DAM SAFETY MONITORING & SURVEILLANCE IN MALAYSIA

Ir. Liew Shaw Shong | En. Mohd Hizan Kamaruzaman | En. Othman bin Darjad

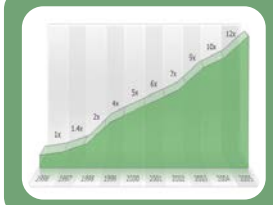
Asia Water 2010 Conference, Kuala Lumpur Convention Centre,
6th – 8th April 2010

CONTENTS

- Introduction
- Objectives
- Role & Responsibility
- Dam Safety Management (Monitoring & Surveillance)
- Future Trend
- Problems in Current Dam Safety Practice
- What Malaysia Needs?

INTRODUCTION

INTRODUCTION:
WHY DAM SAFETY IS IMPORTANT IN MALAYSIA?



Last two decades - steady increase in numbers of dam

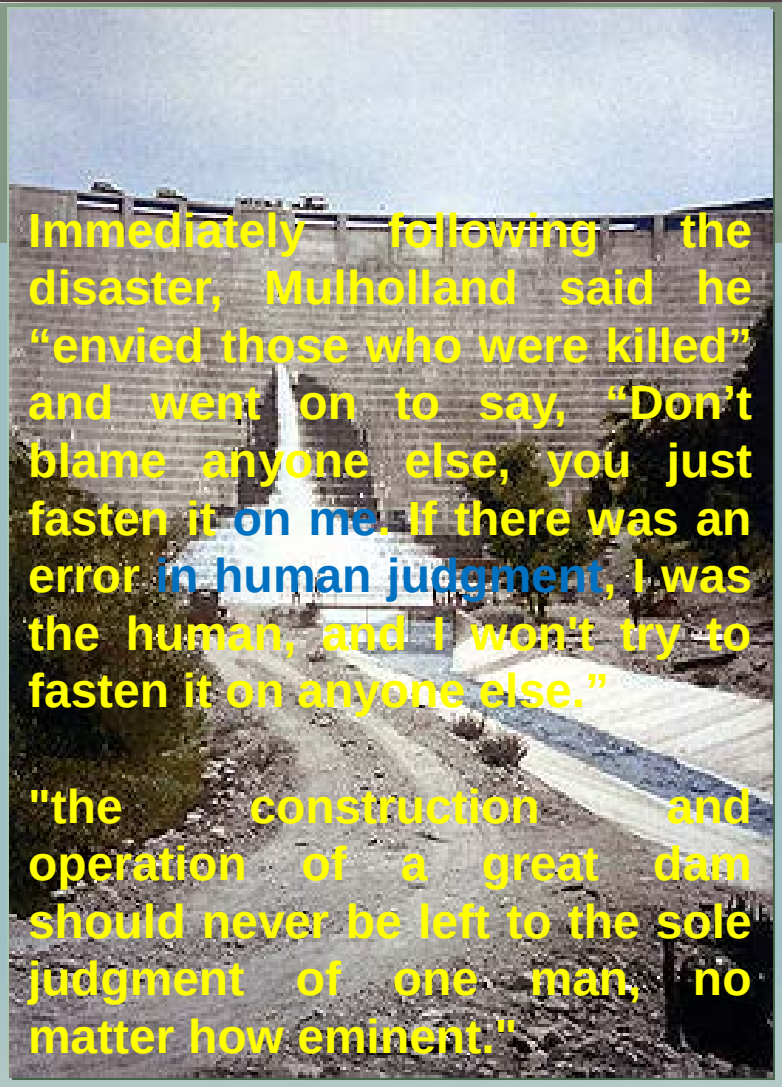
More than 50% of existing dams are constructed more than 25years

Dams subject to ageing process

Changing natural forces

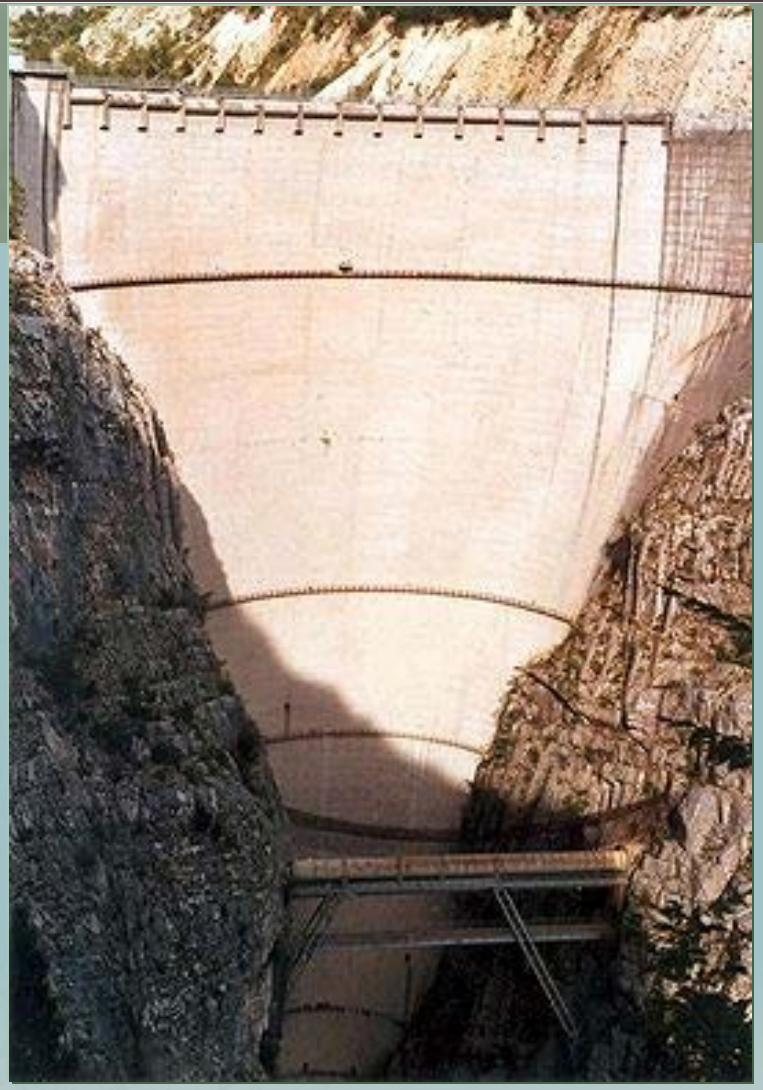
DAM BREACH:
SOME CASE HISTORIES

Teton Dam (1975 – 1976)



St Francis Dam, US
1924-1928

(Killed *600* people)



Vajont Dam, Italy
1959-1963

(Killed *2000* people)

Situ Gintung Dam, Indonesia (1933 –2009)

INVENTORY OF DAMS

CURRENT INVENTORY OF DAMS

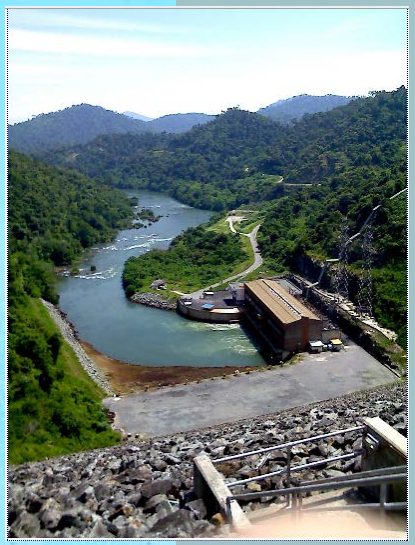
- Total of about 75 dams built in Malaysia
- Purpose & **Owner** :
  - Irrigation (**MADA/JPS**)
  - Water supply (**JKR/JBA**)
  - Flood Defense (**JPS**)
  - Hydropower (**TNB/SESCO/SEB**)
  - Recreation (**PJC**)
  - Mine Tailing & Ash Deposition (**Mining Companies**)

CURRENT INVENTORY OF DAMS

Summary of Dams in Malaysia (as at 2006)

No	Purpose	Dam Operator	Quantity
1	Flood Control	JPS	13
2	Hydroelectric	TNB	12
3	Water Supply	Private & Water Board	47
4	Agriculture	MADA	3
Total			75

DAMS IN PENINSULAR MALAYSIA



DAMS IN EAST MALAYSIA

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
1	Air Keroh	Melaka	W	1890	Sg. Melaka	Earthfill	7.0	12	20.7	NA	NA	S
2	Bukit Merah	Perak	I,W	1906	Sg. Kurau	Earthfill	9.1	610	8.7	93.0	424	GC
3	Lower Pengkalan Bukit	Johor	W	1912	Sg. Muar	Concrete	4.5	55.7	NA	0.0	NA	GC
4	Repas Lama	Pahang	SR	1925	Sg. Bentong	Earthfill	13.4	210	NA	NA	60	S
5	Chenderoh	Perak	H	1930	Sg. Perak	Concrete	32.0	290	60.4	200.0	14700	U
6	Asahan	Melaka	W	1932	Sg. Kesong	Earthfill	8.0	310	71.0	0.7	NA	UC
7	Air Kuning	Selangor	Re	1934	Sg. Air Kuning	Concrete	10.0	50	31.0	0.1	NA	NA
8	Sg. Baru	Selangor	Re	1934	Sg. Baru	Concrete	10.3	67	37.8	0.2	NA	UC
9	Labong	Johor	I, W, F	1949	Sg. Endau	Earthfill	9.3	250	8.0	12.0	85	UC
10	Upper Pengkalan Bukit	Johor	W	1950	Sg. Muar	Concrete	12.0	64	NA	0.2	NA	UC

Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
11	Meru	Selangor	W	1950	Sg. Subang	Earthfill	9.1	127	37.8	3.5	140	UC
12	Ahning Dam	Kedah	W, I	1958	Sg. Kedah	Rockfill	74.0	270	113.0	275.0	115	UC
13	Gunung Ledang	Johor	W	1959	Sg. Muar	Concrete	10.5	79.4	NA	0.3	NA	UC
14	Klang Gates	Selangor	W, F	1959	Sg. Kelang	Earthfill	37.0	139	96.7	32.0	340	GC
15	Chongkok	Johor	W	1960	Sg. Tenglu	Earthfill	2.0	700	NA	0.2	234	UC
16	Gopeng	Perak	SR	1961	Sg. Gopeng	Earthfill	9.0	85	NA	NA	78	S
17	Damansara	Selangor	W	1962	Sg. Damansara	Earthfill	18.0	123	41.0	0.0	NA	S
18	Sultan Abu Bakar	Pahang	H, W	1963	Sg. Bertam	Concrete	40.0	135	1070.8	6.7	963	GC
19	Repas Baru	Pahang	SR	1963	Sg. Rengas	Earthfill	20.0	40	102.7	0.4	85	S
20	Air Hitam	P. Pinang	W	1963	Sg. Air Hitam	Earthfill	47.3	245	234.0	26.0	155	S

Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
21	Padang Saga	Kedah	I, W	1964	Sg. Ulu Melaka	Earthfill	8.3	61	21.2	0.2	57	UC
22	Jor	Perak	H	1967	Sg. Btg. Padang	Earthfill	45.7	210	493.5	3.3	1104	SU
23	Mahang	Perak	H	1967	Sg. Mahang	Earthfill	21.0	230	NA	4.0	50	SU
24	Muda Dam	Kedah	I	1968	Sg. Muda	Earthfill	37.0	250	19.6	160.0	1982	U
25	Pedu Dam	Kedah	I	1969	Sg. Kedah	Rockfill	61.0	220	97.5	1073.0	2832	U
26	Pinangsoo	Sabah	W	1969	NA	Earthfill	12.0	65	15.2	0.2	NA	C
27	Durian Tunggal	Melaka	W	1977	Sg. Melaka	Earthfill	23.0	224	26.0	20.4	453	S
28	Temenggor Dam	Perak	H, F	1978	Sg. Perak	Rockfill	127.0	357	248.4	6168.0	2830	CU
29	Bukit Kwong	Kelantan	I	1979	Sg. Galak	Earthfill	7.7	2000	16.8	14.3	48	UC
30	Lebam	Johor	W	1979	Sg. Lebam	Earthfill	13.0	380	11.6	3.1	212	S

Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
31	Langat Dam	Selangor	W	1979	Sg. Langat	Earthfill	61.0	366	221.0	38.1	520	S
32	Machap	Johor	F, W	1982	Sg. Benut	Earthfill	11.5	550	15.9	12.3	306	GC
33	Bersia	Perak	H	1983	Sg. Perak	Concrete	33.0	252	141.5	57.7	5280	GC
34	Kenering	Perak	H	1983	Sg. Perak	Concrete	48.0	503	111.4	352.0	8960	GC
35	Semberong	Johor	F, W	1984	Sg. Batu Pahat	Earthfill	11.0	1975	8.3	18.0	350	GC
36	Tenom Pangi Dam	Sabah	H	1984	Sg. Pedas	Concrete	NA	83	173.9	4.7	NA	C
37	Kenyir Dam	Terengganu	H, F	1984	Sg. Terengganu	Rockfill	155.0	800	145.0	1360.0	6500	CU
38	Linggiu	Johor	W	1984	Sg. Linggiu	Concrete	39.0	51	100.0	772.0	533	C
39	Bukit Kuda	Labuan	W	1984	Sg. Bangat	Earthfill	10.4	205.7	13.4	4.8	15	S
40	Kerupang	Labuan	W	1984	Sg. Kerupang	Earthfill	13.7	115.82	14.3	0.2	5	U

Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
41	Pagar	Labuan	W	1984	Sg. Pagar	Earthfill	14.6	130.95	14.3	0.4	8	S
42	Sepagaya	Sabah	W	1984	Sg. Silibukan	Rockfill	22.9	73.15	80.0	2.5	NA	S
43	Timbangan	Sabah	W	1984	Sg. Kalumpong	Concrete	15.2	156	53.4	0.8	162	U
44	Batang Ai Dam	Sarawak	H	1985	Sg. Batang Ai	Rockfill	85.0	680	112.0	2800.0	2613	G
45	Anak Endau	Pahang	I, W	1985	Sg. Anak Endau	Earthfill	18.0	700	NA	38.0	250	UC
46	Pontian	Pahang	I, W	1985	Sg. Pontian	Earthfill	15.5	350	5.0	40.0	605	UC
47	Upper Layang	Johor	W	1985	Sg. Layang	Earthfill	26.0	600	26.6	45.0	269	UC
48	Mengkuang	Pulau Pinang	W	1985	Sg. Kulim	Earthfill	31.0	1006	43.3	23.6	12	S
49	Sika, Bintulu	Sarawak	W	1985	Sg. Sika	Earthfill	27.0	270	20.0	3280.0	NA	C
50	Semenyih Dam	Selangor	W	1985	Sg. Langat	Earthfill	49.0	800	111.0	62.6	60	S

Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
51	Kemaman Bunded Storage	Terengganu	W	1985	Sg. Kemaman	Earthfill	8.0	120	8.8	0.1	NA	S
52	Batu Dam	Selangor	F, W	1986	Sg. Kelang	Earthfill	44.0	550	NA	36.0	193	UC
53	Bukit Bauk Bunded Storage	Sarawak	W	1986	NA	Earthfill	9.0	10	7.5	0.2	NA	S
54	Serdang Bunded Storage	Terengganu	W	1986	NA	Earthfill	27.5	846	7.5	0.2	NA	S
55	Malut	Kedah	W	1987	Sg. Malut	Earthfill	40.0	265	76.0	7.2	150	S
56	Sg. Terip	N. Sembilan	W, I	1987	Sg. Terip	Earthfill	43.0	500	103.0	48.0	340	S
57	Lower Layang	Johor	W	1989	Sg. Layang	Earthfill	8.0	600	6.0	16.0	385	GC?
58	Bekok	Johor	F, W	1990	Sg. Batu Pahat	Earthfill	15.0	4320	13.3	125.0	1152	UC
59	Pedas	N. Sembilan	W	1990	Sg. Beringin	Concrete	22.0	141	135.0	0.5	215	UC
60	Air Kuning	Perak	W	1991	Sg. Ranting	Earthfill	18.0	520	34.0	1.8	8	S

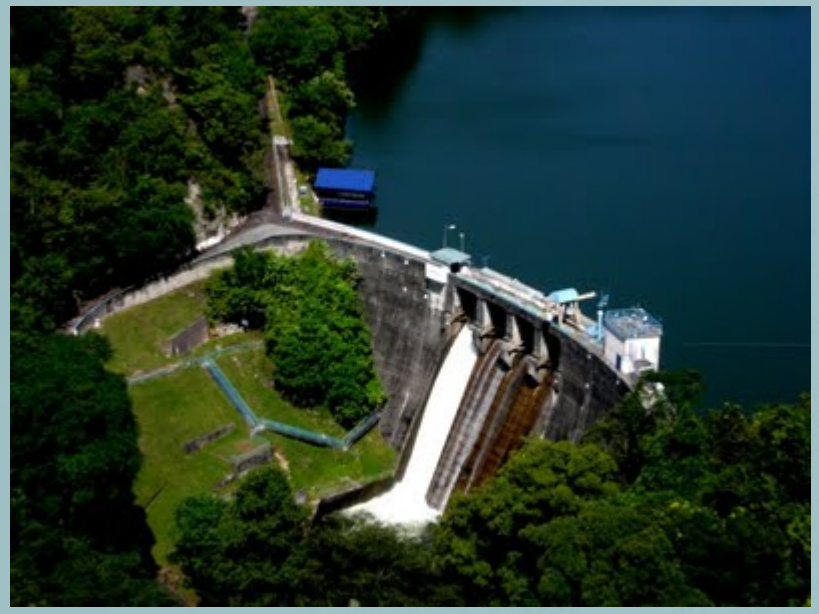
Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

INVENTORY OF DAMS

	Name of Dam	State	Purpose	Year Completed	River System	Type	Height (m)	Crest Length (m)	Reservoir FSL Storage Level (m)	Reservoir Storage at FSL (MCM)	Design Flood (m^3/s)	Weir Type
61	Juaseh	Johor	W	1991	Sg. Juaseh	Earthfill	29.5	220	82.5	33.2	382	Ogee crest
62	Upper Muar	N. Sembilan	W	1992	Sg. Muar	Earthfill	52.0	300	154.0	53.0	2150	C
63	Timah Tasoh	Perlis	I, W, F	1992	Sg. Perlis	Earthfill	17.3	3500	NA	27.4	418	GC
64	Pergau Dam	Kelantan	H	1996	Sg. Pergau	Earthfill	75.0	750	636.0	62.3	2403	C
65	Sg. Tinggi Dam	Selangor	W	1996	Sg. Tinggi	Earthfill	36.0	280	NA	107.5	NA	S
66	Babagon	Sabah	W	1997	Sg. Babagan	Rockfill	50.0	133	128.0	20.2	NA	S
67	Kelinci	N. Sembilan	W	1998	Sg. Kelinci	Earthfill	70.0	270	215.0	50.0	576	C
68	Teluk Bahang	Pulau Pinang	W	1999	Sg. Teluk Bahang	Earthfill	58.5	700	48.0	21.0	320	OC
79	Putrajaya	Selangor		2001	Sg. Bisa	Rockfil	30.0	750	22.9	NA	NA	Labryinth
70	Beris	Kedah	I,W	2004	Sg. Muda	C-R	40.0	155	88.0	122.4	NA	C

