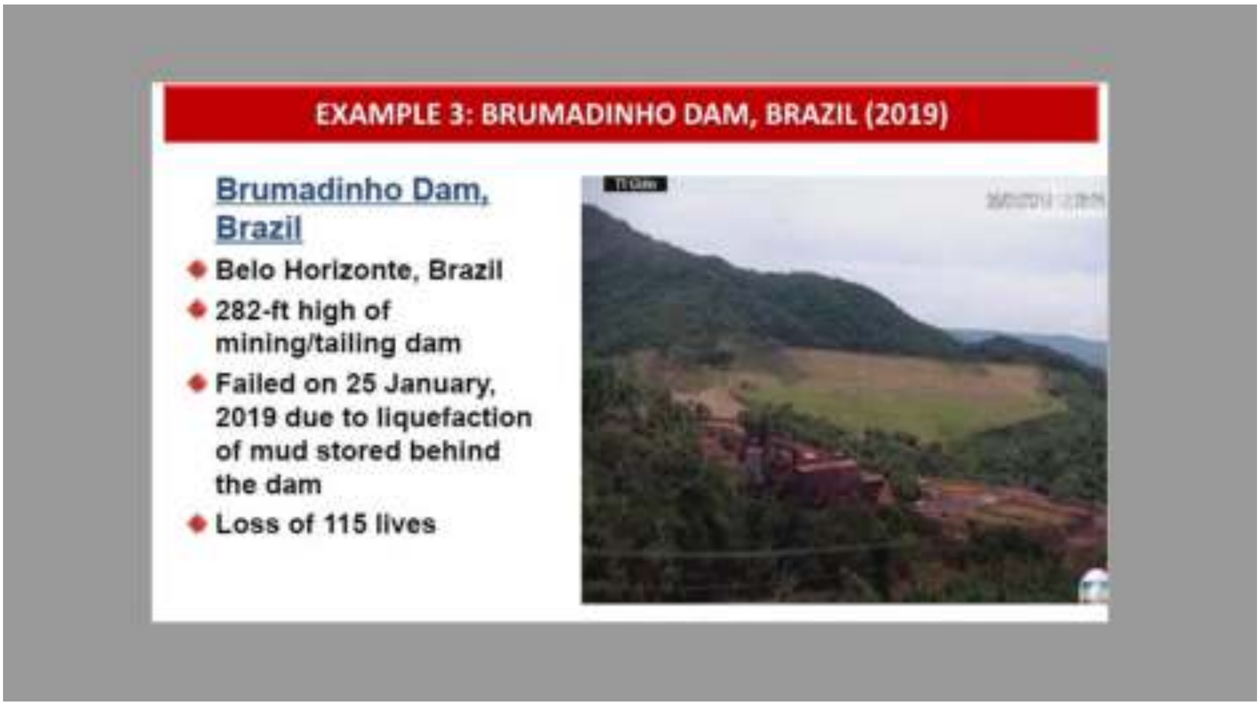
Dam	Location	Type of dam	Year failure	Type of failure	Impact
Brumadinho Dam	Brazil	Tailing dam	2019	[illegible]	110 deaths
Xe Namnoy Dam	Laos	Earth-fill dam	2018	Faulty Construction	71 deaths 1,200 homes damaged
Situ Gintung Dam	Indonesia	Earth-fill dam	2009	Overtopping	98 deaths 850 homes damaged
Jaswant Sagar Dam	India	Earthen	2007	Overtopping	7 people moved
Taum Sauk	USA	Concrete	2005	Overtopping	Damage of several vehicle
[illegible] Dam	India	Earthen	[illegible]	Piping	More than 50 deaths
Big Bay Dam	USA	Earthen	2004	Overtopping	100 homes damaged
Folsom Dam	USA	Concrete	1995	Spillway Failure	22 deaths
Val di Stava Dam	Italy	Earthen	1985	Improper Design	268 deaths 133 million in damage
Tous Dam	Spain	Rock fill	1982	Spillway Failure	20 deaths
Machhu River Dam	India	Earthen	1979	Overtopping	15,000 deaths
Laurel Run Dam	USA	Earthen	1977	Overtopping	40 deaths 5.3 million in damage
Kelly Barnes Dam	USA	Earthen	1977	Piping	39 deaths 2.5 million in damage
Teton Dam	USA	Earth-fill dam	1976	Piping	14 deaths 1 billion in damage
Banqiao Dam	China	Embankment Dam	1975	Overtopping	230,000 deaths
Malpasset Dam	France	Concrete Arch	1959	Overtopping	450 deaths
St Francis Dam	USA	Concrete Arch	1928	Foundation	431 deaths
Austin Dam	USA	Concrete	1911	Foundation	87 deaths

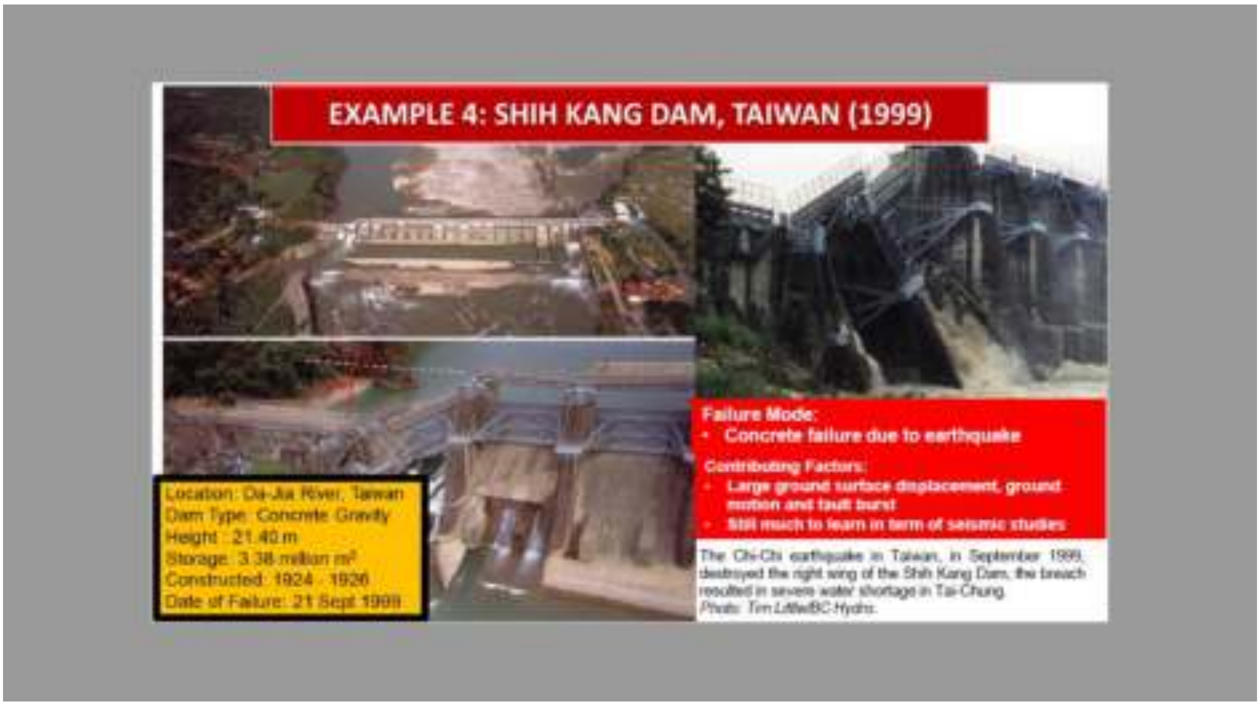

EXAMPLE 1: XE-PIAN DAM, LAOS (2018)
Xe-Pian Xe-Namnoy Dam (Laos)
Attapeu Province, Laos
Saddle Dam D (part of dam) under construction collapsed during rainstorms
Dam was 8m wide, 770m long and 16m high designed to help divert water around a local reservoir
Failed on Monday 23 July 2018
Damage
- Loss of 36 live, 130 missing

