DAM SAFETY MONITORING & SURVEILLANCE IN MALAYSIA

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DAM BREACH: SOME CASE HISTORIES

Teton Dam (1975 – 1976)

Immediately following the disaster, Mulholland said he "envied those who were killed" and went on to say, "Don't blame anyone else, you just fasten it on me. If there was an error in human judgment, I was the human, and I won't try to fasten it on anyone else."

"the construction and operation of a great dam should never be left to the sole judgment of one man, no matter how eminent."

St Francis Dam, US
1924-1928

(Killed *600* people)

Vajont Dam, Italy
1959-1963

(Killed *2000* people)

Situ Gintung Dam, Indonesia (1933 –2009)

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

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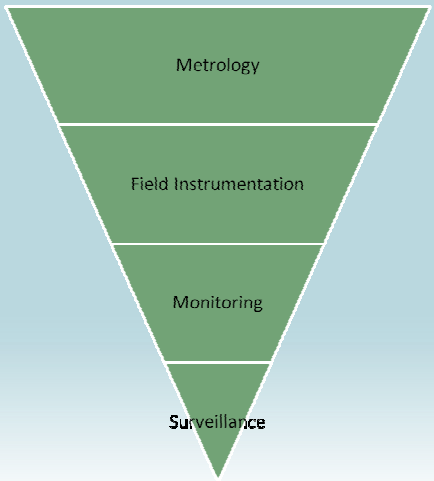
- Prevent **disastrous consequences** to:
  - National Security
  - Public Safety
  - Social Economy
  - Environmental

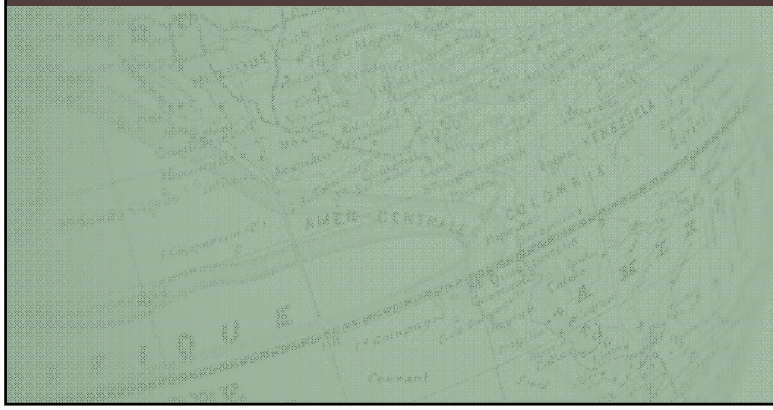


OBJECTIVE OF DAM SAFETY MONITORING & SURVEILLANCE

Dam Safety Monitoring & Surveillance should include identifying :

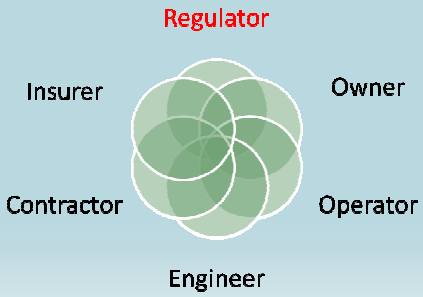
- **Factors** that influence
  - **Safe operation** of dam / appurtenant structures
  - **Dam's potential** to adversely affect human life, human health, property, and the environment surrounding it.
- **Adequacy** of operations, maintenance & emergency plan of the dams