Dam Purpose: W-Water Supply I-Irrigation H-Hydropower F-Flood Control Re-Recreation SR-Silt Retention
Type of Spillway: G-Gated U-Ungated C-Chute

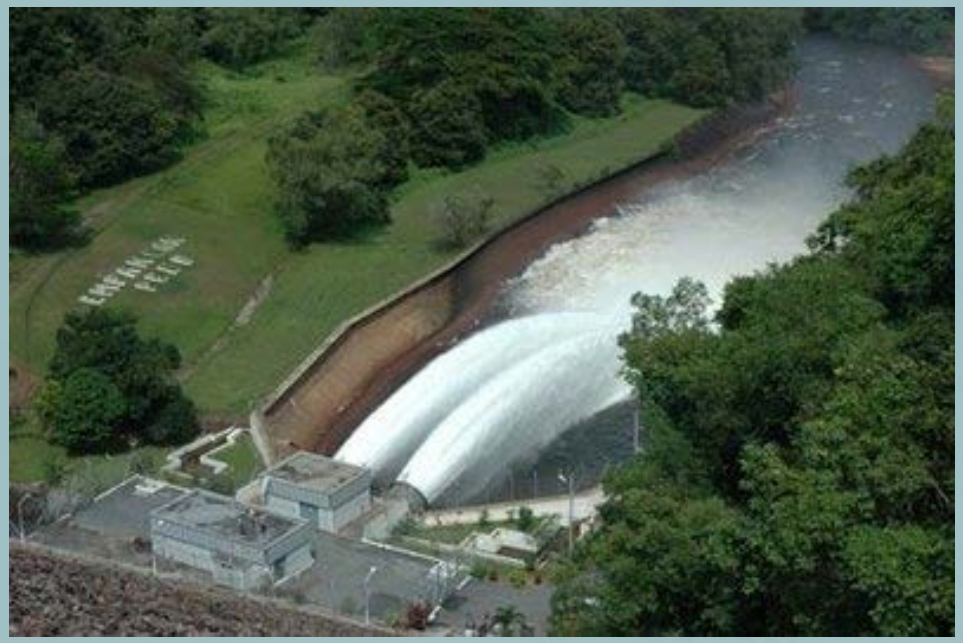
CURRENT INVENTORY OF DAMS



Water Supply Dam – Klang Gates (**Taman Melawati**)

Water Supply Dam (**Sg. Selangor**)

CURRENT INVENTORY OF DAMS



Irrigation Dam – Pedu Dam
(**Alor Setar**)

Flood Defense Dam
– Beris Dam
(**Kedah**)

CURRENT INVENTORY OF DAMS

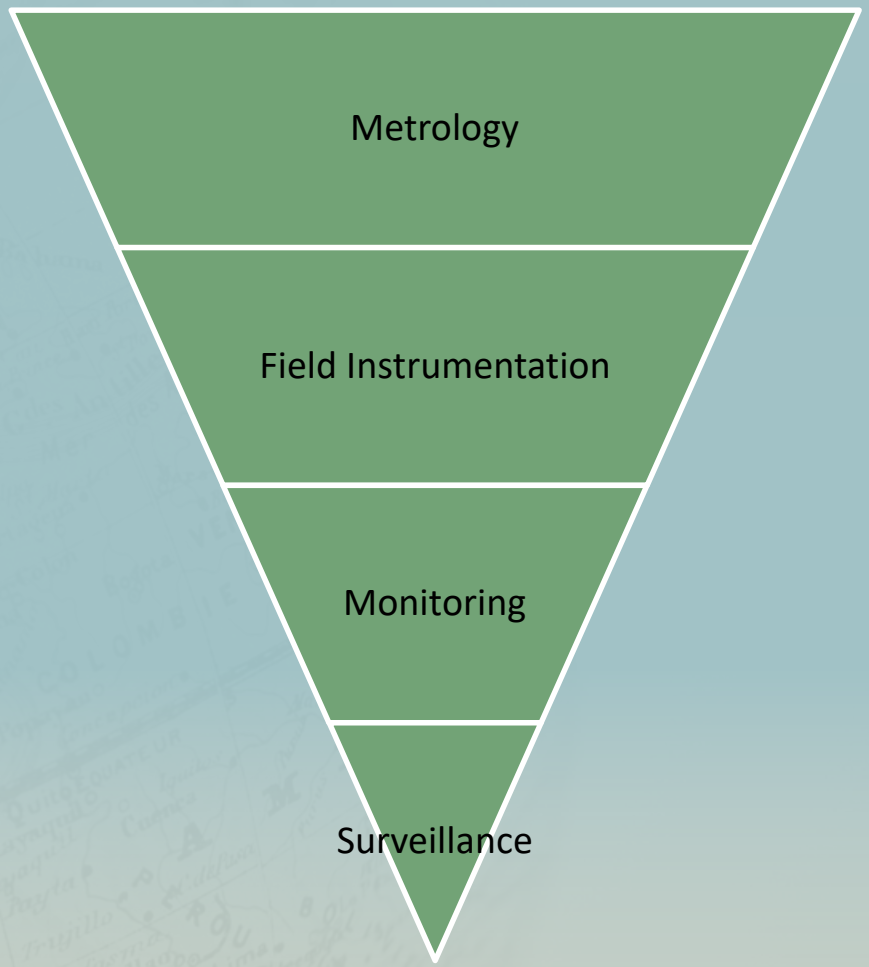
Hydropower Dam - Bakun
(**SESCO**)

Recreation Dam
(**Putra Jaya**)

OBJECTIVE OF DAM SAFETY MONITORING & MAINTENANCES

OBJECTIVE OF DAM SAFETY MONITORING & MAINTENANCES

- Prevent **disastrous consequences** to:
  - National Security
  - Public Safety
  - Social Economy
  - Environmental



OBJECTIVE OF DAM SAFETY MONITORING & SURVEILLANCE

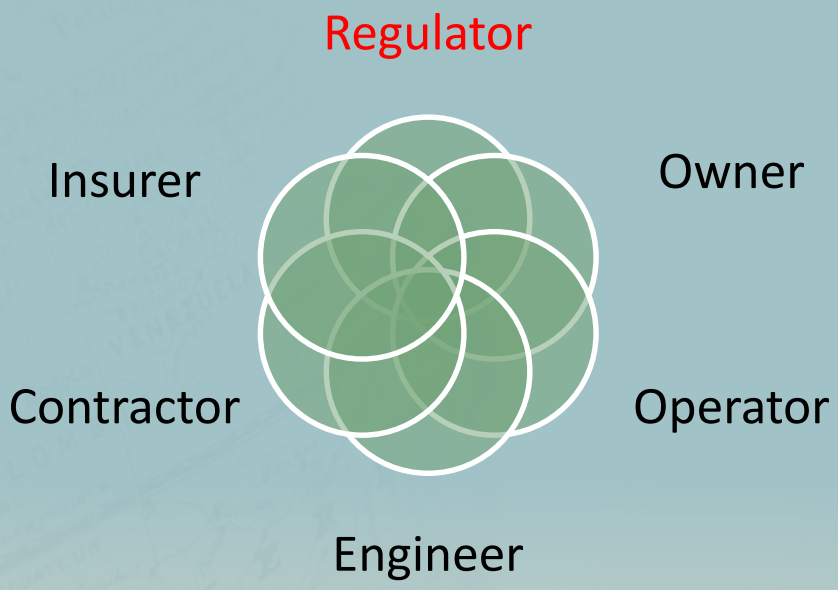
Dam Safety Monitoring & Surveillance should include identifying :

- **Factors** that influence
  - **Safe operation** of dam / appurtenant structures
  - **Dam's potential** to adversely affect human life, human health, property, and the environment surrounding it.
- **Adequacy** of operations, maintenance & emergency plan of the dams

ROLE & RESPONSIBILITY OF STAKEHOLDERS

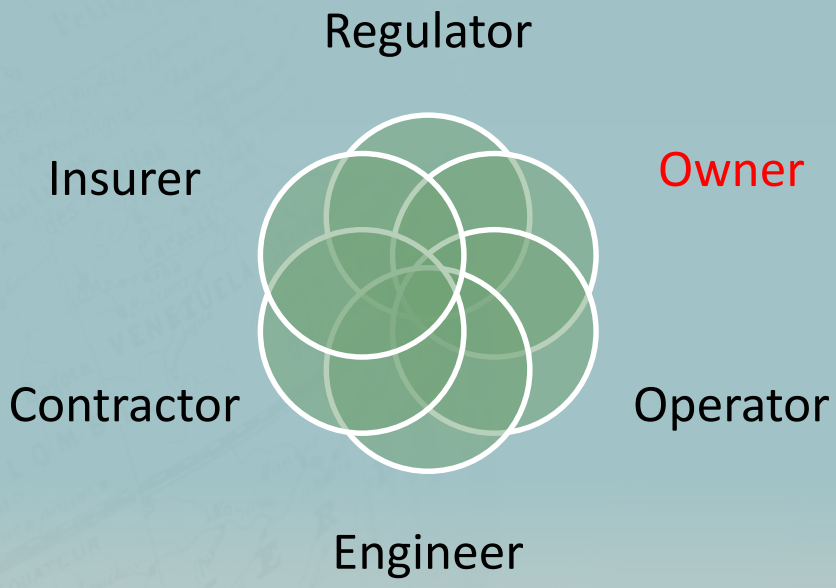
ROLE & RESPONSIBILITY OF DAM REGULATOR

- **Regulator**
  - Monitor obligatory tasks (**monitoring** & **surveillance**) by dam owner
  - **Review & approve competency** of technical staff by the owner for monitoring & surveillance
  - Organize scheduled **independent inspection** for compliance check
  - Review & approve **surveillance report**



