SISGEO®
Latinoamérica S.A.S

— DAMS
SAFETY AND MONITORING

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DAMS SAFETY AND MONITORING

WHY DAM MONITORING?

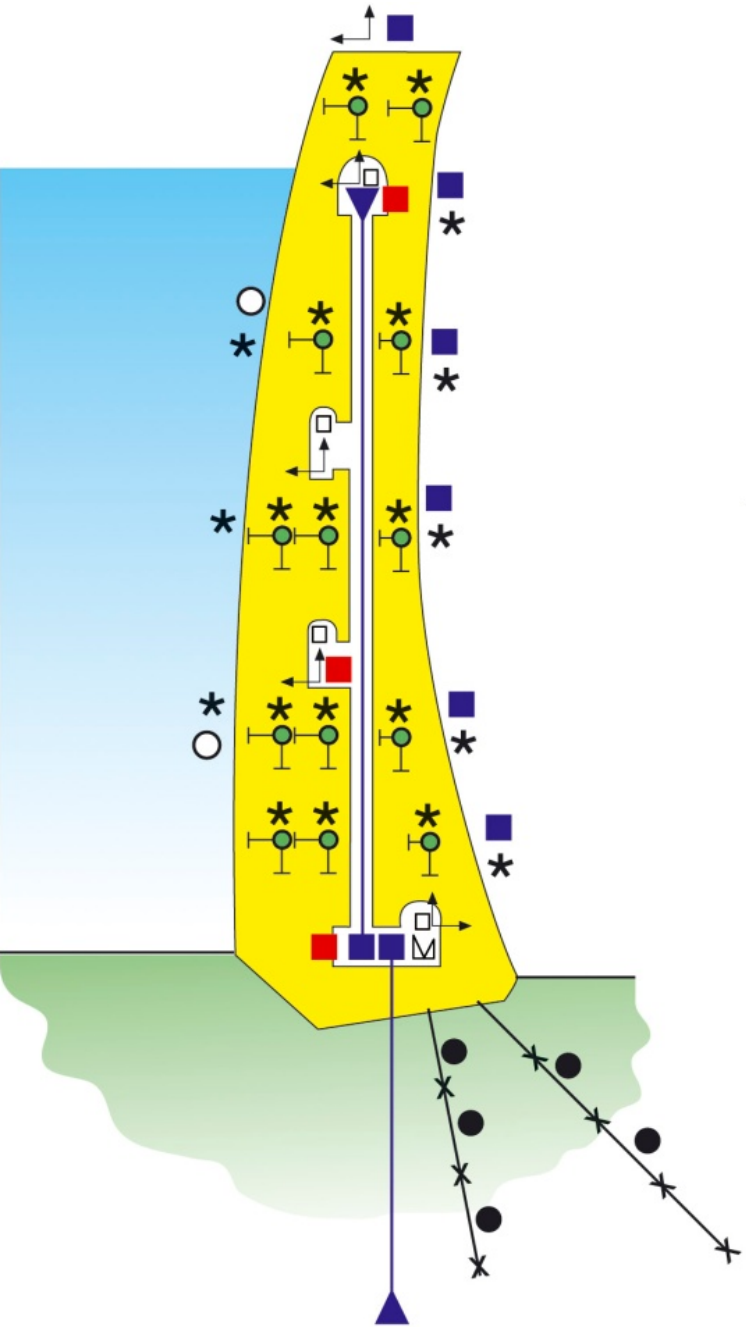
The most common causes of failure of operating dams are:

- *poor construction materials*
- *geological instability*
- *landslide into reservoir*
- *poor maintenance*
- *human, computer or design error*
- *internal erosion (earth-fill dams)*
- *earthquakes*

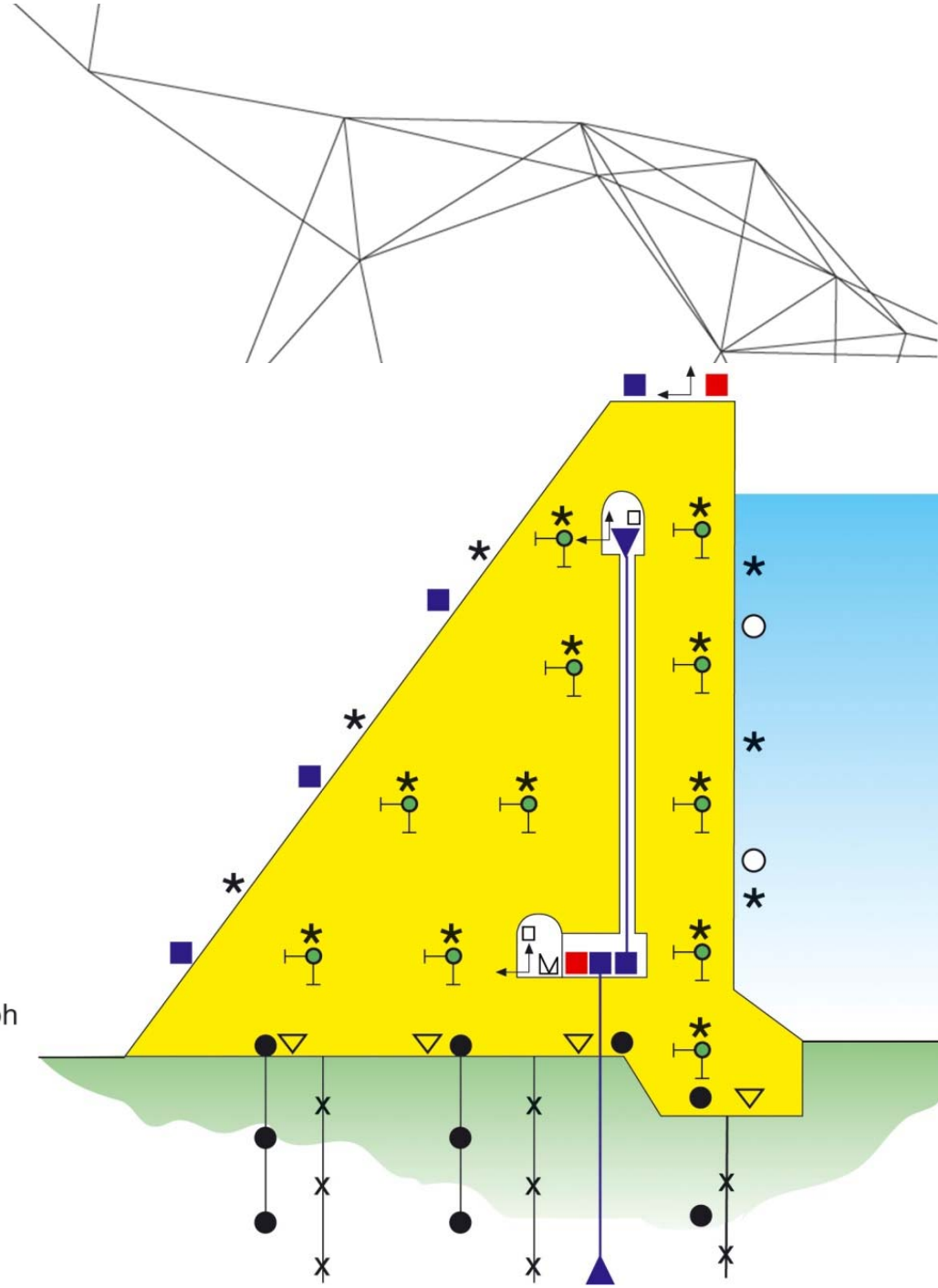
→ ***Inadequate monitoring system***

Vajont Dam, Italy

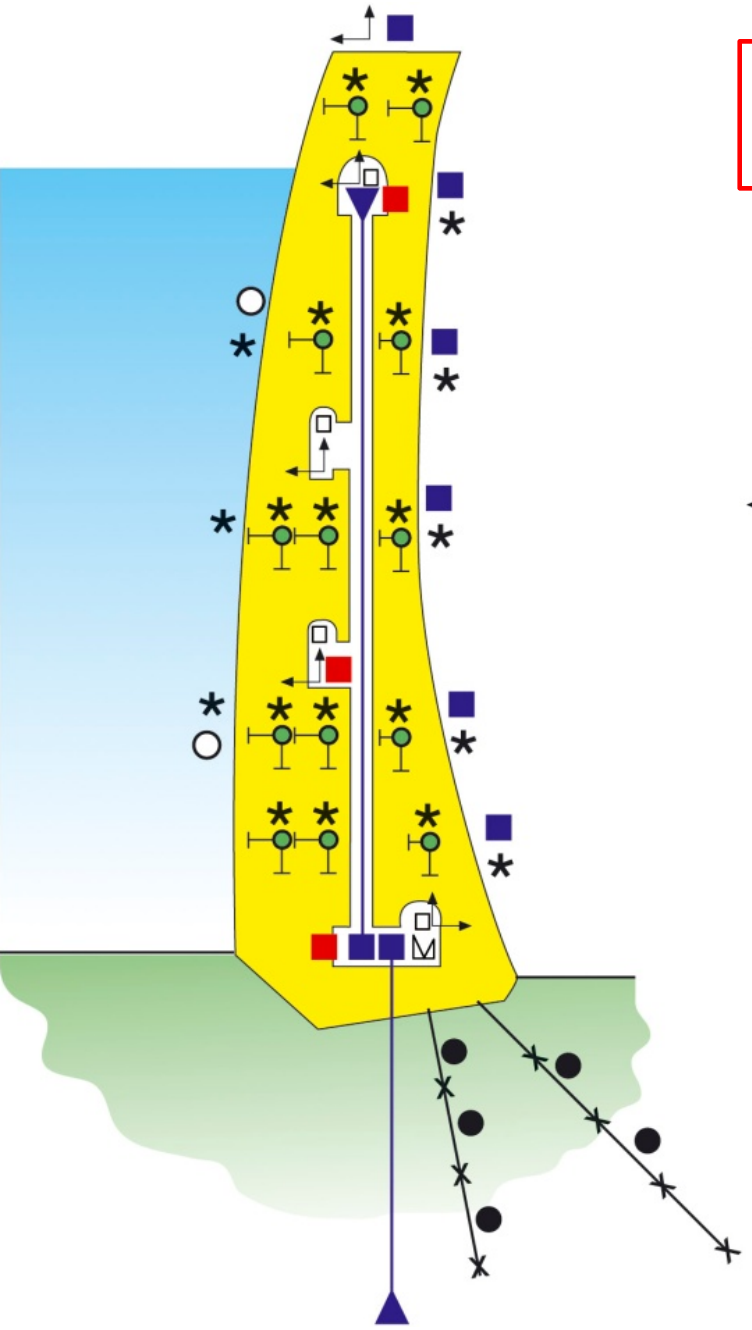
ARCH AND GRAVITY DAMS



- Direct pendulum
- Inverted pendulum
- Embedded strain-gauge
- Thermometer
- Weir (flow meter)
- Tiltmeter (clinometer)
- Joint meter
- Borehole extensometer
- Piezometer
- Earth pressure cell
- Water level meter
- Survey point
- Strong motion accelerograph



PENDULUMS AND READOUTS



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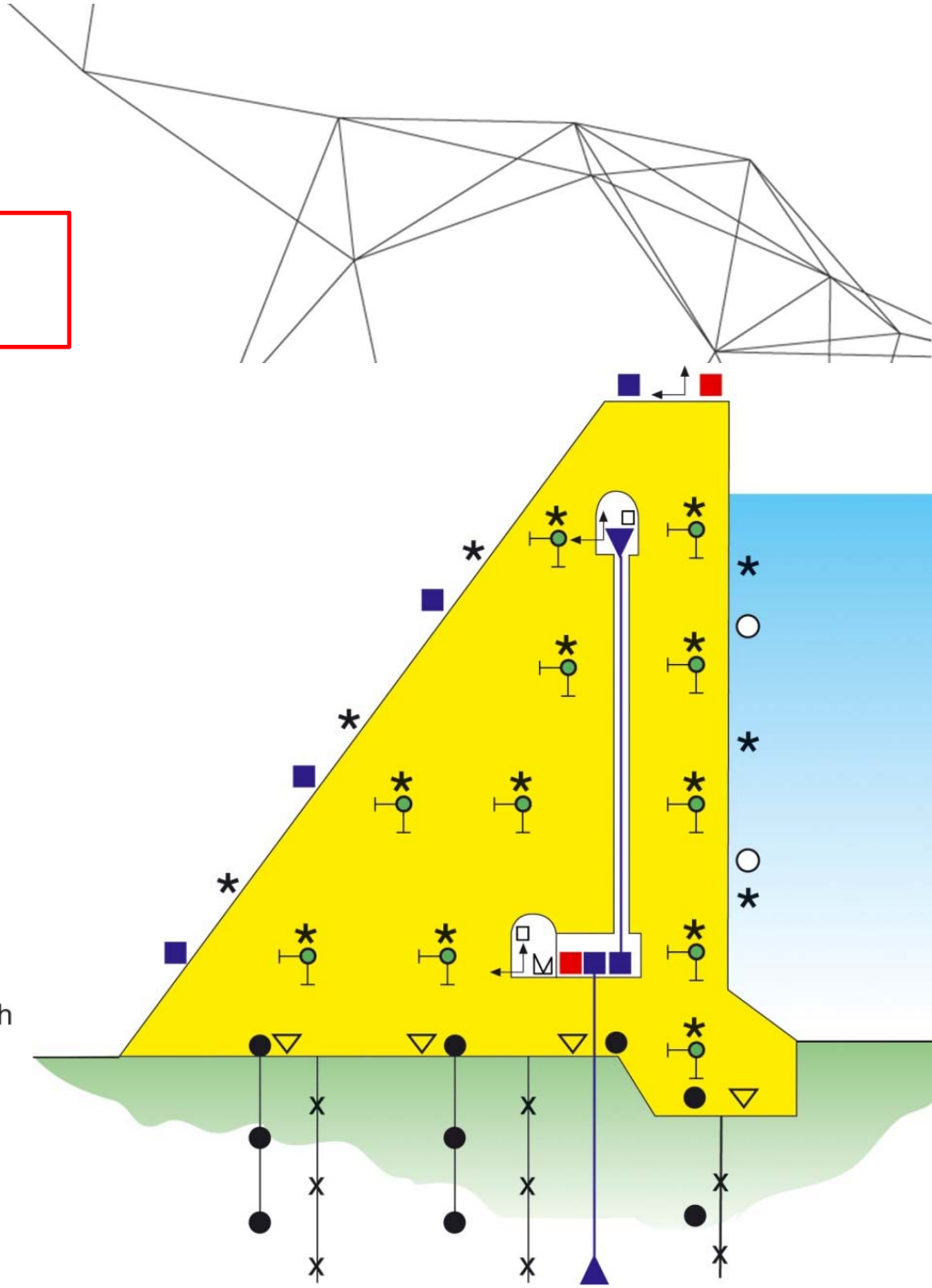
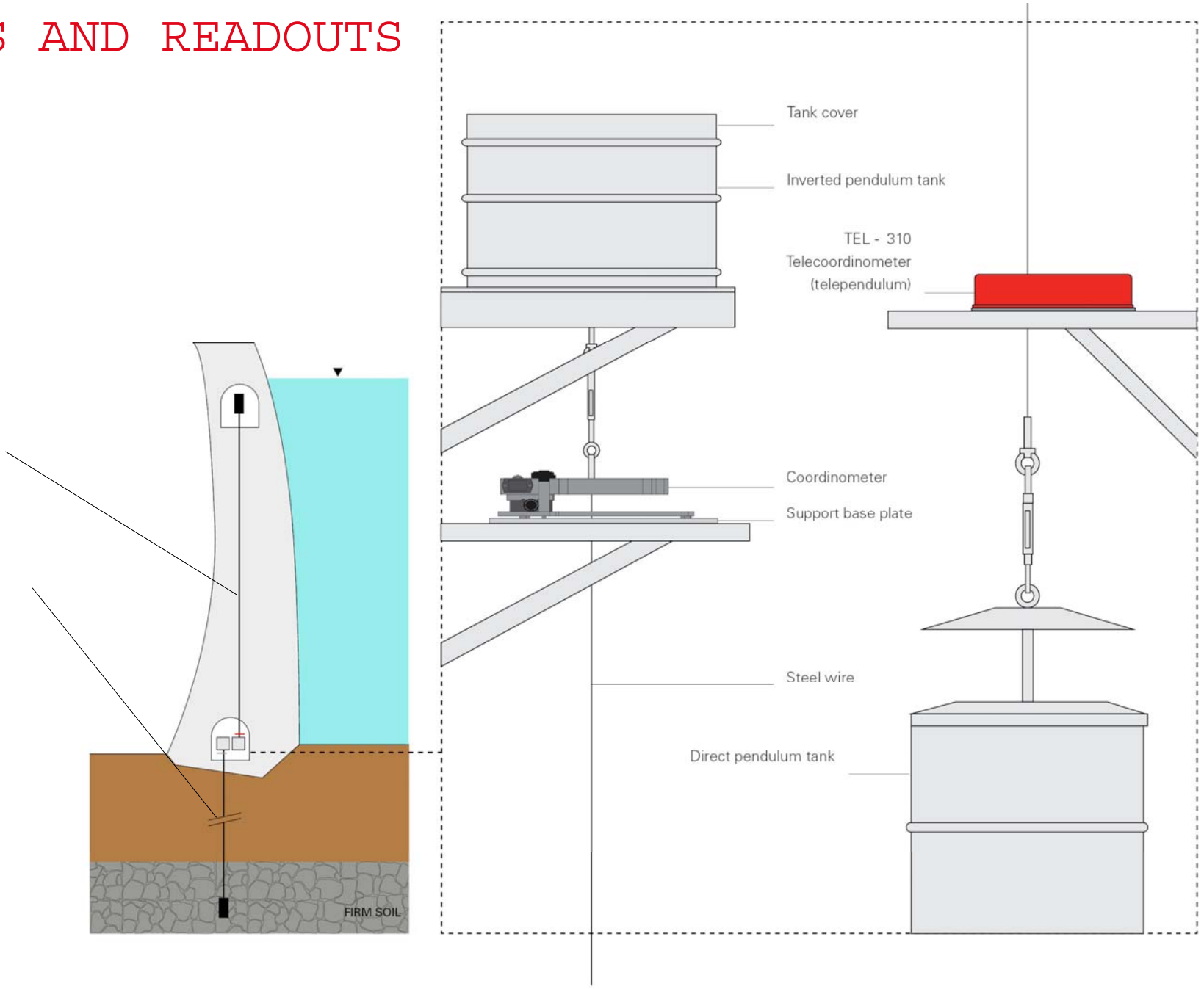


PENDULUMS AND READOUTS

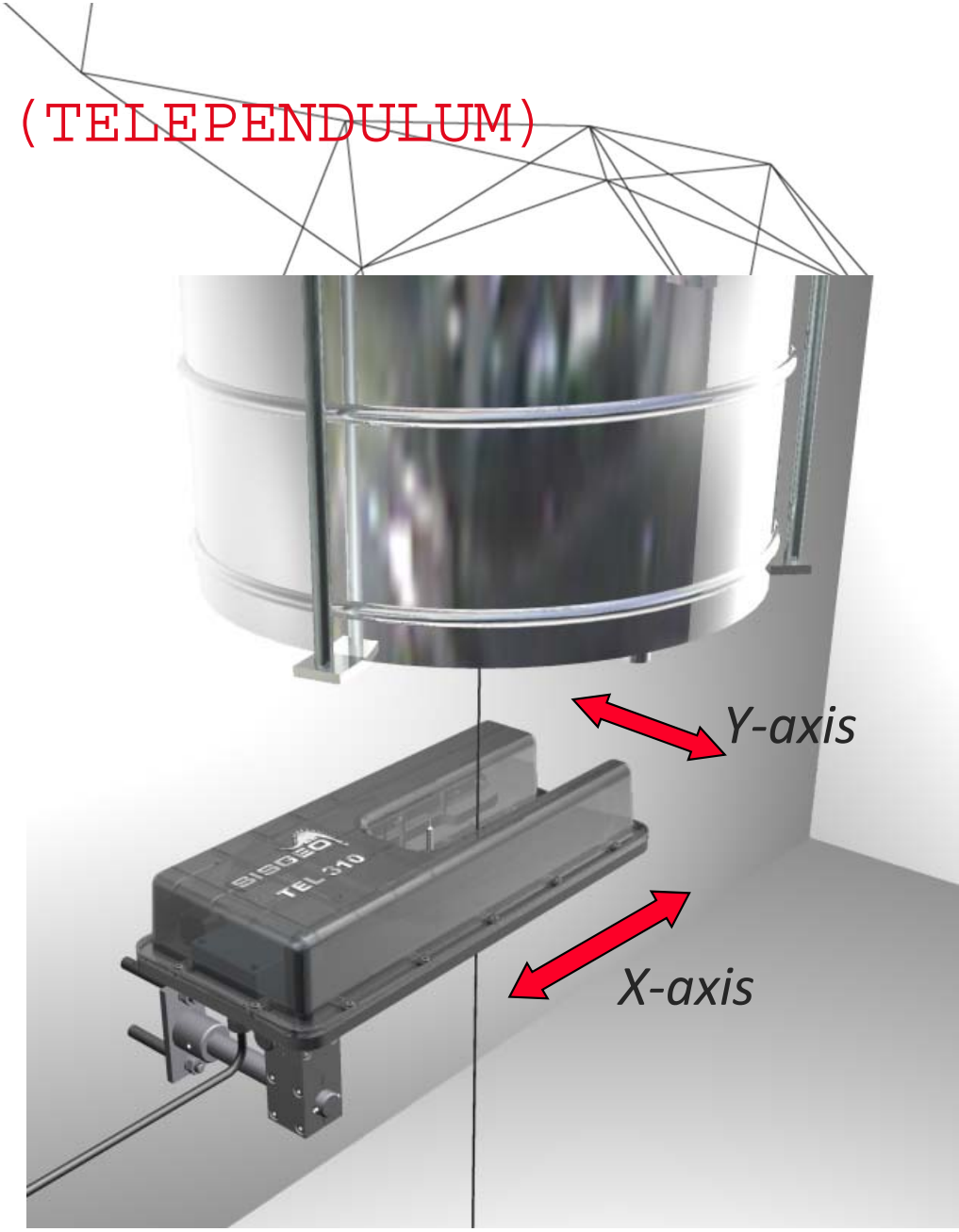
Direct pendulum

Inverted pendulum



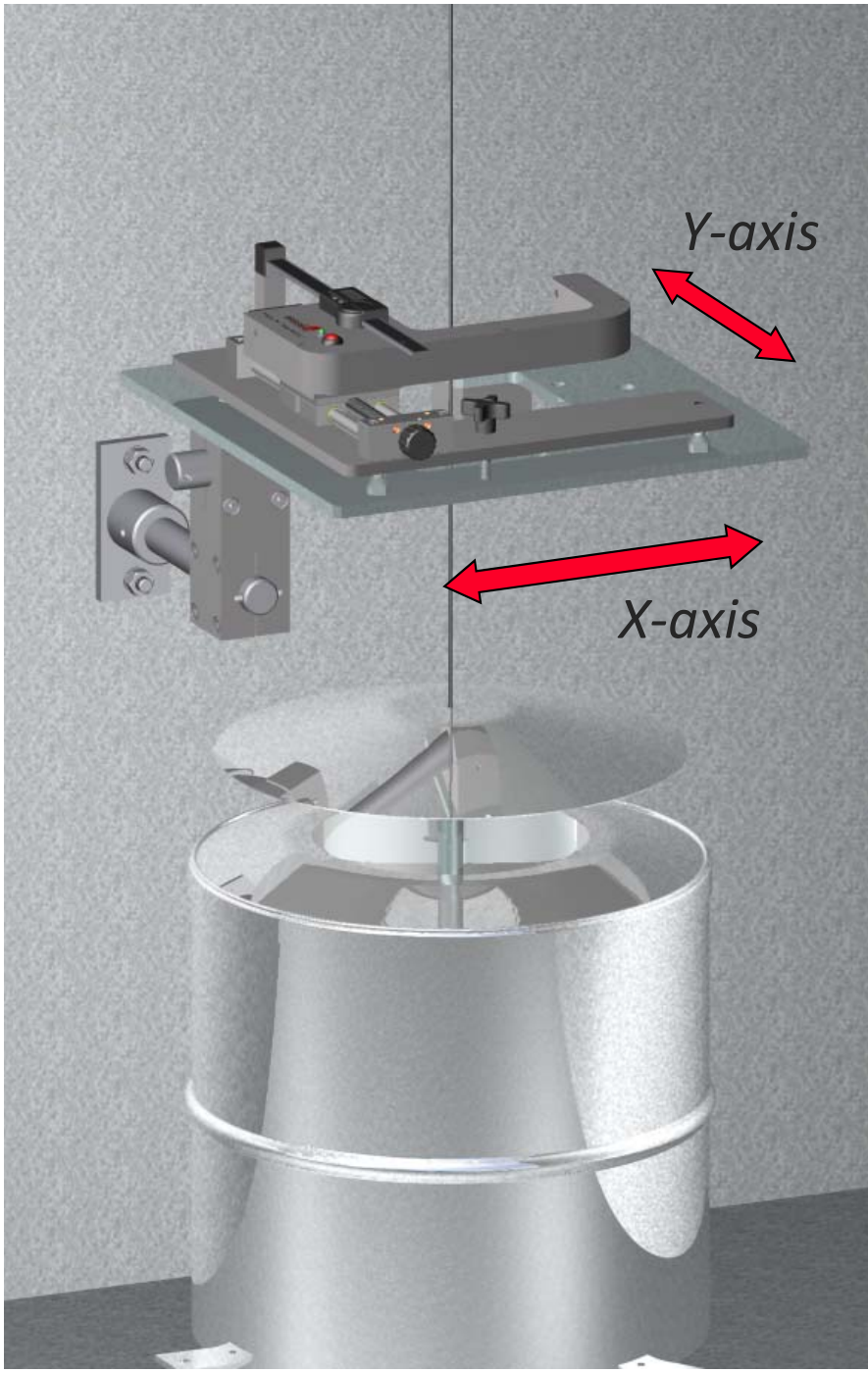
TEL-310 TELECOORDINOMETER (TELEPENDULUM)