ROLE & RESPONSIBILITY OF STAKEHOLDERS



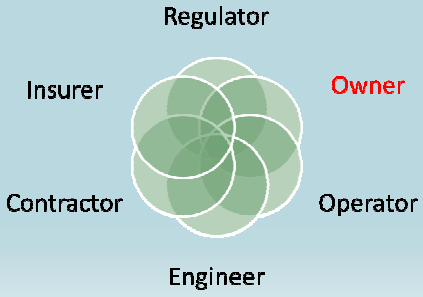
ROLE & RESPONSIBILITY OF DAM REGULATOR

- **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**



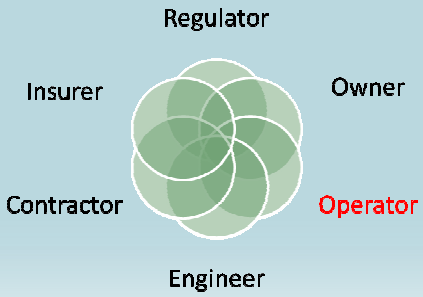
ROLE & RESPONSIBILITY OF DAM OWNER & OPERATOR

- **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**



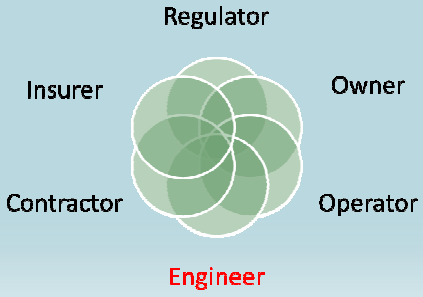
ROLE & RESPONSIBILITY OF DAM OWNER & OPERATOR

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



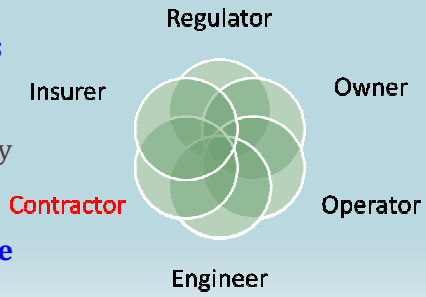
ROLE & RESPONSIBILITY OF DAM ENGINEER

- **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