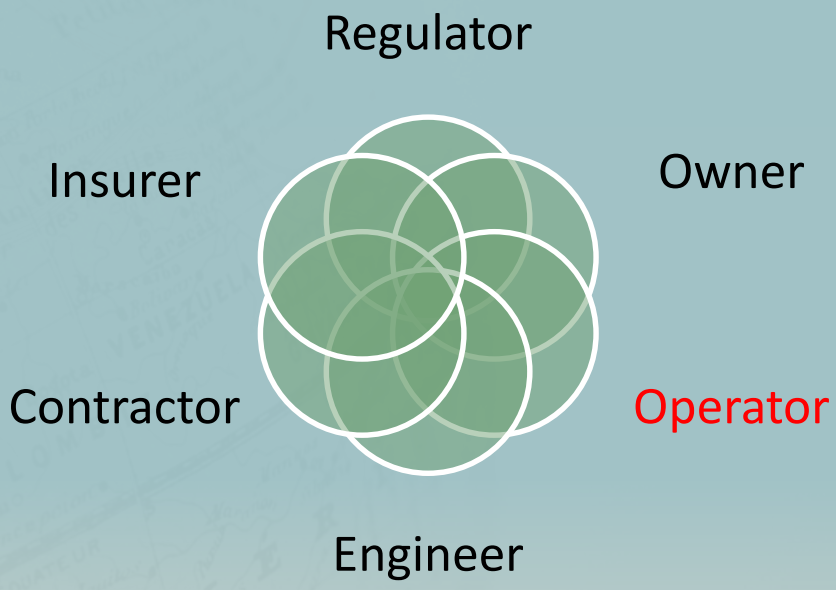
ROLE & RESPONSIBILITY OF DAM OWNER & OPERATOR

- **Owner**
  - **Collect and storage** of up-to-date documentations :
    - **Static data** in Data Book - design, as-built, operating manual
    - **Dynamic data** in Dam Safety & Surveillance Report - maintenance, monitoring, repair & incident reports of dam
  - Implement **Monitoring & Surveillance**
  - Implement **Maintenance Scheme**



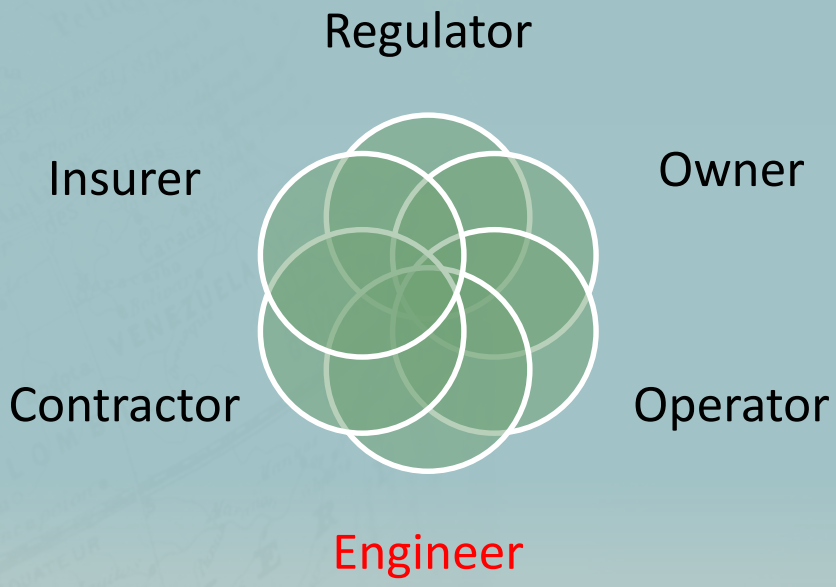
ROLE & RESPONSIBILITY OF DAM OWNER & OPERATOR

- **Operator**
  - Perform **regular visual inspection**
  - Perform **periodical check** and **maintenance** of control systems, discharge structures, etc
  - Annual reporting



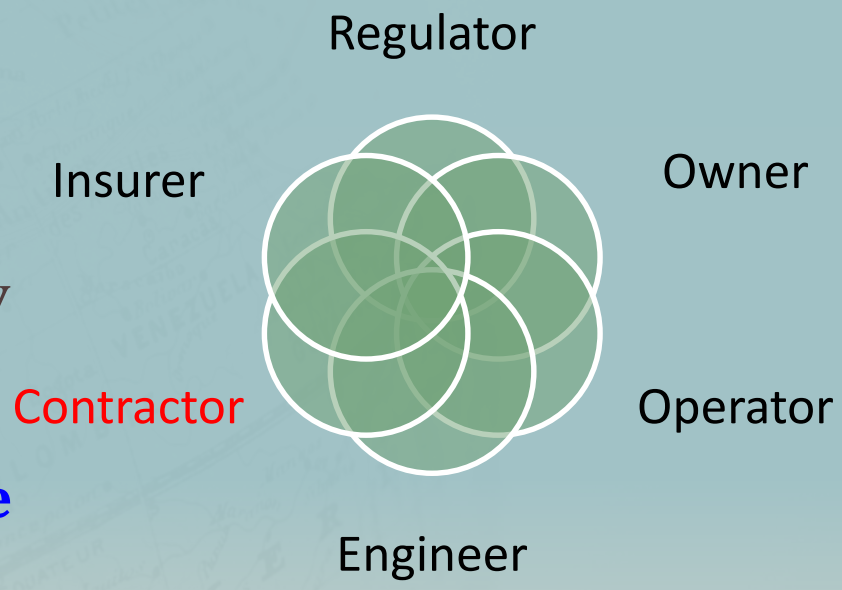
ROLE & RESPONSIBILITY OF DAM ENGINEER

- **Engineer**
  - Perform comprehensive **technical inspections**
  - Plan additional **monitoring** & taking measurements at scheduled interval or changes in **operational conditions**
  - **Interpret, analyze data** collected & visually present outcome in graphical form
  - **Highlight** any slowly developing but rapid deteriorating **dangerous trends** or signs (**anomalous behaviors**)
  - Prepare surveillance report



ROLE & RESPONSIBILITY OF DAM CONTRACTORS

- **Contractor**
  - **Assist** the **Engineer** on their tasks
  - **Repair** damaged **instruments** or **install** additional instruments
  - **Improve** precision & reliability of **instruments** & measurements
  - Take measurements & **compile data** collected
  - Prepare factual monitoring report



DAM SAFETY MANAGEMENT

DAM SAFETY MANAGEMENT

- Responsibilities of dam owners in Malaysia :
  1. **Guidelines for Operation, Maintenance and Surveillance of Dams** (Malaysia Inter-Departmental Committee on Dam Safety, 1989)
  2. **Guideline of ICOLD** (International Committee on Large Dams)
- However, a holistic dam safety policy for the country is required:
  - Legislation → **Lack of Institutional Power**
  - Regulator → **Need of One Stop Agency**
  - Enforcement

DAM SAFETY MANAGEMENT

- **Safety Inspection**
  - Routine Safety Inspection
  - Periodic Safety Inspection
  - Special Safety Inspection
- **Dam Safety Management Plan**
- **ERP – Emergency Response Plan**
  - Prepared based on dam break study
  - ERP during construction and operation phases
  - Avoid and minimized injury/loss of life to employees and public during emergency incidents

DAM SAFETY REGULATORY FRAMEWORKS

MONITORING & SURVEILLANCE

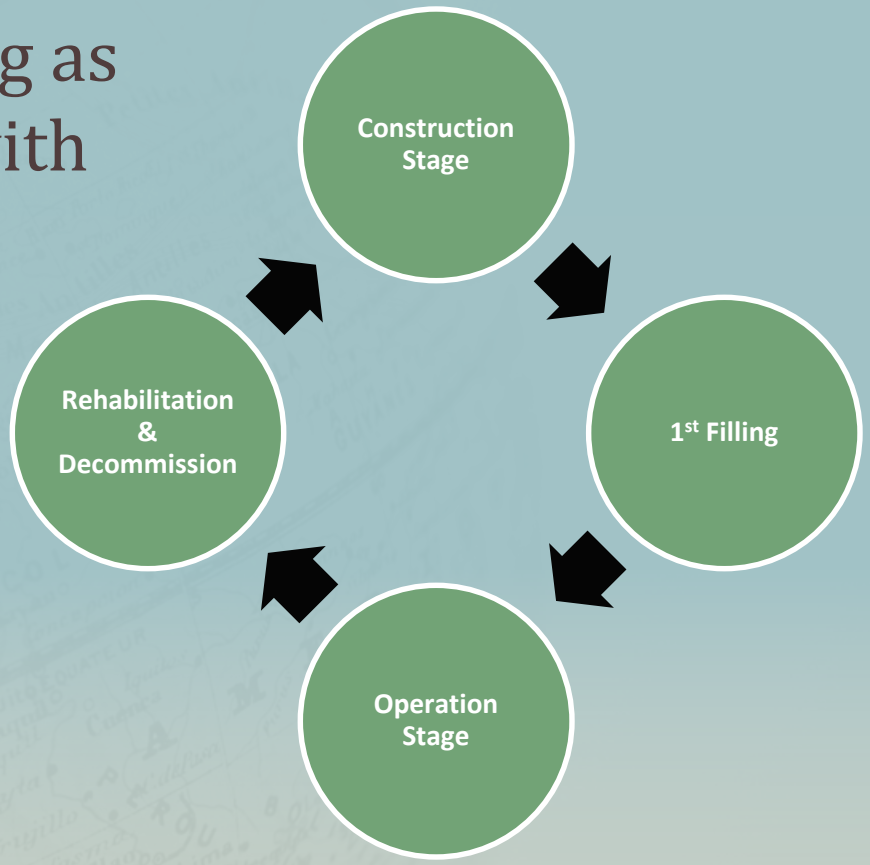
MONITORING & SURVEILLANCE

ANCOLD (1976 & 2003) defines :