- *Wide measuring range: 60x145mm;*
- *Waterproof components IP68 until 50kPa (5m water head);*
- *Remote auto-diagnostic through "log file";*
- *High level built-in software for data elaboration and validation.*

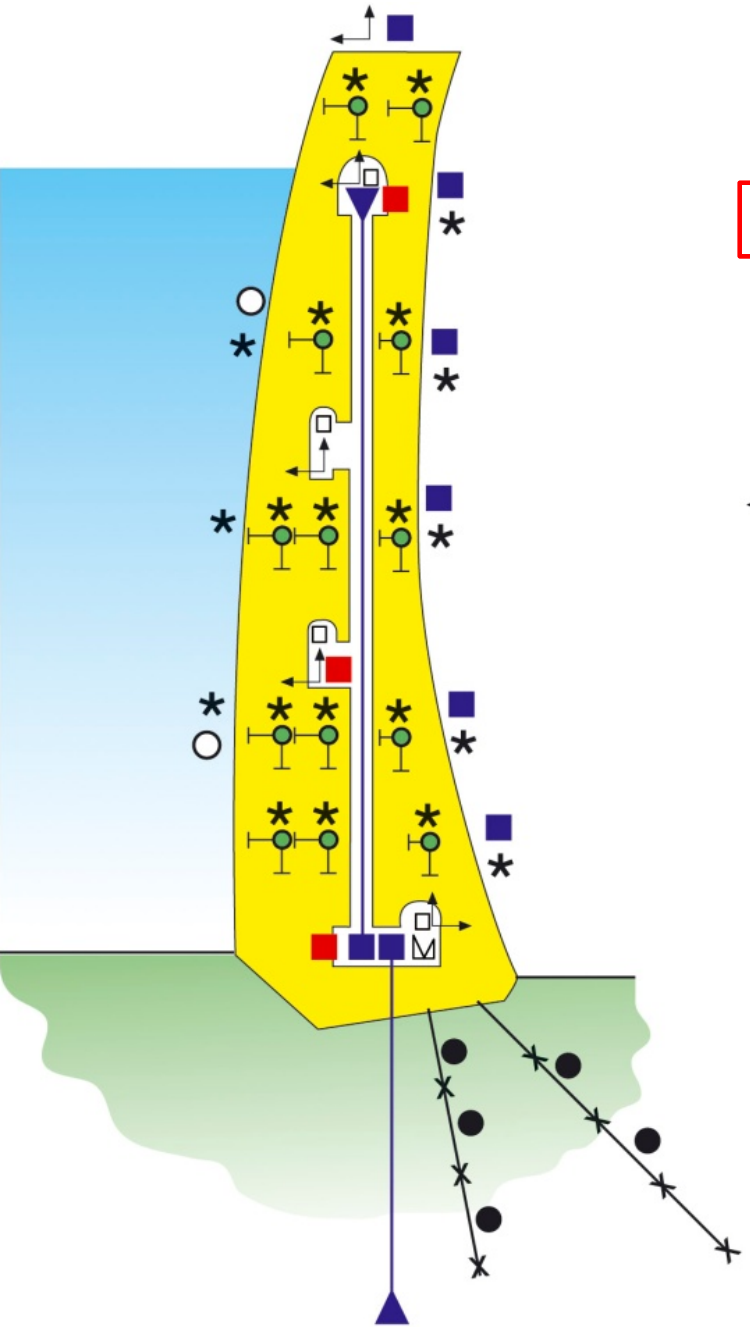


MANUAL COORDINOMETER

- *Simple to use*
- *Removable in order to take readings in different location*
- *Suitable to substitute TEL310 telecoordinoometer under service*



VIBRATING WIRE STRAIN GAUGES



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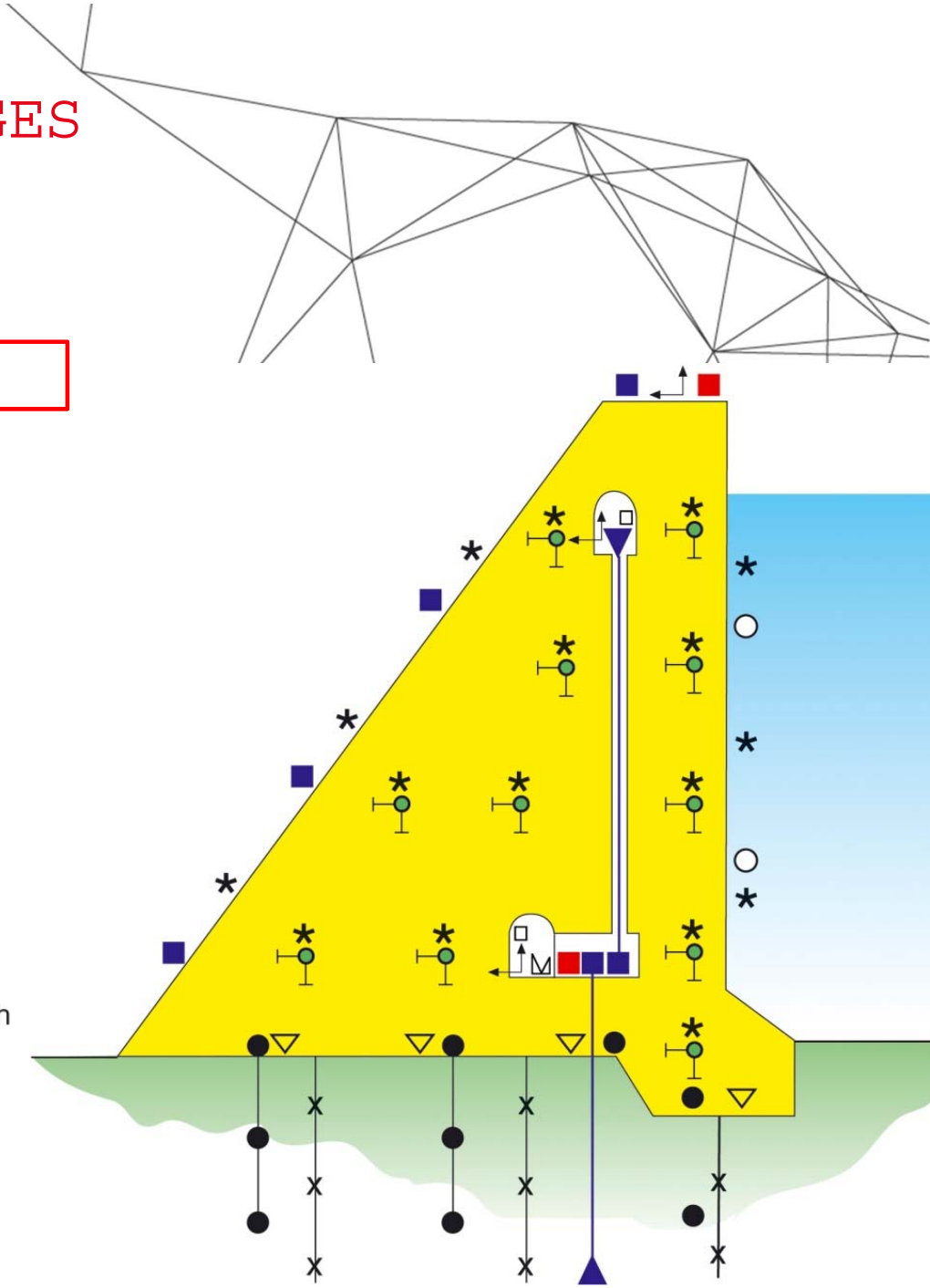
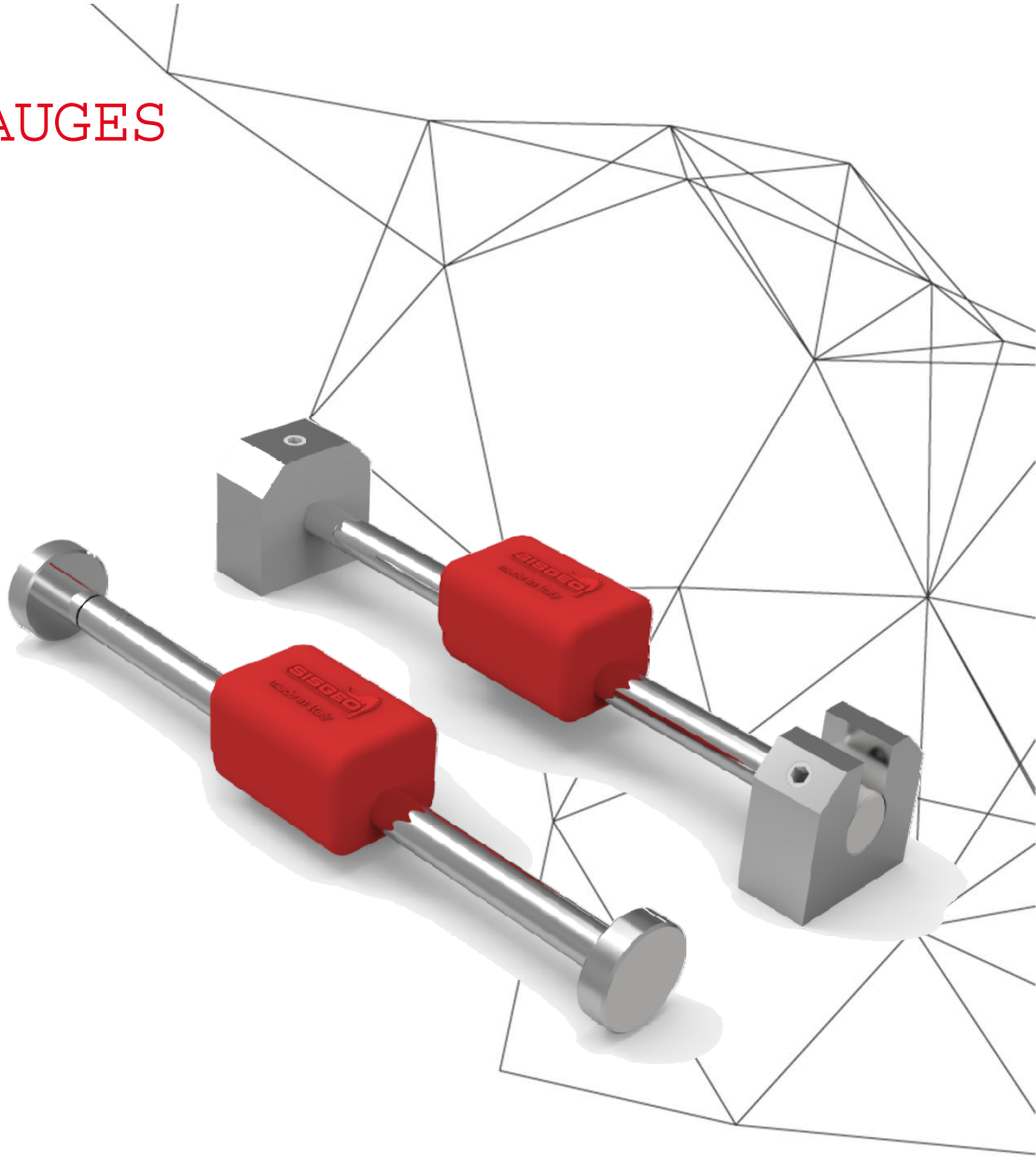


VIBRATING WIRE STRAIN GAUGES

Stress monitoring into concrete structures or on metal supports.

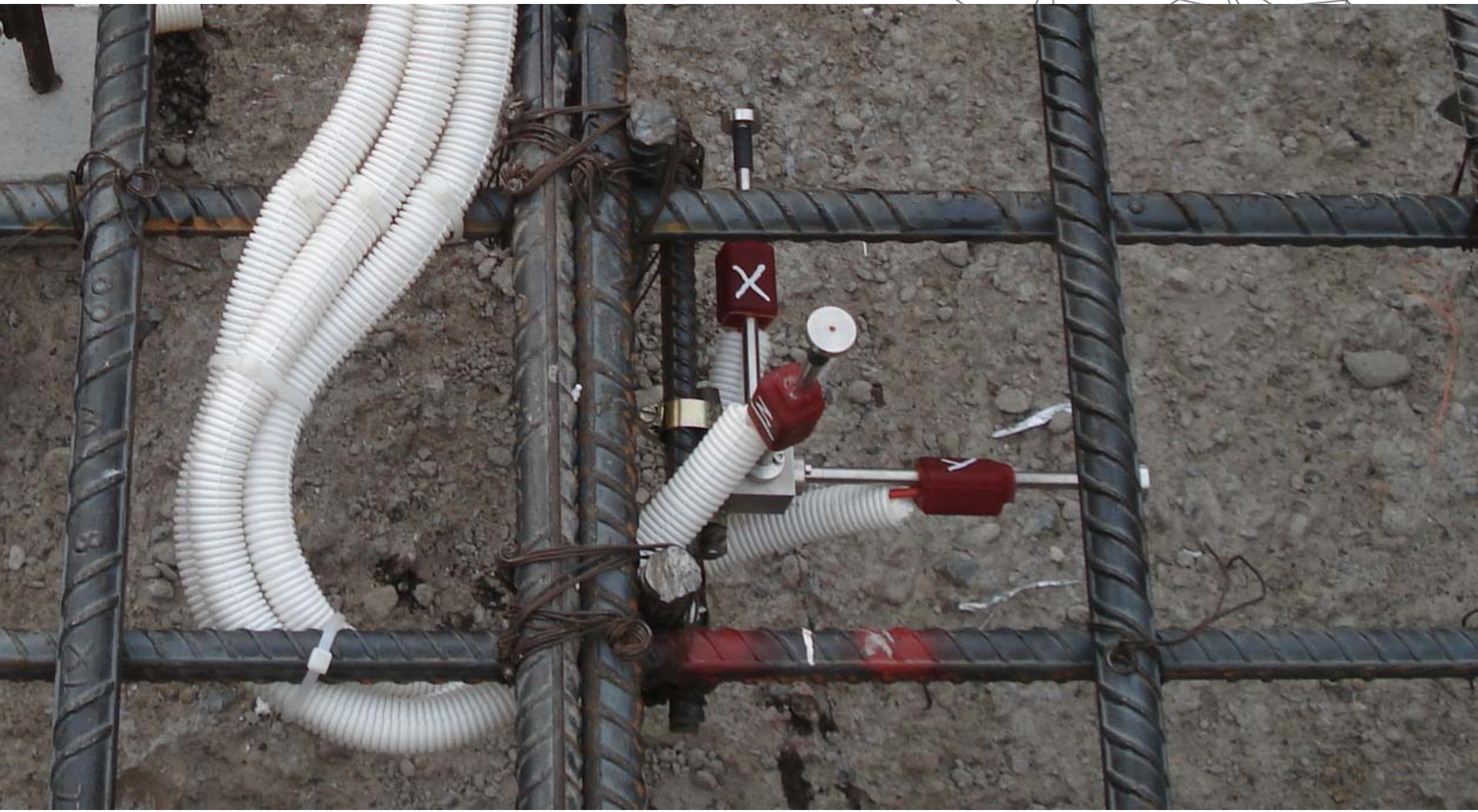
- *Arc-weldable model*
- *Embedment model*
- *3-D mounting available*



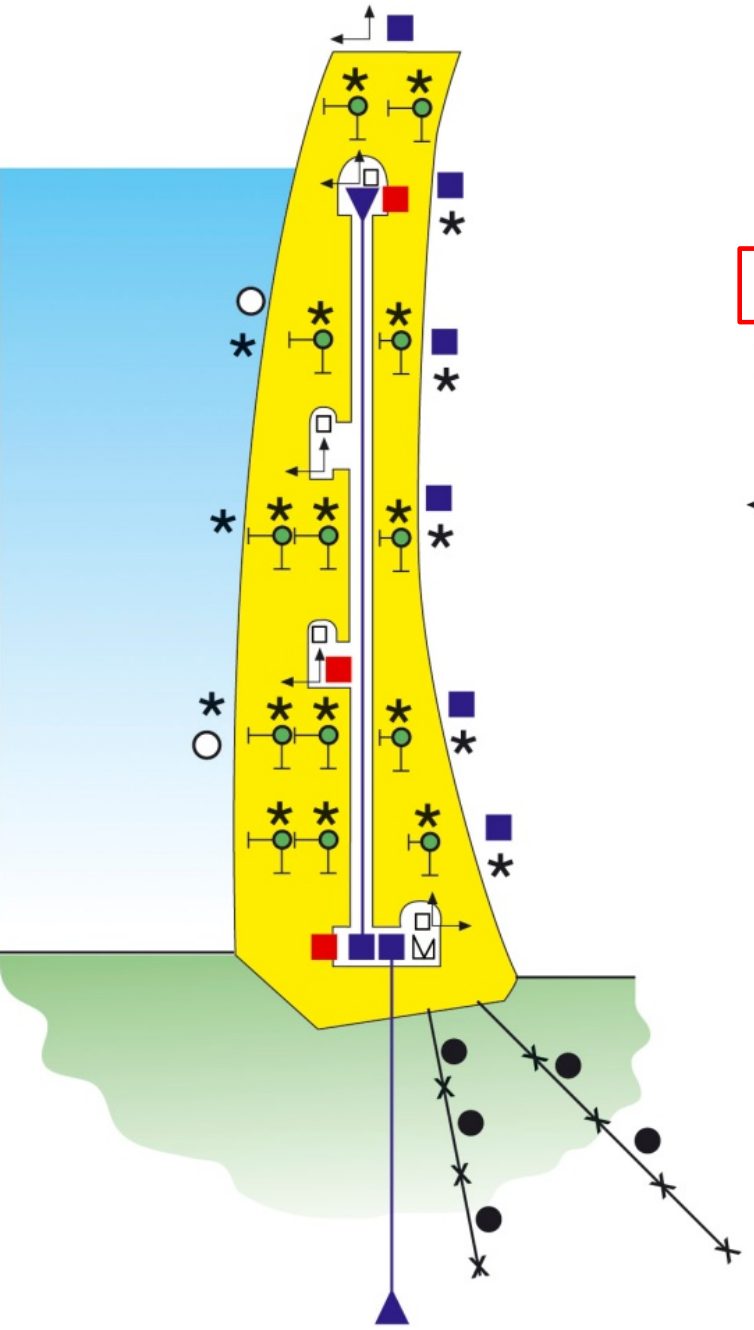
EMBEDMENT VIBRATING WIRE STRAIN GAUGES

ARC-WELDABLE VIBRATING WIRE STRAIN GAUGES

3-D ROSETTE MOUNTING STRAIN GAUGES



TEMPERATURE GAUGES



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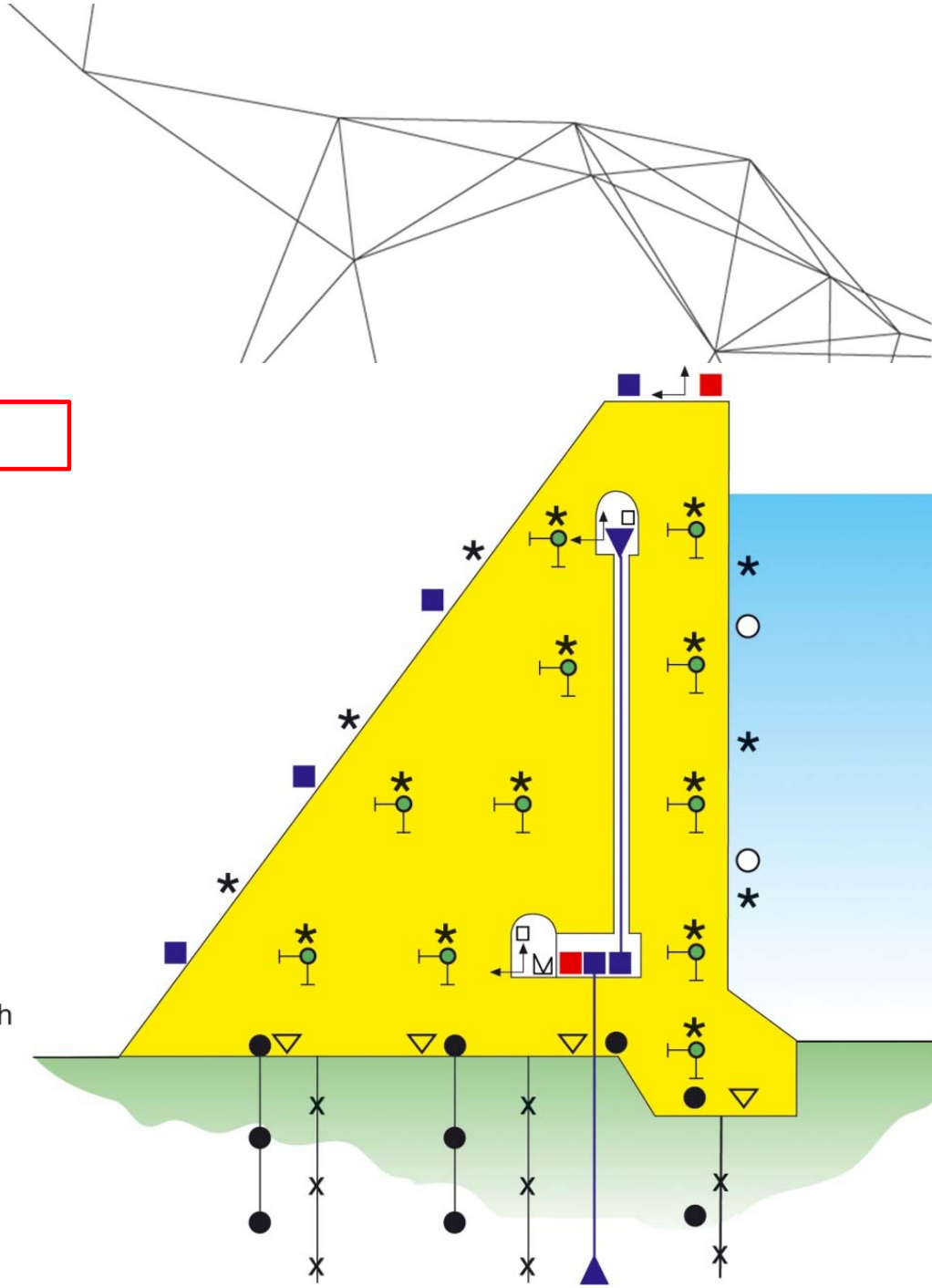
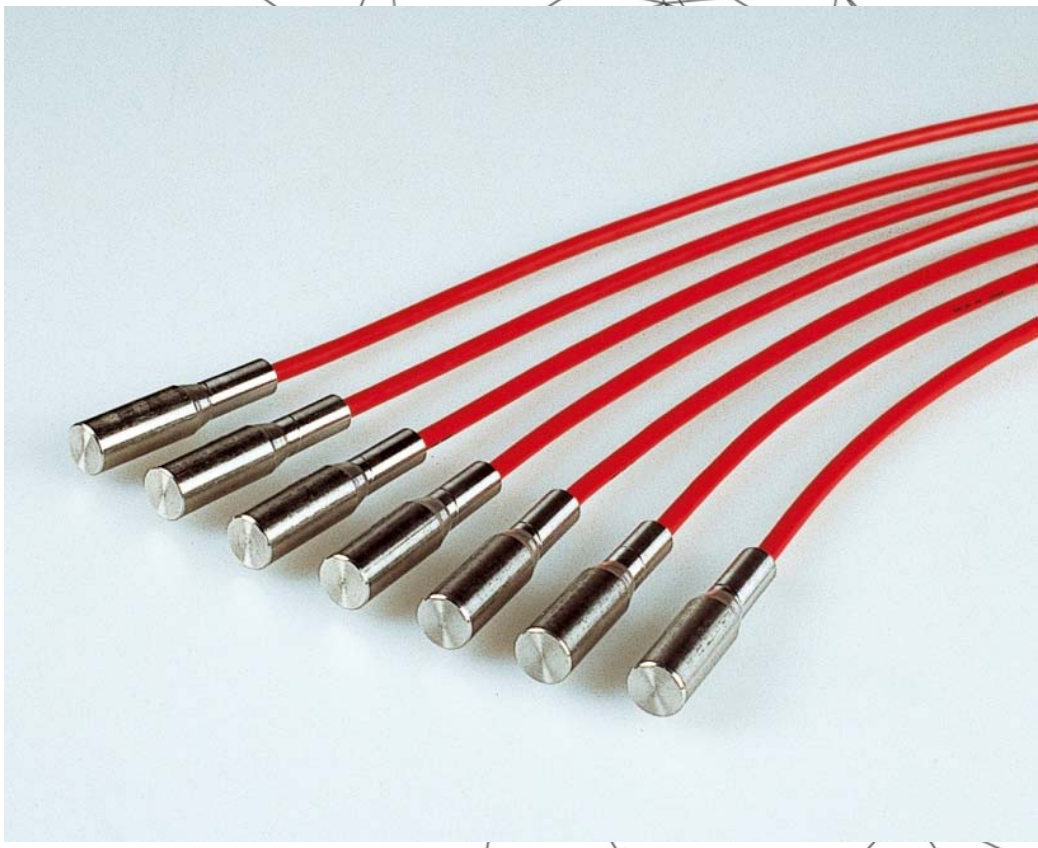


TEMPERATURE GAUGES

- *Concrete curing*
- *evaluating the influence of thermal effects on the measurements and on the structure which is monitored*
- *Monitor the water temperature inside boreholes, wells, basin, etc…*

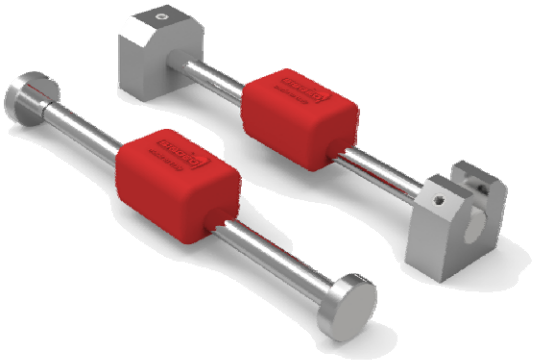


All models are housed in a shock resistant stainless steel body to be embedded in concrete.