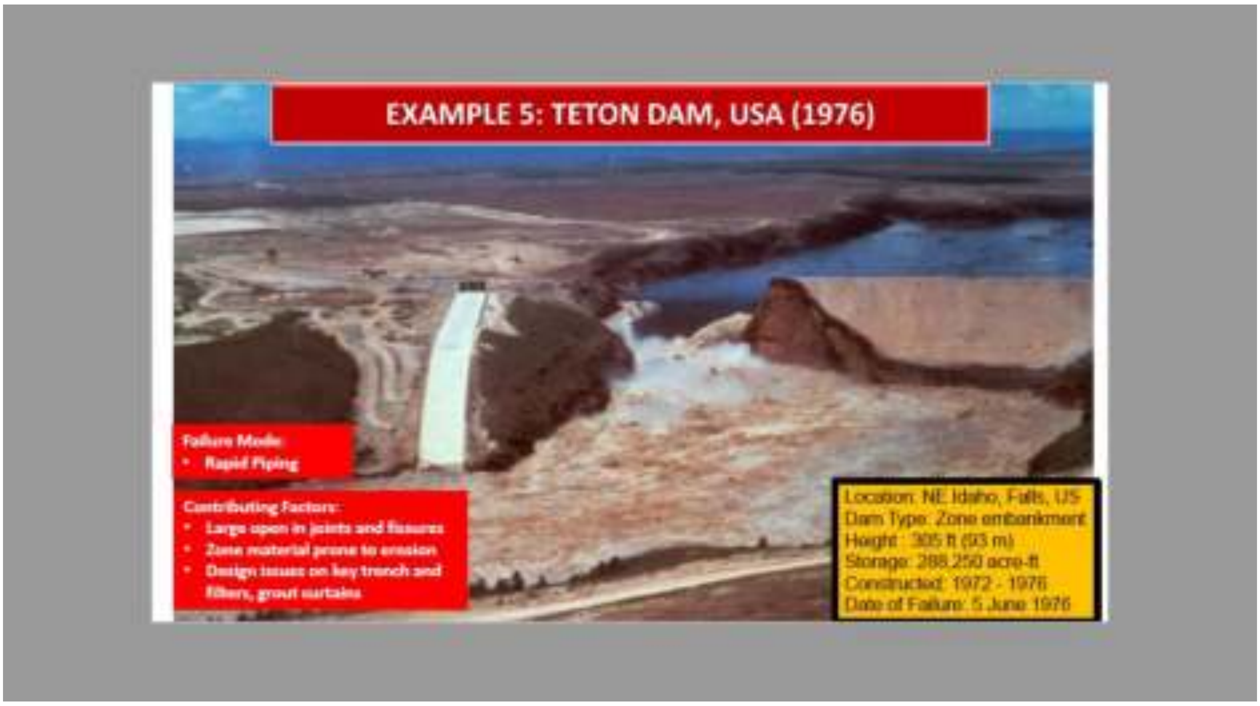

EXAMPLE 2: OROVILLE DAM, USA (2017)
Failure Mode:
Concrete Spillway Failed

e-ISSN : 2621-7469

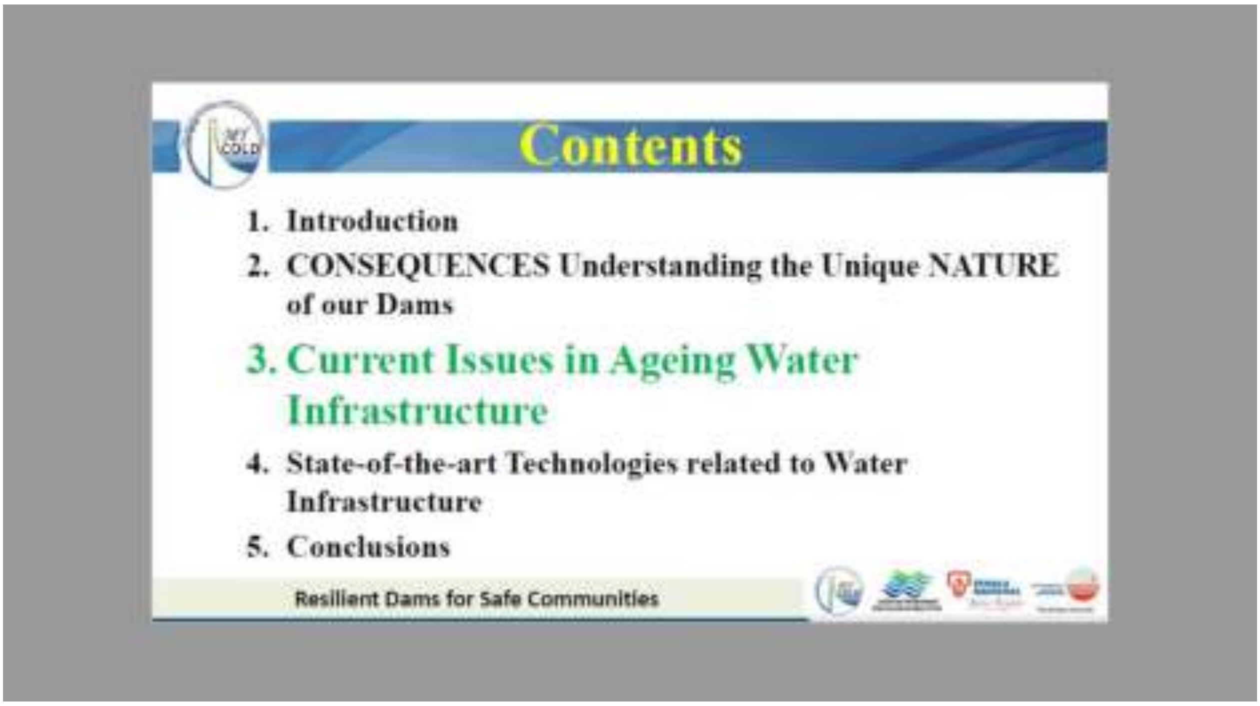


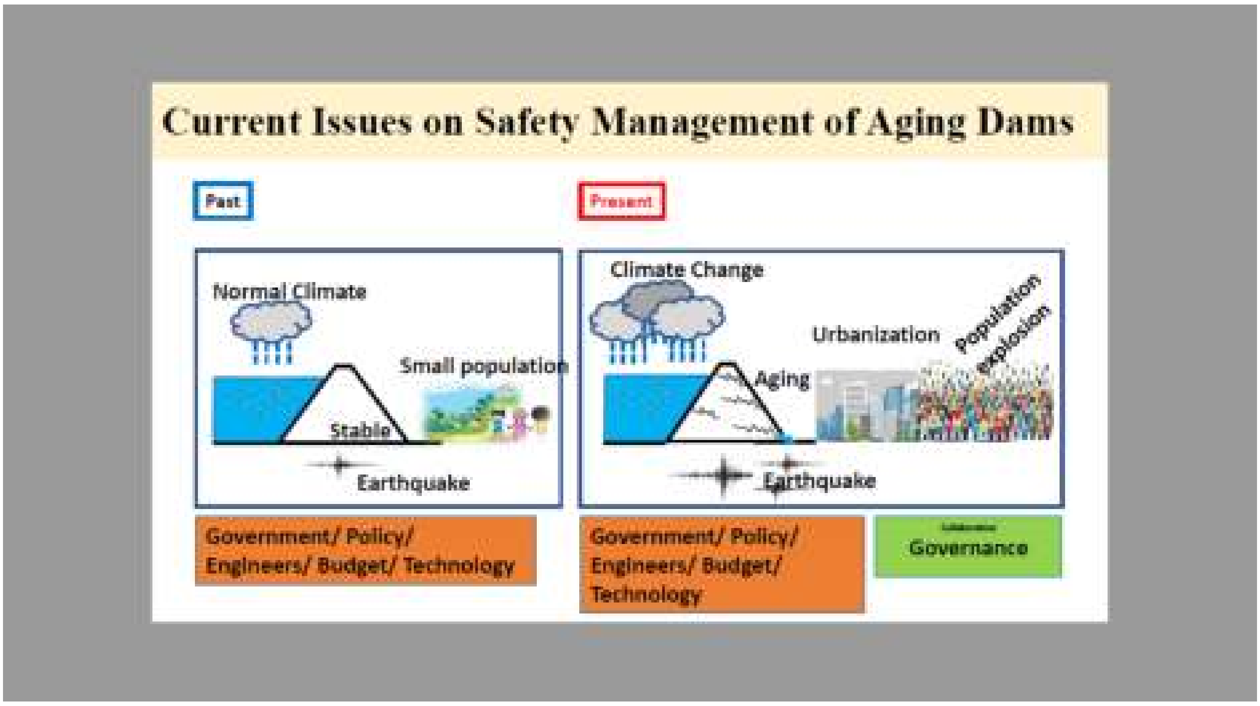


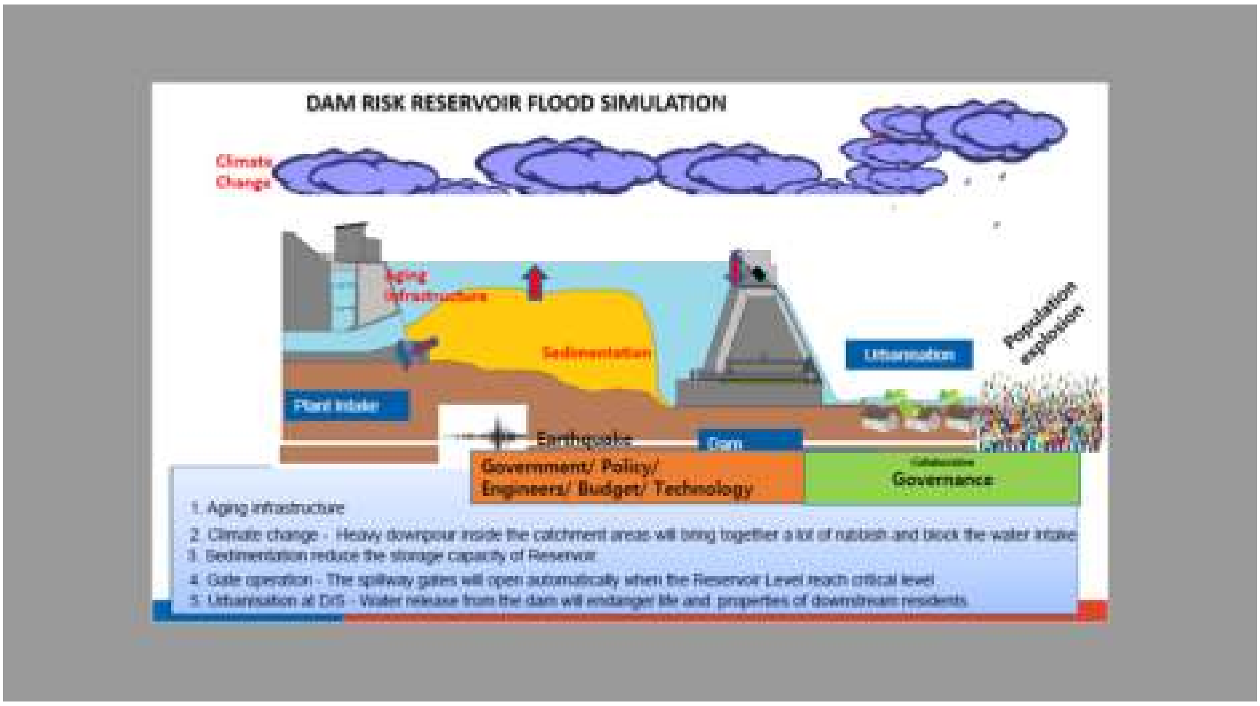

EXAMPLE 4: SHIH KANG DAM, TAIWAN (1999)
Failure Mode:
• Concrete failure due to earthquake
Contributing Factors:
• Large ground surface displacement, ground motion and fault burst
• Still much to learn in term of seismic studies
The Chi-Chi earthquake in Taiwan, in September 1999, destroyed the right wing of the Shih Kang Dam, the breach resulted in severe water shortage in Tai-Chung.
Photo: Tim Little/BC Hydro.
Location: Da-Jia River, Taiwan
Dam Type: Concrete Gravity
Height : 21.40 m
Storage: 3.38 million m³
Constructed: 1924 - 1926
Date of Failure: 21 Sept 1999


EXAMPLE 5: TETON DAM, USA (1976)
Failure Mode:
• Rapid Piping
Contributing Factors:
• Large open in joints and fissures
• Zone material prone to erosion
• Design issues on key trench and filters, grout curtains
Location: NE Idaho, Falls, US
Dam Type: Zone embankment
Height : 305 ft (93 m)
Storage: 288.250 acre-ft
Constructed: 1972 - 1976
Date of Failure: 5 June 1976

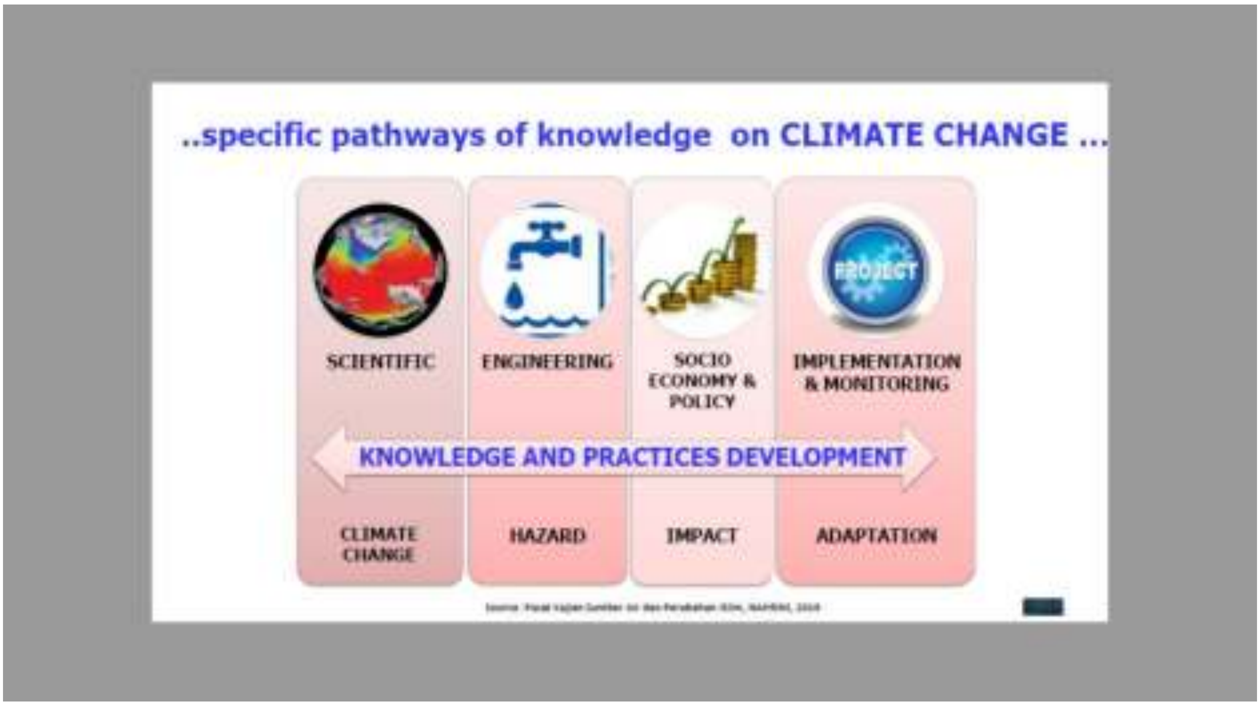

DISASTER WAITING TO HAPPEN.....
WARNING
Can we predict them??
Are we in DANGER??

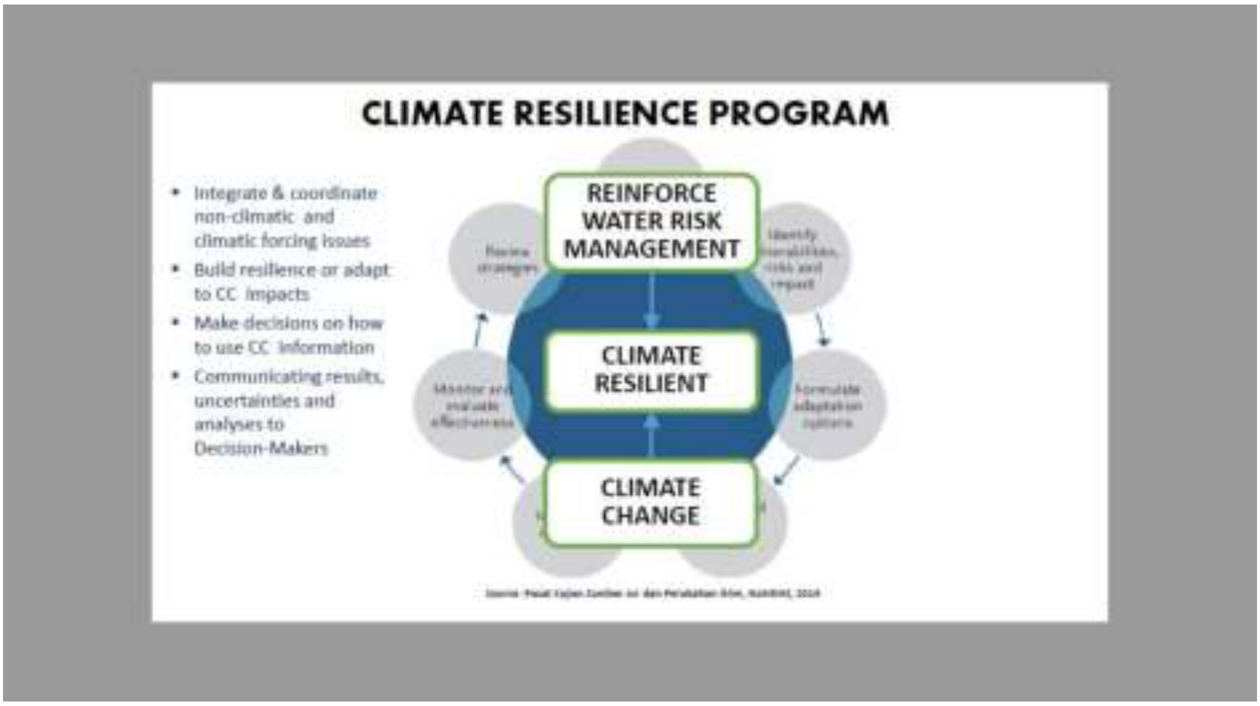

Contents
1. Introduction
2. CONSEQUENCES Understanding the Unique NATURE of our Dams
3. Current Issues in Ageing Water Infrastructure
4. State-of-the-art Technologies related to Water Infrastructure
5. Conclusions
Resilient Dams for Safe Communities

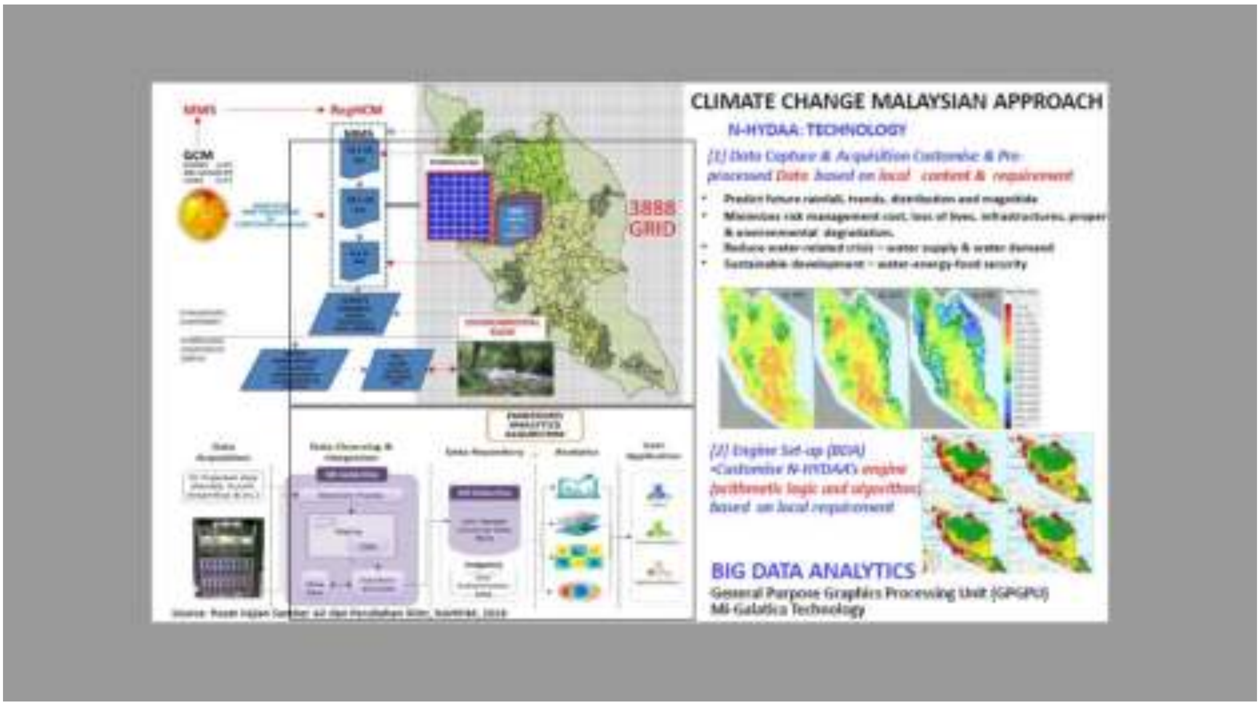

Current Issues on Safety Management of Aging Dams
Past
Present
Normal Climate
Small population
Stable
Earthquake
Climate Change
Urbanization
Population explosion
Aging
Earthquake
Government/ Policy/ Engineers/ Budget/ Technology
Government/ Policy/ Engineers/ Budget/ Technology
Governance