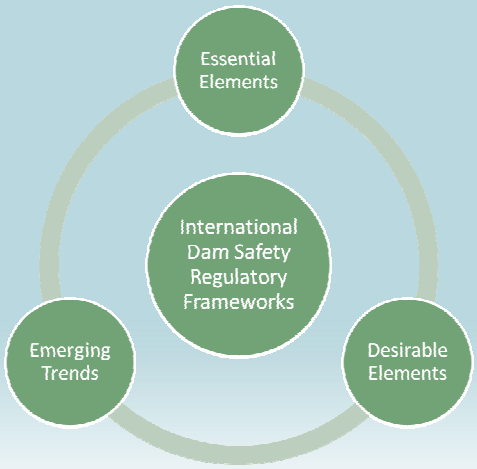


DAM SAFETY MANAGEMENT

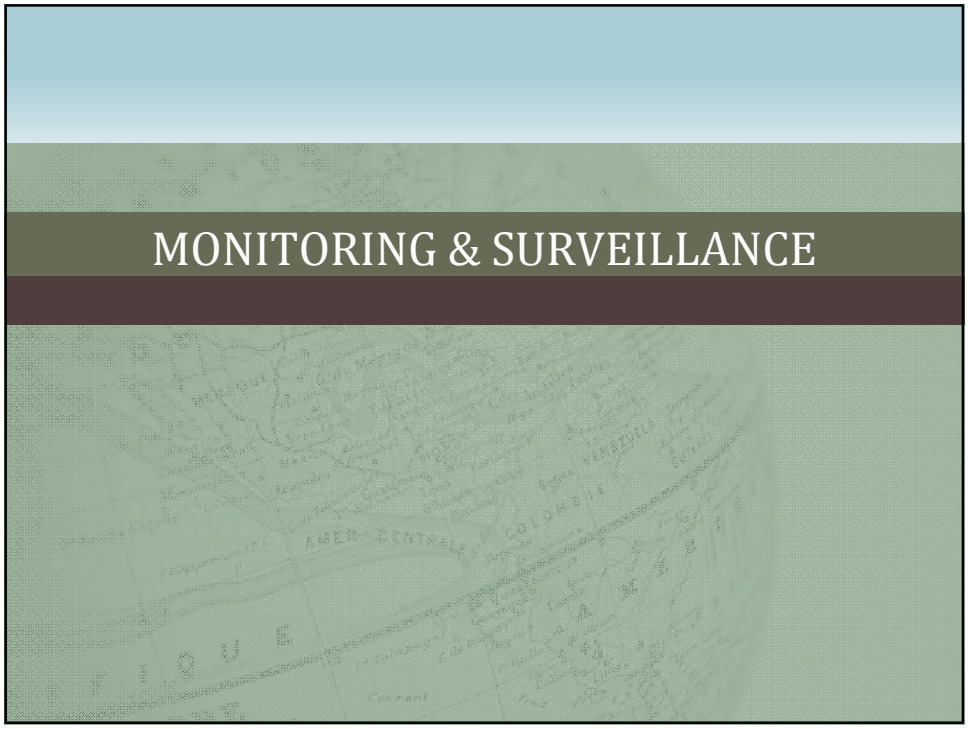
DAM SAFETY MANAGEMENT

- **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



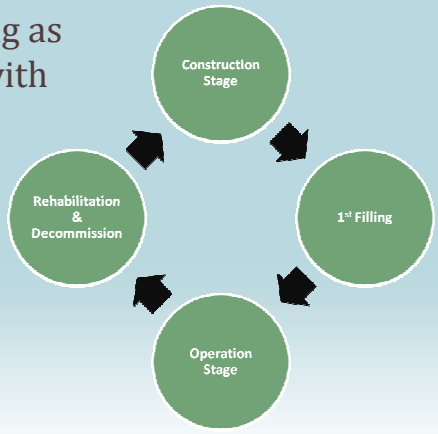
MONITORING & SURVEILLANCE

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

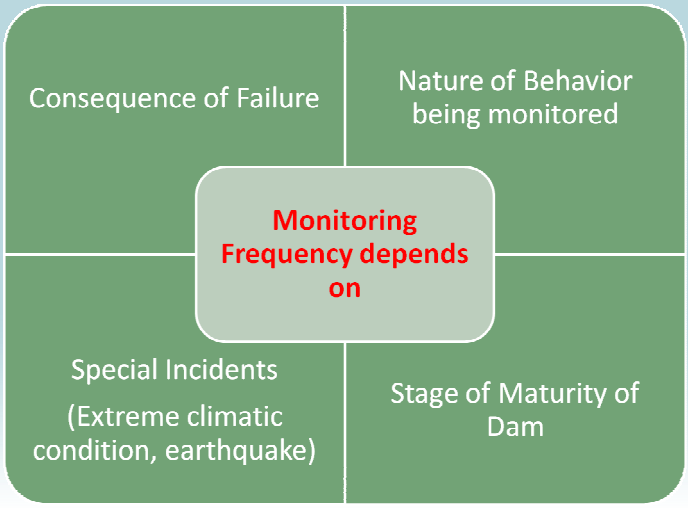
- Monitoring & Surveillance shall be **continued** as long as the **hazards** associated with the existence of the dam present.
- **Level** of Monitoring & Surveillance depends on **consequences** of failure.