- **Monitoring**
  - Acquiring data from measuring devices
  - Recording of data
  - Deducing performance and behavioral trends
- **Surveillance**
  - Continuing examination of conditions
  - Reviewing operation, maintenance and monitoring procedures and results
  - Determining whether hazardous trend is developing or appears likely to develop

MONITORING & SURVEILLANCE

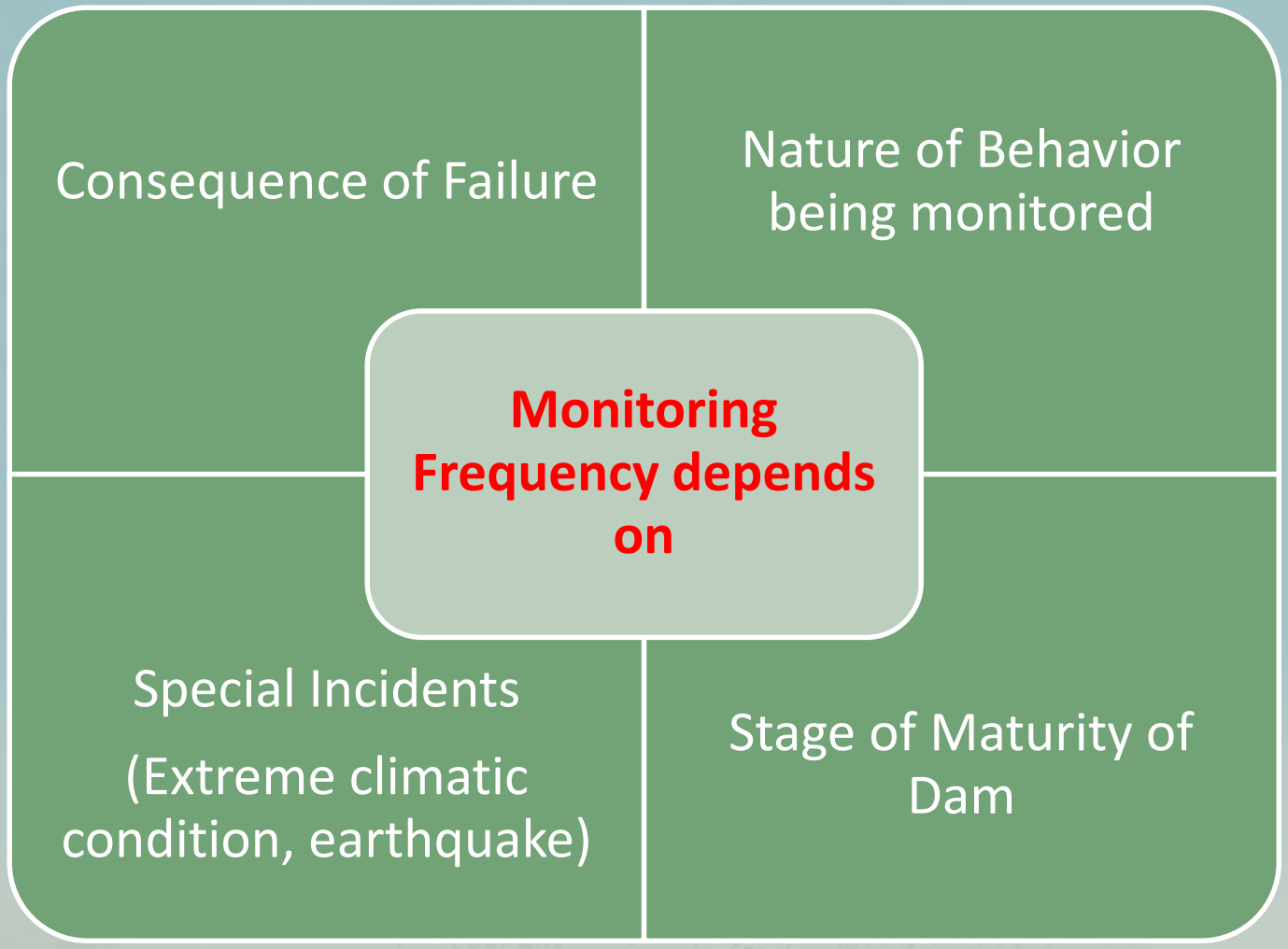
- Monitoring & Surveillance shall be **continued** as long as the **hazards** associated with the existence of the dam present.
- **Level** of Monitoring & Surveillance depends on **consequences** of failure.



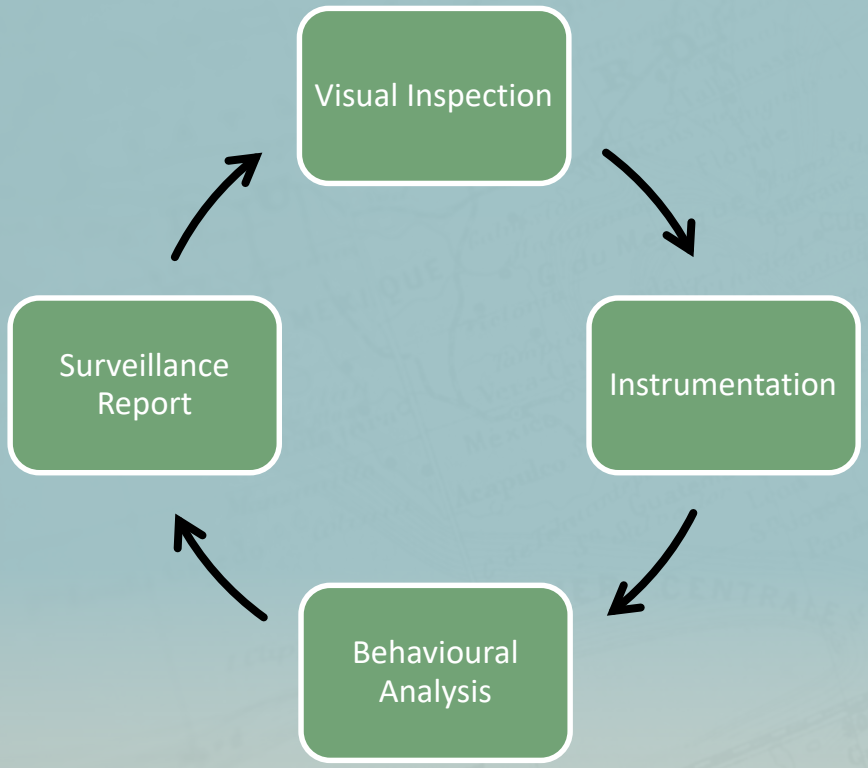
MONITORING

- **Survey** on :
  - Deformation of dam
  - Reservoir level & rainfall
- **Measurement**s on :
  - Seepage & pore pressure
  - Foundation pressure
  - Stresses in dam & structures
- **Spillway performance** & condition
- Monitoring on :
  - Cracks
  - Erosion
  - Seismicity (esp. for large reservoir or at seismically active areas)

MONITORING


Consequence of Failure
Nature of Behavior being monitored
Monitoring Frequency depends on
Special Incidents
(Extreme climatic condition, earthquake)
Stage of Maturity of Dam

SURVEILLANCE



- **Safety Inspection**
  - Routine Safety Inspection
  - Periodic Safety Inspection
  - Special Safety Inspection
- **Dam Safety Management Plan**

VISUAL INSPECTION OF DAM

UNCONTROLLED LEAKAGE/SEEPAGE

CRACKS ON DAM STRUCTURES

TENSION CRACKS ON DAM CREST

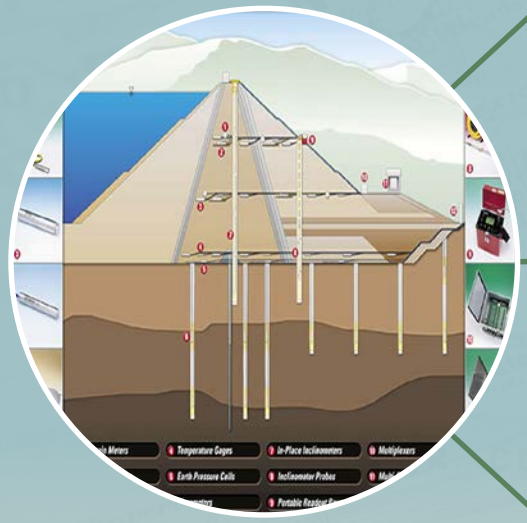
EROSION ON EMBANKMENT SLOPES

Erosion at the Downstream Face of Dam

Erosion due to Dam Overtopped

INSTRUMENTATION MONITORING OF DAM

STATE-OF-ART & FUTURE TREND OF INSTRUMENTATION



Instruments

- Fiber Optic Sensors
- Automated Total Station
- LiDAR Terrestrial Survey
- GPS Displacement
- Real Time Data Acquisition & Communication Systems