DAM RISK RESERVOIR FLOOD SIMULATION
Climate Change
Aging Infrastructure
Sedimentation
Urbanization
Population explosion
Plant Intake
Earthquake
Dam
Government/ Policy/ Engineers/ Budget/ Technology
Governance
1. Aging infrastructure
2. Climate change - Heavy downpour inside the catchment areas will bring together a lot of rubbish and block the water intake
3. Sedimentation reduce the storage capacity of Reservoir
4. Gate operation - The spillway gates will open automatically when the Reservoir Level reach critical level
5. Urbanisation at D/S - Water release from the dam will endanger life and properties of downstream residents

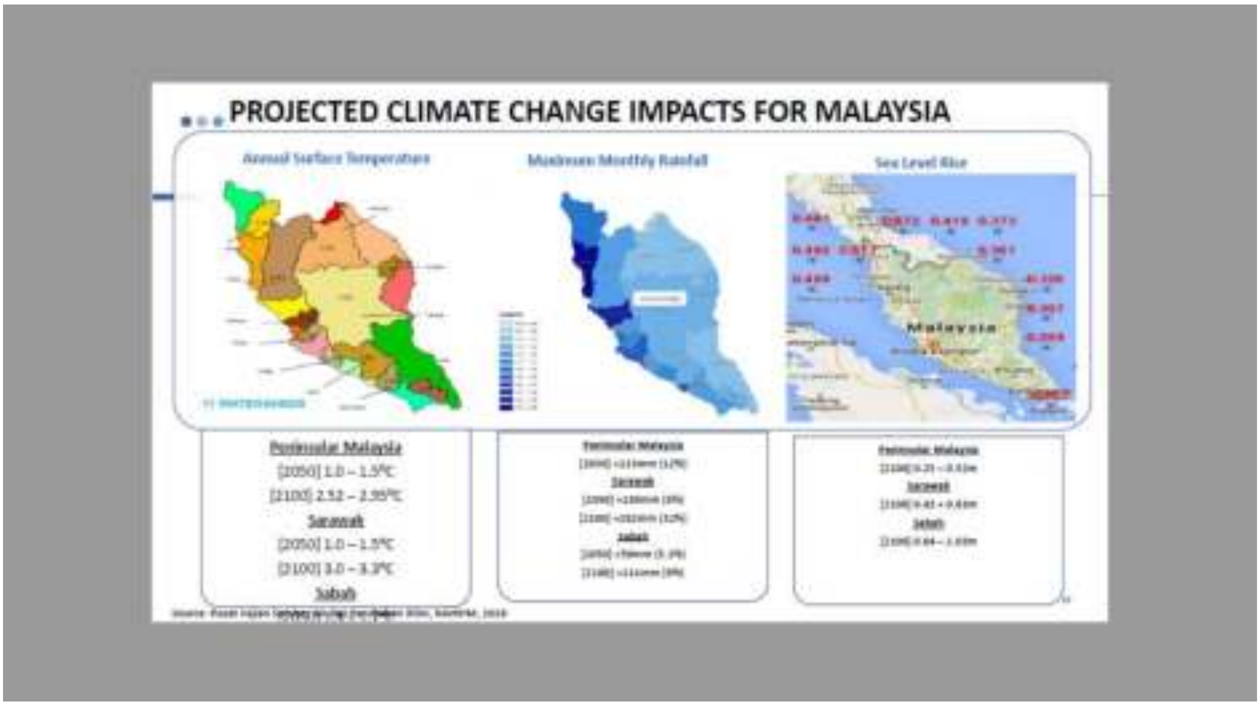

Resilience Recognizes and Adapts to ....
Changing Conditions of Dam Safety
Resilient Dams for Safe Communities
Ageing of existing infrastructure
New countries are now building dams
New Dams
New Engineers
Increasing influence of the private sector
A New Governance
Climate Change
Resilience and Environmental Awareness

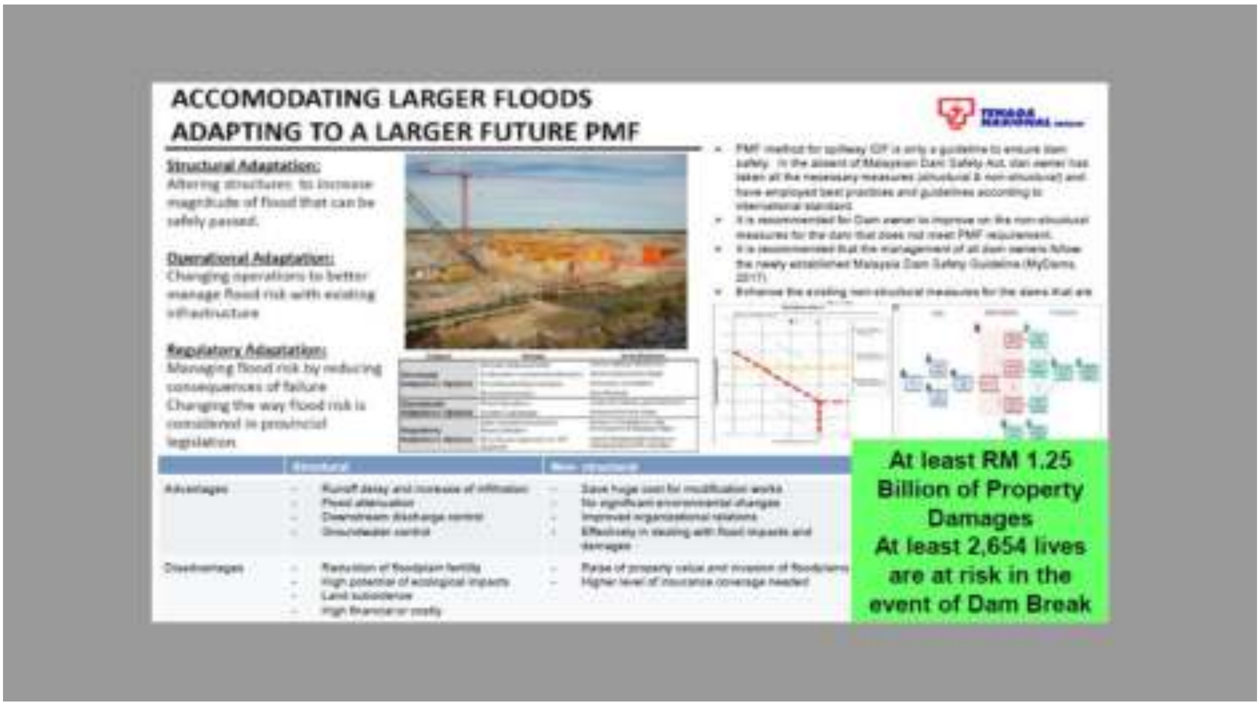

..specific pathways of knowledge on CLIMATE CHANGE ...
SCIENTIFIC
ENGINEERING
SOCIO ECONOMY & POLICY
IMPLEMENTATION & MONITORING
PROJECT
KNOWLEDGE AND PRACTICES DEVELOPMENT
CLIMATE CHANGE
HAZARD
IMPACT
ADAPTATION

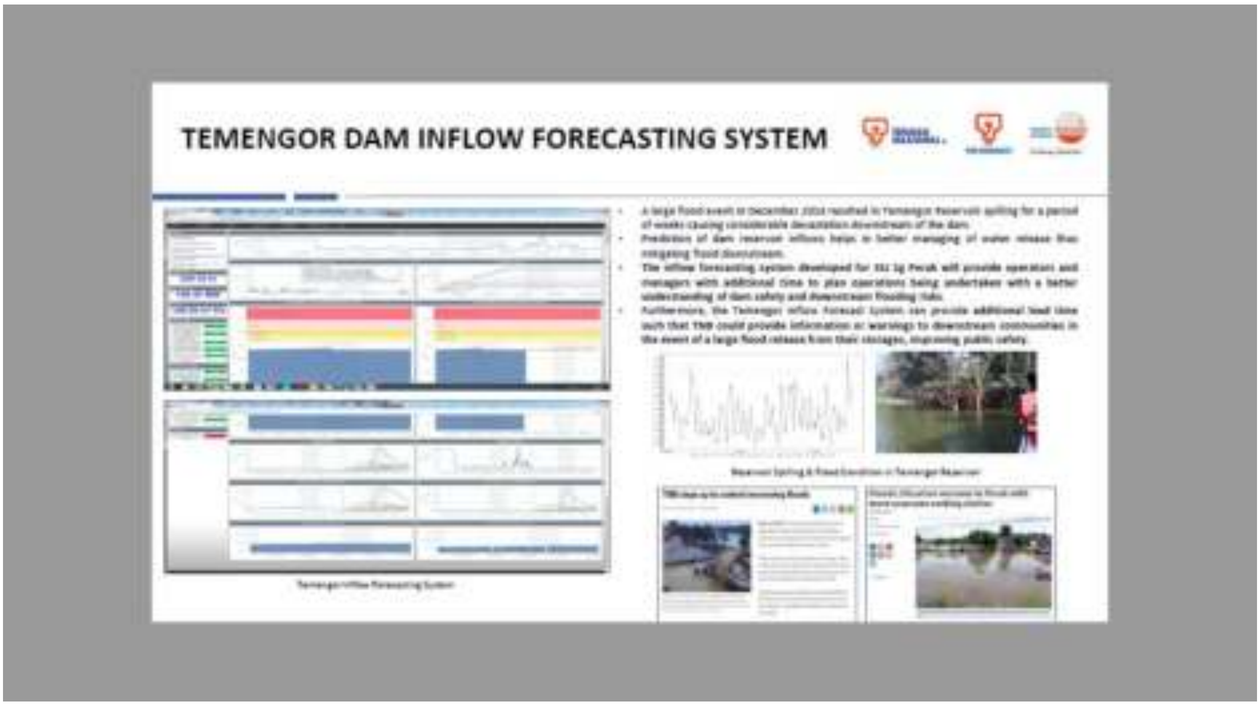

CLIMATE RESILIENCE PROGRAM
Integrate & coordinate non-climatic and climatic forcing issues
Build resilience or adapt to CC impacts
Make decisions on how to use CC information
Communicating results, uncertainties and analyses to Decision-Makers
REINFORCE WATER RISK MANAGEMENT
CLIMATE RESILIENT
CLIMATE CHANGE

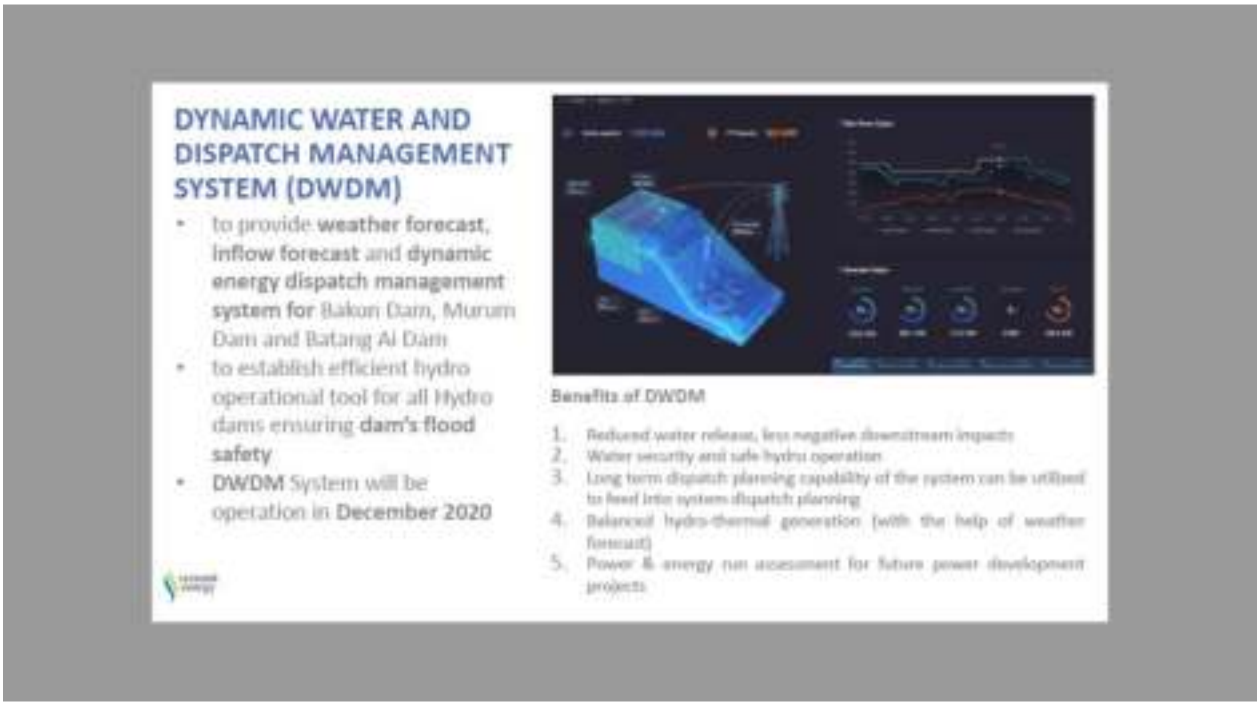

CLIMATE CHANGE MALAYSIAN APPROACH
N-HYDAA TECHNOLOGY
3888 GRID
BIG DATA ANALYTICS

e-ISSN : 2621-7469




ACCOMODATING LARGER FLOODS
ADAPTING TO A LARGER FUTURE PMF
Structural Adaptation:
Altering structures to increase magnitude of flood that can be safely passed.
Operational Adaptation:
Changing operations to better manage flood risk with existing infrastructure
Regulatory Adaptation:
Managing flood risk by reducing consequences of failure
Changing the way flood risk is considered in provincial legislation
At least RM 1.25 Billion of Property Damages
At least 2,654 lives are at risk in the event of Dam Break