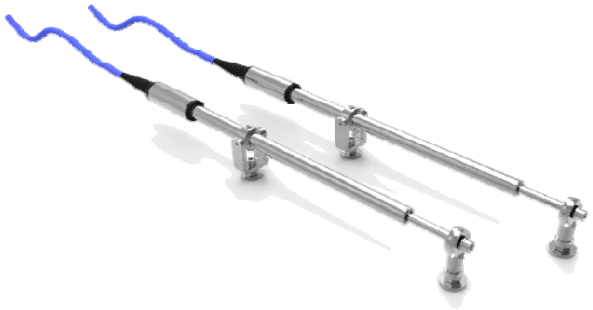
TEMPERATURE GAUGES

TEMPERATURE GAUGES

Most Sisgeo's instruments
have a built-in temperature sensor (thermistor)

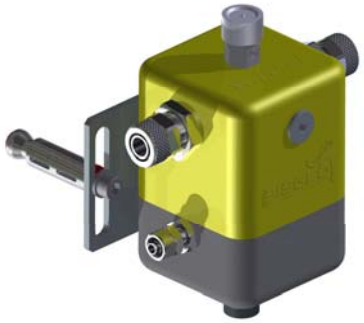


VW STRAIN GAUGES

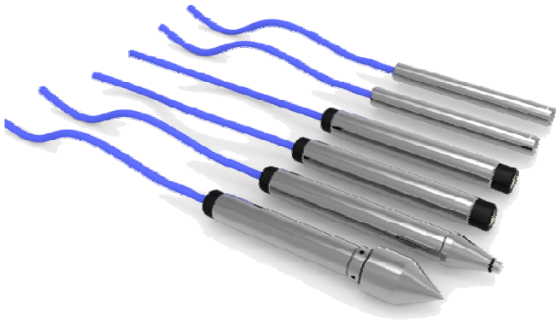


VW CRACK METERS

MEMS IPIs



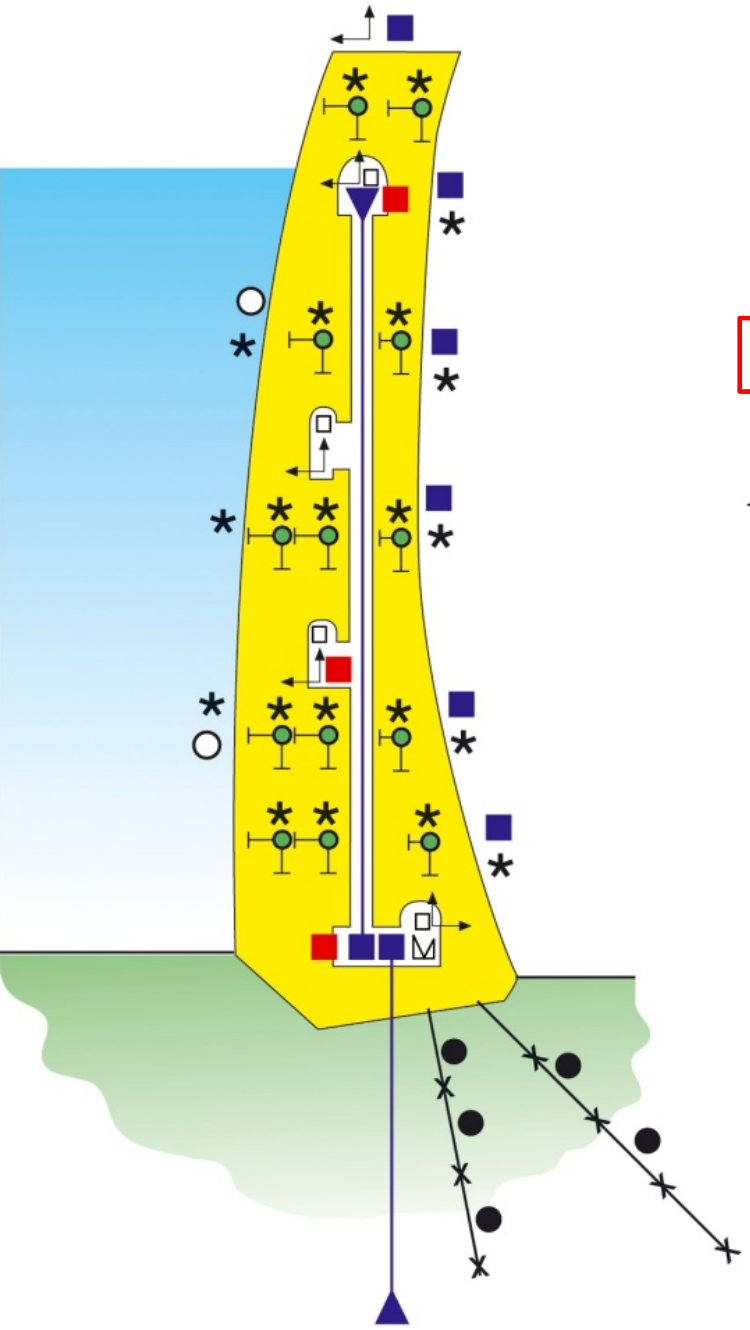
H-LEVEL SETTLEMENT GAUGES



VW PIEZOMETERS

MEMS TILT METERS

WEIR (FLOW) METERS - V-NOTCHES



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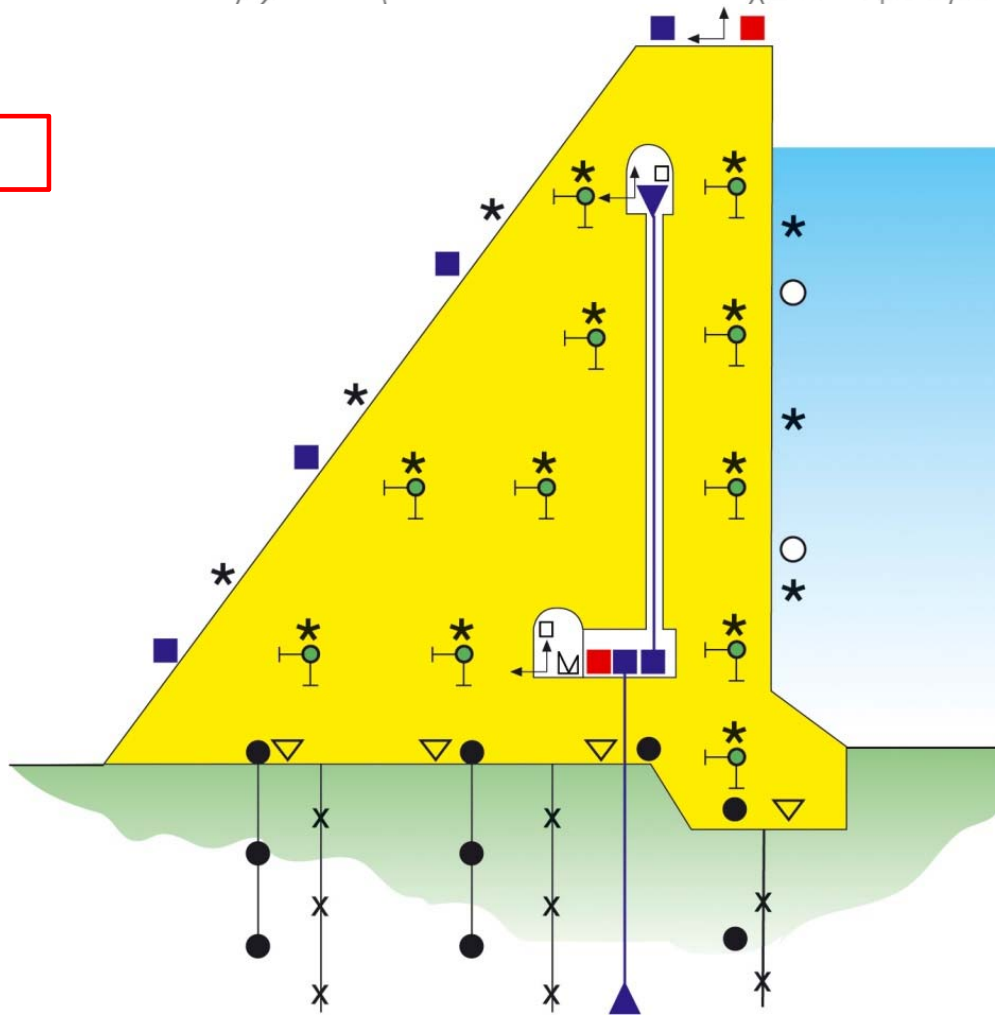


WEIR (FLOW) METERS – V-NOTCHES

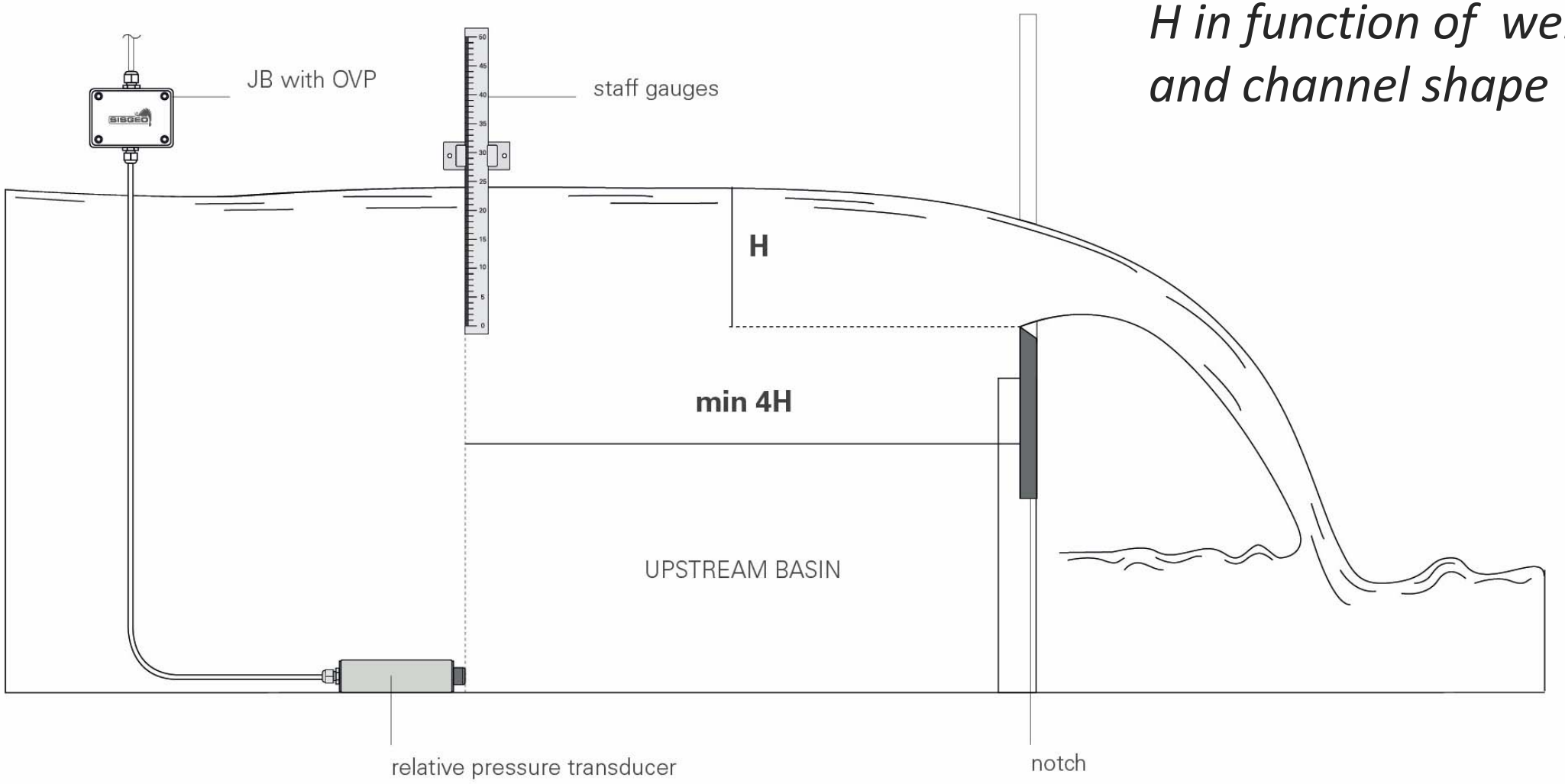
Leakage measurement is one of the most important indicator of overall performance of dams

Leakage monitoring provides data for evaluation of dam long term stability

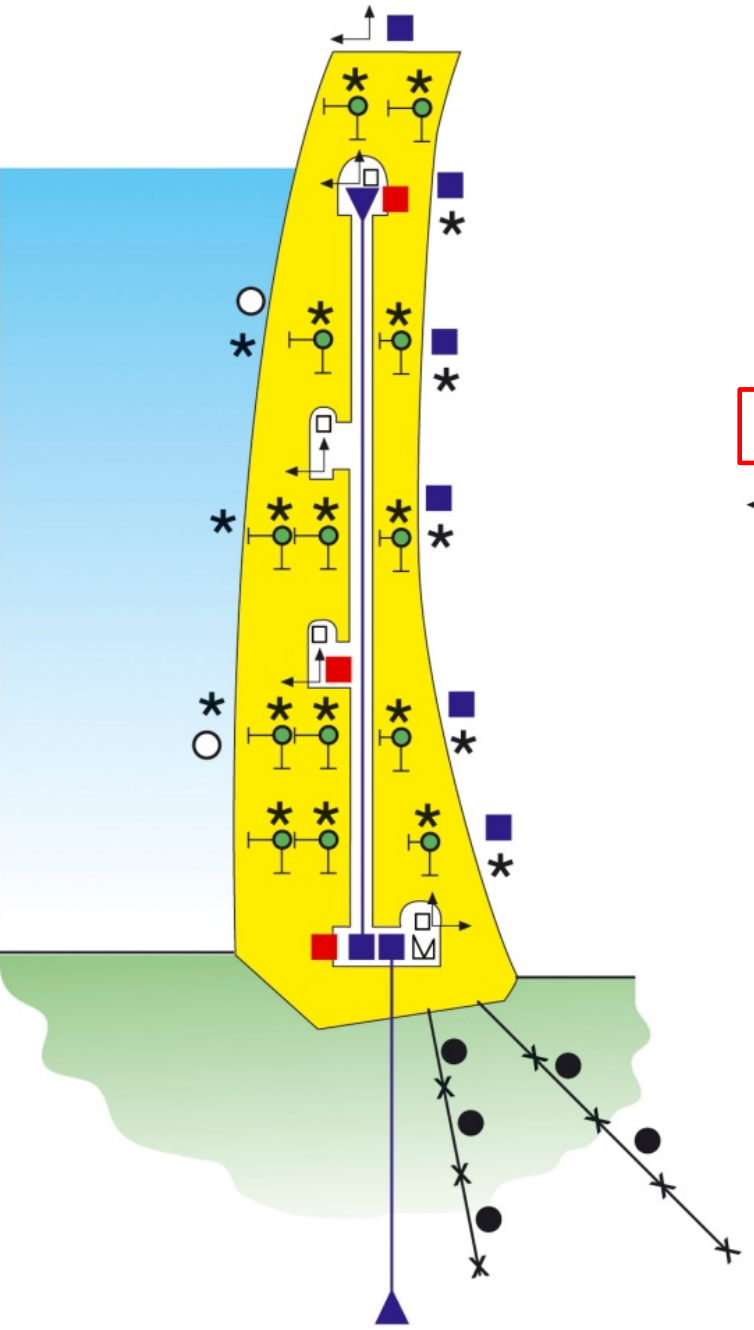
WEIR (FLOW) METERS – V-NOTCHES

H = water head

Flow is proportional to H in function of weir and channel shape



TILT METERS (CLINOMETERS)



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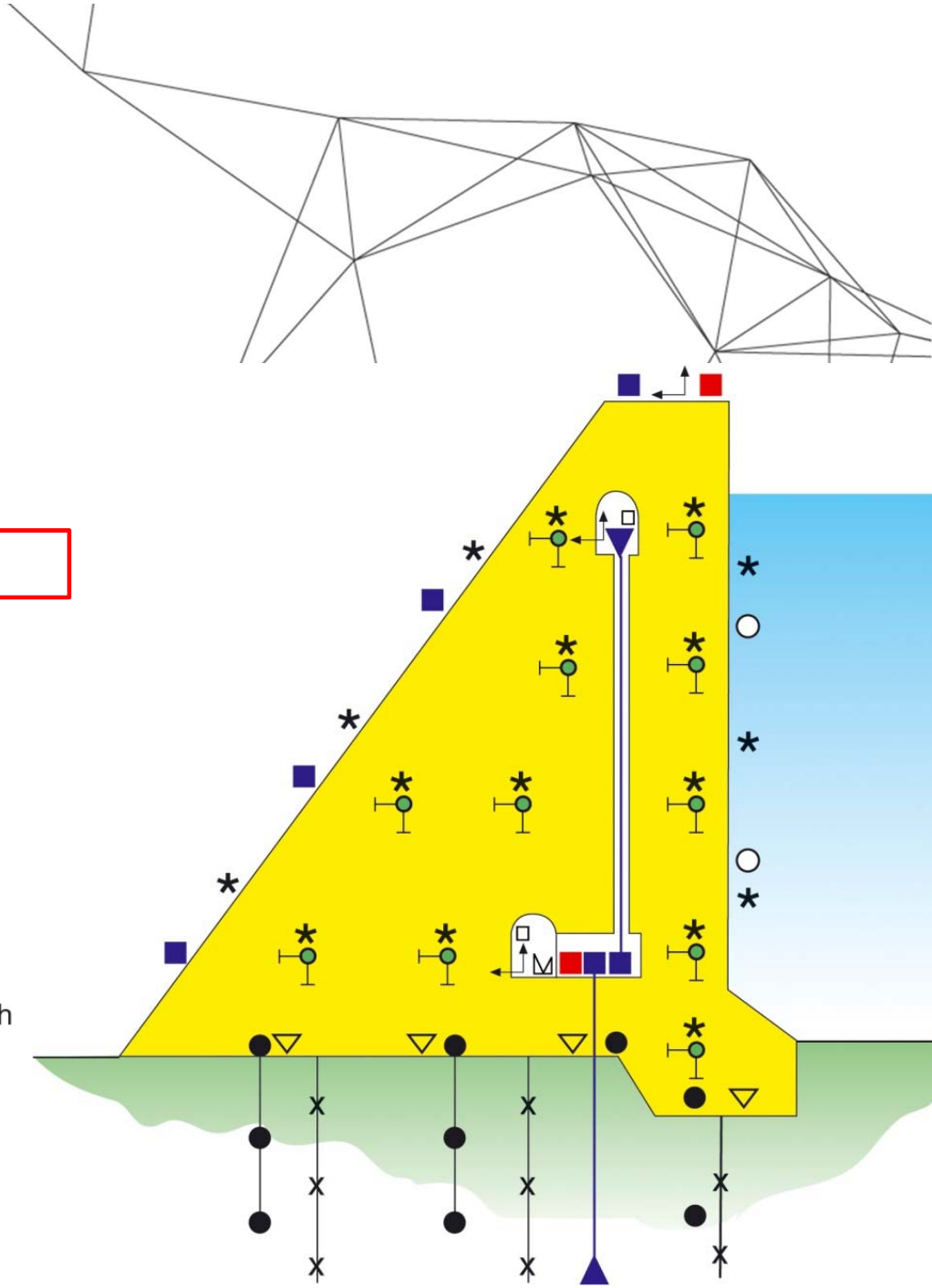
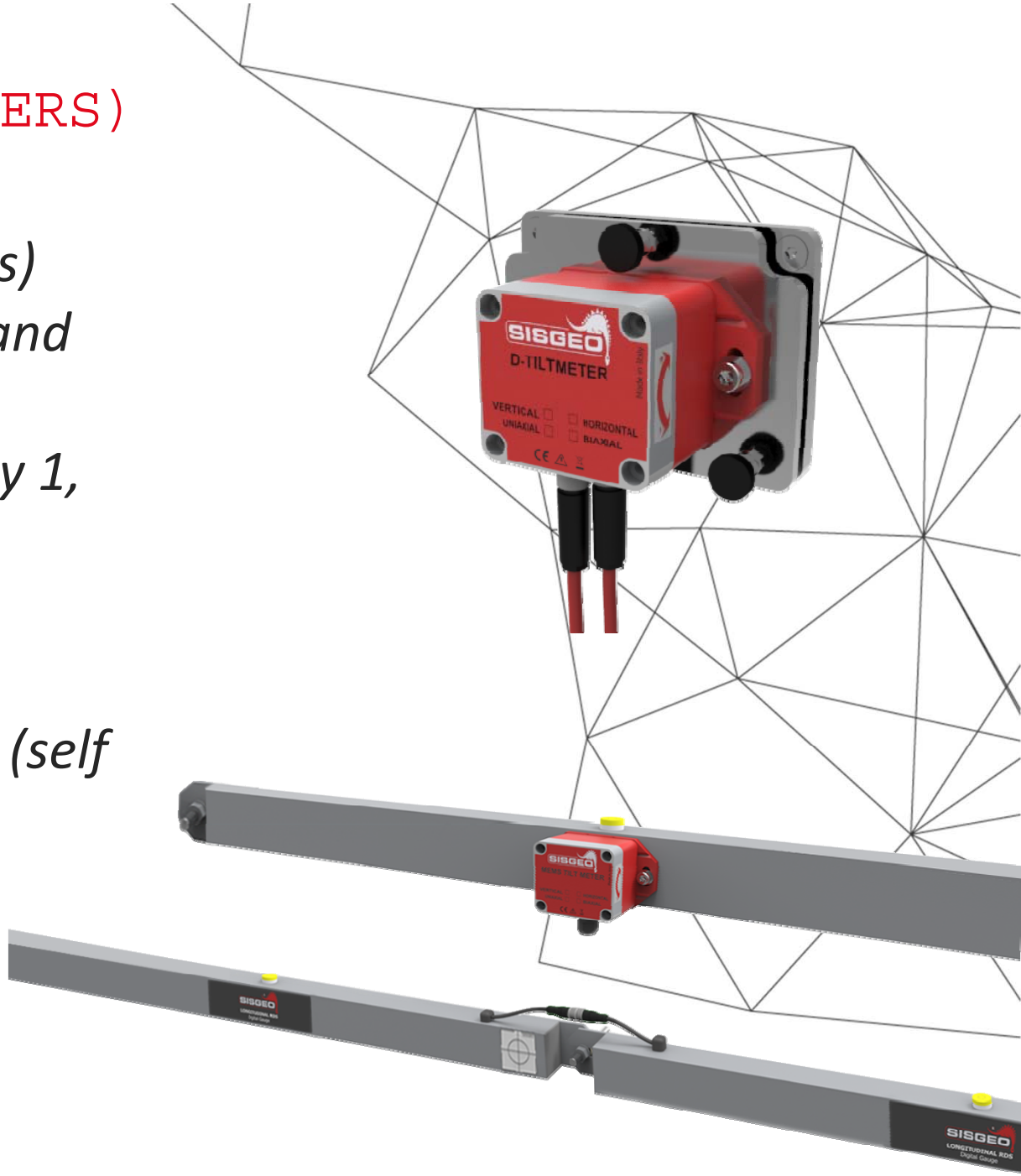


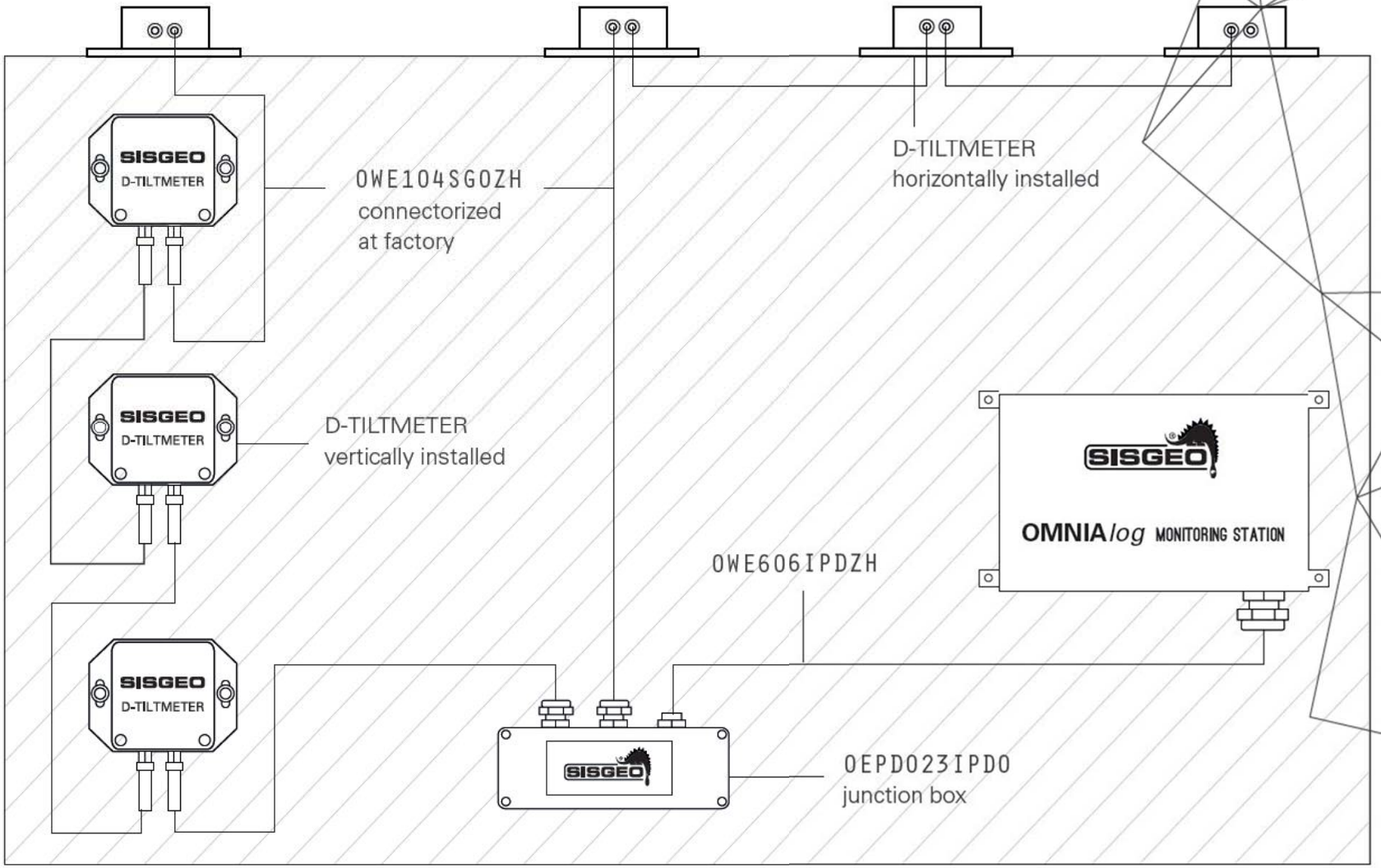
TILT METERS (CLINOMETERS)

Tilt meters (or surface clinometers) are often used to monitor tilting and rotation on critical point or on a short base length, typically 1, 2 or 3m.