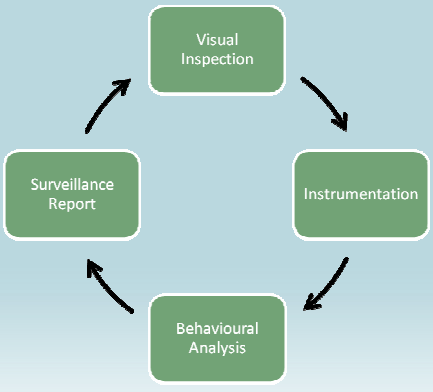
MONITORING

- **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



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

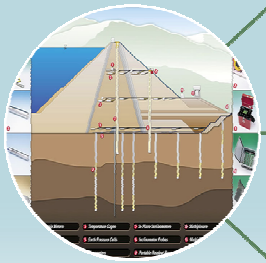
EROSION ON EMBANKMENT SLOPES

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

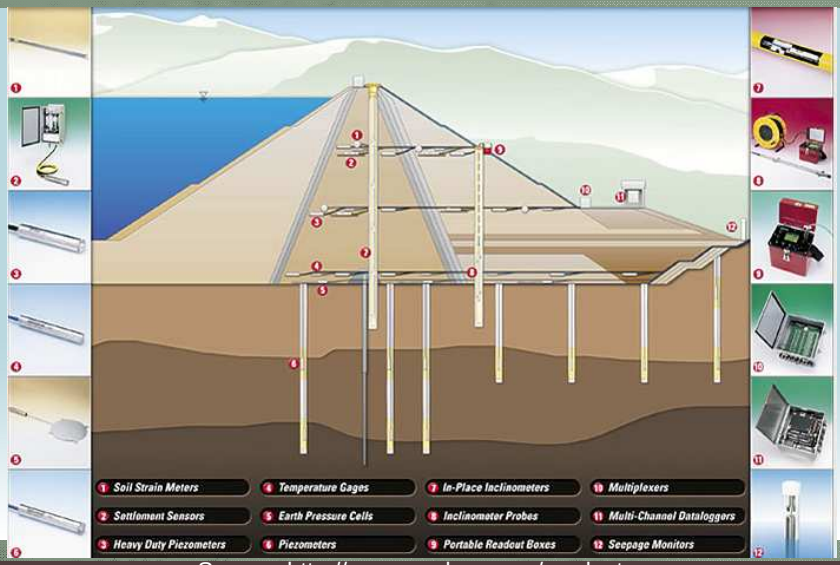
Problems & Solutions

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

Analysis & Software

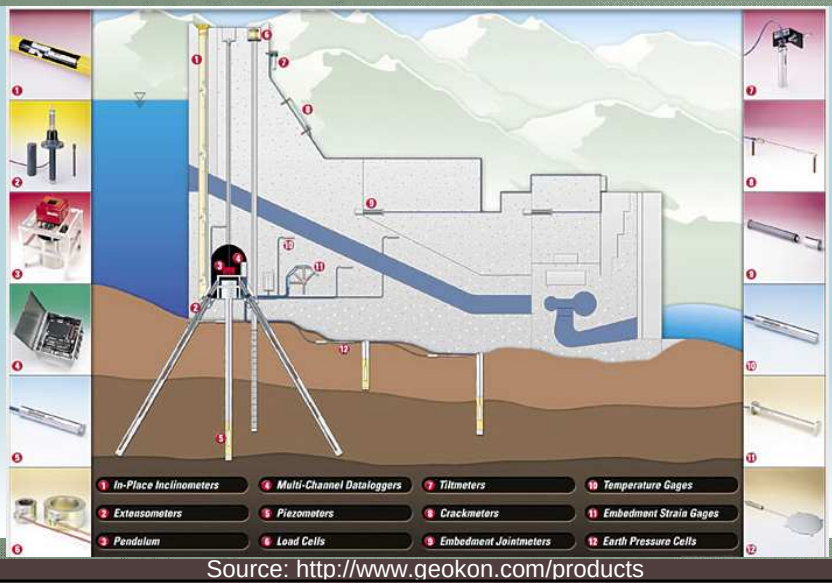
- Early Warning System
- Data Processing, Interpretation & Presentation Software
- Databases & Data Management System