TEMENGOR DAM INFLOW FORECASTING SYSTEM

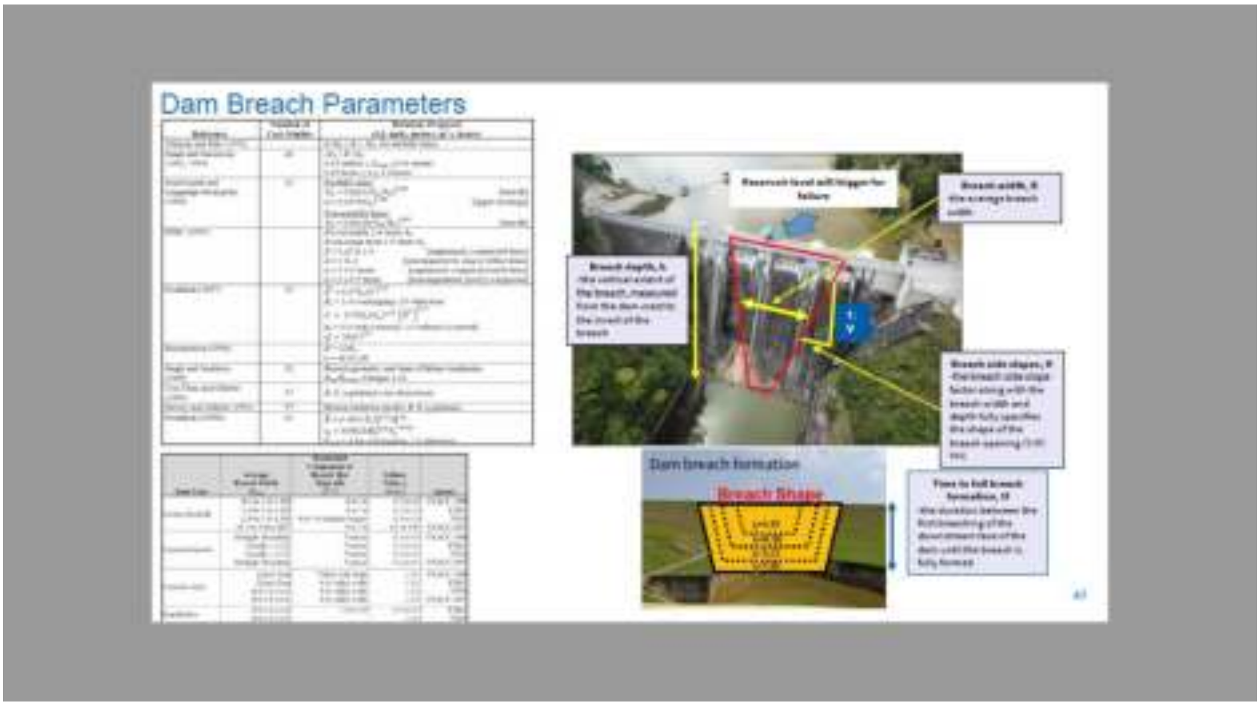

DYNAMIC WATER AND DISPATCH MANAGEMENT SYSTEM (DWDM)
to provide weather forecast, inflow forecast and dynamic energy dispatch management system for Bakun Dam, Murum Dam and Batang Ai Dam
to establish efficient hydro operational tool for all Hydro dams ensuring dam's flood safety
DWDM System will be operation in December 2020
Benefits of DWDM