Tilt meters have last developed MEMS technology (self compensated sensor) and are available in both analogue (4-20mA) or digital model (RS485).



DIGITAL TILT METERS



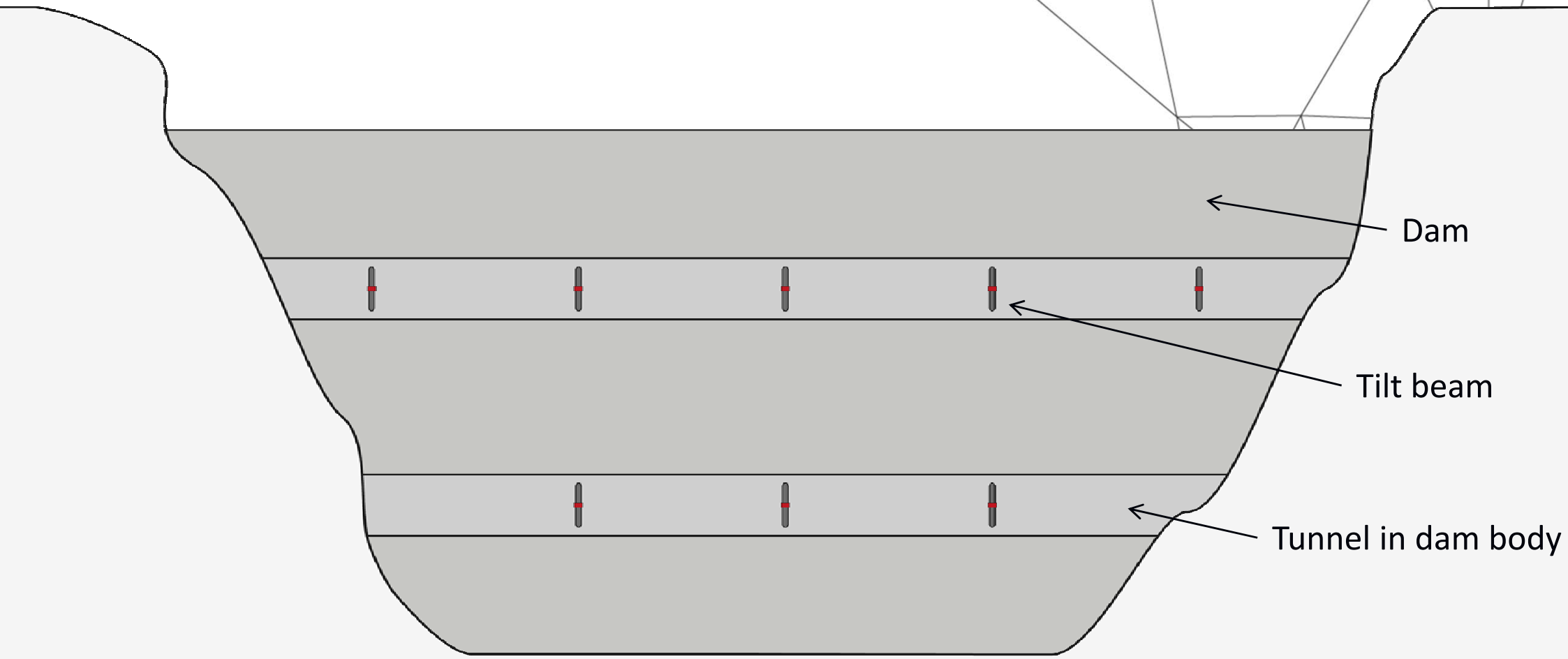
IP68 WATERPROOF TILTMETERS ON DAM UP-STREAM

DAM UP-STREAM AFTER INSTALLATIONS

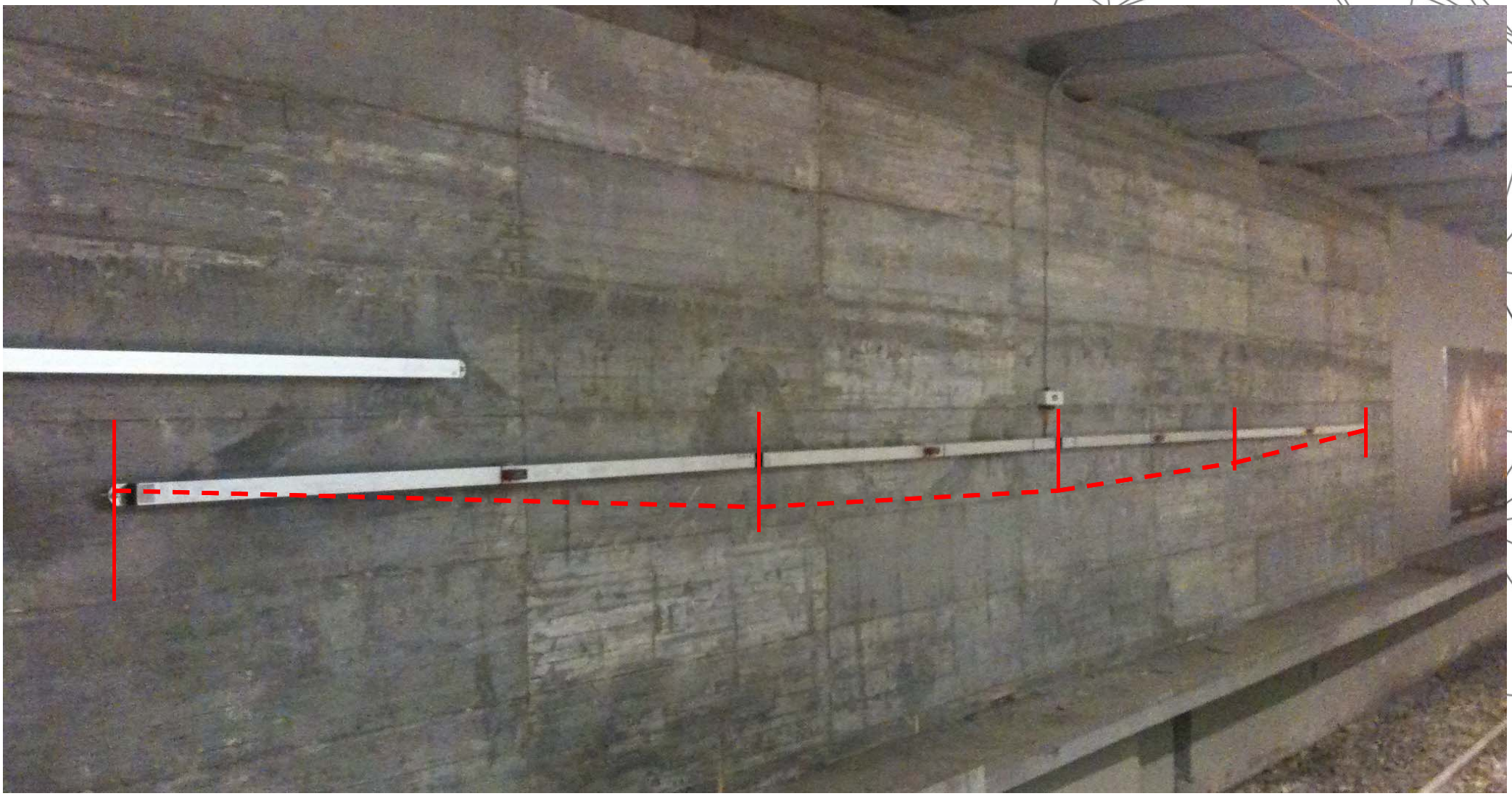
TILT BEAM (TB) - STAND ALONE APPLICATION

Aim: measure the inclination between two points.

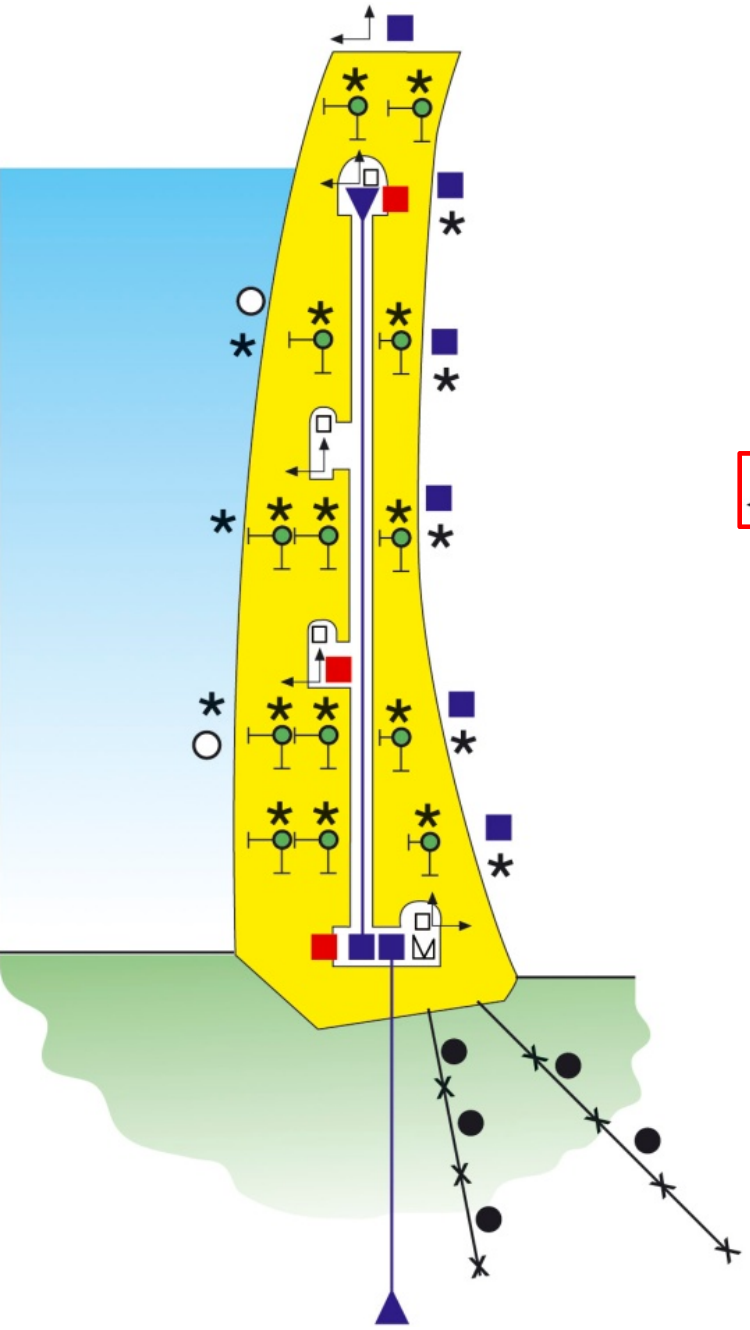
Available beam lengths: 1, 2 or 3 meter



CHAIN OF TILT BEAMS (TB) FOR SETTLEMENT MONITORING



JOINT METERS



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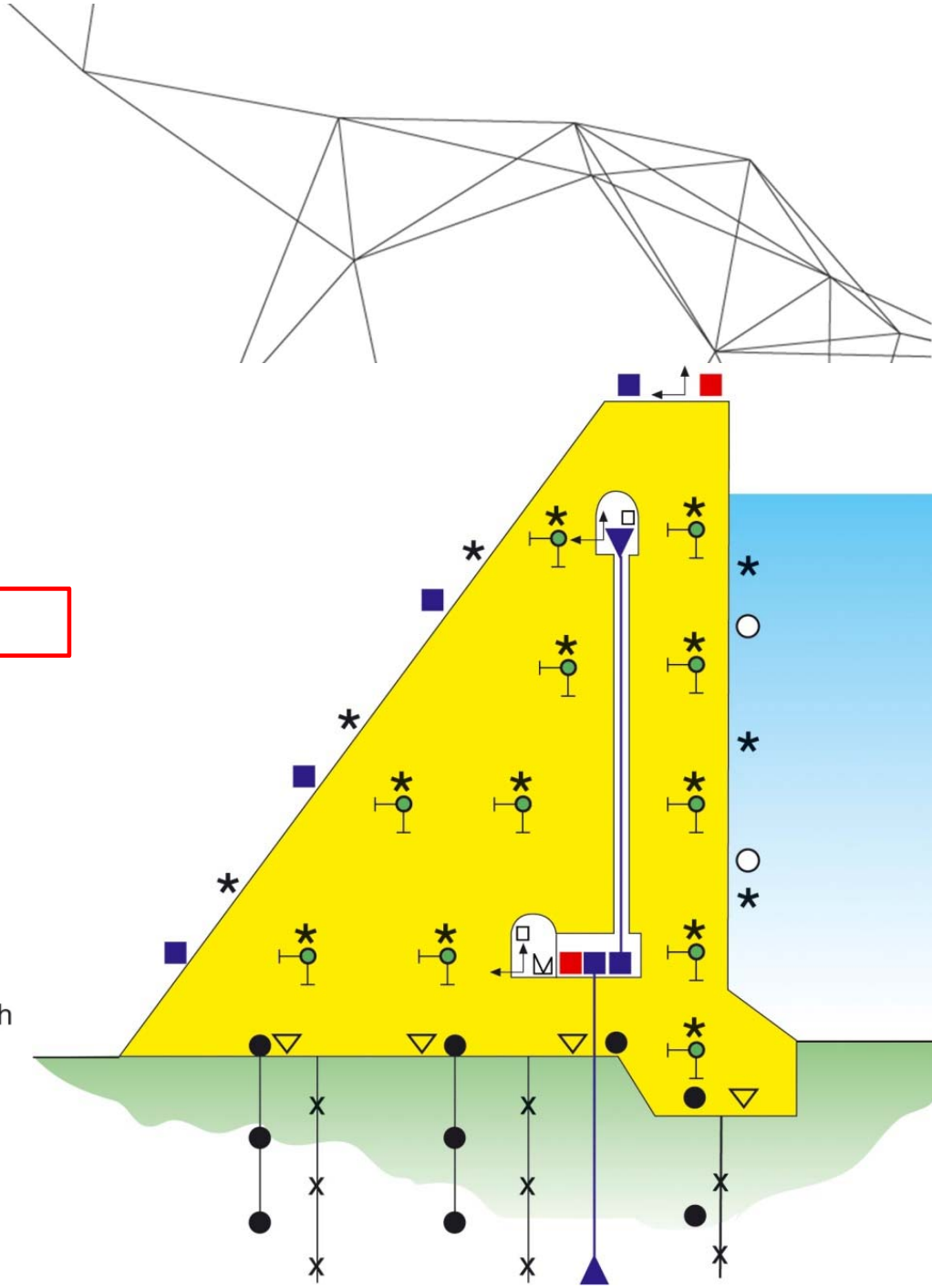
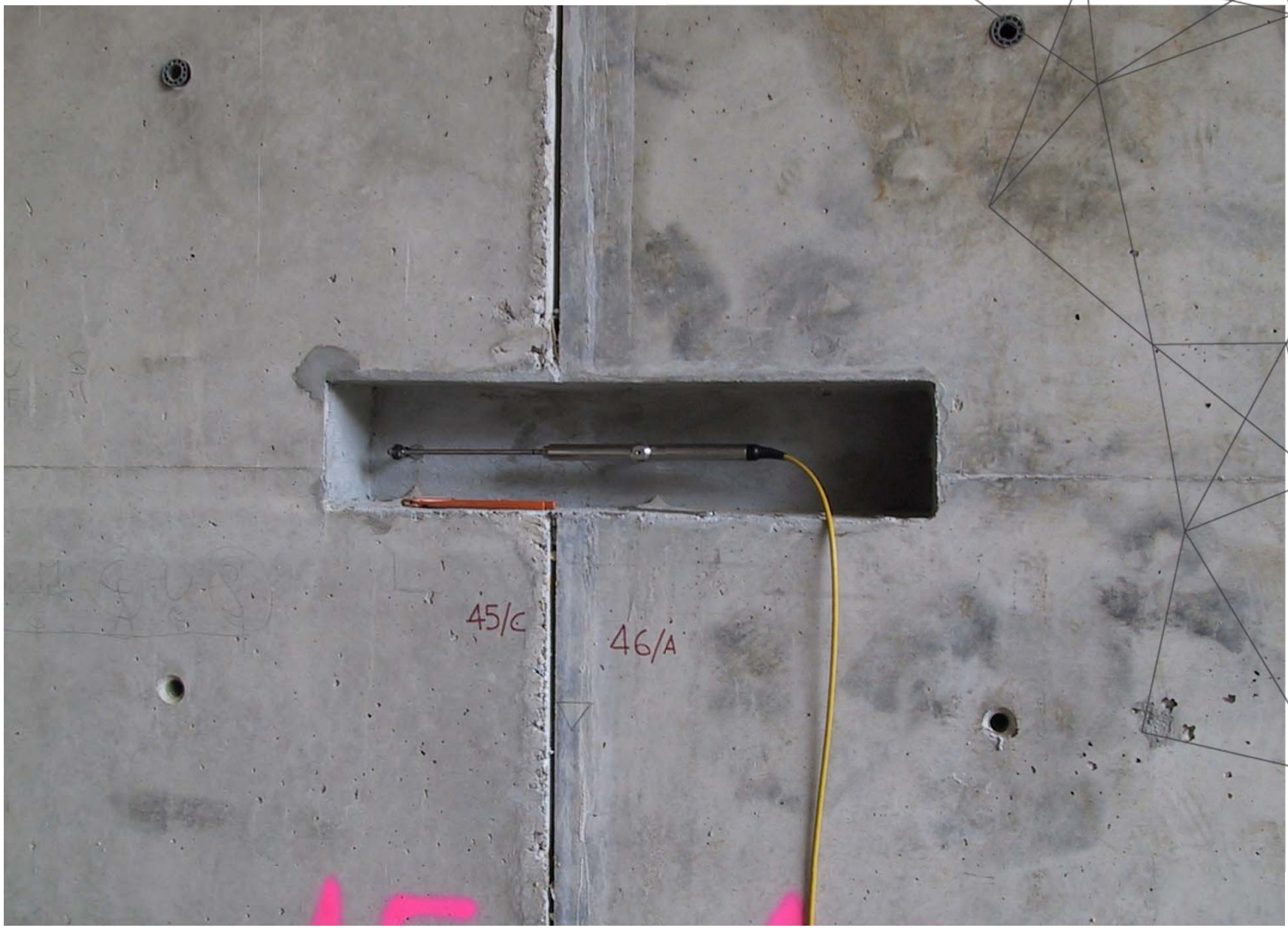
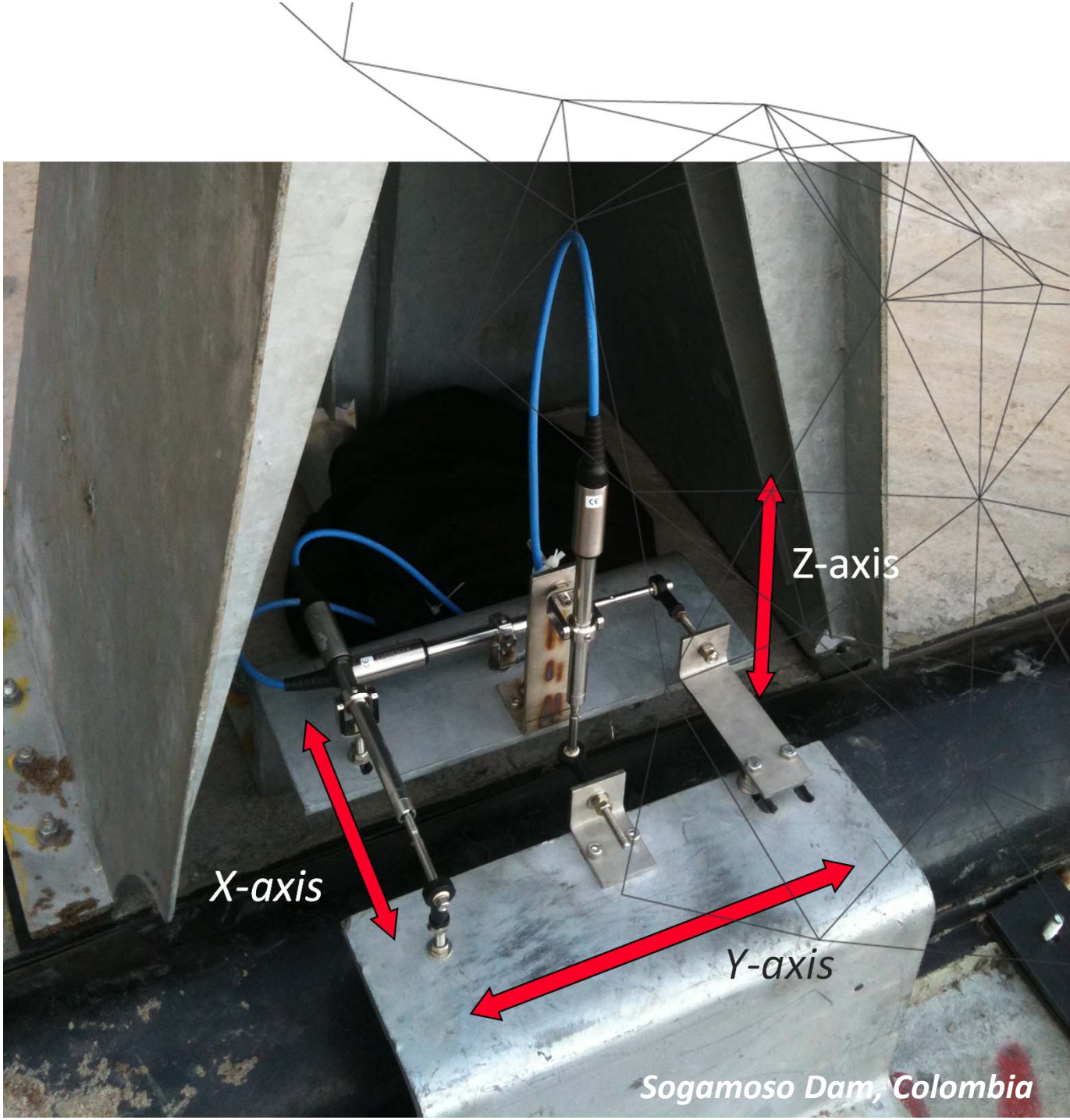


JOINT METER ON STRUCTURAL JOINT

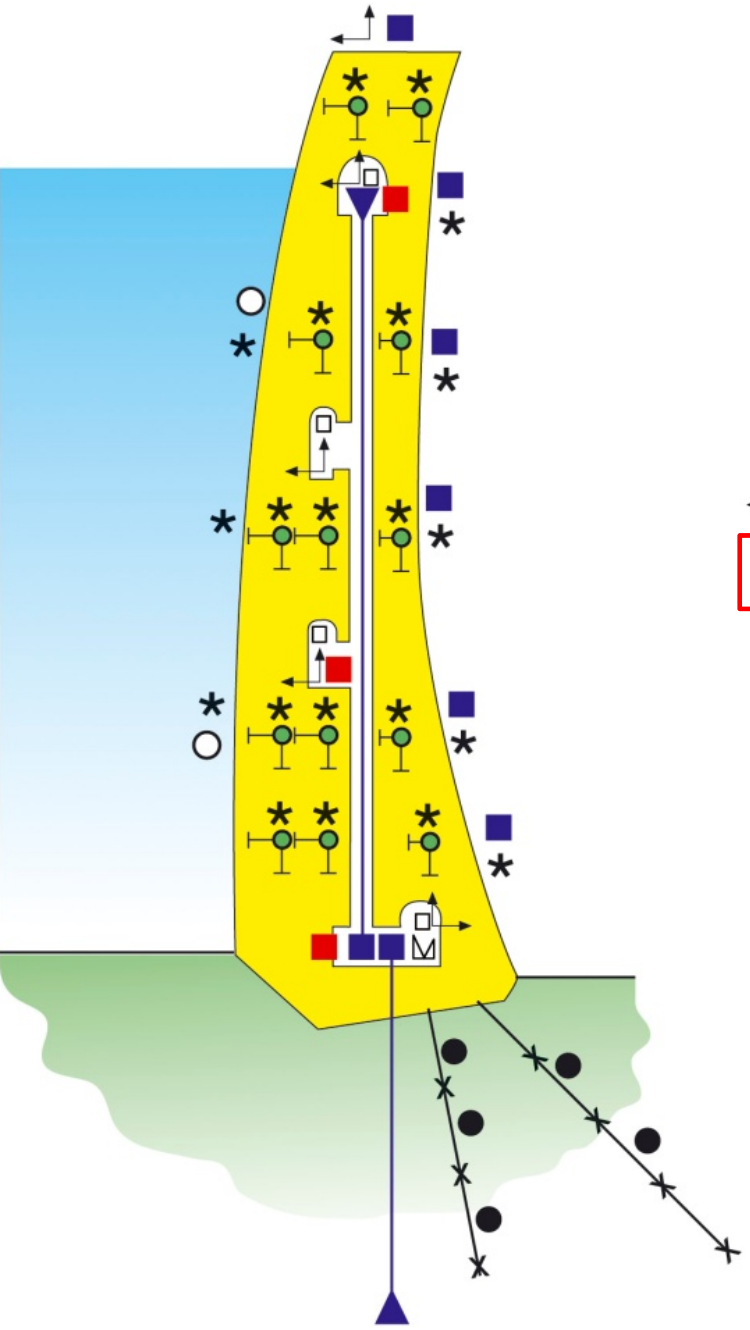


3-D JOINT METERS

With different model of steel supports, joint meters could be installed to measure constructive joint movements in three directions (3-D)