TYPICAL INSTRUMENTATION FOR EARTH DAM



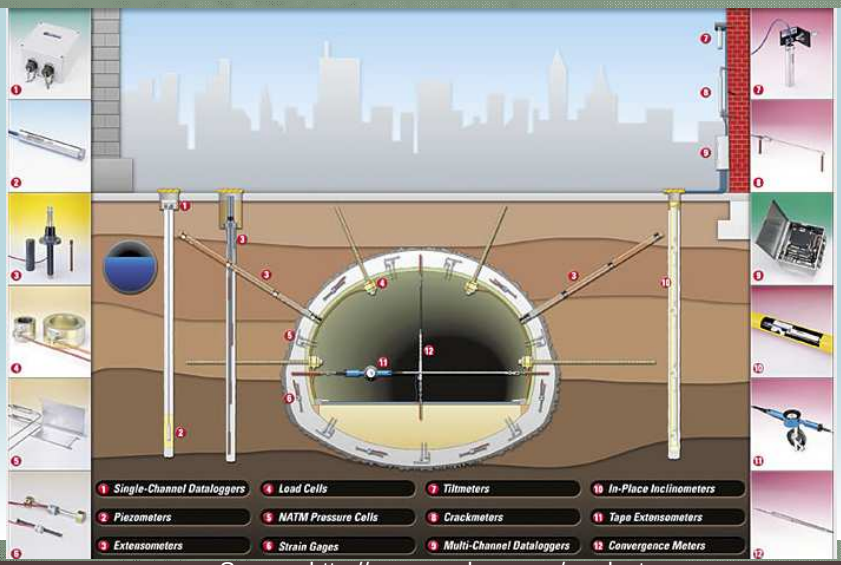
Source: http://www.geokon.com/products

TYPICAL INSTRUMENTATION FOR CONCRETE DAM



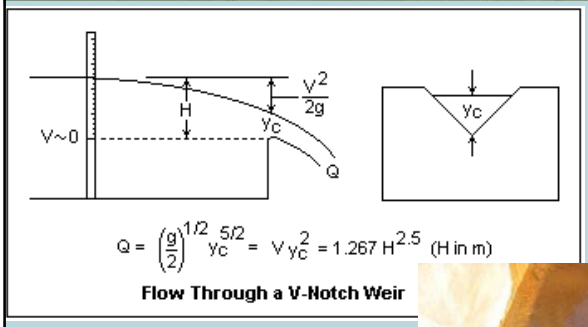
Source: http://www.geokon.com/products

TYPICAL INSTRUMENTATION FOR TUNNEL



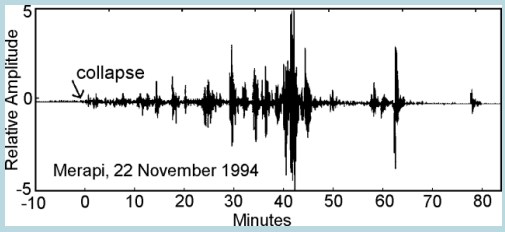
Source: http://www.geokon.com/products

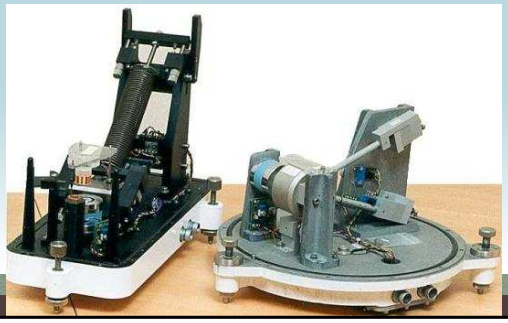
DAM LEAKAGE/SEEPAGE MEASUREMENT



Flow Through a V-Notch Weir

SEISMOMETER





HYDROLOGICAL INSTRUMENTATION

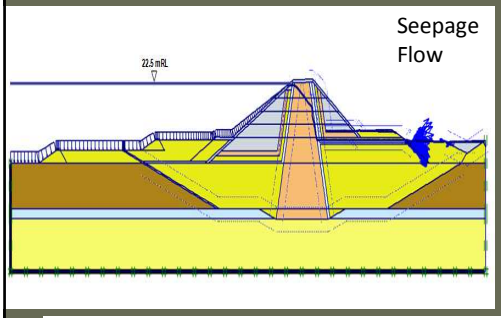
Flip Bucket Rain Gauge

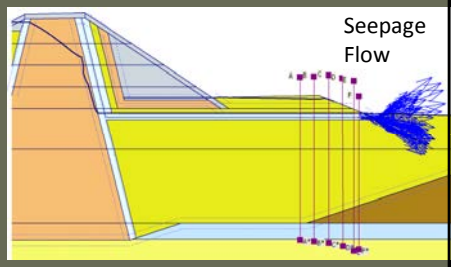
DISPLACEMENT SURVEY USING 3D GROUND BASED TERRESTRIAL LiDAR

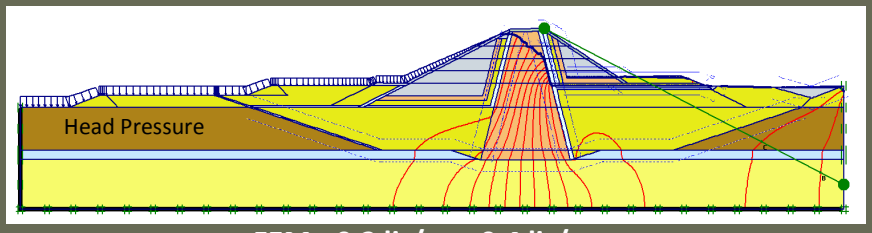
3D Light Detection and Ranging Equipment (LiDAR)

BEHAVIOURAL ANALYSIS

BEHAVIOURAL ANALYSIS
Seepage Analysis (FEM Modelling)