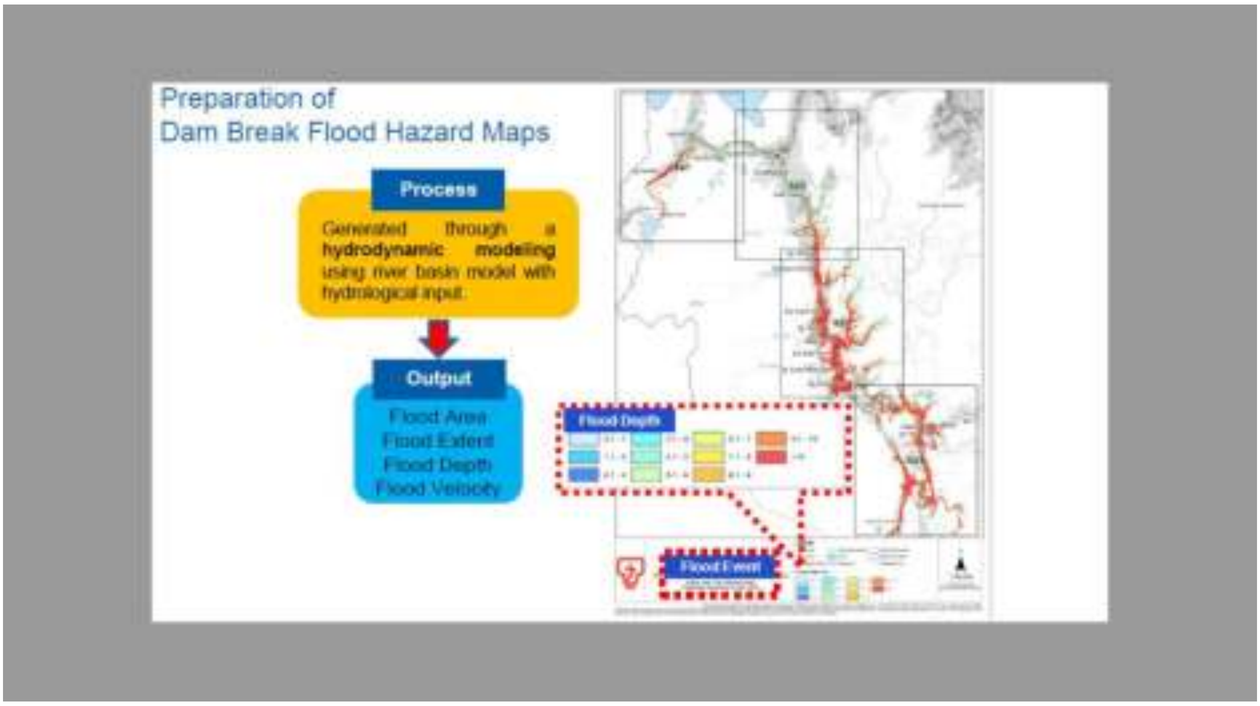

DAM SAFETY ERP PROGRAM FOR TNB HYDROPOWER SCHEME


INTEGRATED COMMUNITY-BASED DISASTER
MANAGEMENT (ICBDM) FOR DAM SAFETY

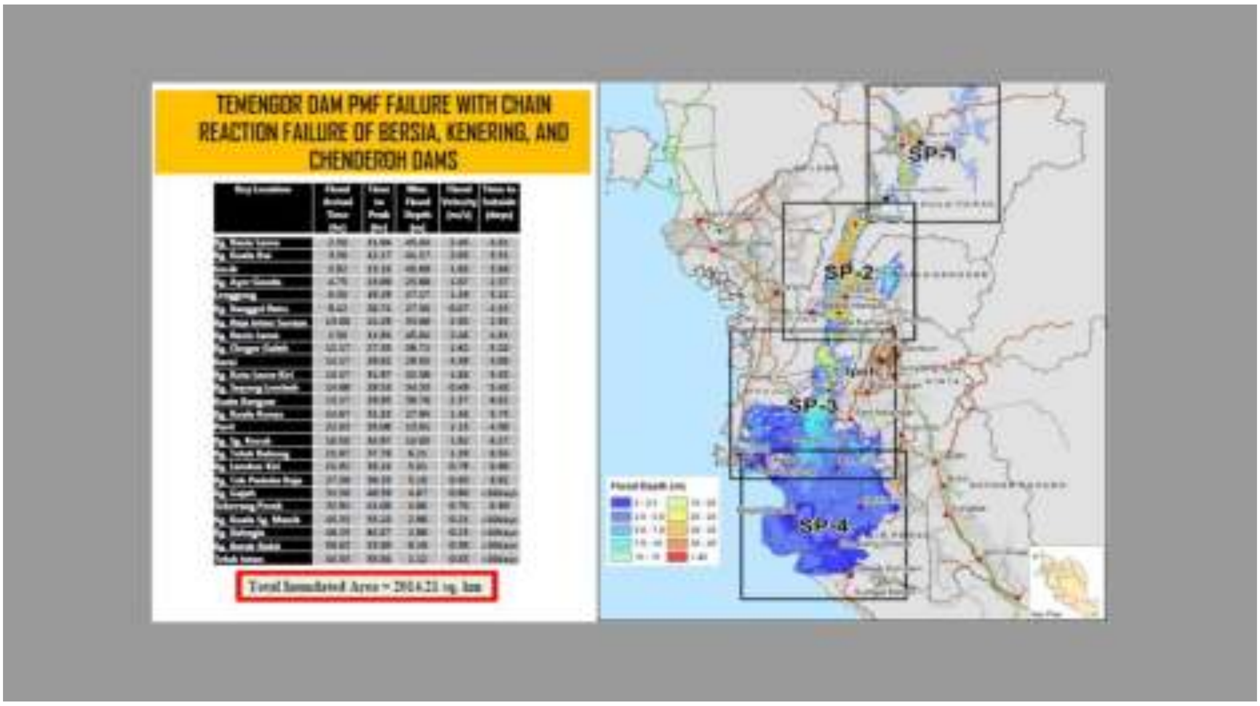

SCENARIO
TEMENGOR DAM PMF FAILURE WITH CHAIN REACTION
FAILURE OF BERSIA, KENERING, AND CHENDEROH DAMS

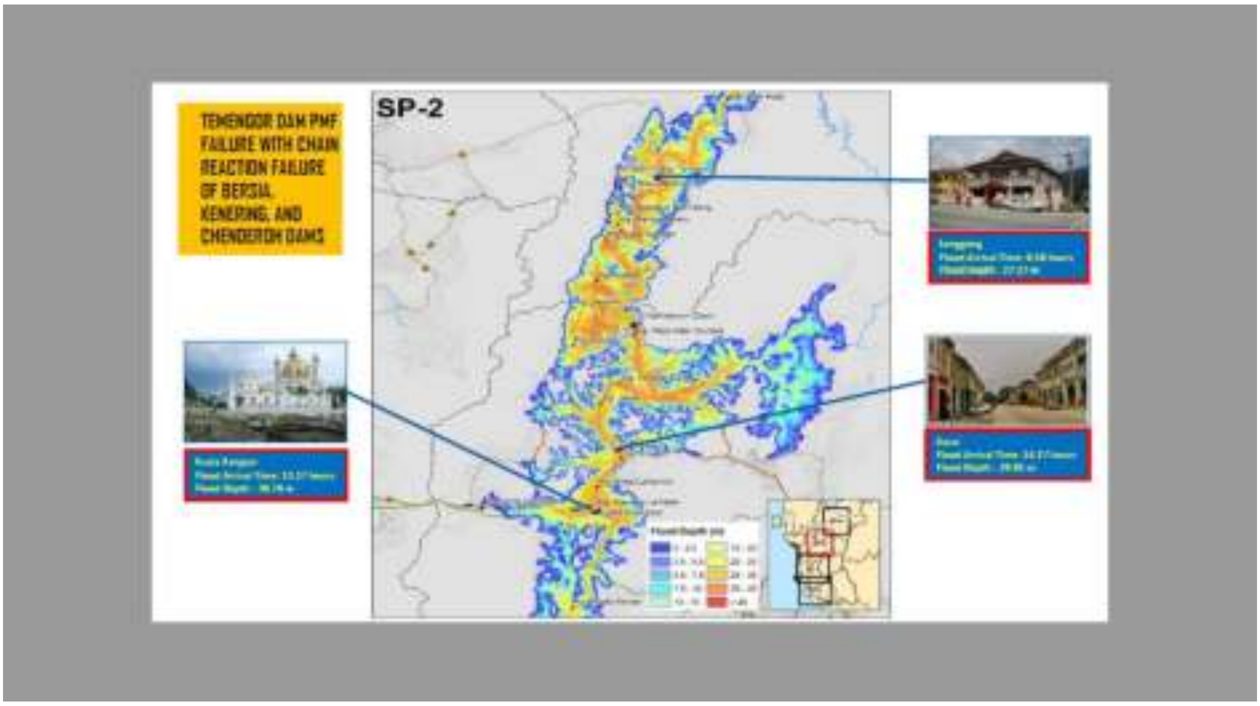
e-ISSN : 2621-7469



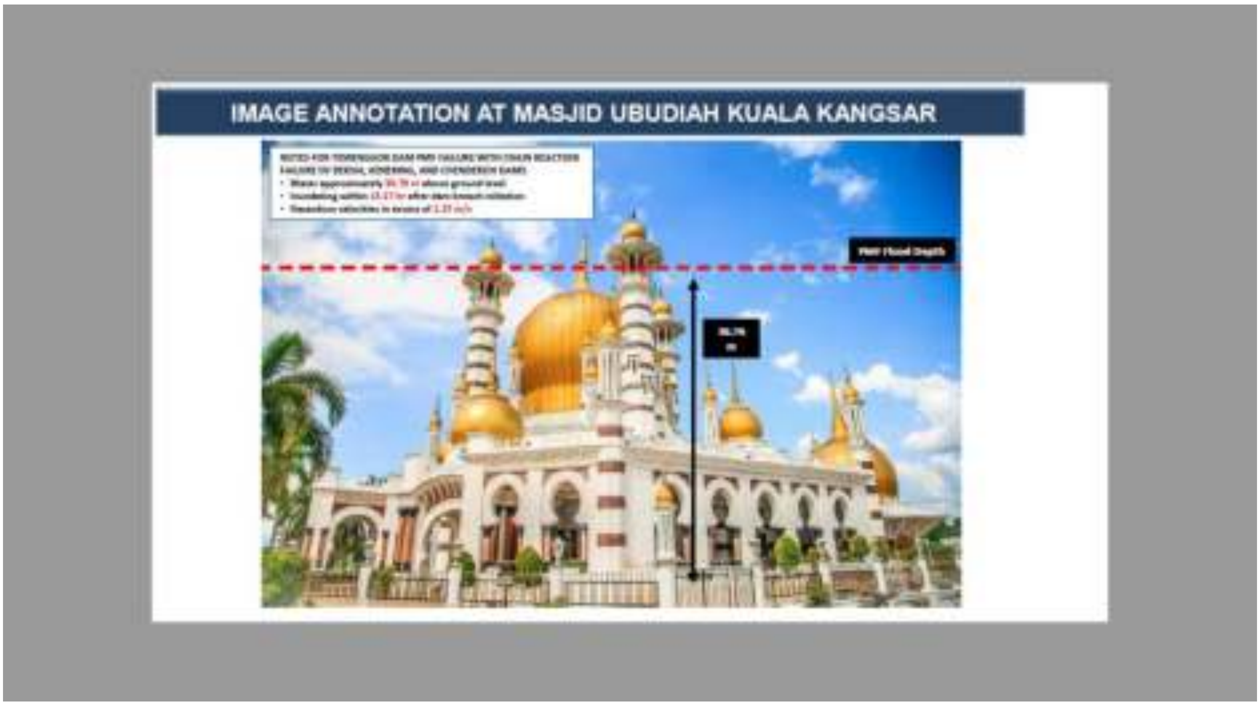


e-ISSN : 2621-7469



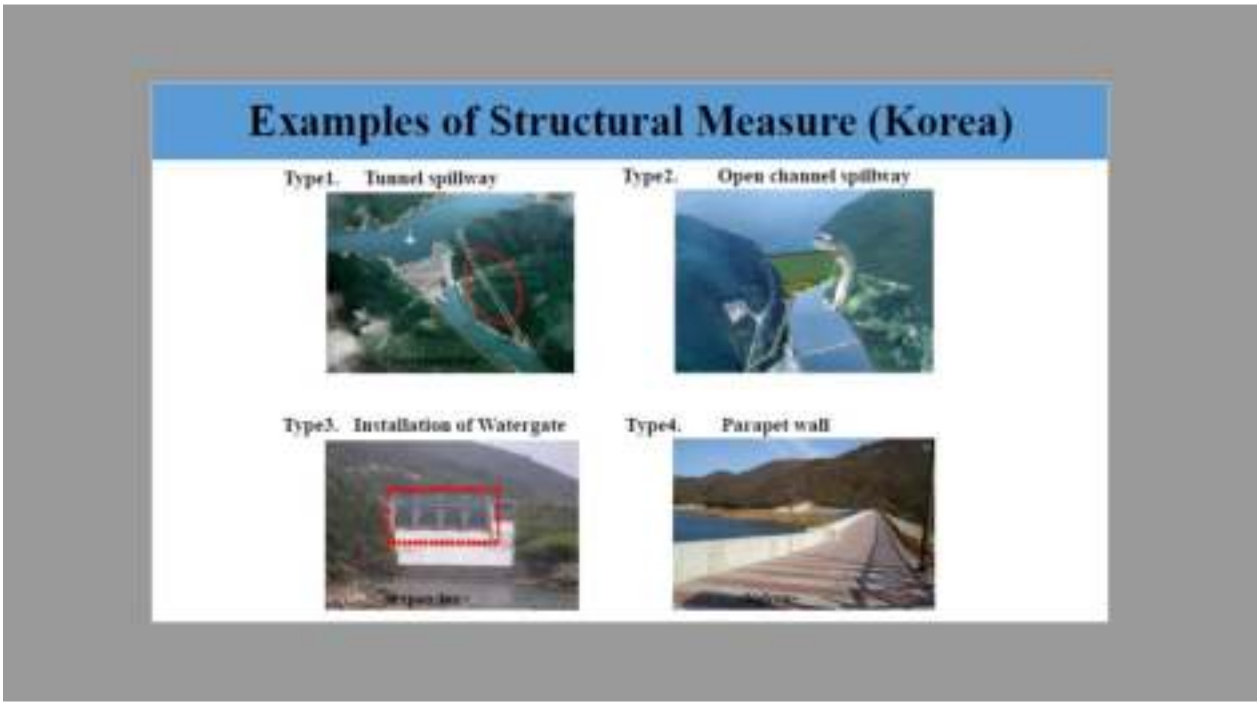


e-ISSN : 2621-7469



e-ISSN : 2621-7469


Country: South Korea
Sung-ju Dam Reinforced by PMF in 2003 after TYPHOON STORM RUSA
New Emergency Spillway
Heightening Embankment 2.6m
New Storage Volume
Existing Spillway
New Emergency Spillway Outlet
Intake Tower


Examples of Structural Measure (Korea)
Type1. Tunnel spillway
Type2. Open channel spillway
Type3. Installation of Watergate
Type4. Parapet wall

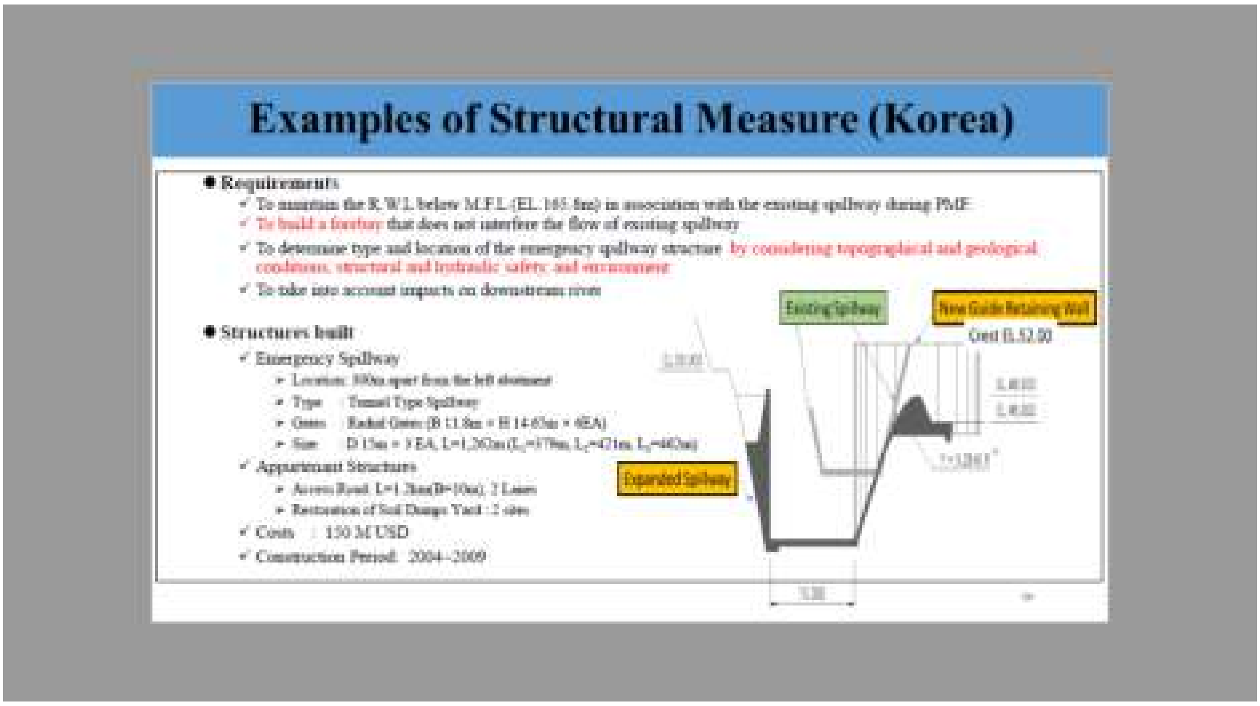
Tunnel Type: Imha Dam

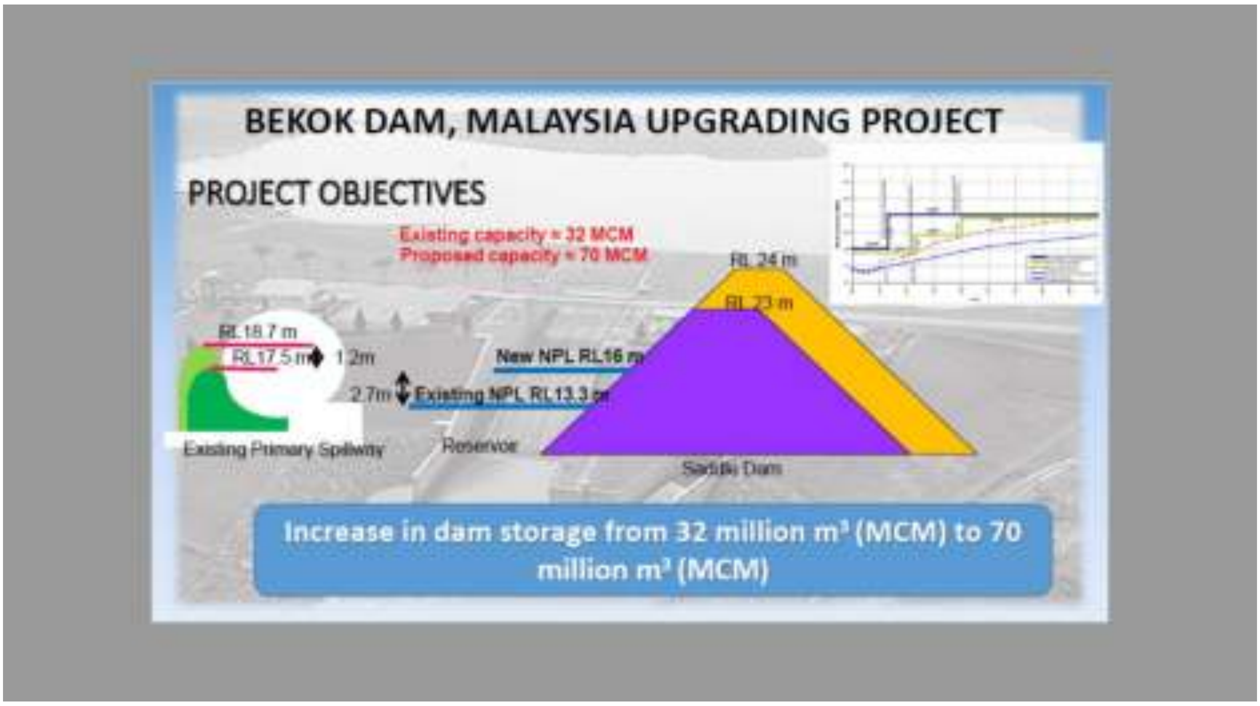
● **Necessity**

✓ The updated design flood exceeds the original design flood based on a 200 year frequency flood, and thus when an inflow of PMF happens, then Imha dam shall be overflowed.