MULTIPOINT BOREHOLE EXTENSOMETERS (MPBX)



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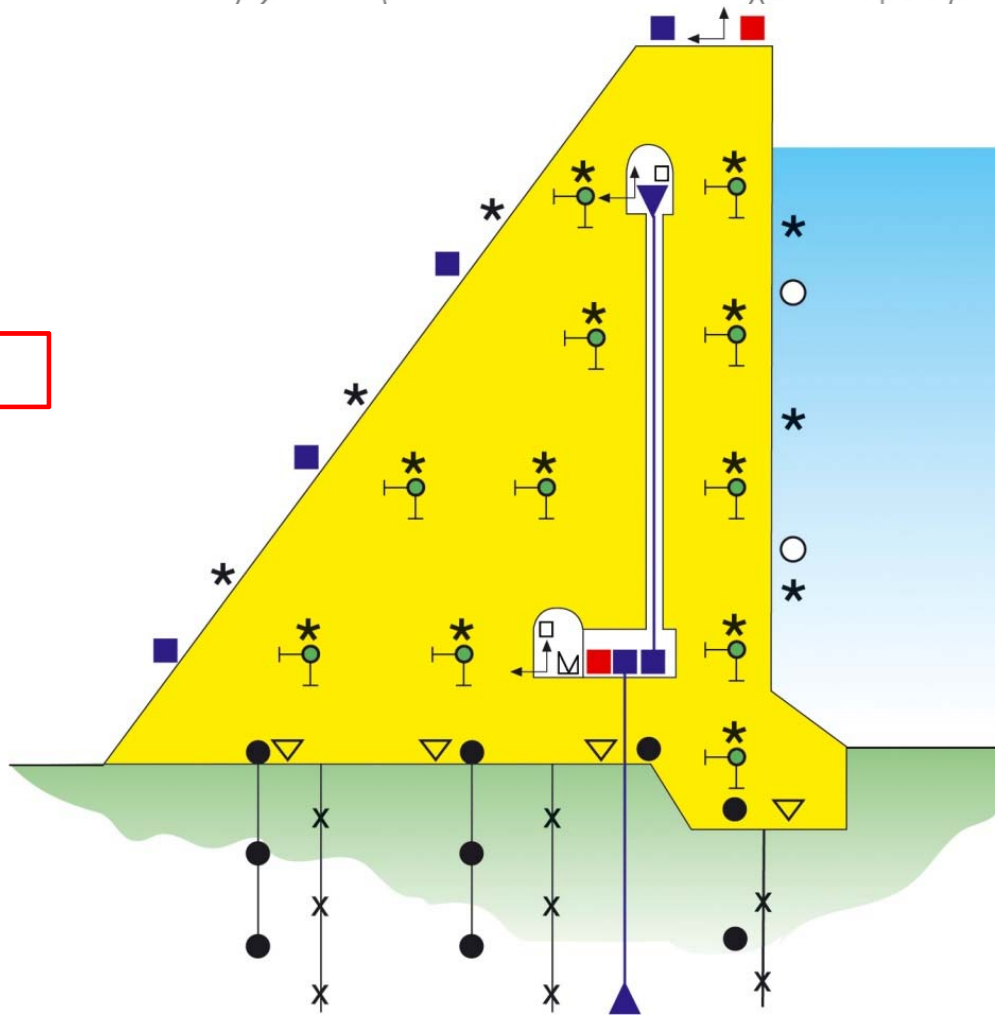
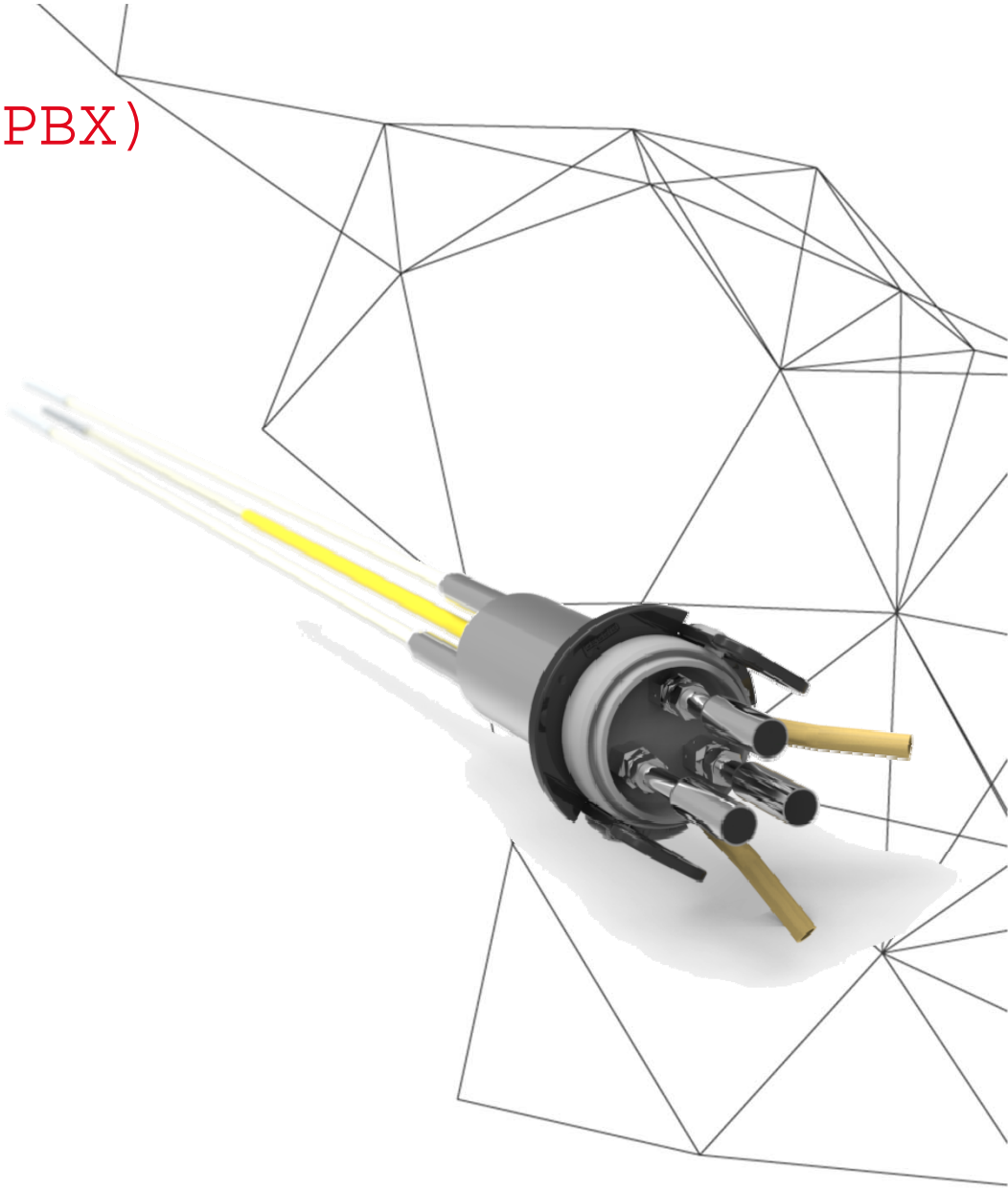


BOREHOLE EXTENSOMETERS (MPBX)

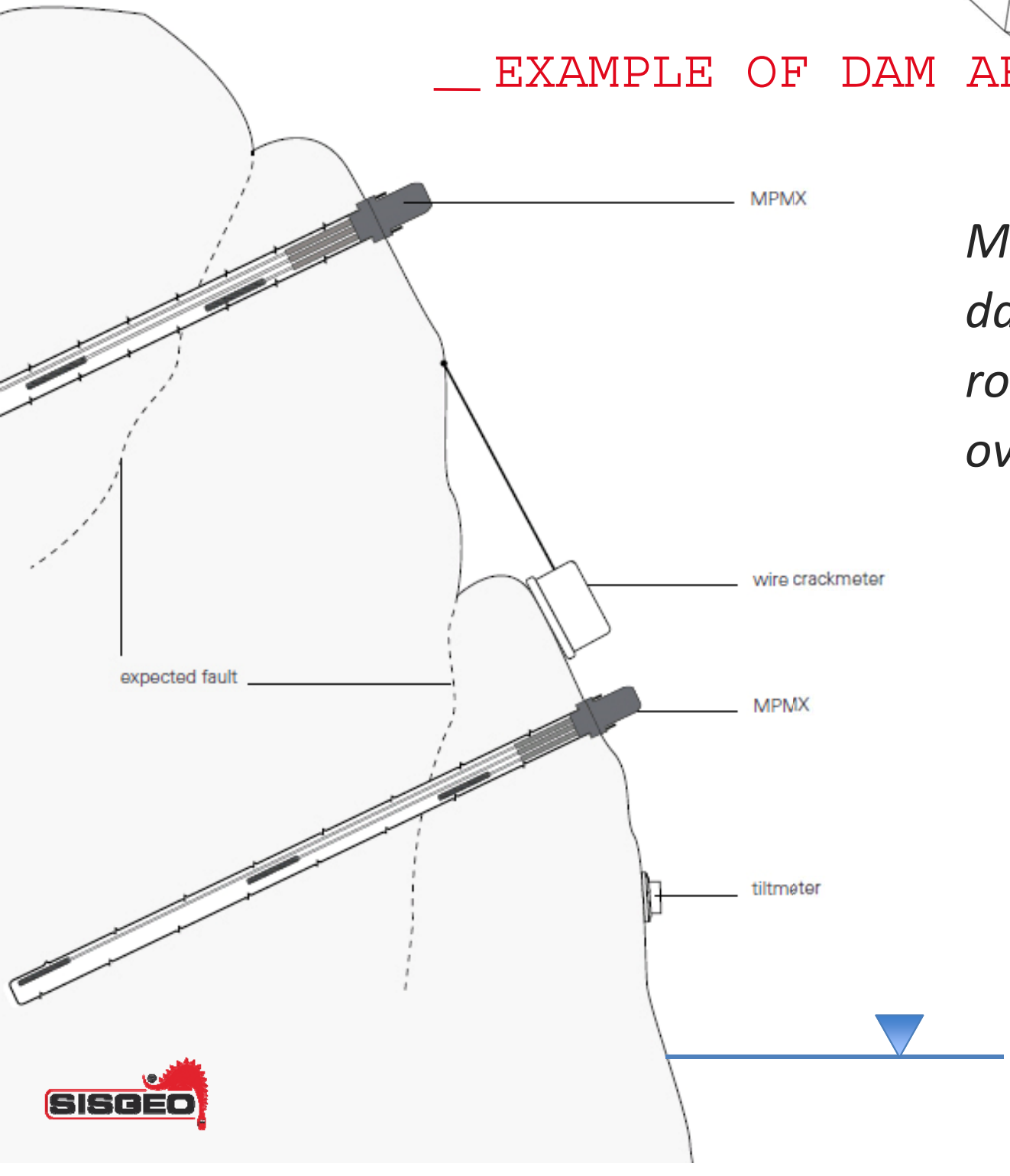
Available with:

- *Fiber Glass rods*
- *Stainless steel rods*

Number of rods for each extensometer: from 2 to 6 (7 points on request)



EXAMPLE OF DAM ABUTMENT MONITORING



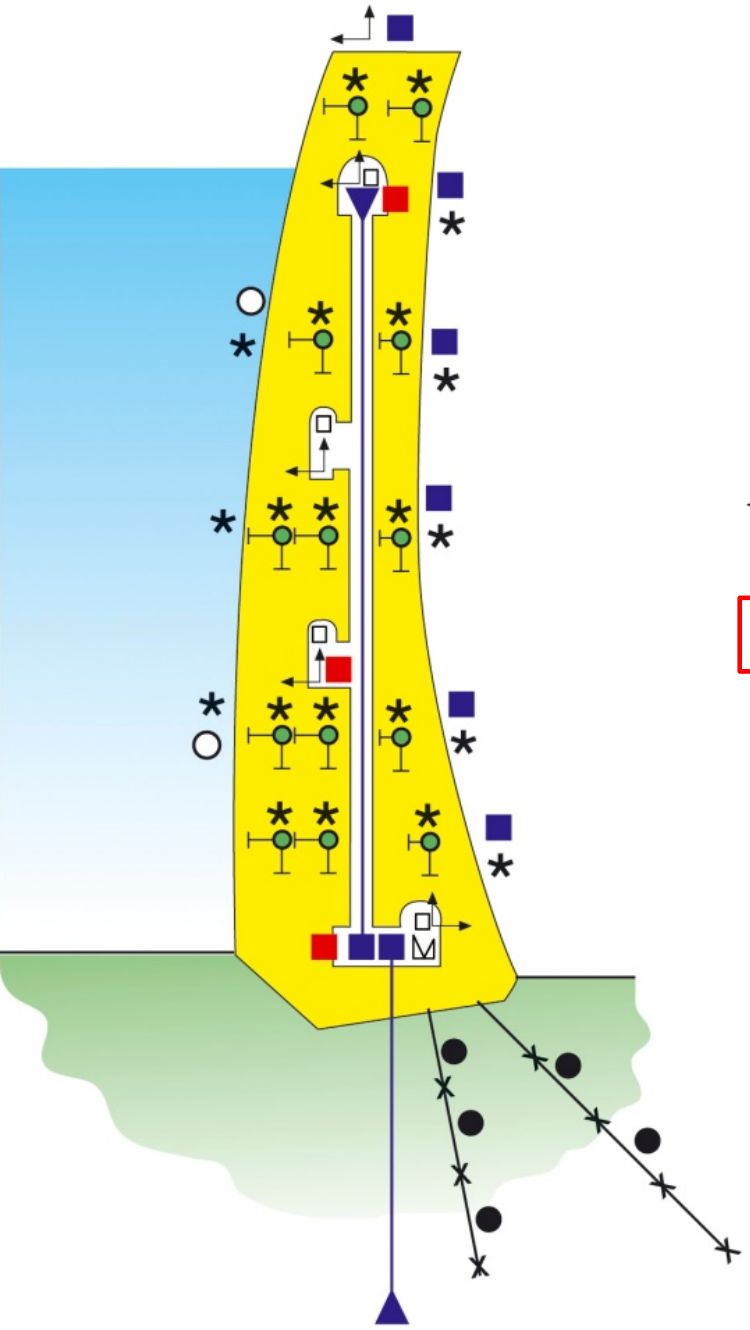
MPBX can be installed on dam abutments or on possible rockfall / topple landslide over the reservoir.

BOREHOLE EXTENSOMETERS (MPBX)

MPBX on dam abutment

MPBX in dam lower tunnel

PIEZOMETERS (PORE PRESSURE GAUGES)



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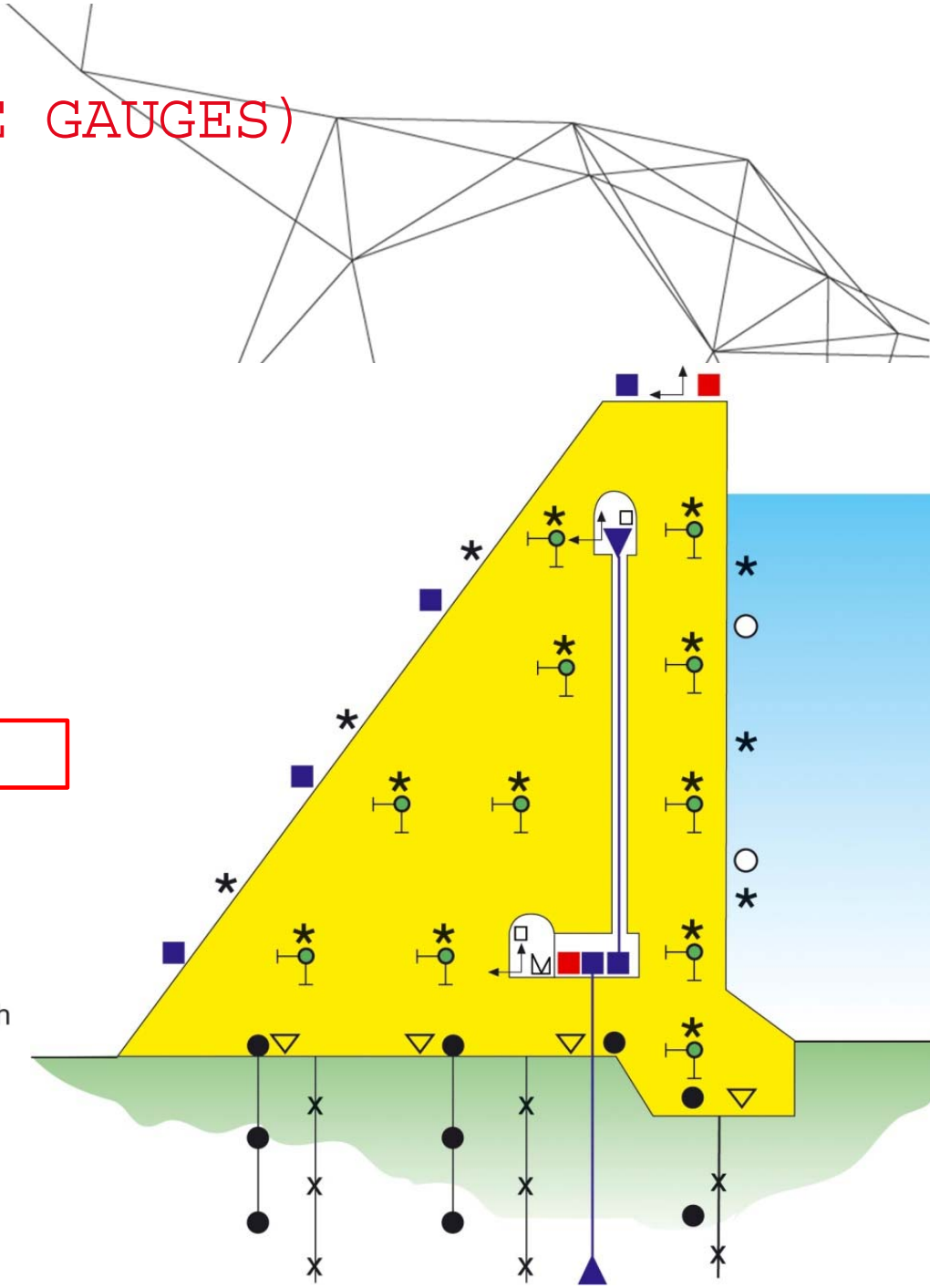
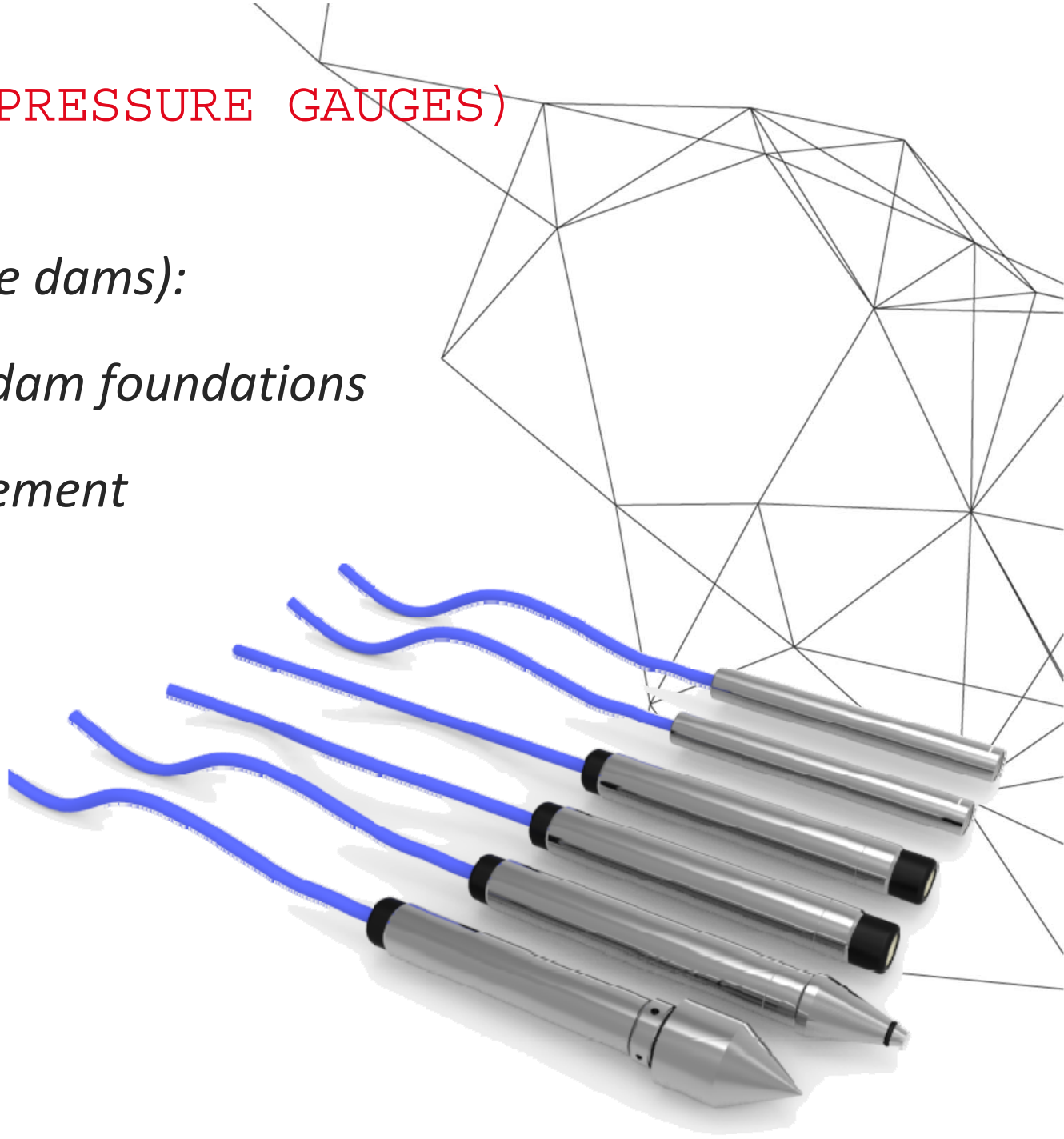


PIEZOMETERS (PORE PRESSURE GAUGES)

Main applications (concrete dams):

1. *Water pore pressure in dam foundations*
2. *Up-lift pressure measurement*



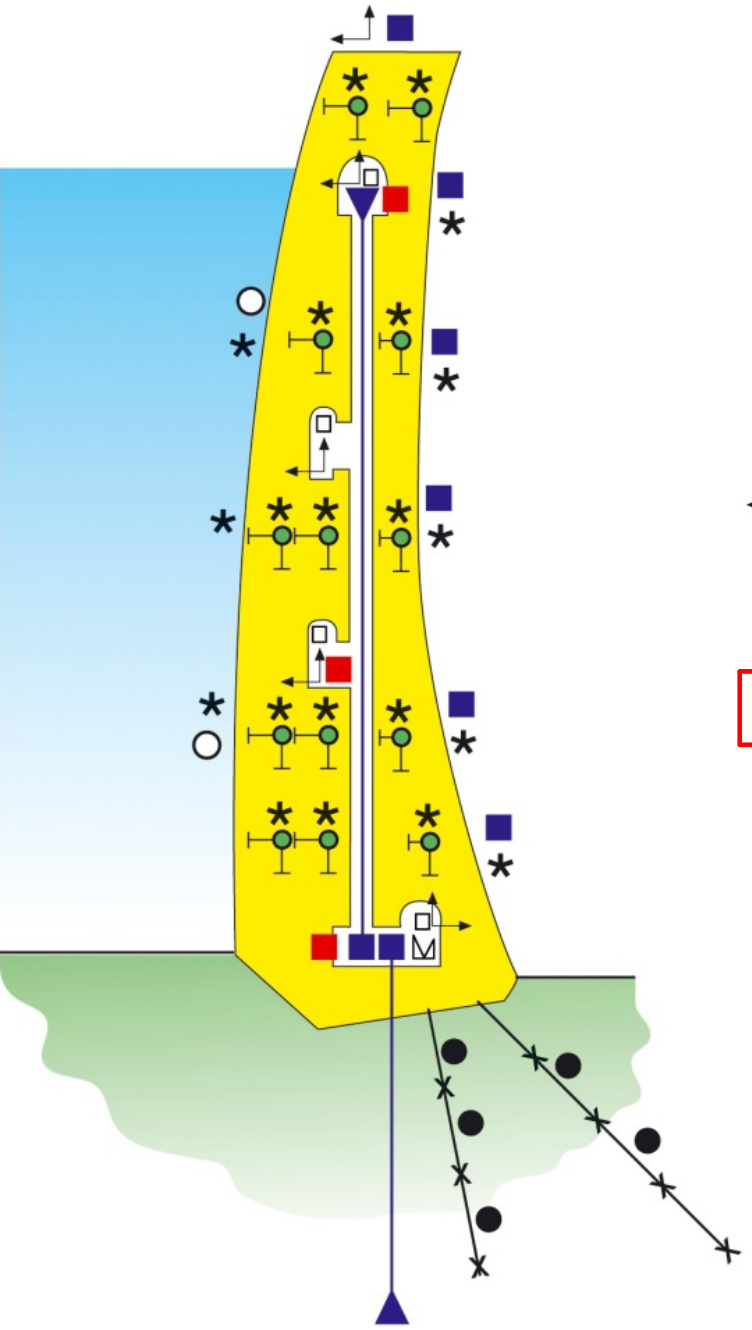
PORE PRESSURE: INSTALLATION PHASES

Insert the transducer in the borehole

Filling with bentonite pellets (sealing)