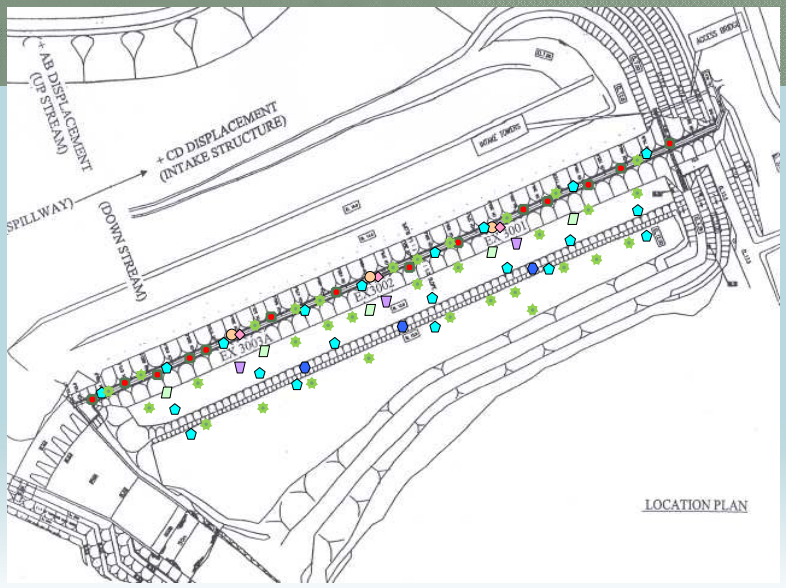






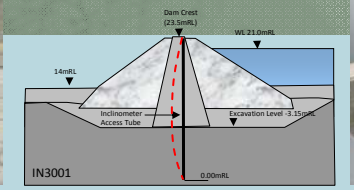
FEM - 0.2 lit/s to 0.4 lit/s

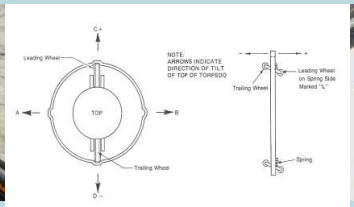
INSTRUMENTS LAYOUT PLAN



- Inclinometer Location (CH250,400,550)
- Magnetic Probe Extensometer
- Surface Settlement Markers
- Vibrating Wire Piezometer (CH250,400,550)
- Standpipe Piezometer (CH100,250,400,550,650)
- Seepage Measurement Chambers (CH250,400,550)
- Optical Prism
- Settlement Pin

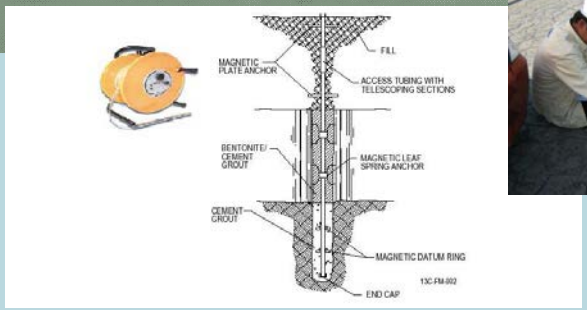
1. Inclinometer Monitoring



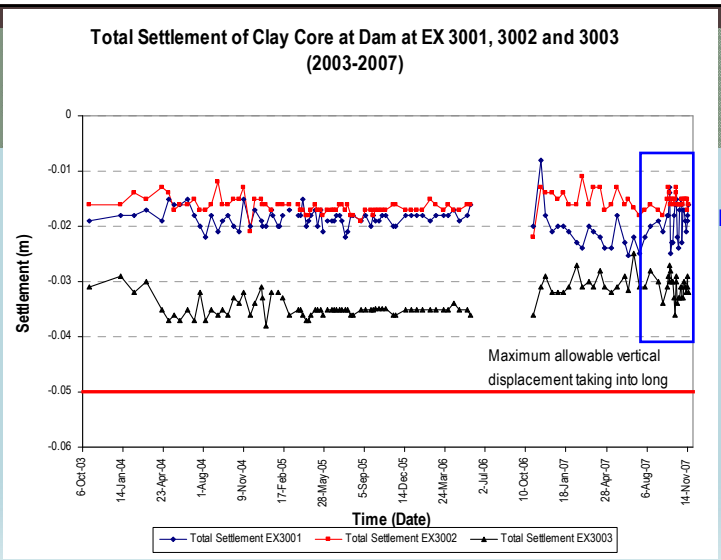


3 inclinometer stations were installed at respective chainages to measure horizontal movement in the dam embankment (e.g. A-B direction: Upstream-downstream direction).

2. Magnectic Probe Extensometer



Magnetic Probe Extensometer is used to monitor the internal vertical displacement of embankment and foundation of the dam.