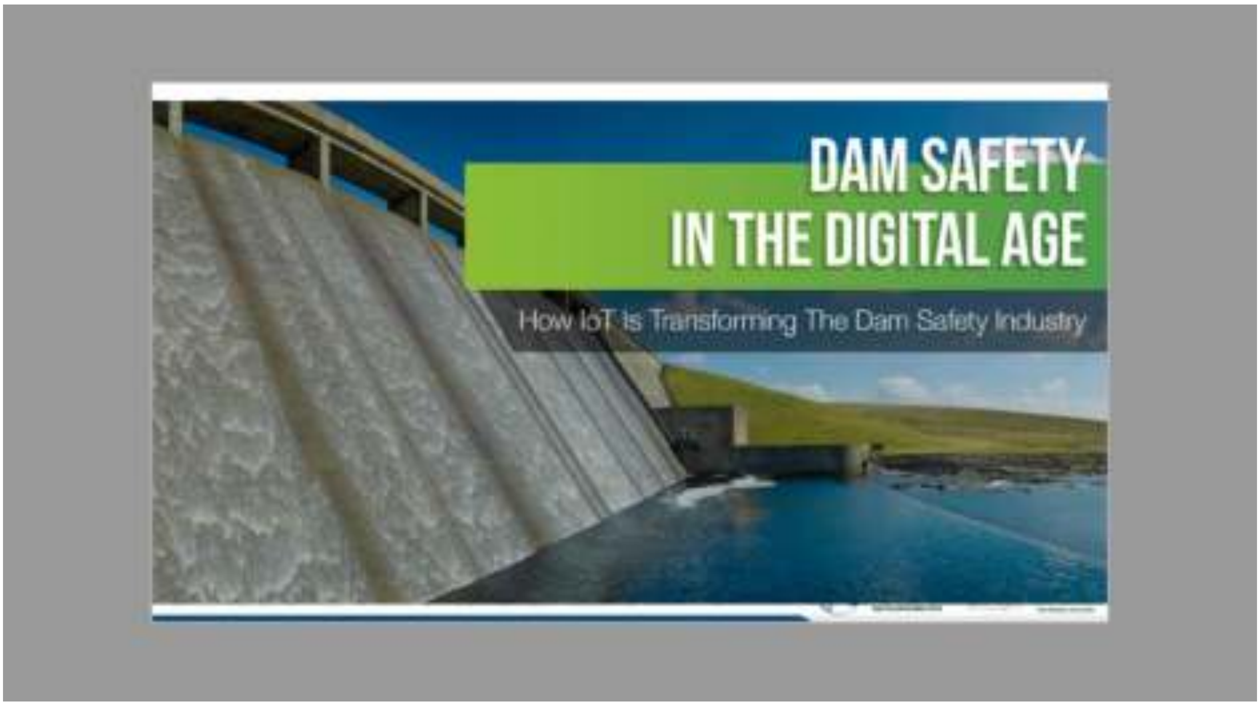
● **Hydrological Safety**

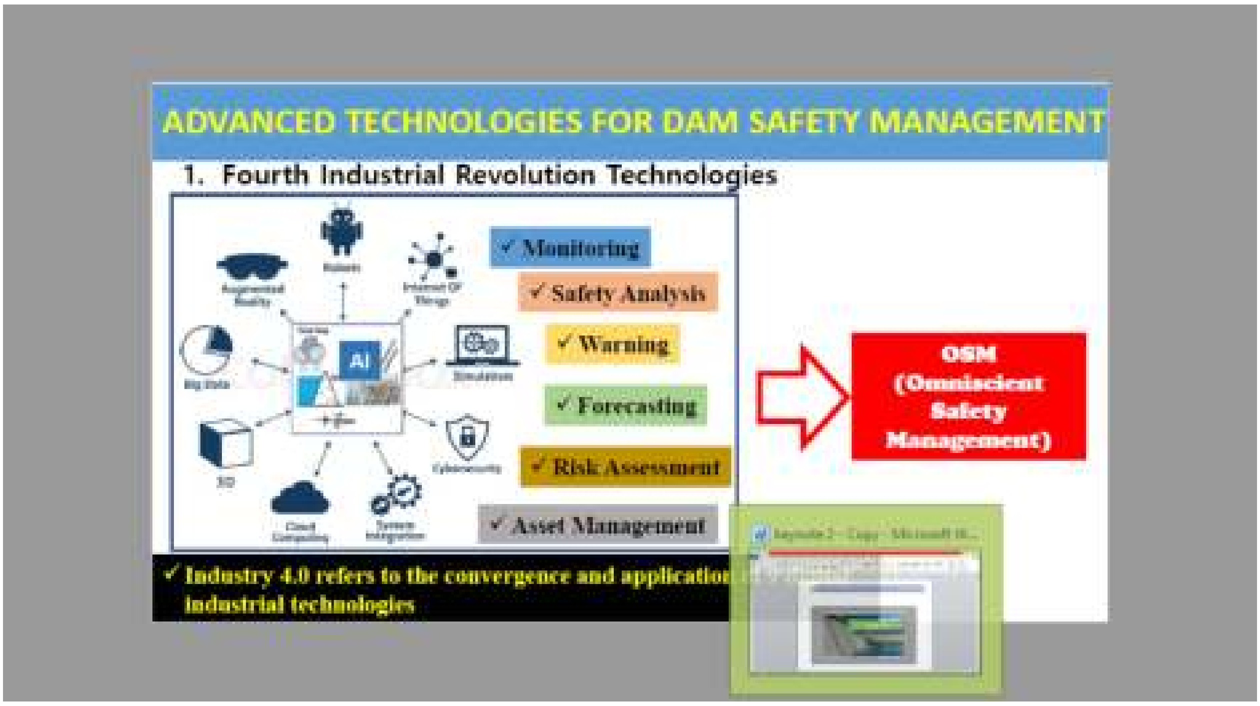
	Original Design	Updated Design		Remarks
		Only Existing Spillway	With Auxiliary Spillway	
Rainfall (mm)	424 (PMP)	561 (PMP)		↑ 137
Design Flood (m³/s)	7,550 (PMF)	14,809 (PMF)		↑ 7,259
Peak Discharge (m³/s)	5,908 (PMF)	8,278 (PMF)	8,213 (PMF) (Existing: 5,133)	↑ 8,600
M.F.L (EL.m)	163.80 (PMF)	170.97	163.63 (PMF)	Overflow (Crest : EL.168.0m)


Examples of Structural Measure (Korea)
Requirements
To take into account impacts on downstream river
Structures built
Emergency Spillway
Type : Tunnel Type Spillway
Appurtenant Structures
Costs : 150 M USD
Construction Period : 2004~2009
Existing Spillway
New Guide Retaining Wall
Crest EL.52.50
Expanded Spillway

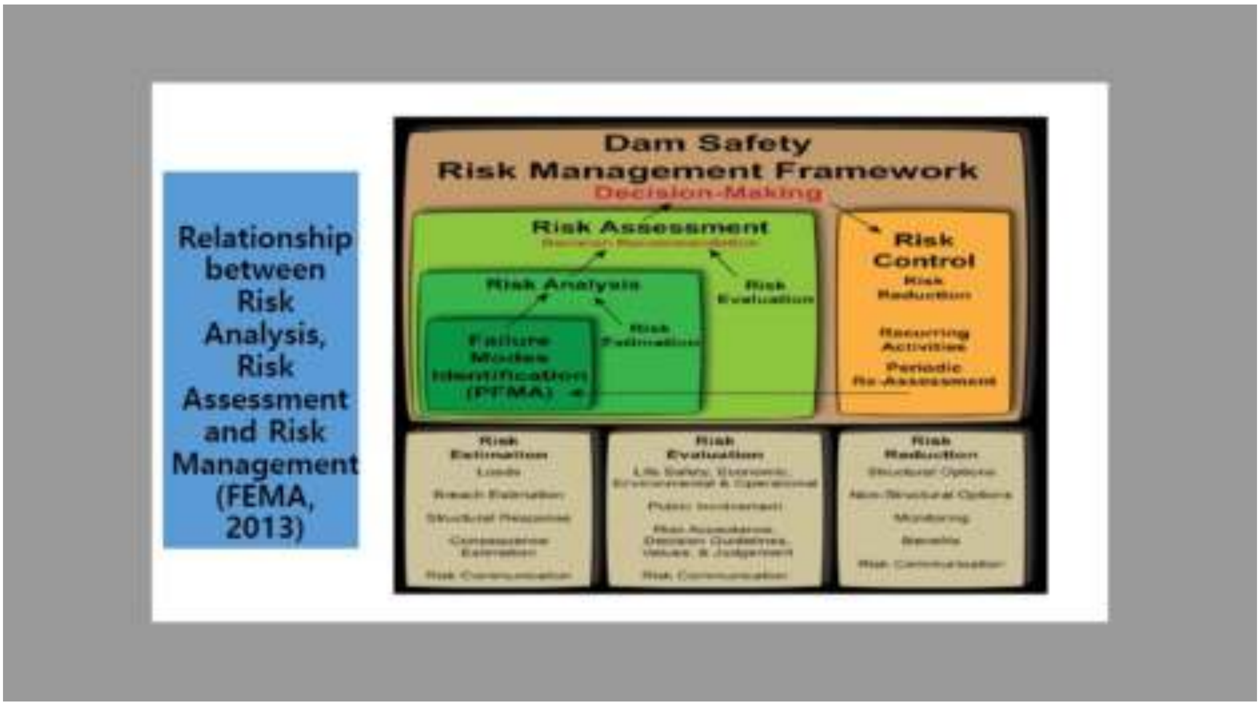

BEKOK DAM, MALAYSIA UPGRADING PROJECT
PROJECT OBJECTIVES
Existing capacity = 32 MCM
Proposed capacity = 70 MCM
RL 24 m
RL 23 m
RL 18.7 m
RL 17.5 m
1.2m
2.7m
New NPL RL16 m
Existing NPL RL13.3 m
Existing Primary Spillway
Reservoir
Saddle Dam
Increase in dam storage from 32 million m³ (MCM) to 70 million m³ (MCM)

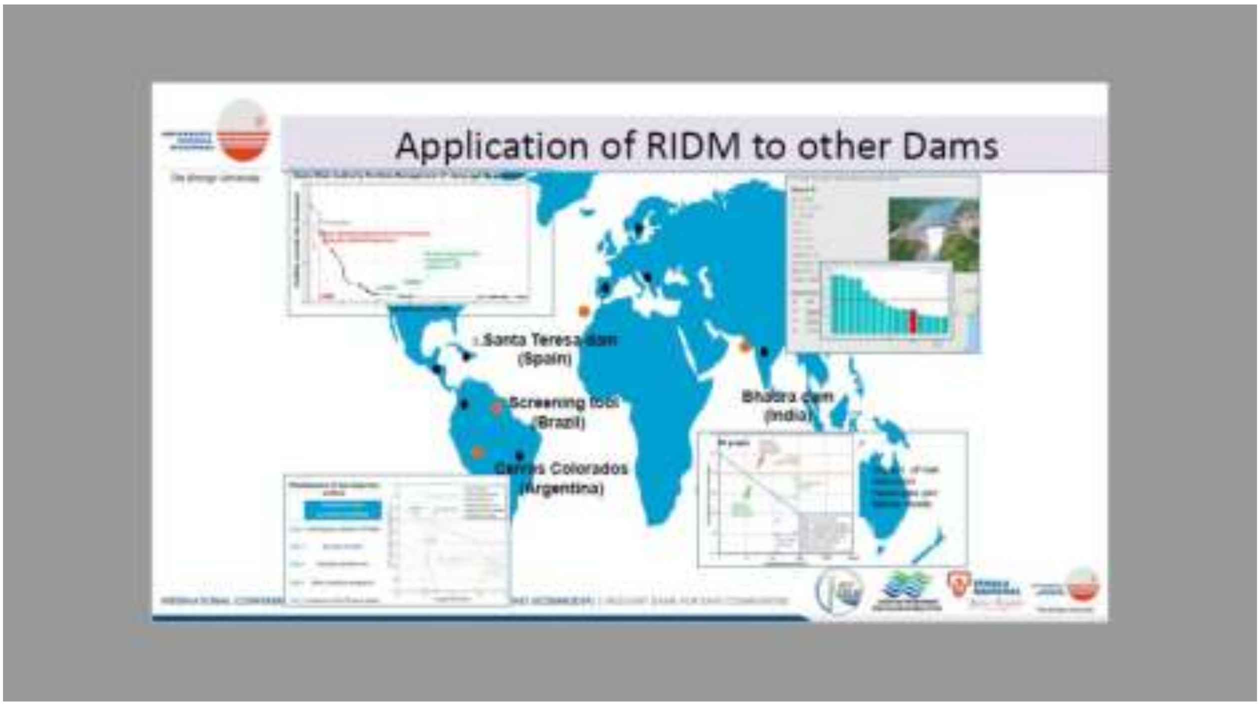
e-ISSN : 2621-7469





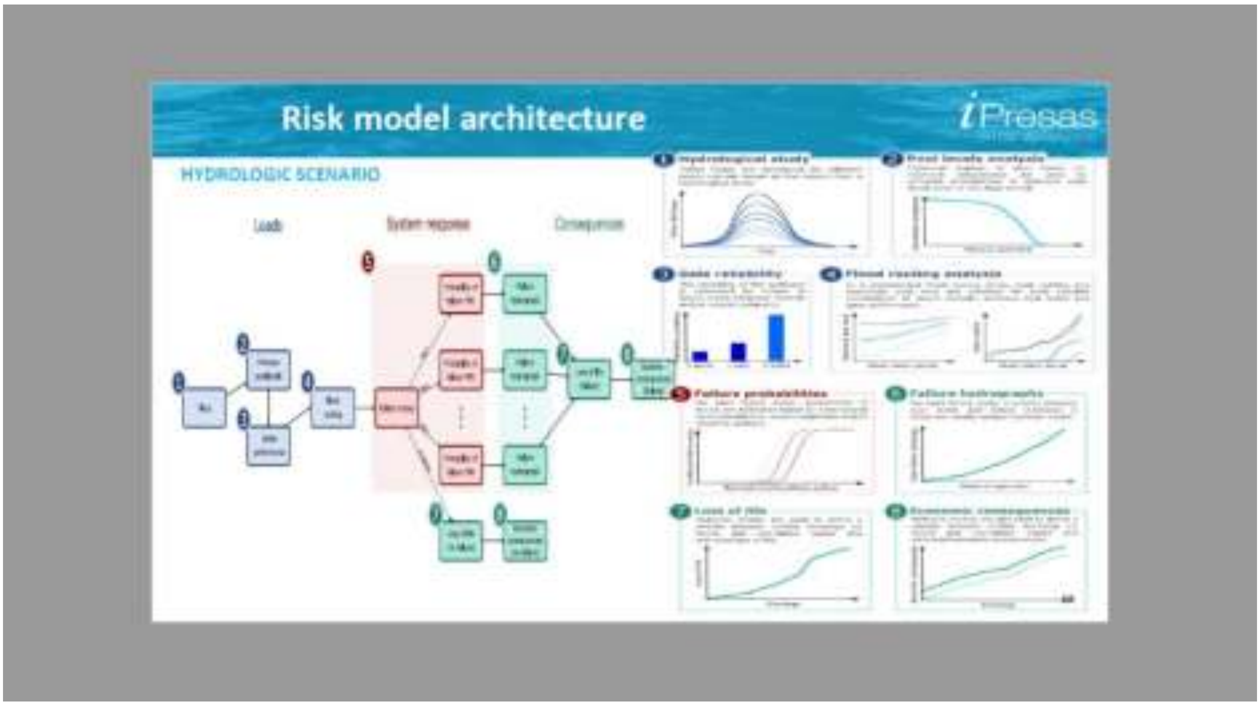

Introduction – risk based safety management
Advanced integrated dam safety management
From deterministic safety evaluation to probabilistic risk management
SAFETY
Dam Safety Paradigm Shift
Change the Dam Safety Approach
RISK
Traditional
Present
Factor of safety
No RISK

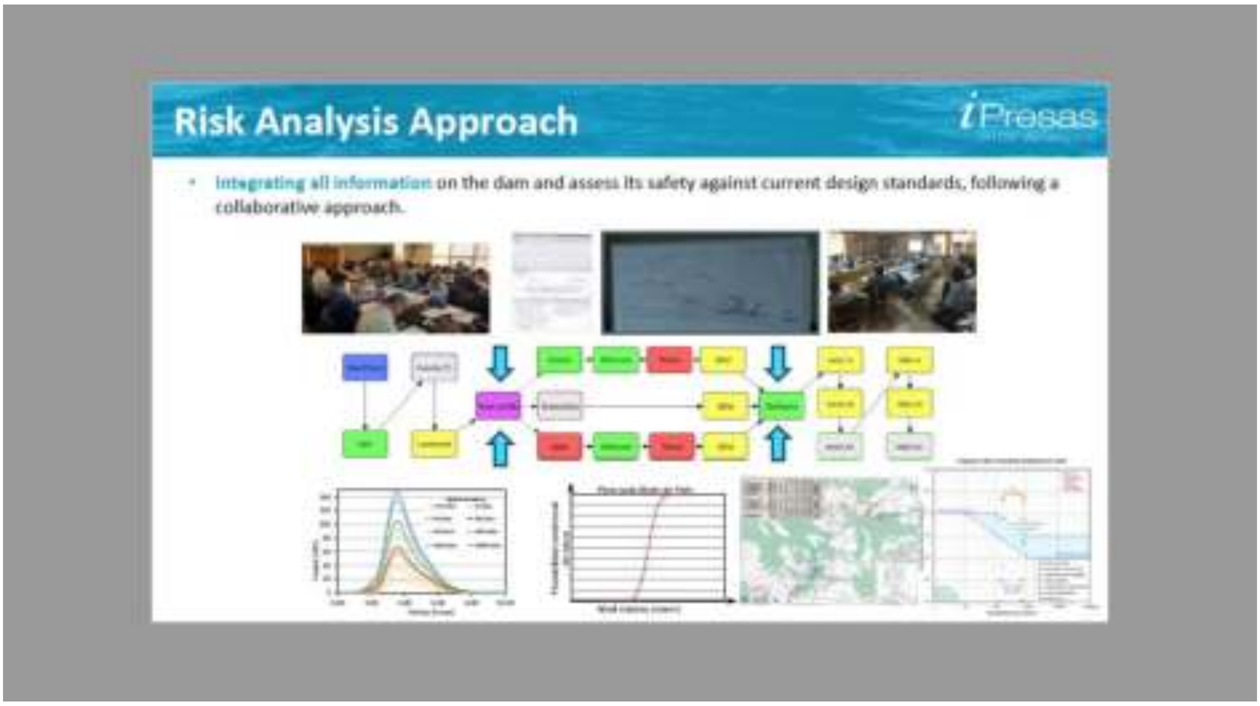

Relationship between Risk Analysis, Risk Assessment and Risk Management (FEMA, 2013)
Dam Safety
Risk Management Framework
Decision-Making
Risk Assessment
Risk Control
Risk Analysis
Risk Evaluation
Failure Modes Identification (PFMA)