Take zero reading

EARTH (TOTAL) PRESSURE CELLS



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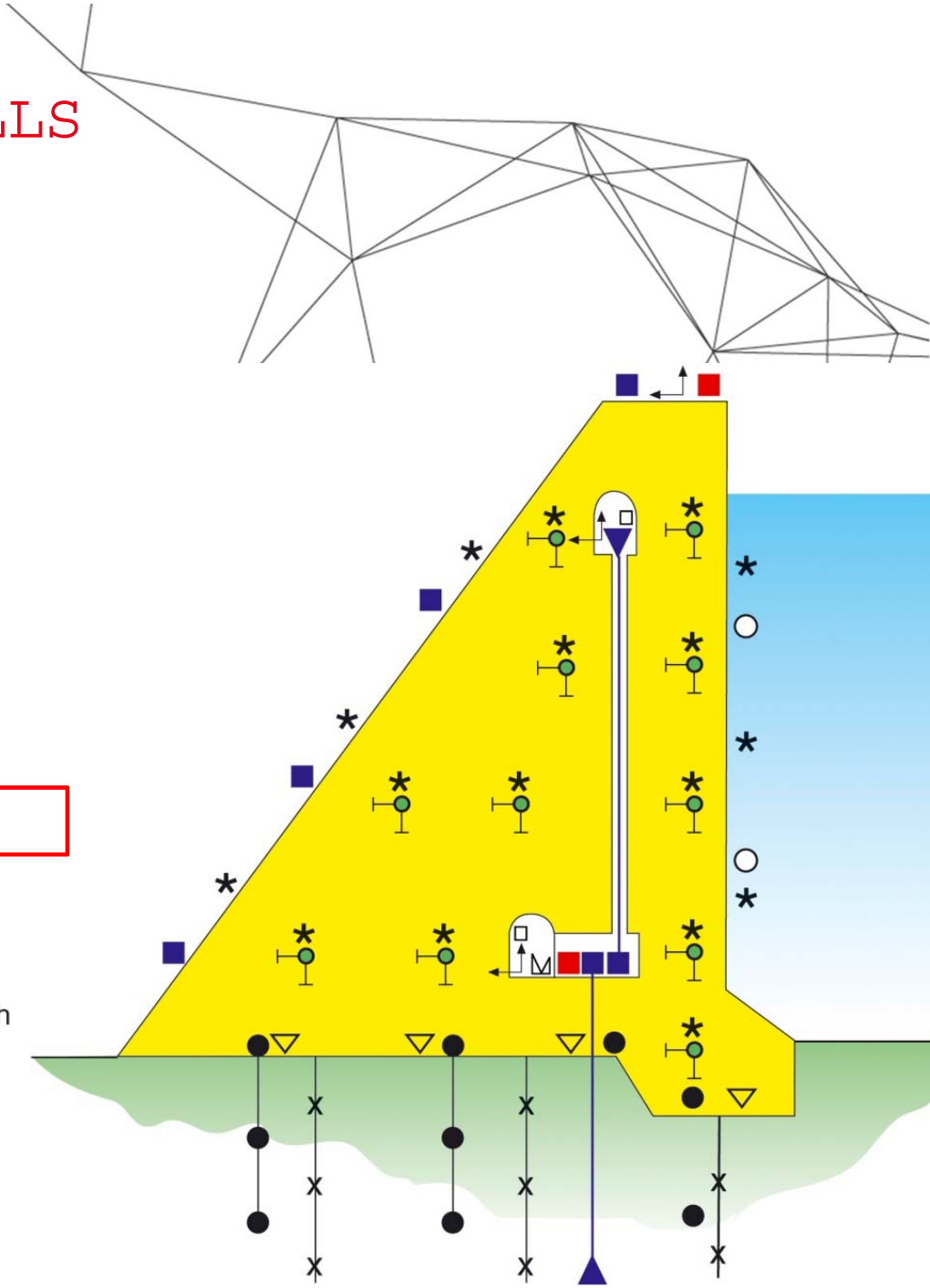
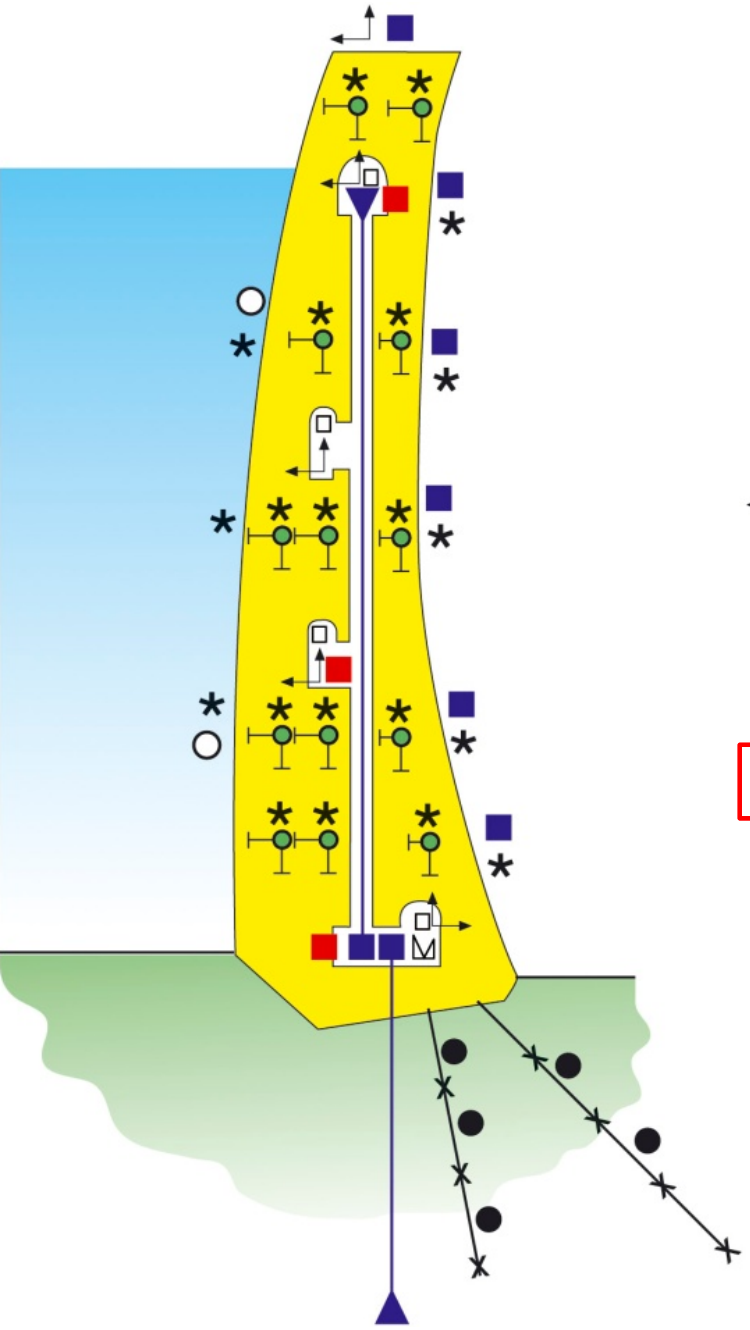


EARTH (TOTAL) PRESSURE CELLS

They are installed in order to monitor the pressure applied from the growth of the dam body.

The main application is in earth fill dams or embankments

WATER LEVEL METER (WATER BASIN LEVEL)



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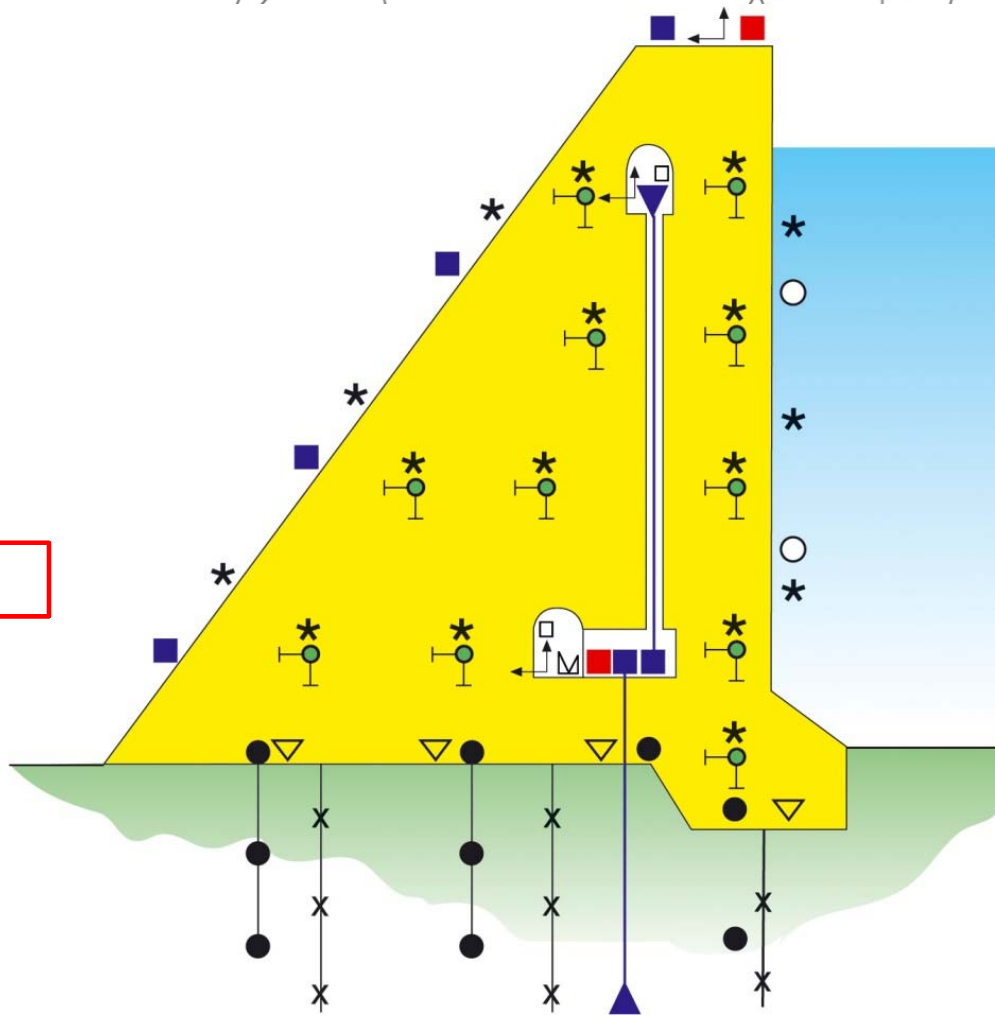
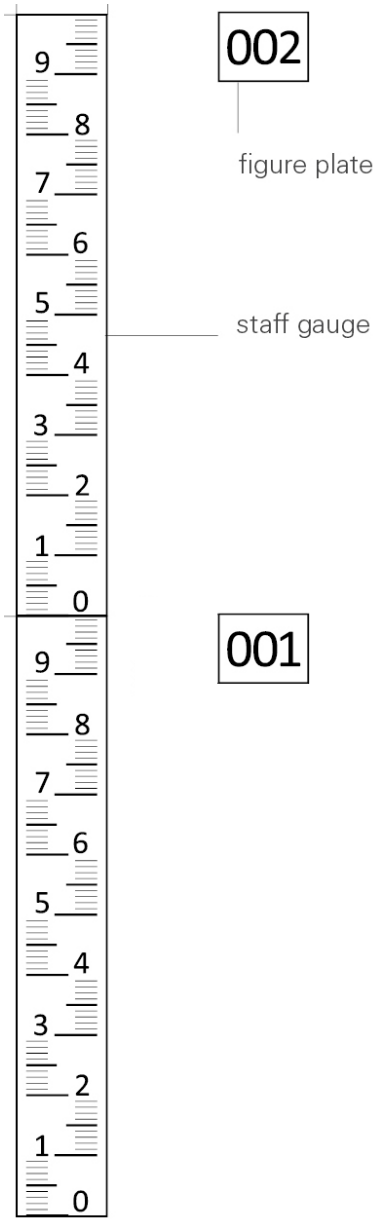
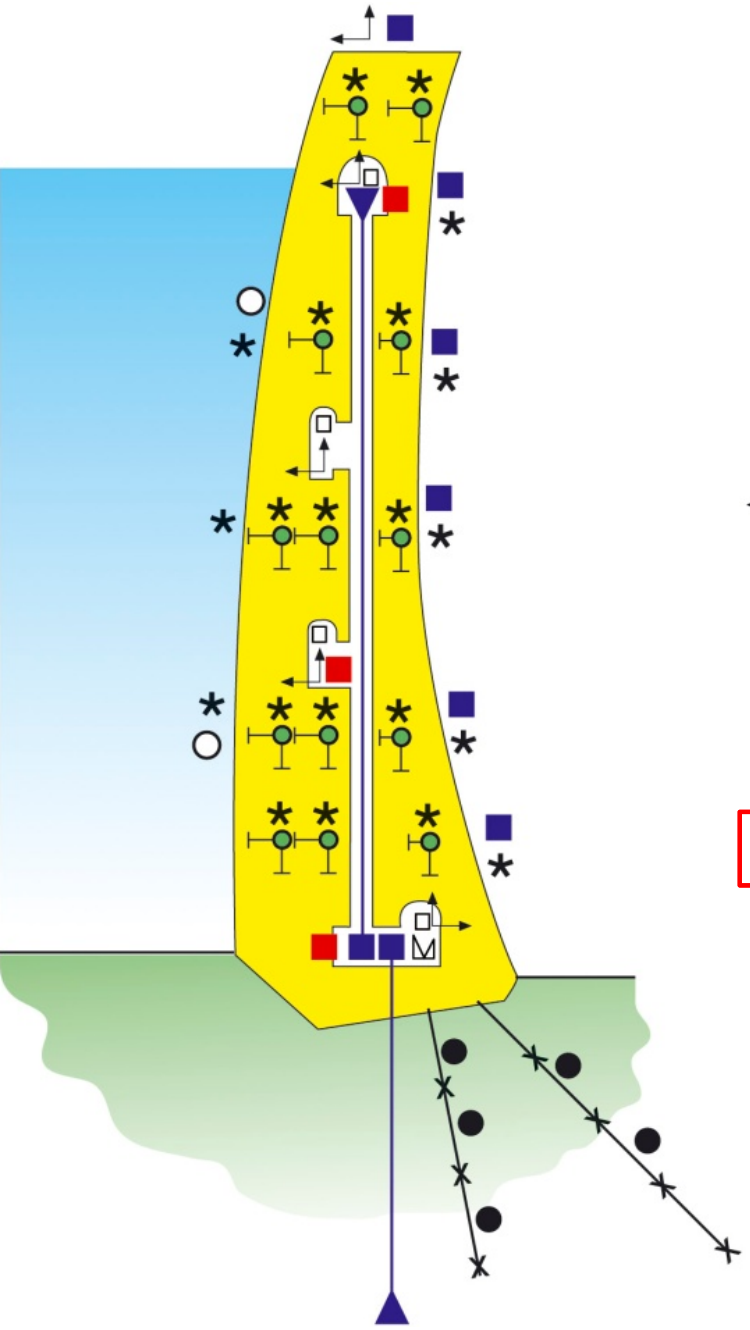


WATER BASIN LEVEL - STAFF GAUGES



WATER BASIN LEVEL - ULTRASONIC GAUGE

SURVEY POINTS (GEODETICAL MEASUREMENTS)



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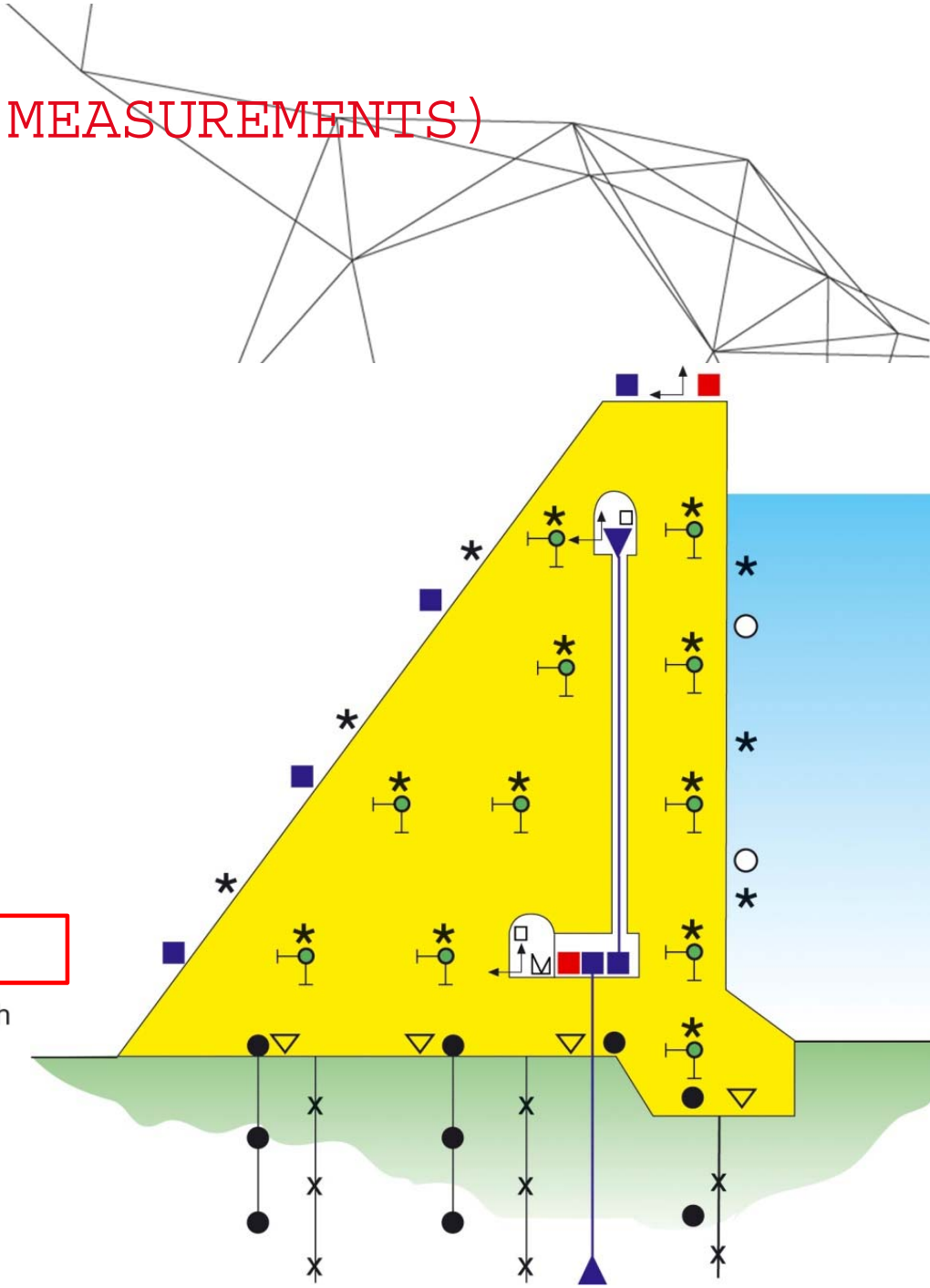
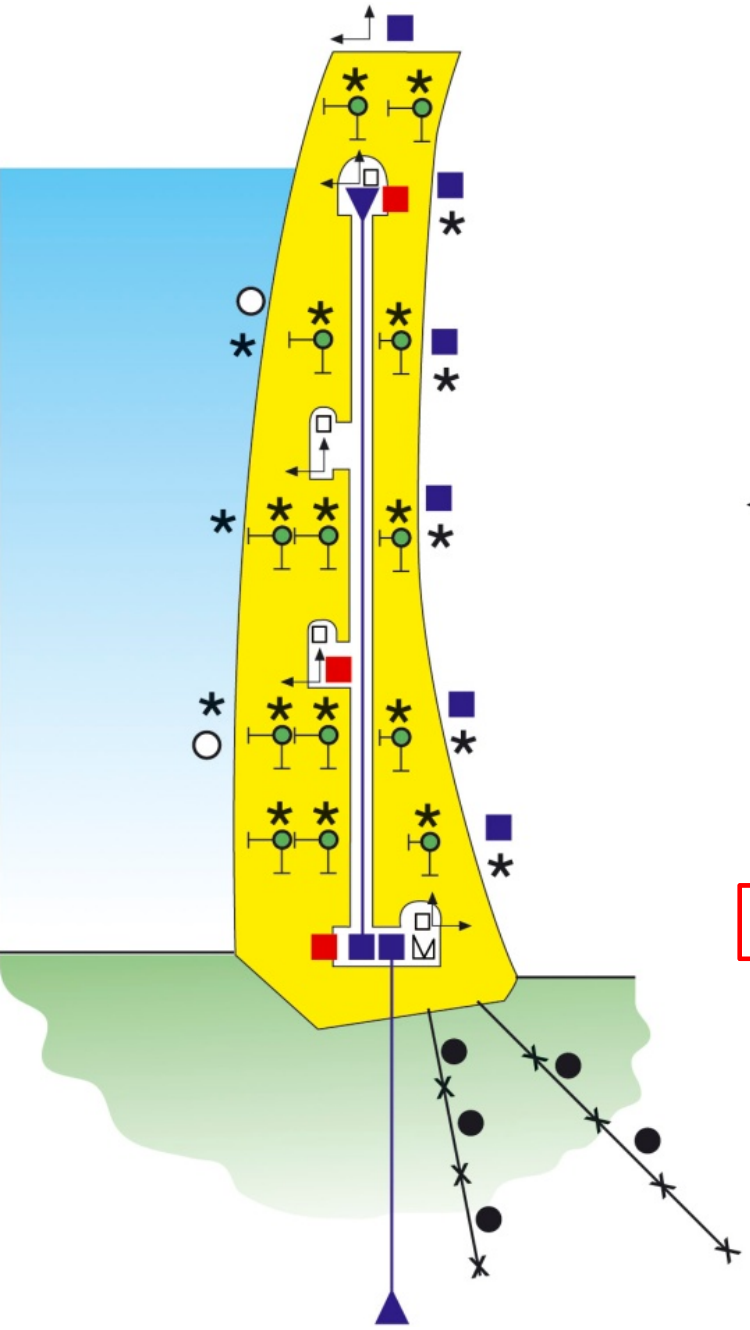
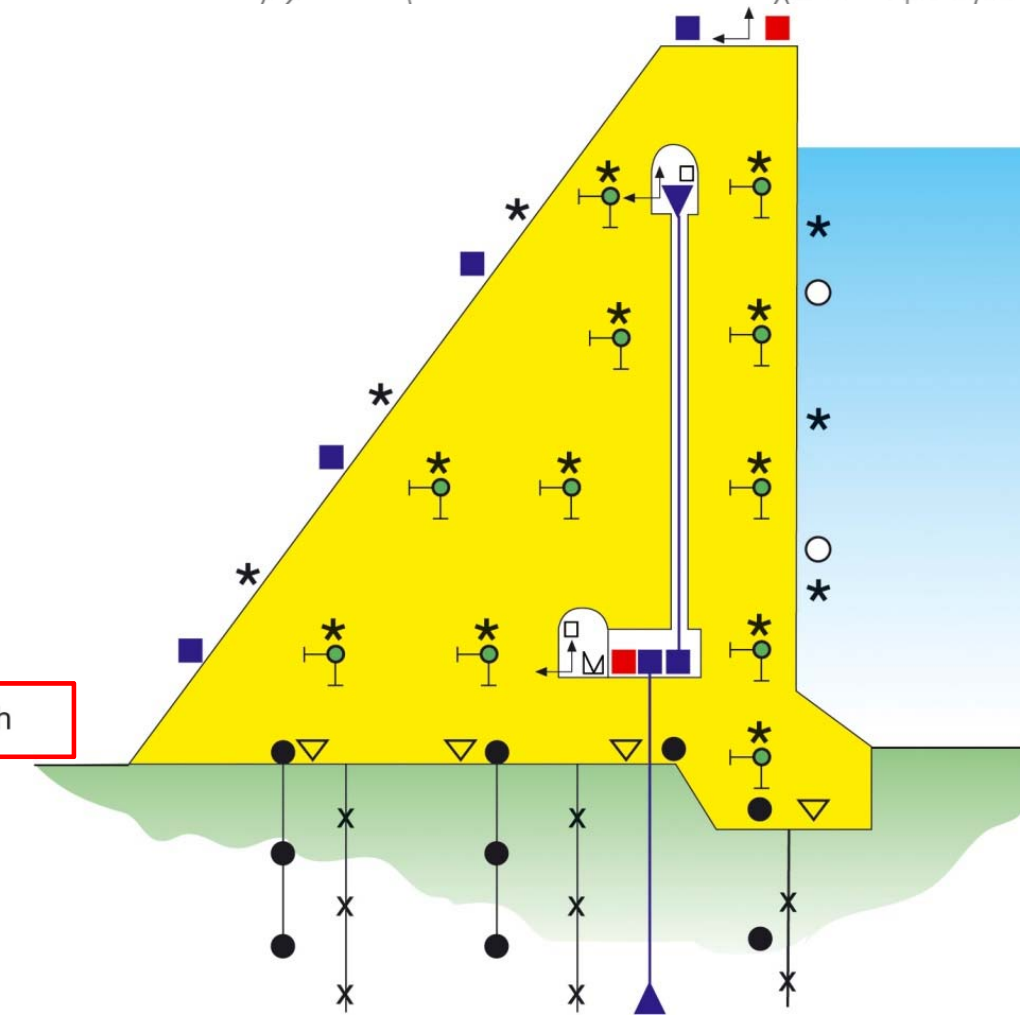