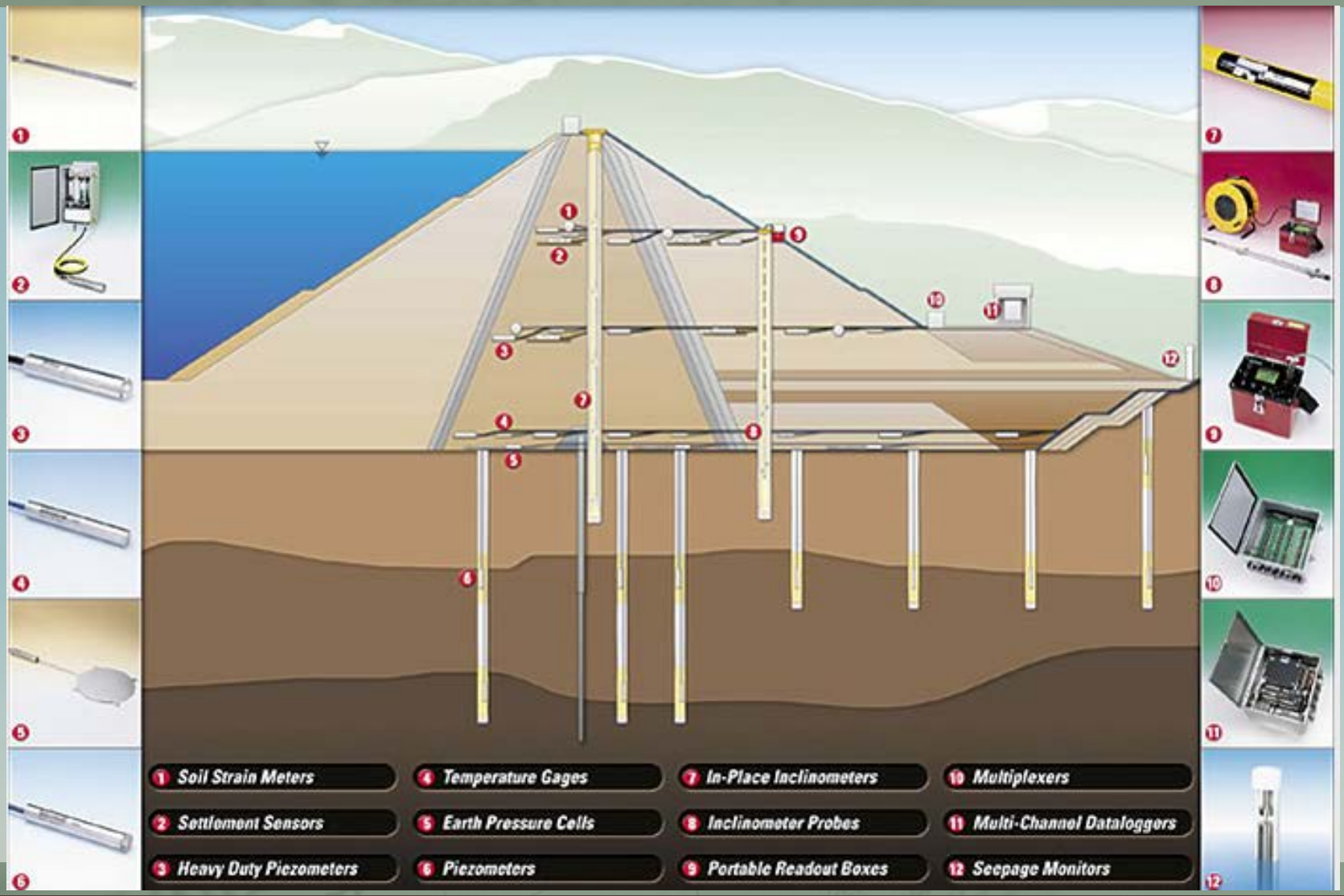
Problems & Solutions

- Electromagnetic Interference (EMI)
- Damages during Electrical Storms
- Data Reliability
- Longevity of Instruments

Analysis & Software

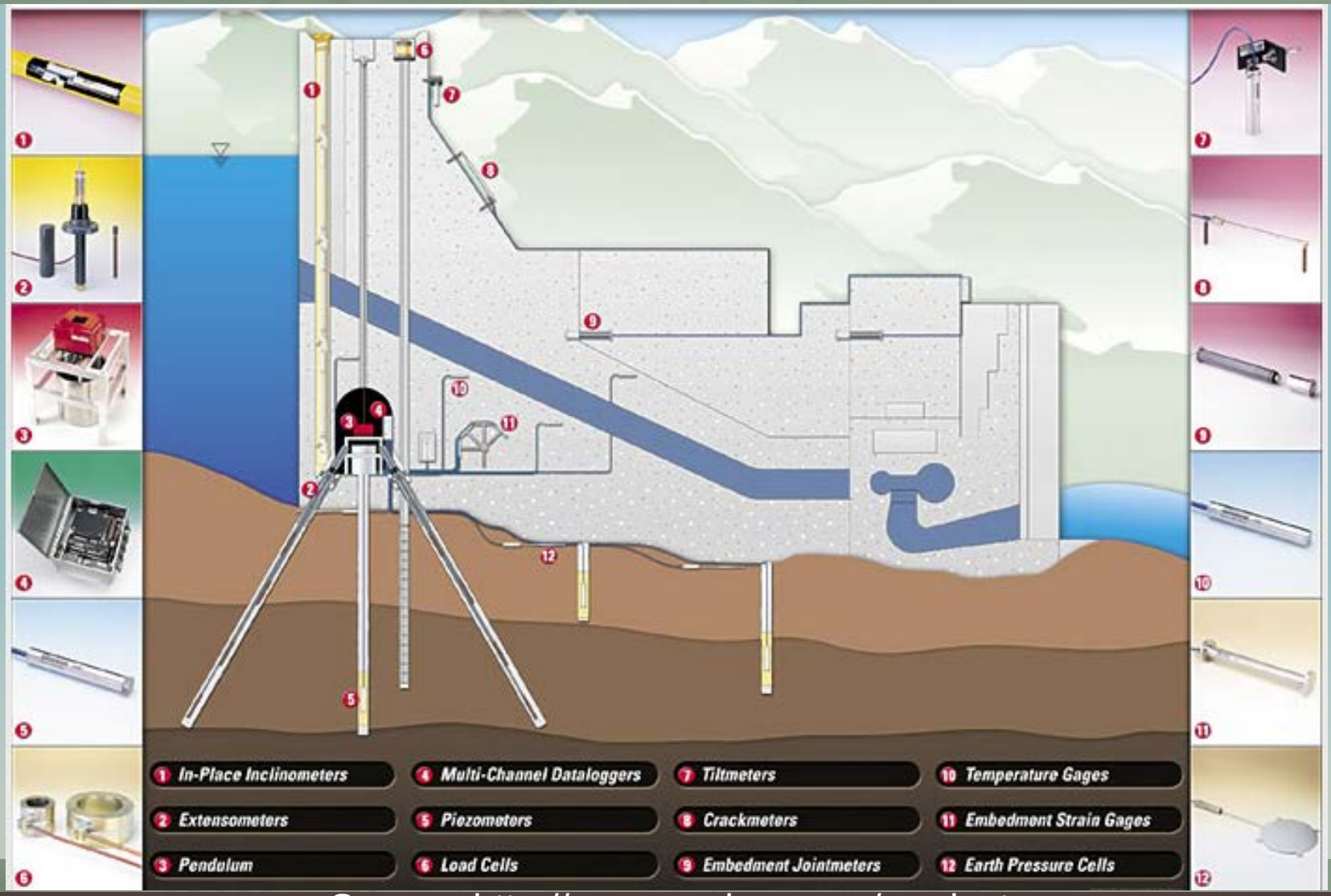
- Early Warning System
- Data Processing, Interpretation & Presentation Software
- Databases & Data Management System