Application of RIDM to other Dams
Santa Teresa dam
(Spain)
Screening tool
(Brazil)
Cerros Colorados
(Argentina)
Bhadra dam
(India)

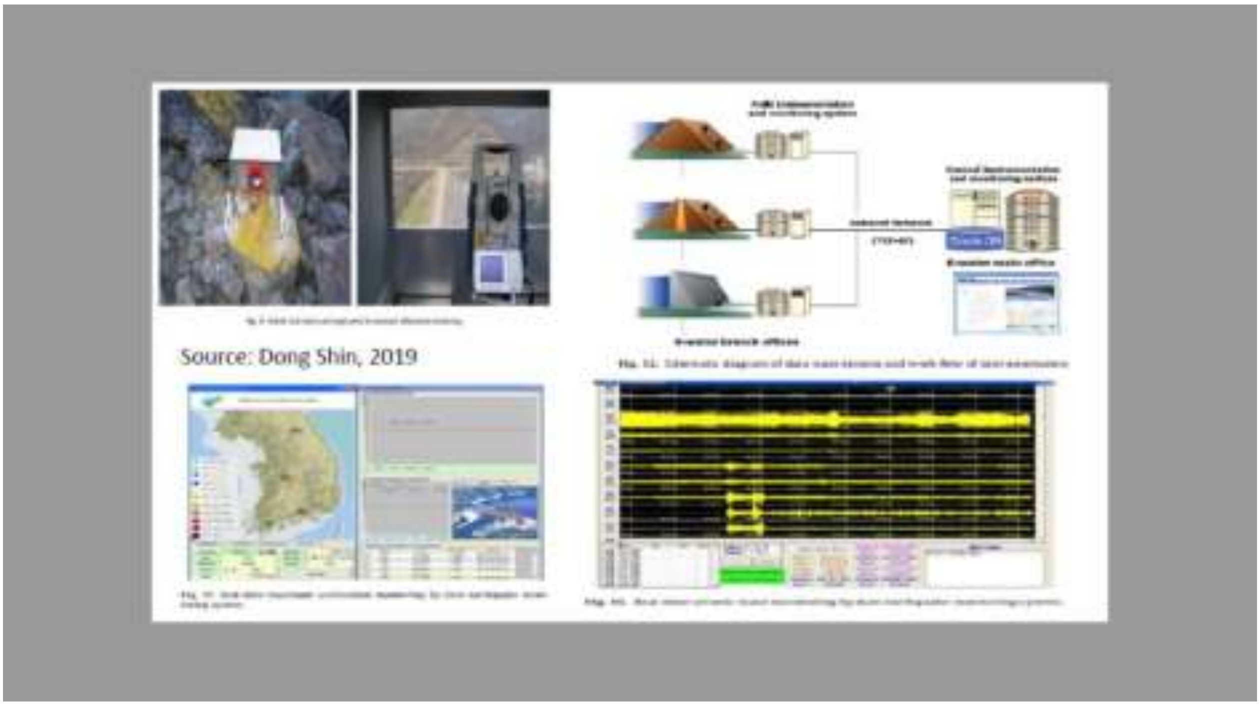

RISK INFORMED DAM SAFETY MANAGEMENT FOR TEMENGOR DAM, MALAYSIA
MAIN DAM CREST
SPILLWAY
POWER HOUSE
DOWNSTREAM
RISK =

e-ISSN : 2621-7469

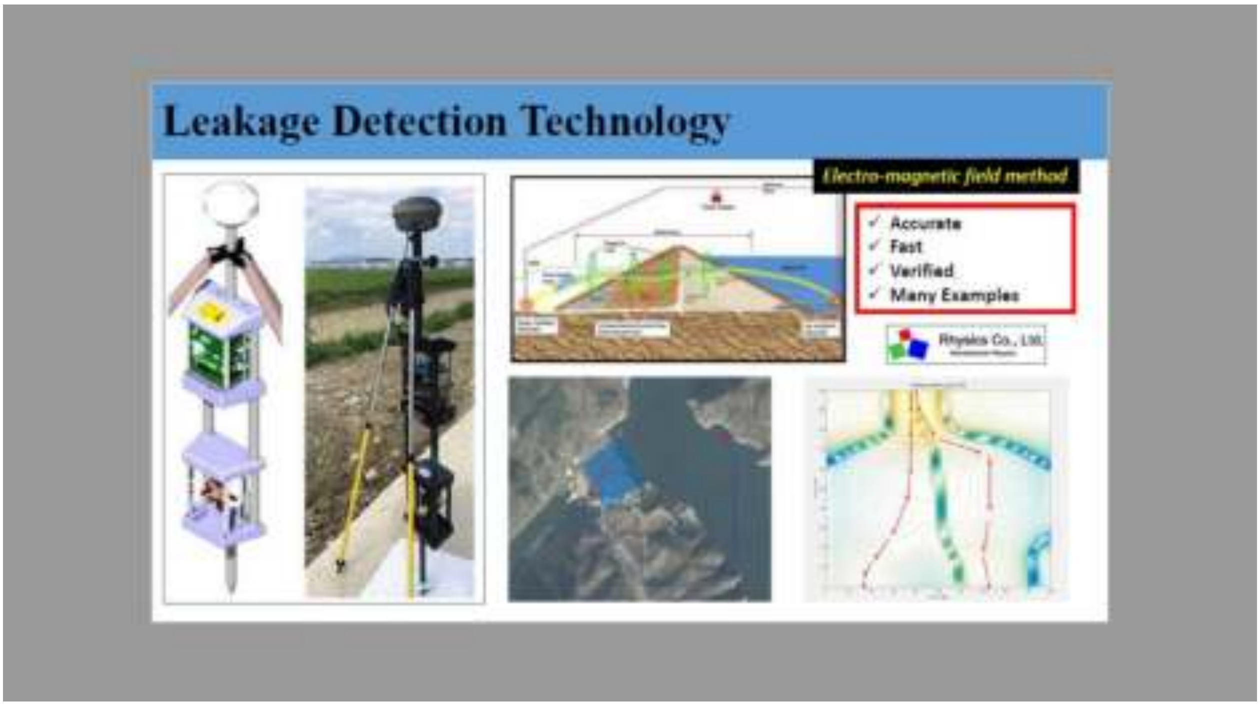





Risk Assessment Tool (Korea)
D-SMART

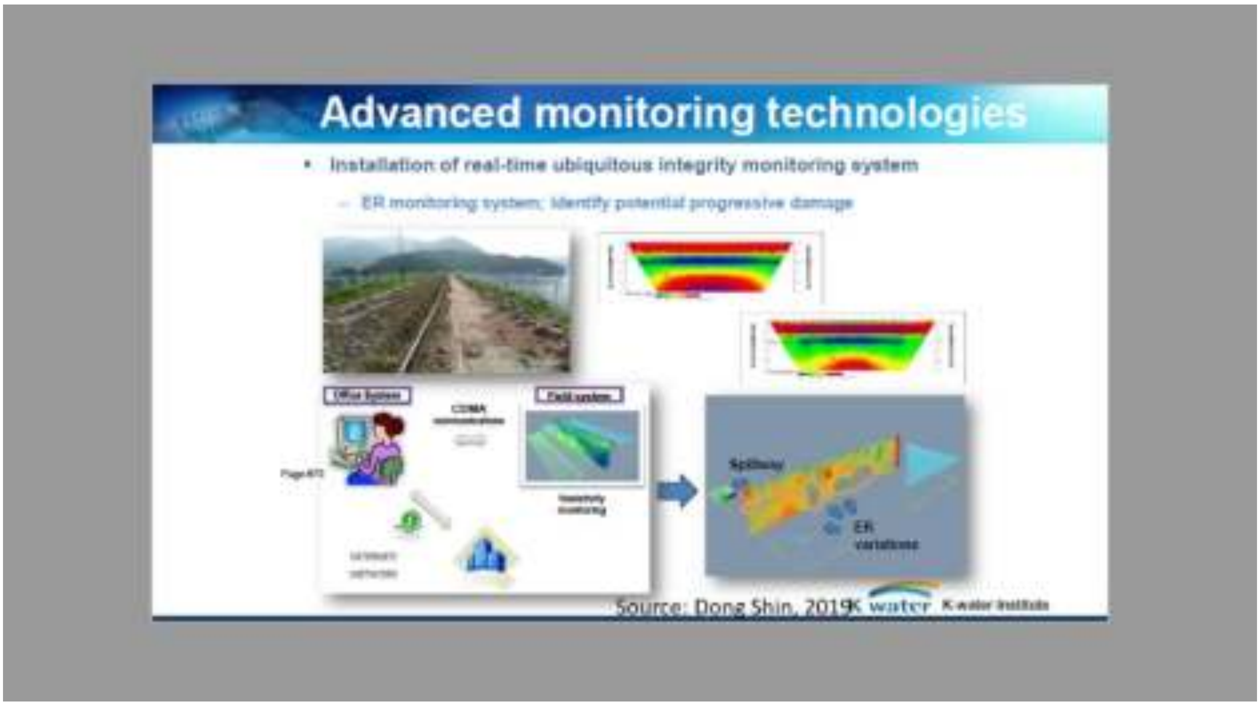

Source: Dong Shin, 2019

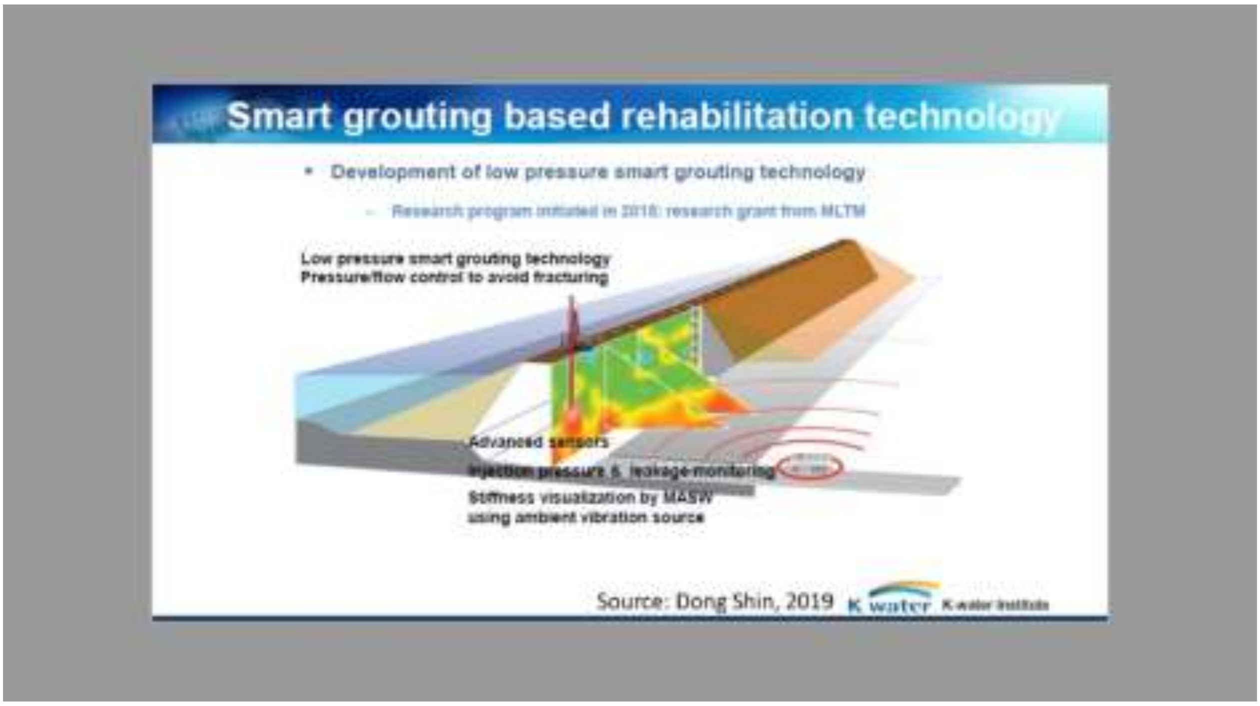

IMPLEMENTING NEW INSPECTION TECHNOLOGY FOR DAM FACILITIES
for Dam Facilities
✓ Real time instrumentation data collection
✓ Automation and remote monitoring
✓ The usage of UAV
• Crack investigation using UAV (Unmanned Aerial Vehicles)
• Inspection of Dam Concrete Using Infrared Camera


Leakage Detection Technology
Electro-magnetic field method
✓ Accurate
✓ Fast
✓ Verified
✓ Many Examples