SURVEY POINTS (BENCHMARKS, PRISMS, ETC…)

SURVEY POINTS (GEODETICAL MEASUREMENTS)



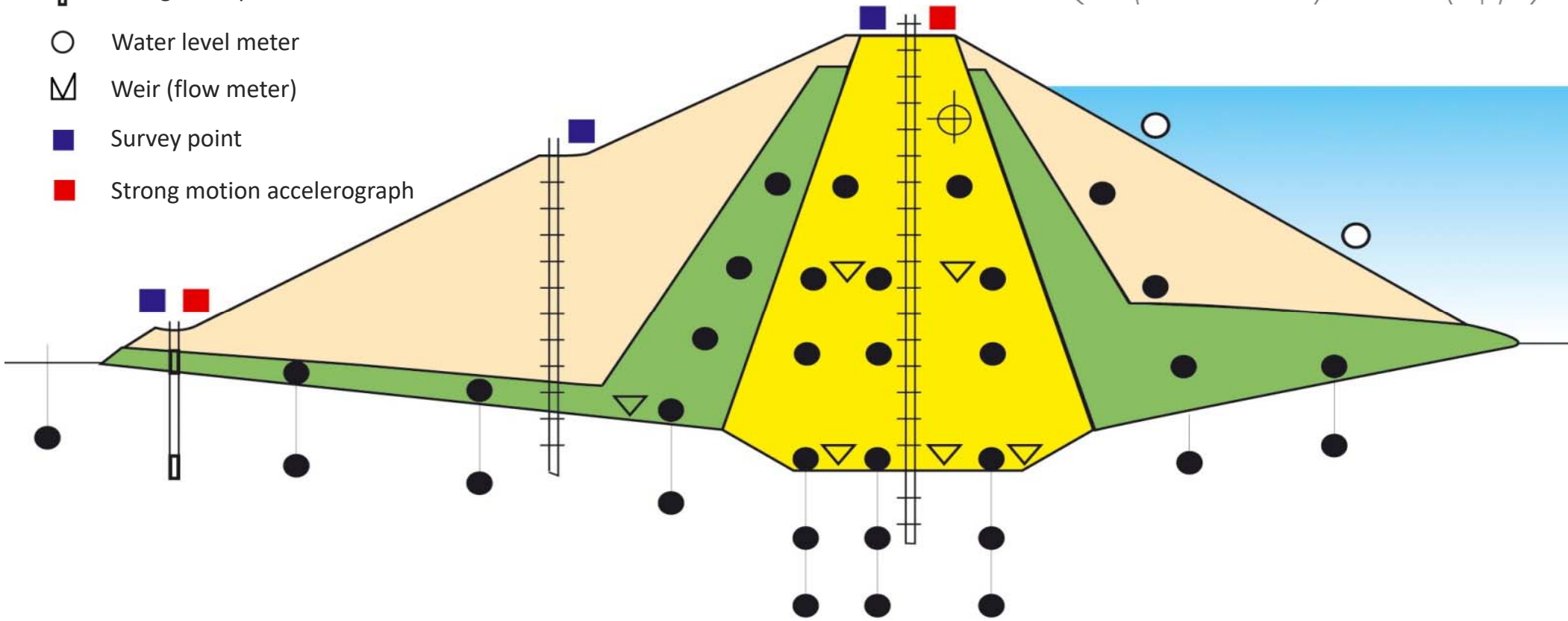
- Direct pendulum
- Inverted pendulum
- Embedded strain-gauge
- Thermometer
- Weir (flow meter)
- Tiltmeter (clinometer)
- Joint meter
- Borehole extensometer
- Piezometer
- Earth pressure cell
- Water level meter
- Survey point
- Strong motion accelerograph



STRONG MOTION ACCELEROGRAPH

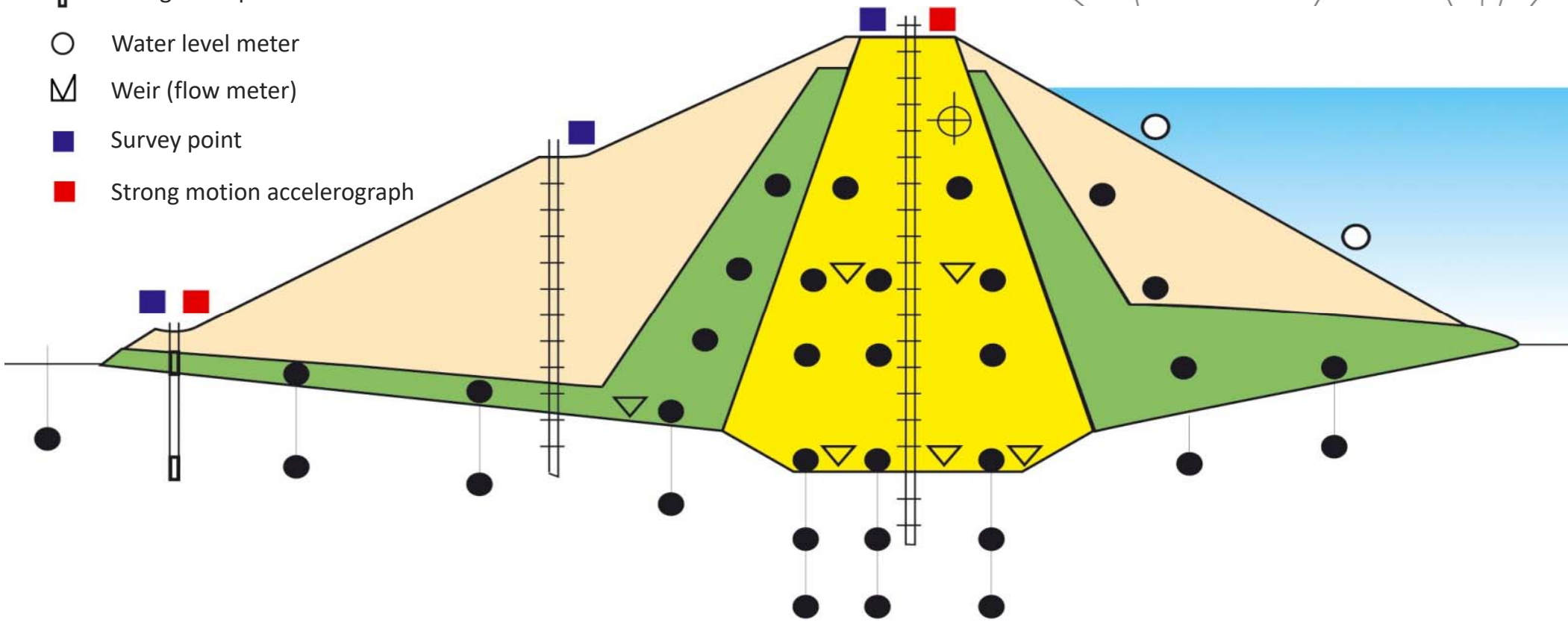
EMBANKMENT DAMS

- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- Inclino-settlement column
- Casagrande piezometer
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph



PIEZOMETERS (PORE PRESSURE)

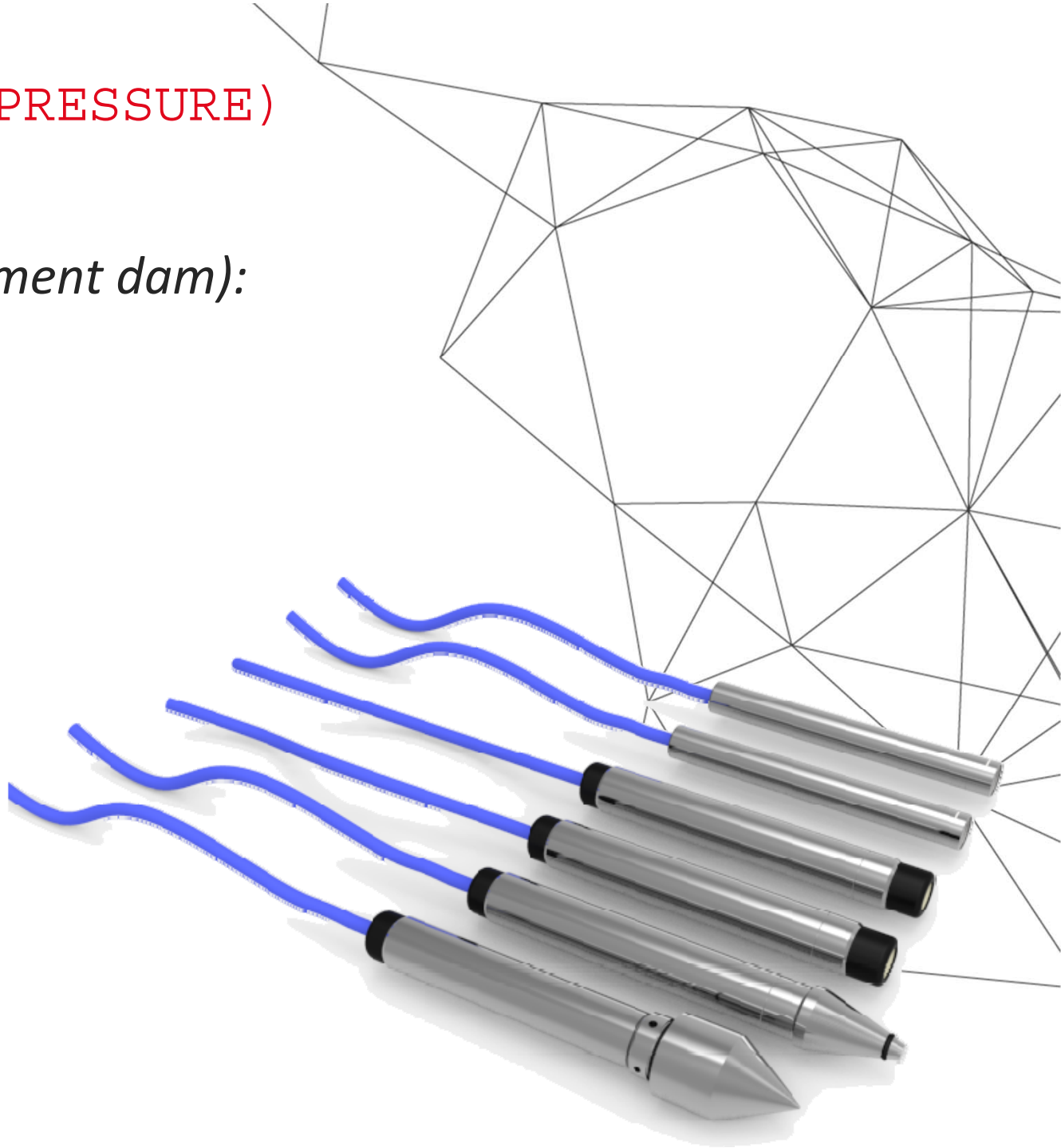
- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- Inclino-settlement column
- Casagrande piezometer
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph



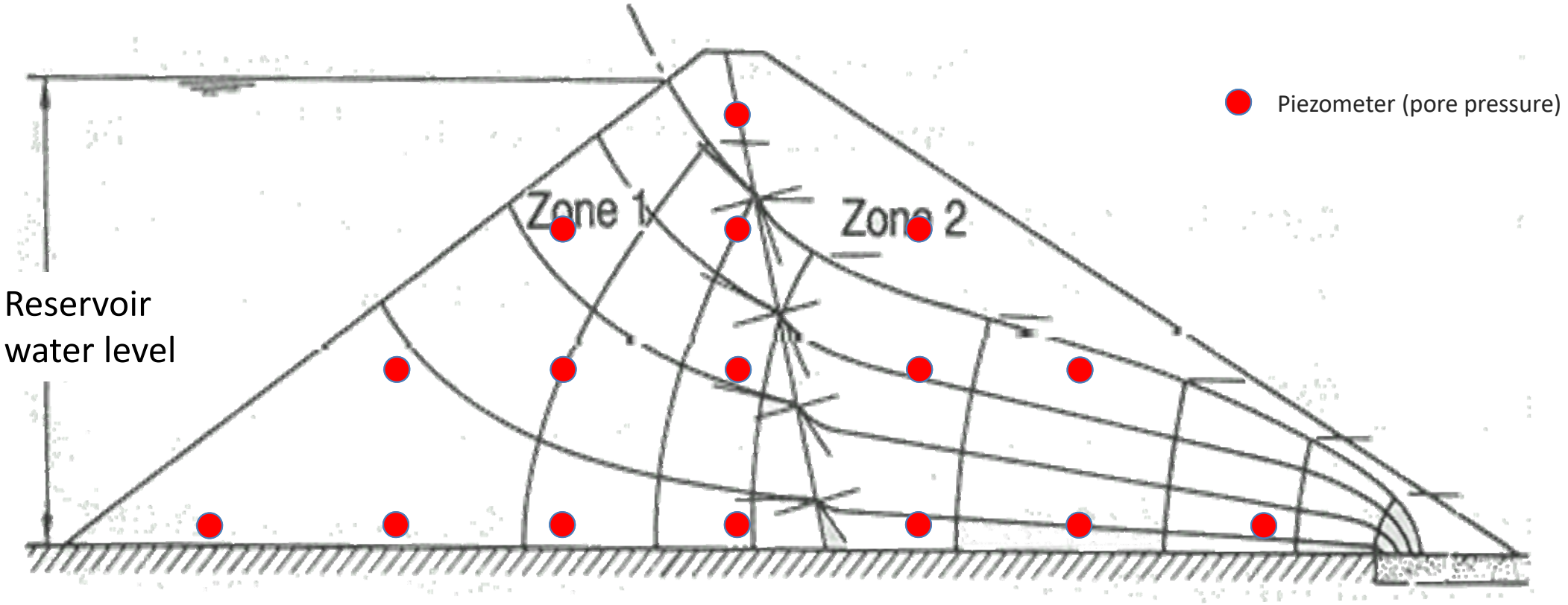
PIEZOMETERS (PORE PRESSURE)

Main application (embankment dam):

Pore pressure behaviour in dam body and foundations



PIEZOMETERS (PORE PRESSURE)



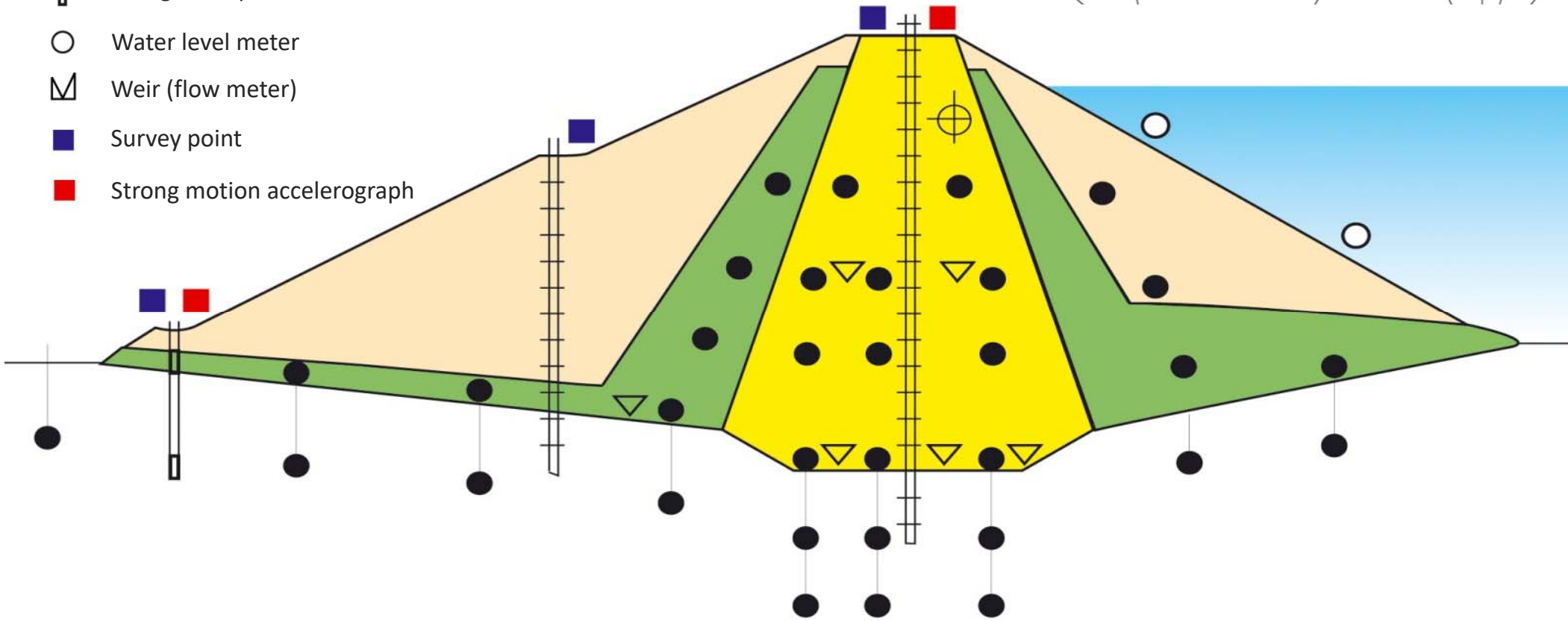
Example of water filtration in homogeneus embankment dam with drainage.

VW piezometer monitor pressure in different points.

PIEZOMETERS (PORE PRESSURE IN FOUNDATION)

EARTH (TOTAL) PRESSURE CELL

- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- Inclino-settlement column
- Casagrande piezometer
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph



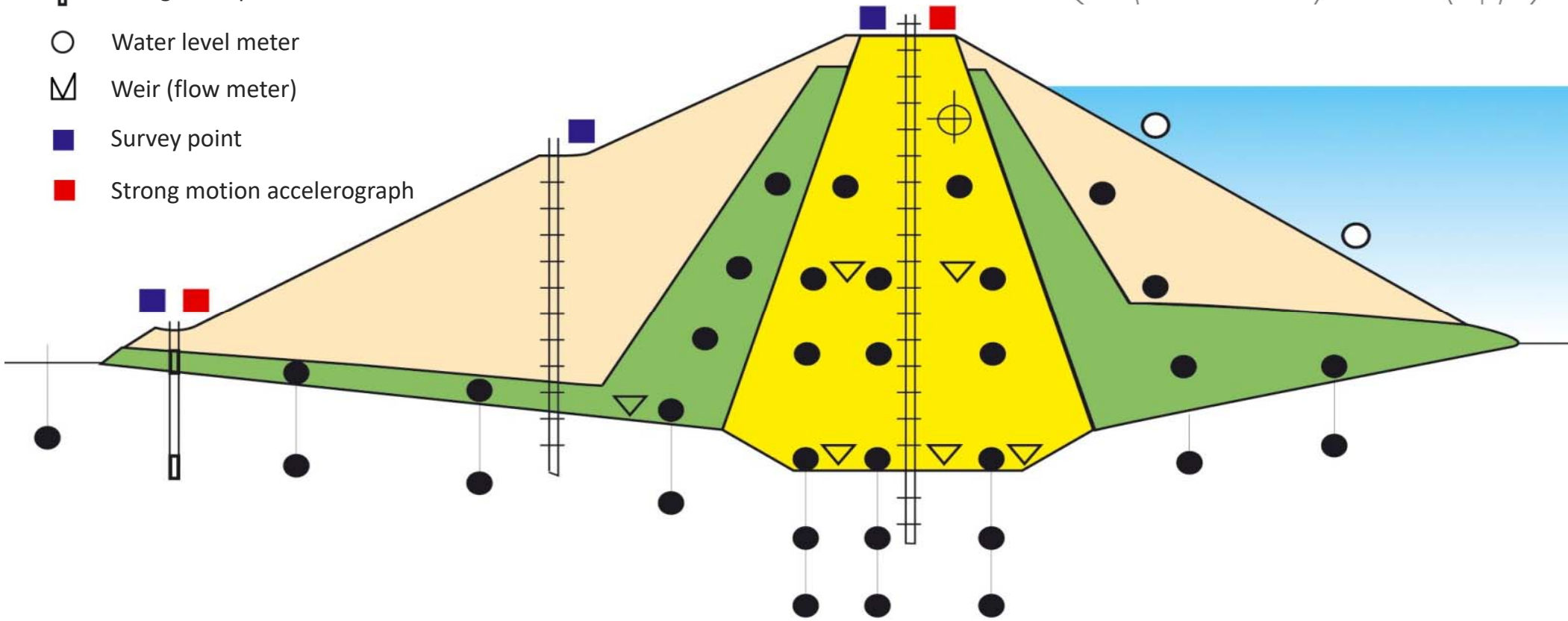
EARTH (TOTAL) PRESSURE CELL

Theta Dam, Kenya

Taking zero reading

EMBANKMENT EXTENSOMETER

- Piezometer (pore pressure)
- Earth (total) pressure cell
- **Embankment extensometer**
- Inclino-settlement column
- Casagrande piezometer
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph

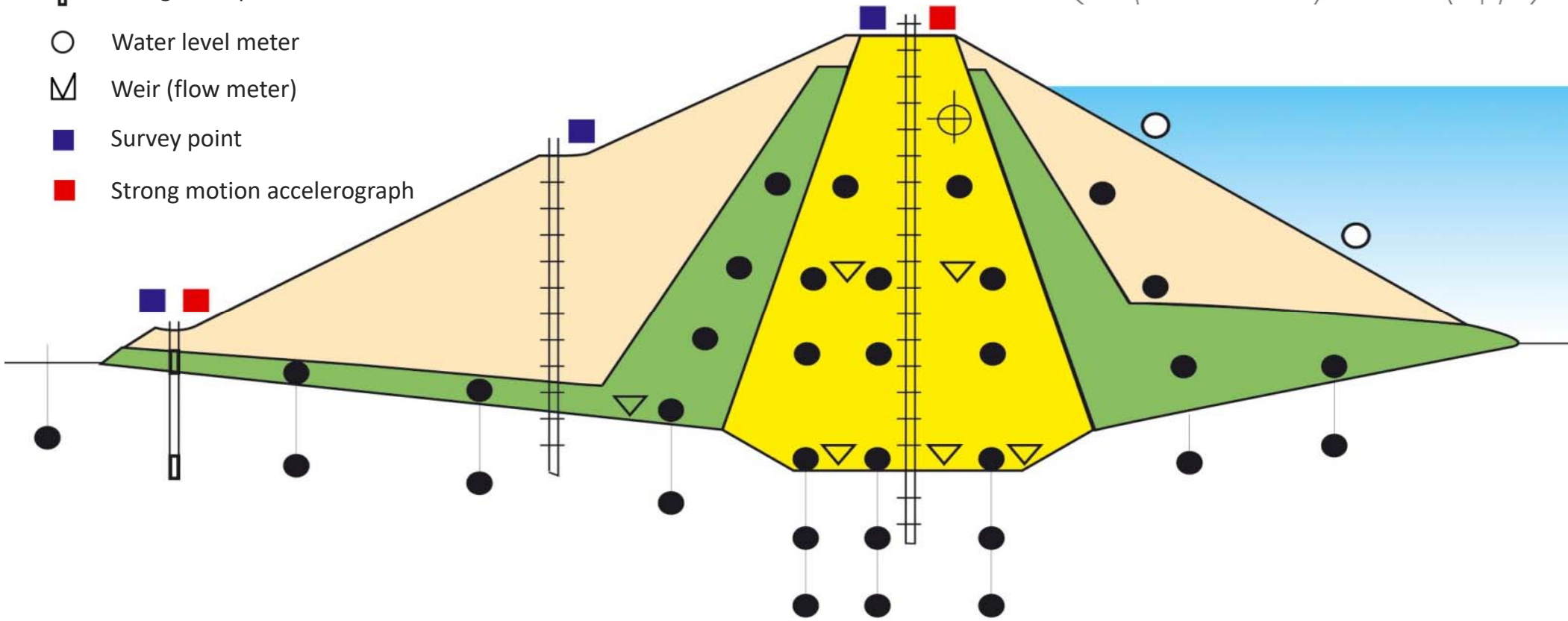


EMBANKMENT EXTENSOMETER

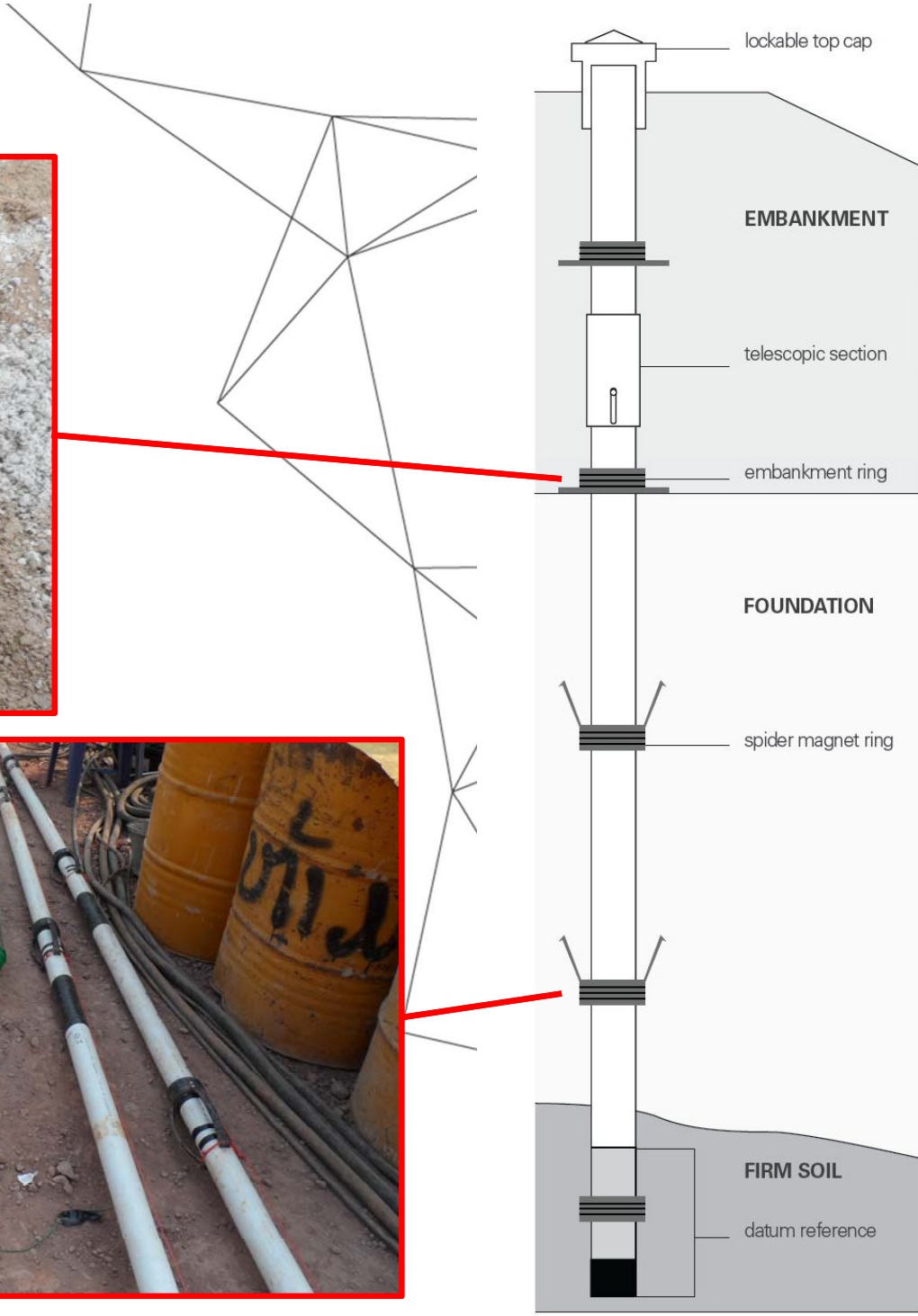
They are usually incorporated in the filling material, chained together by means of extension rod and sensed section.