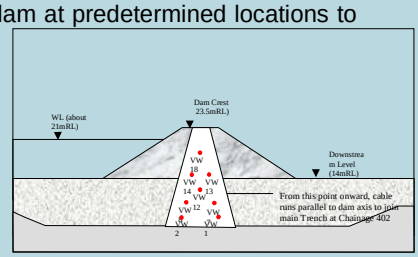


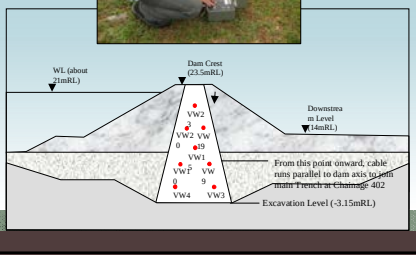
IMP

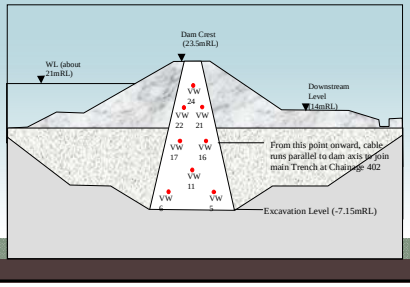
Total settlement for all 3 stations EX 3001, EX 3002 and EX 3003 are well below the specified permissible limit of 50mm in the past (2002-2006) and during the IMP

3. Vibrating Wire Piezometer

There are 24 numbers of vibrating wire piezometer gauges installed/embedded in clay core of the dam at predetermined locations to measure the pore pressure.

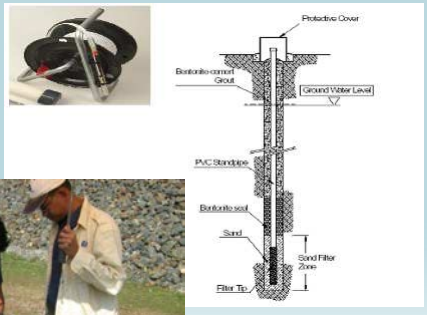






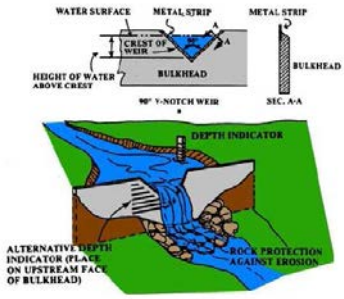
4. Standpipe Piezometer

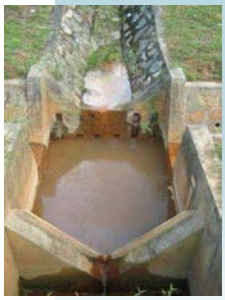
Standpipe piezometers are used to monitor the Groundwater Table in the stability berm at the downstream of the dam. There are five stations installed at the dam toe.



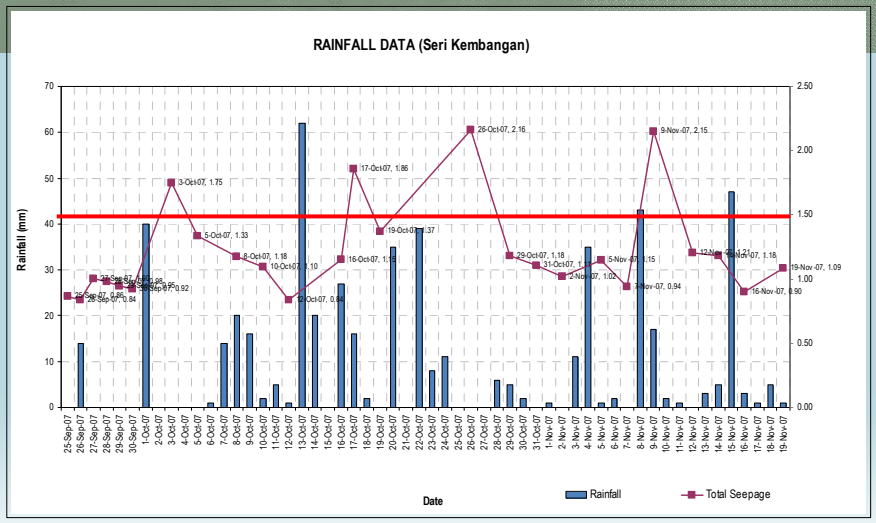
5. Seepage Measurement Chamber

There are 3 seepage measurement chambers (v-notch weir) downstream of the dam at SC 01, SC 02 and SC 03 to measure the amount of the dam seepage water.