Drone Inspection
Source: Dong Shin, 2019

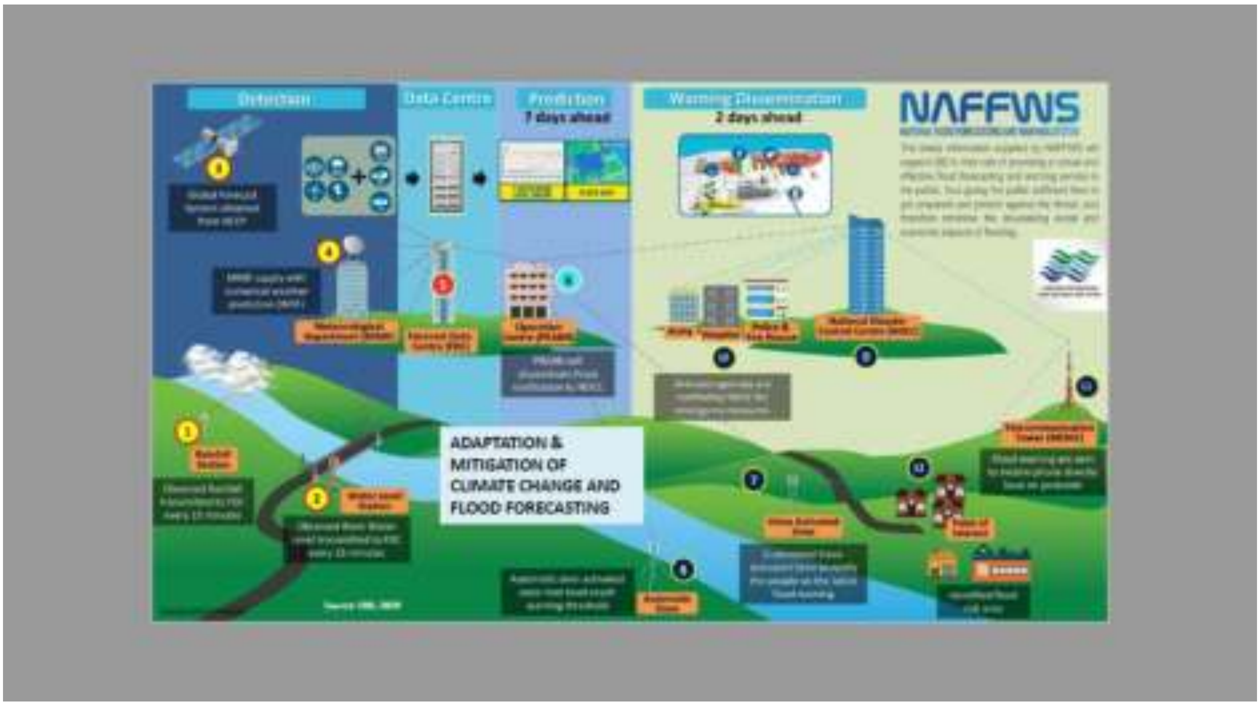

Advanced inspection and monitoring technologies
Various NDE technologies to evaluate integrity of dams
Visualizing spatial variation of material properties inside of the structure; identify location of anomaly or potential deteriorated zone
Advanced electro-magnetic technology: potential seepage path
MASW survey
Resistivity tomography
Willowstick technology
-Seepage induced EM field & inversion
Source: Dong Shin, 2019
K water

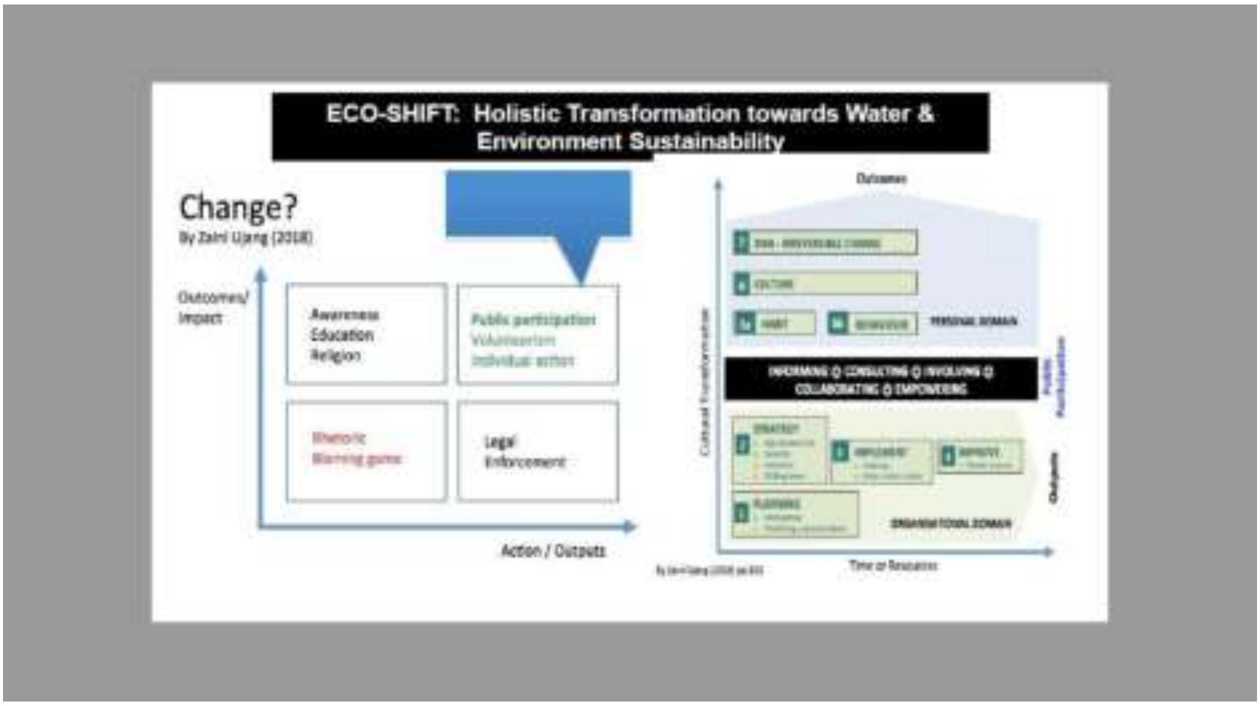

Advanced monitoring technologies
Installation of real-time ubiquitous integrity monitoring system
ER monitoring system; identify potential progressive damage
Spillway
ER variations
Source: Dong Shin, 2019
K water
K-water Institute


Smart grouting based rehabilitation technology
Development of low pressure smart grouting technology
Low pressure smart grouting technology
Pressure/flow control to avoid fracturing
Advanced sensors
Injection pressure & leakage monitoring
Stiffness visualization by MASW
using ambient vibration source
Source: Dong Shin, 2019
K water
K-water Institute

e-ISSN : 2621-7469


Water Accounting
Availability
Demand
Water Allocation
Water Quality
Water Auditing
WR & Drought Index
Dam Release & Storage
NAWABS


Detection
Data Centre
Prediction
7 days ahead
Warning Dissemination
2 days ahead
NAFFWS
ADAPTATION &
MITIGATION OF
CLIMATE CHANGE AND
FLOOD FORECASTING

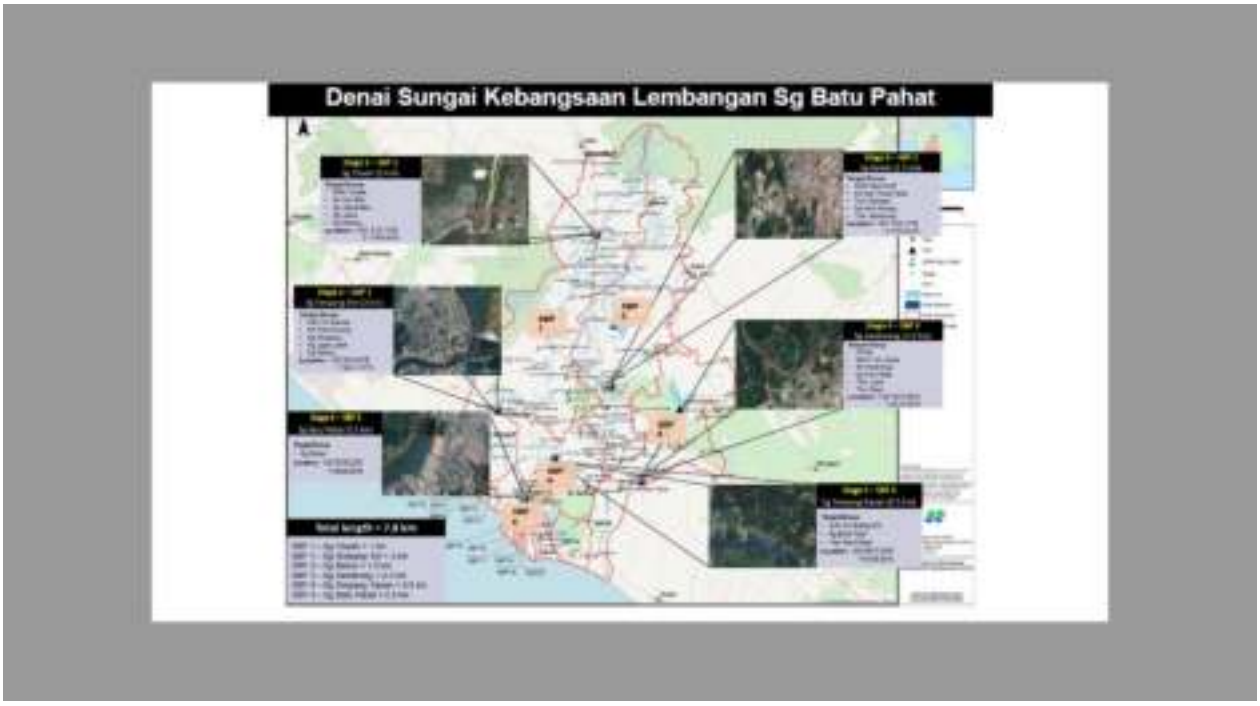

ECO-SHIFT: Holistic Transformation towards Water & Environment Sustainability
Change?
By Zaini Ujang (2018)
Outcomes/ Impact
Awareness
Education
Religion
Public participation
Volunteerism
Individual action
Rhetoric
Blaming game
Legal
Enforcement
Action / Outputs

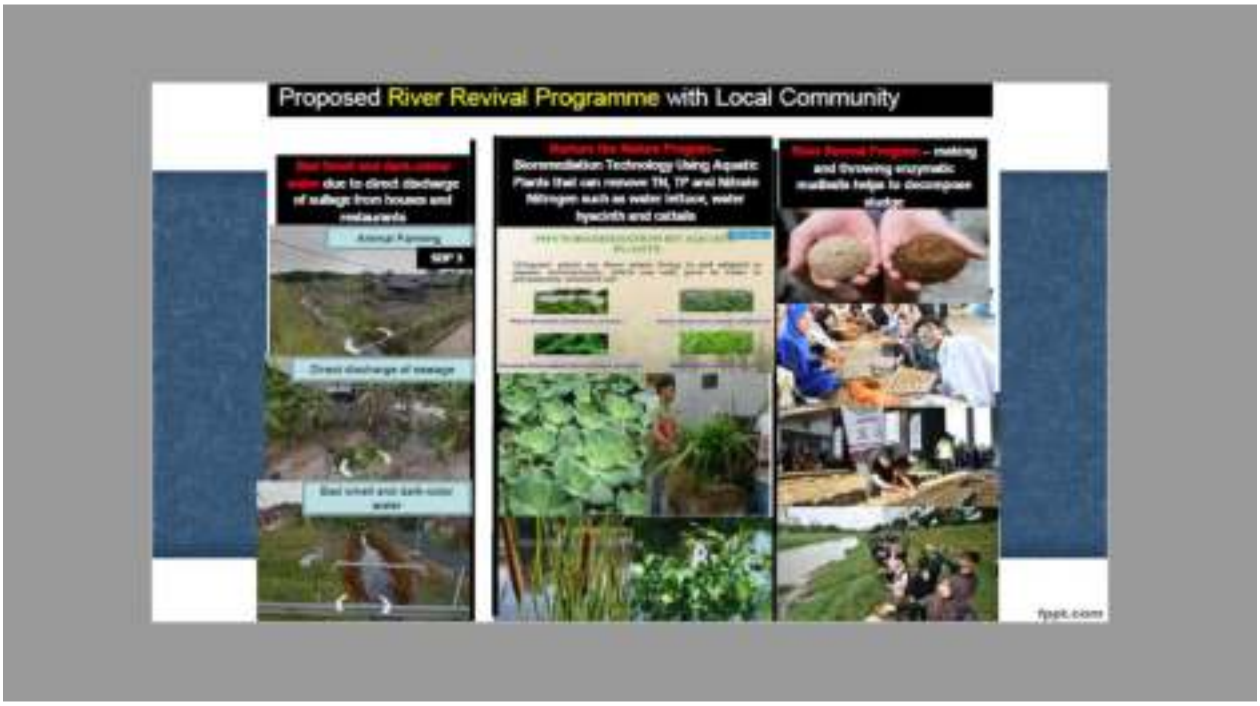

Gotong Royong Sg. Langat at Taman Pinggiran Sungai, Seksyen 7, Bandar Baru Bangi
Current conditions
Downstream
IWK + UNITEN
11 May 2018
12 Jun 2018
21 Jun 2018
23 Jun 2018
23 Julai 2018

e-ISSN : 2621-7469

e-ISSN : 2621-7469

e-ISSN : 2621-7469




Proposed River Revival Programme with Local Community
Bioremediation Technology Using Aquatic Plants that can remove TN, TP and Nitrate Nitrogen such as water lettuce, water hyacinth and cattails
and throwing enzymatic mudballs helps to decompose sludge
Direct discharge of sewage
fppt.com


Proposed Dam Safety Awareness Program with NGO & Community
Dam in Batu Pahat
Bekok Dam
DISASTER RISK REDUCTION GUIDANCE FOR PUBLIC SAFETY AROUND THE DAMS

e-ISSN : 2621-7469


Socio Survey
Website Sustainable Campus Office@UTHM
UTHM
Sustainable Campus Office@UTHM
https://scu.uthm.edu.my/


LIVING WITH WATER INFRASTRUCTURES
Sustainable Water Infrastructure Development
Economic
Catalysing Economic Sustainability
Social
Transitioning Social Outcomes
Environment
Improving Our Environmental Footprint

Conclusions

- **BEST PRACTICES** in **WATER INFRASTRUCTURE** Begin With **RESILIENCE**
- **Safety** is a **CORE VALUE** of our Dams Profession (Protect People, Property & Environment)
- CURRENT ISSUES & **STATE OF THE ART TECHNOLOGIES** related to WATER INFRASTRUCTURE SAFETY MANAGEMENT under CLIMATE CHANGE and AGING DAMS
- **TRADITIONAL** Approach (Deterministic – good practices) to **EMERGING** Approach (RIDM, PFMA and Life Cycle Risk Assessment)
- **GOVERNMENT SUPPORT** or Political will & Financial Support and Societal Consensus
- Capacity building & R&D needs to be accelerated to minimize the impact of ageing dams

Resilient Dams for Safe Communities