TYPICAL INSTRUMENTATION FOR EARTH DAM



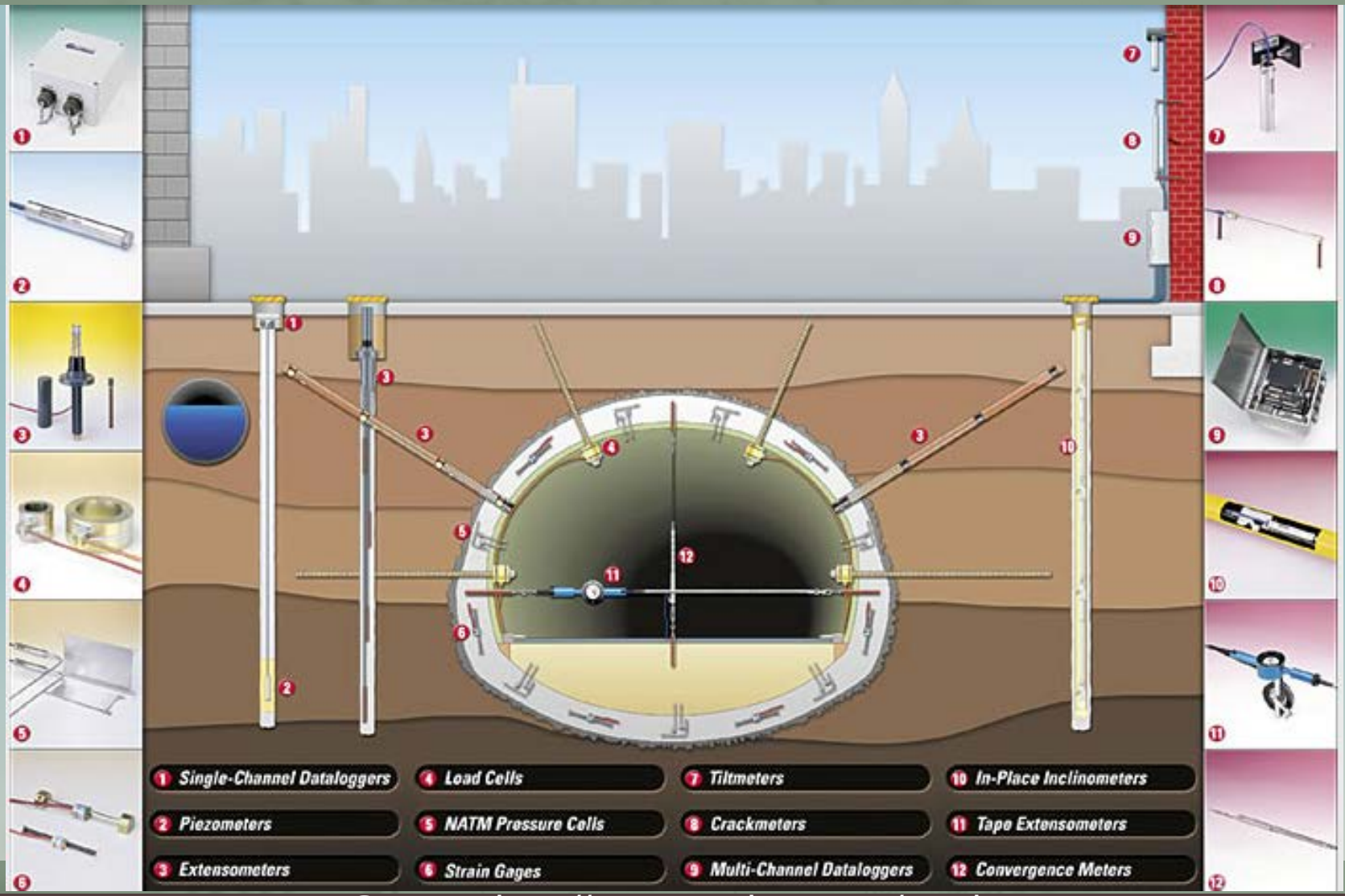
Source: http://www.geokon.com/products

TYPICAL INSTRUMENTATION FOR CONCRETE DAM



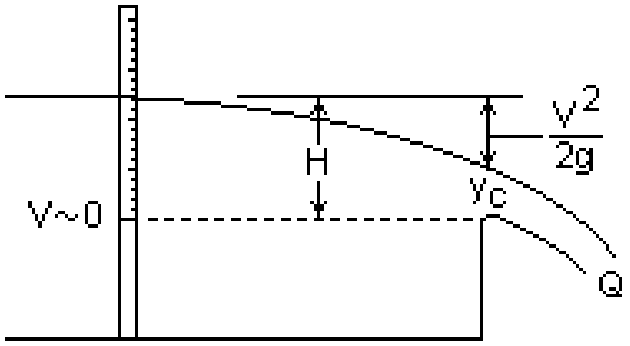
Source: http://www.geokon.com/products

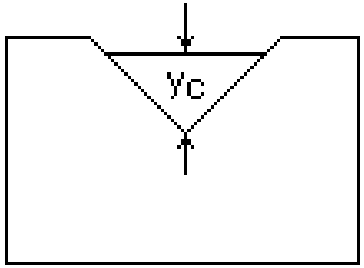
TYPICAL INSTRUMENTATION FOR TUNNEL



Source: http://www.geokon.com/products

DAM LEAKAGE/SEEPAGE MEASUREMENT

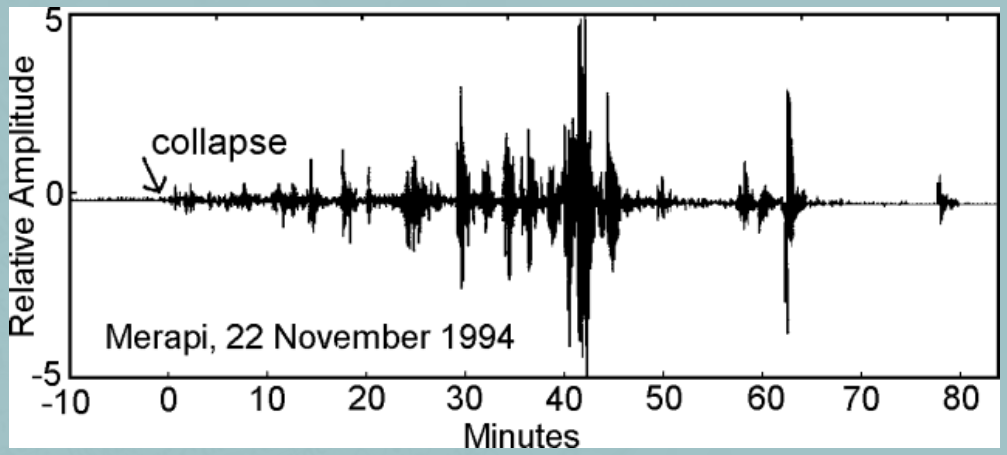




$$Q = \left(\frac{g}{2}\right)^{1/2} y_c^{5/2} = V y_c^2 = 1.267\, H^{2.5} \quad (H \text{ in m})$$