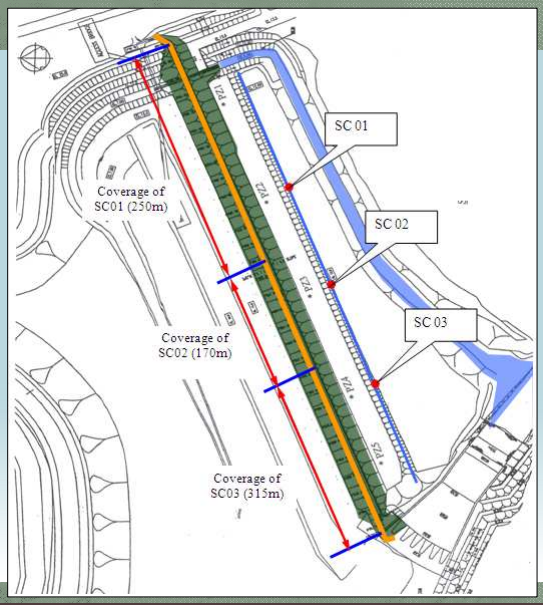


Rainfall Data vs Seepage

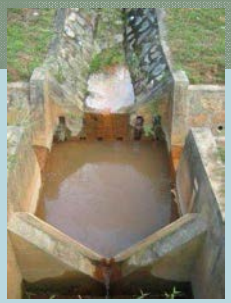


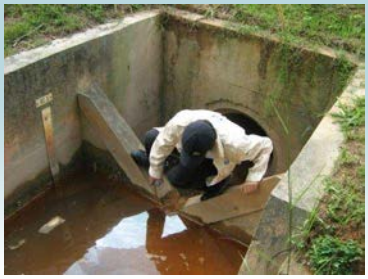
It is evident that high seepage readings invariably were attributed to high rainfall values recorded at Seri Kembangan station located within the Putrajaya upper catchment boundary.

Seepage Chamber Coverage Area



SITE PHOTO





7. Total Station and Optical Prism Position, Precise Settlement Monitoring

To monitor any settlement or movement along the dam crest and its profile. Survey work was carried out during the IMP to monitor the following instruments:

1.Existing Surface Settlement Marker (21 pts)
2.Additional Optical prism (32 pts), and
3.Additional Settlement Pin (14 pts)

SSM Survey

OP Survey

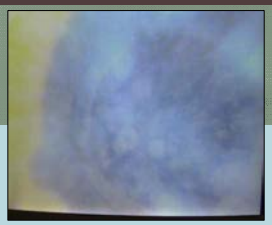
SP Survey

8. Visual Inspection of inclinometer tubing

Micro camera for inclinometer tubing inspection

The recorded video images show that there is no physical damage found in all the 3 inclinometer tubing. The inspection also confirmed that the maximum displacement recorded for the inclinometer was all at the joint locations.

It has cleared the earlier doubt that the useful life of these tubing ended when tubing curvature had forced the inclinometer probe out of the access grooves in the tube and prevented passage of the inclinometer probe.

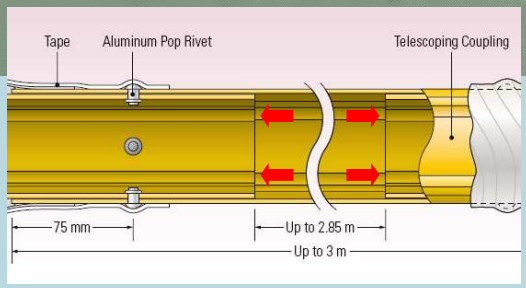


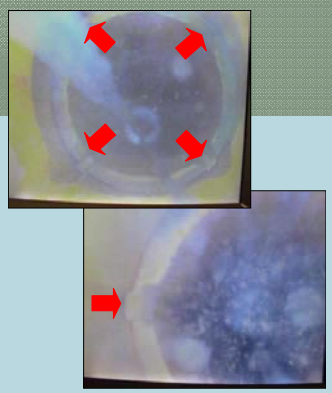
Depth at 13.5m (Joint)

Depth at 16.5 (Joint)

Closer look at the joint.

Finding





The ramp at the access groove interface between the tubings and the telescoping coupling has introduced slight discontinuity, caused the new inclinometer probe (Bluetooth inclinometer), which is much lighter compared to the old inclinometer probe, to experience difficulty to advance into the tubing.