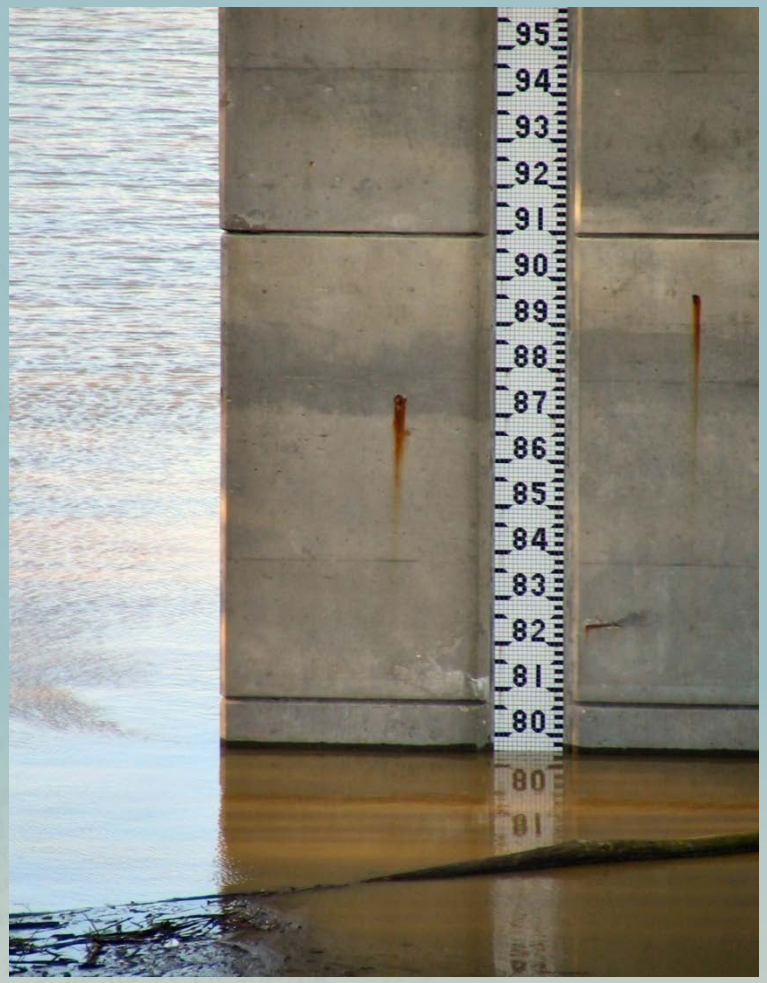
Flow Through a V-Notch Weir

SEISMOMETER



HYDROLOGICAL INSTRUMENTATION

Flip Bucket Rain Gauge

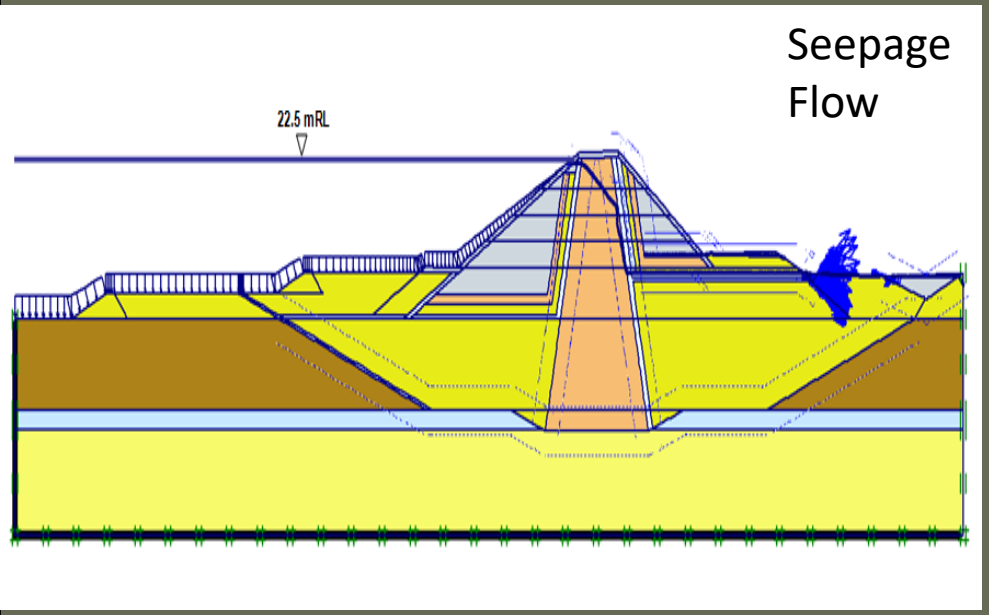


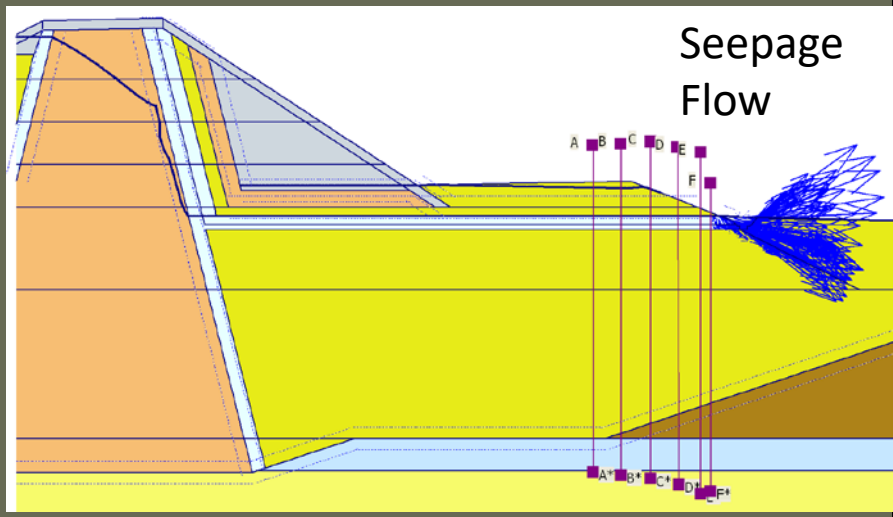
DISPLACEMENT SURVEY USING 3D GROUND BASED TERRESTRIAL LiDAR

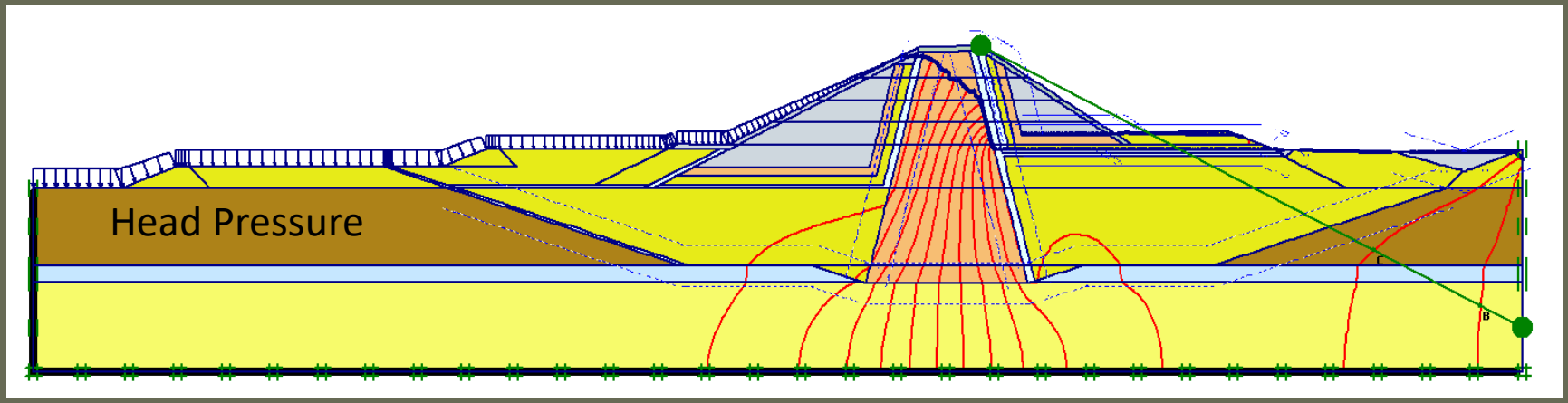
3D Light Detection and Ranging Equipment (LiDAR)

BEHAVIOURAL ANALYSIS

BEHAVIOURAL ANALYSIS
Seepage Analysis (FEM Modelling)





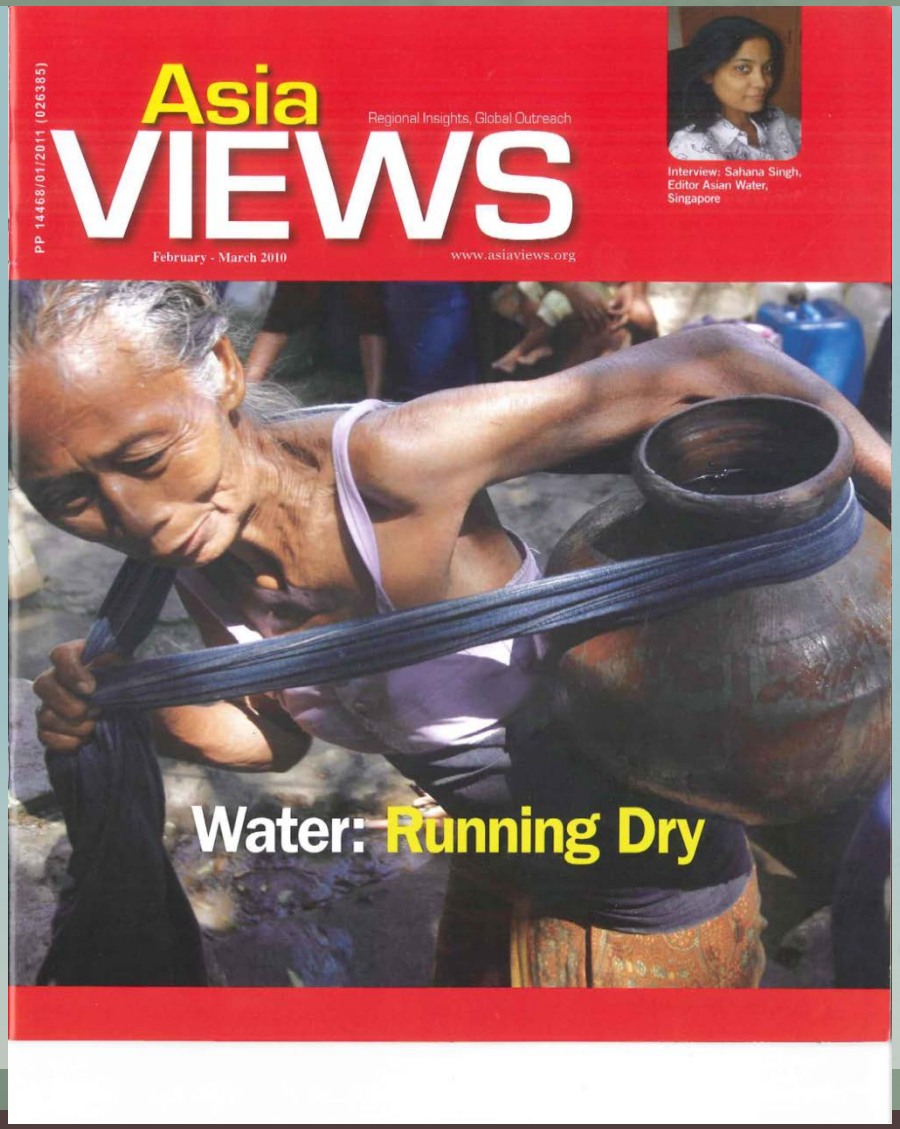


FEM - 0.2 lit/s to 0.4 lit/s

TREND OF FUTURE DAM DEVELOPMENT

- More future dam development due to:
  - Energy shortage & green energy encourage hydropower dam development
  - Climate change & urbanisation lead to development of dams with multi-purposed water supply, irrigation & flood defense dams
- More dam projects under private initiated fund
- Uncontrolled development within water catchment (lack of development land)

CLIMATE CHANGE & WATER CRISIS



- March 2010
- Dried-out reservoir in Kunming, China

UNDERLYING PROBLEMS OF CURRENT MALAYSIA DAM SAFETY PRACTICE

- Lack of legal institutional power in Regulatory Frameworks
- Unclear line of responsibility among the stakeholders
- Inconsistent practice & reporting of Dam Safety
- Lack of inter-agency coordination hinders efficient development of multi-purpose dams with combined interests
- Tailing dams are exclusive under the current guidelines
- Landslides, siltation & water quality problems arise from uncontrolled development within water catchment
- Lack of **Central Regulatory Agency**

WHAT MALAYSIA NEEDS FOR DAM SAFETY REGULATORY FRAMEWORKS?

- Regulatory frameworks for Dam Safety
  - **Legal form of the regulation**

    (***Statue/acts, regulations, decrees*** *or* ***guidelines***)
  - **Institutional arrangement**

    (*position of regulatory authority within government structure, their independence from policymakers & regulated entities, relationship with other government bodies*)

Current stage of Malaysia

WHAT MALAYSIA NEEDS FOR DAM SAFETY REGULATORY FRAMEWORKS?

- Regulatory frameworks for Dam Safety (Cont'd)
  - **Powers of regulating entity**

    (*advisory function or regulation binded decisions [issue License/Permit to construct & operate], rule and policymaking & enforcement power of the regulator, ability to monitor & inspect the operations of the regulated entities*)
  - **Content of regulatory scheme**

    (*regulated entities' obligations, scope of regulations, consequences of non-compliance*)
- Classify **essential elements**, **desirable elements** & **emerging trends** in the regulatory frameworks

THANK YOU

Lord Kelvin (1827 - 1907) :

When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.

KeTTHA
KEMENTERIAN TENAGA, TEKNOLOGI HIJAU DAN AIR