INCLINO-SETTLEMENT COLUMN

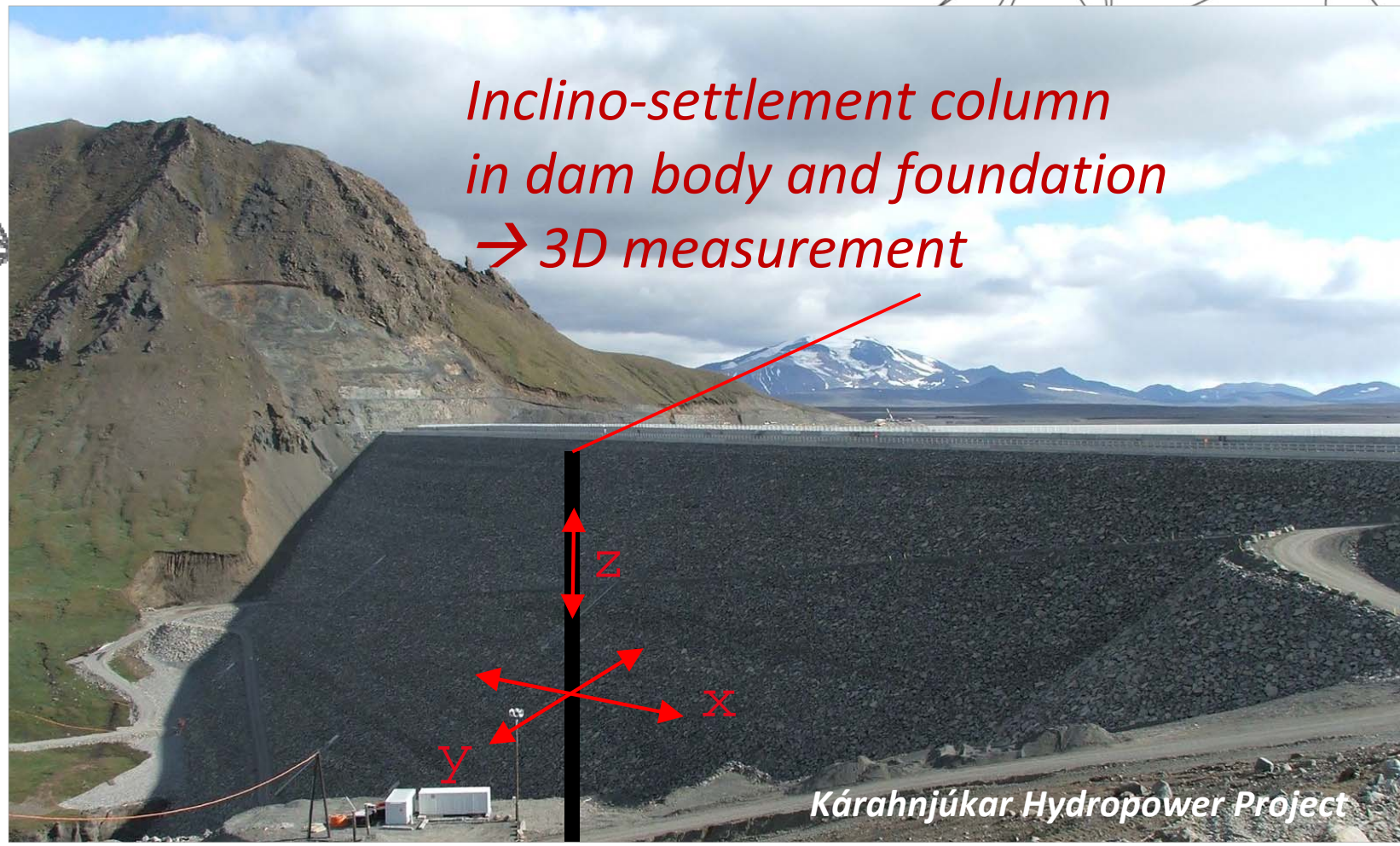
- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- **Inclino-settlement column**
- Casagrande piezometer
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph



INCLINO-SETTLEMENT COLUMN



INCLINO-SETTLEMENT COLUMN

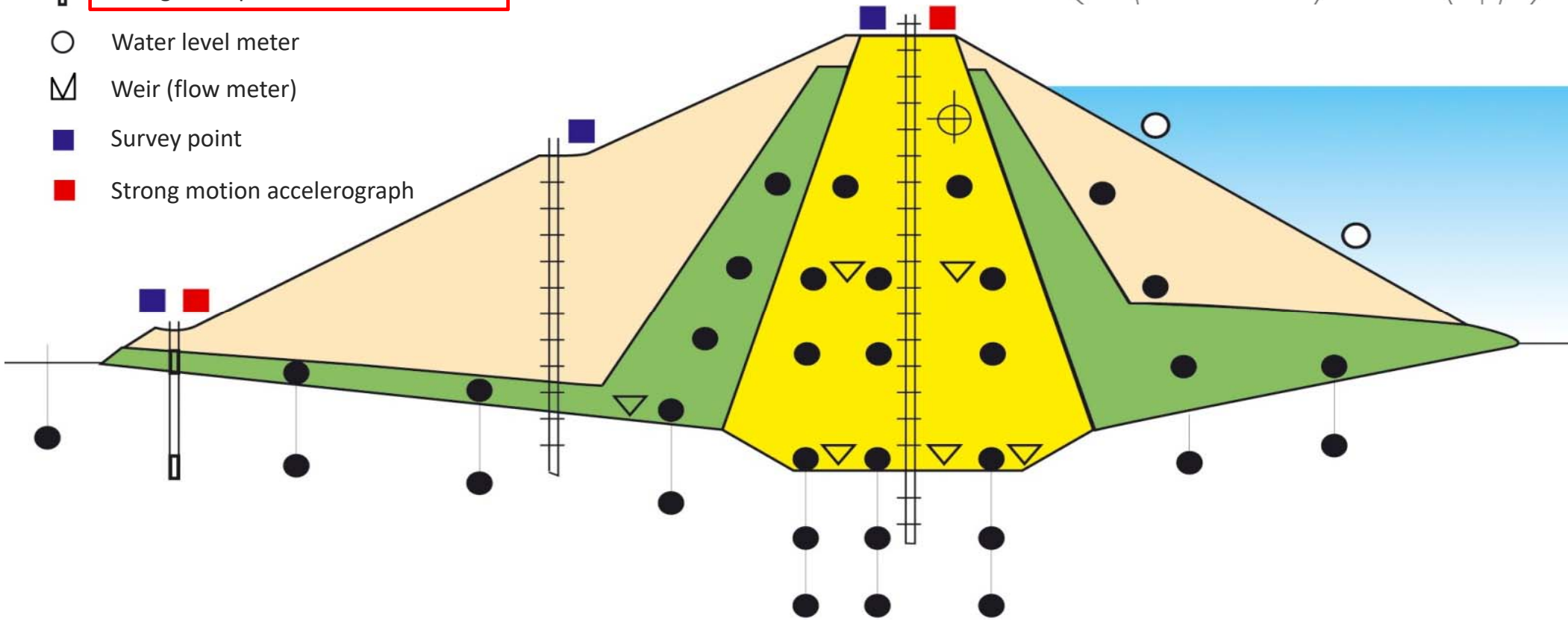


INCLINO-SETTLEMENT COLUMN: INCLINOMETER SURVEY

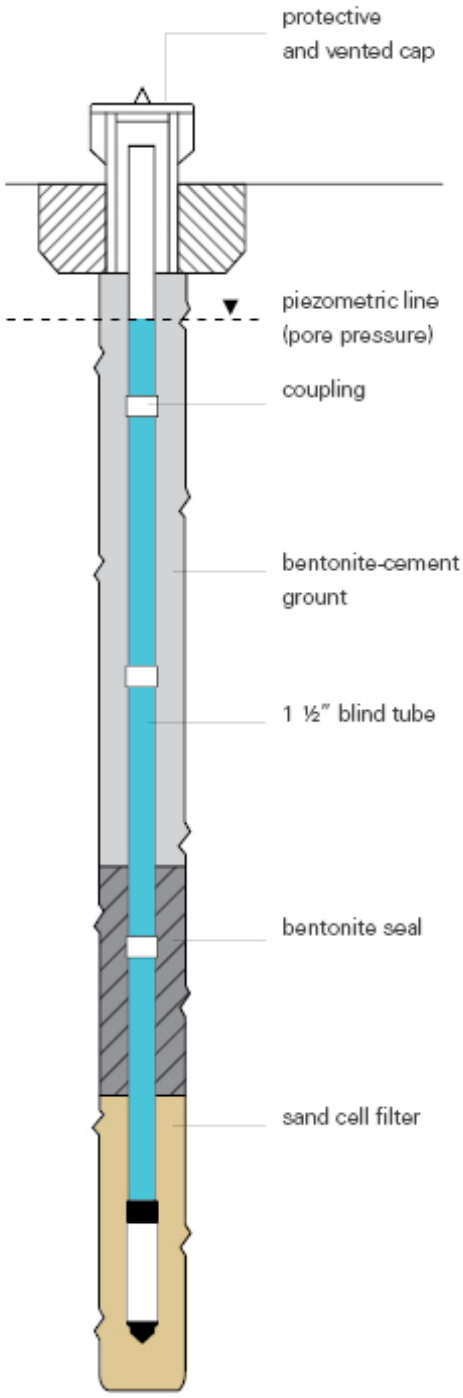
INCLINO-SETTLEMENT COLUMN: SETTLEMENT MEASUREMENT

CASAGRANDE PIEZOMETER

- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- Inclino-settlement column
- **Casagrande piezometer**
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph

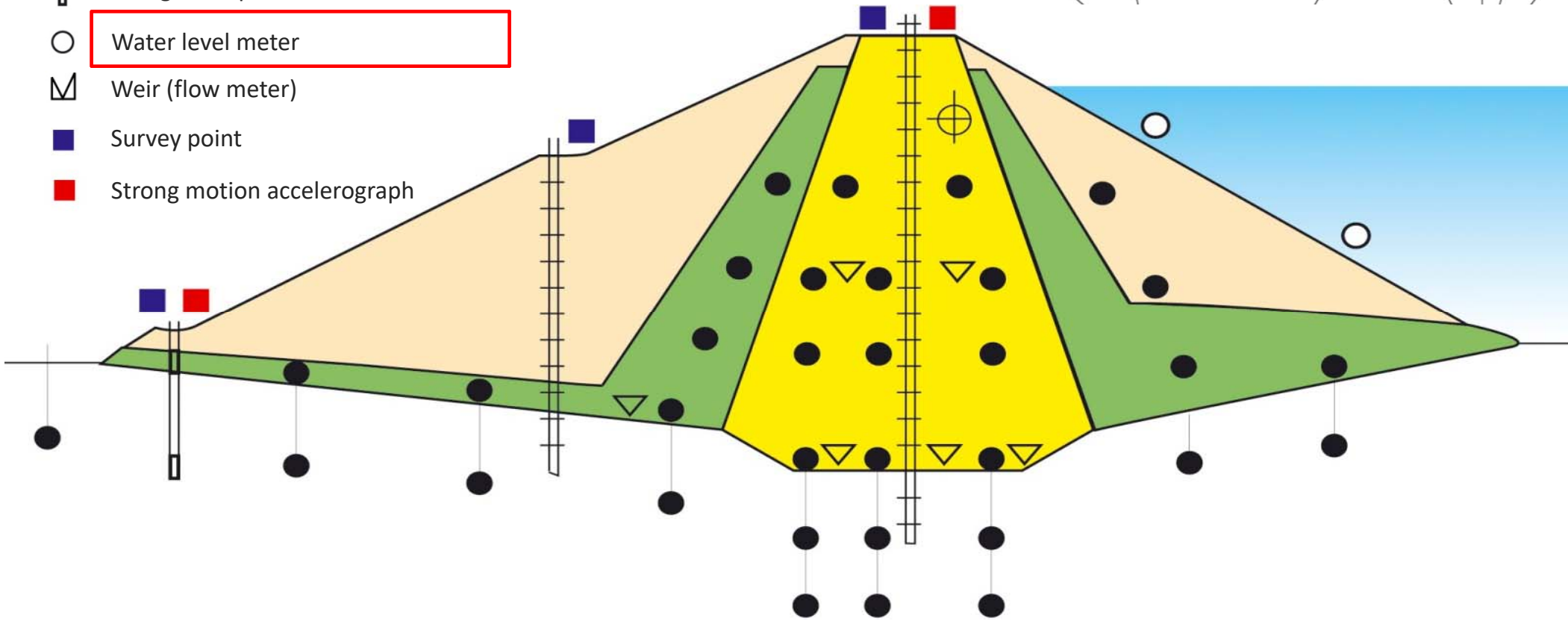


CASAGRANDE PIEZOMETER



WATER LEVEL METER

- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- Inclino-settlement column
- Casagrande piezometer
- **Water level meter**
- Weir (flow meter)
- Survey point
- Strong motion accelerograph

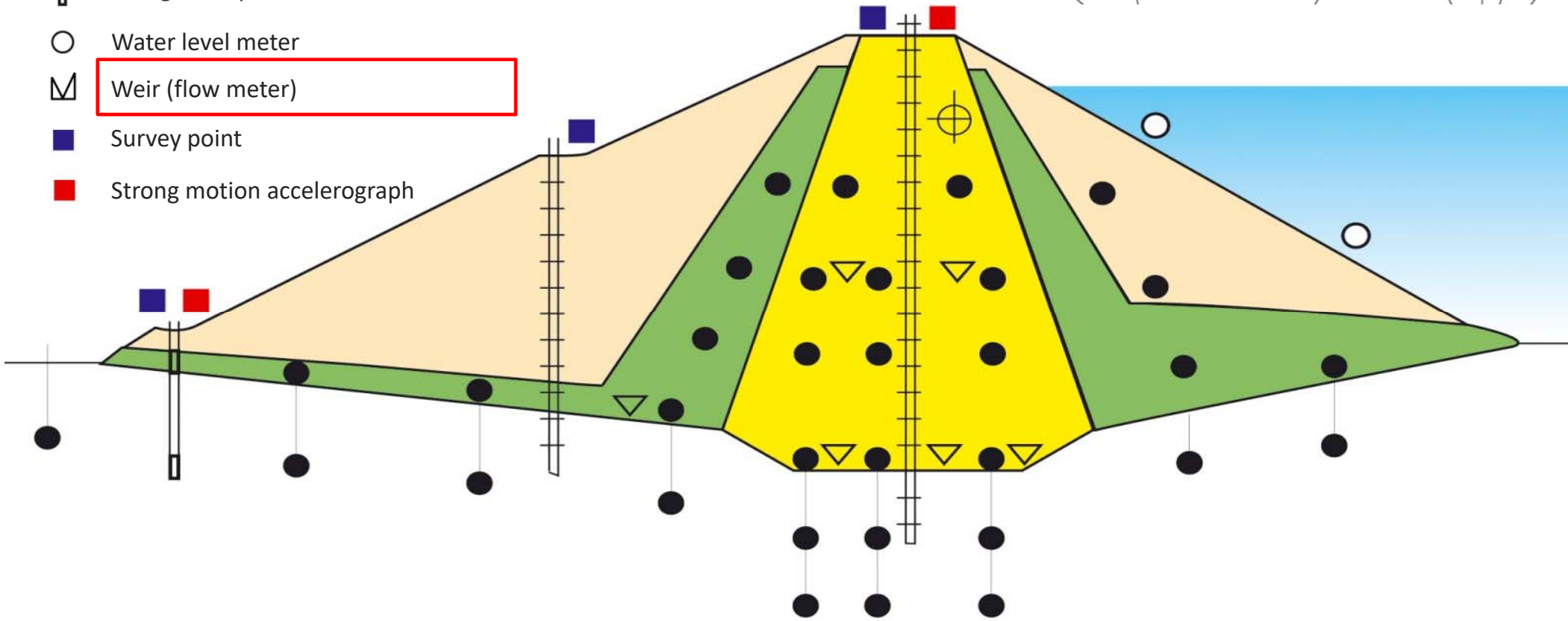


WATER LEVEL METER

Relative pressure transducer

WEIR (FLOW) METER

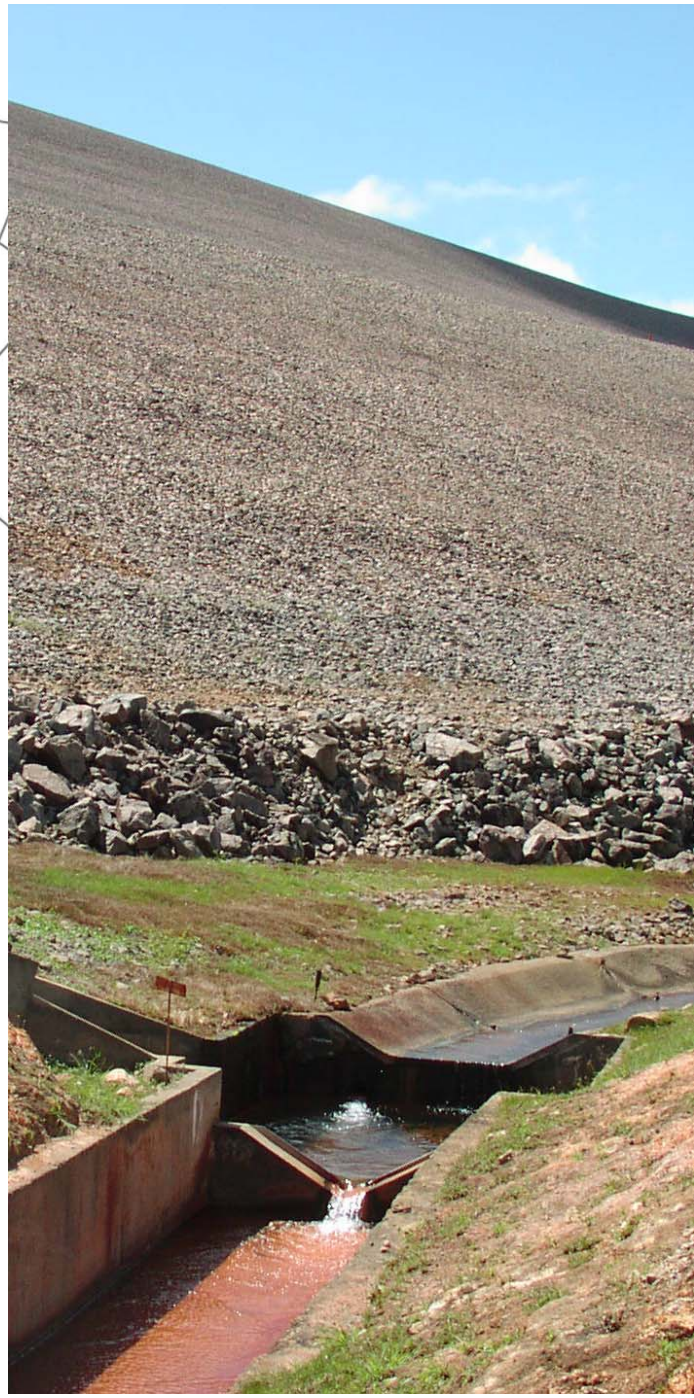
- Piezometer (pore pressure)
- Earth (total) pressure cell
- Embankment extensometer
- Inclino-settlement column
- Casagrande piezometer
- Water level meter
- Weir (flow meter)
- Survey point
- Strong motion accelerograph



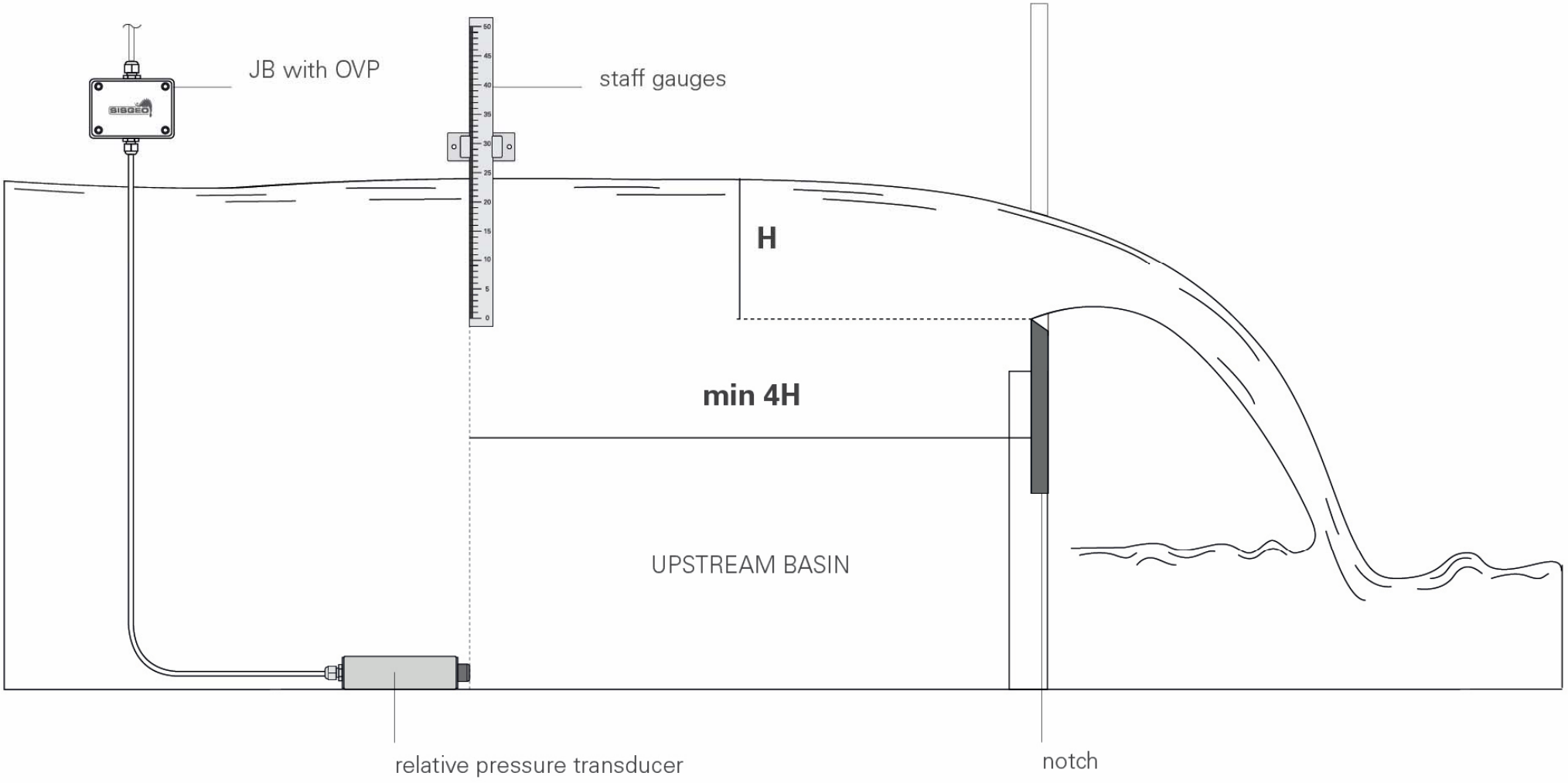
WEIR-FLOW METERS - V-NOTCHES

Leakage measurement is one of the most important indicator of overall performance of dams

Leakage monitoring provides data for evaluation of dam long term stability



WEIR (FLOW) METERS - V-NOTCHES



SURVEY POINT

- Piezometer (pore pressure)
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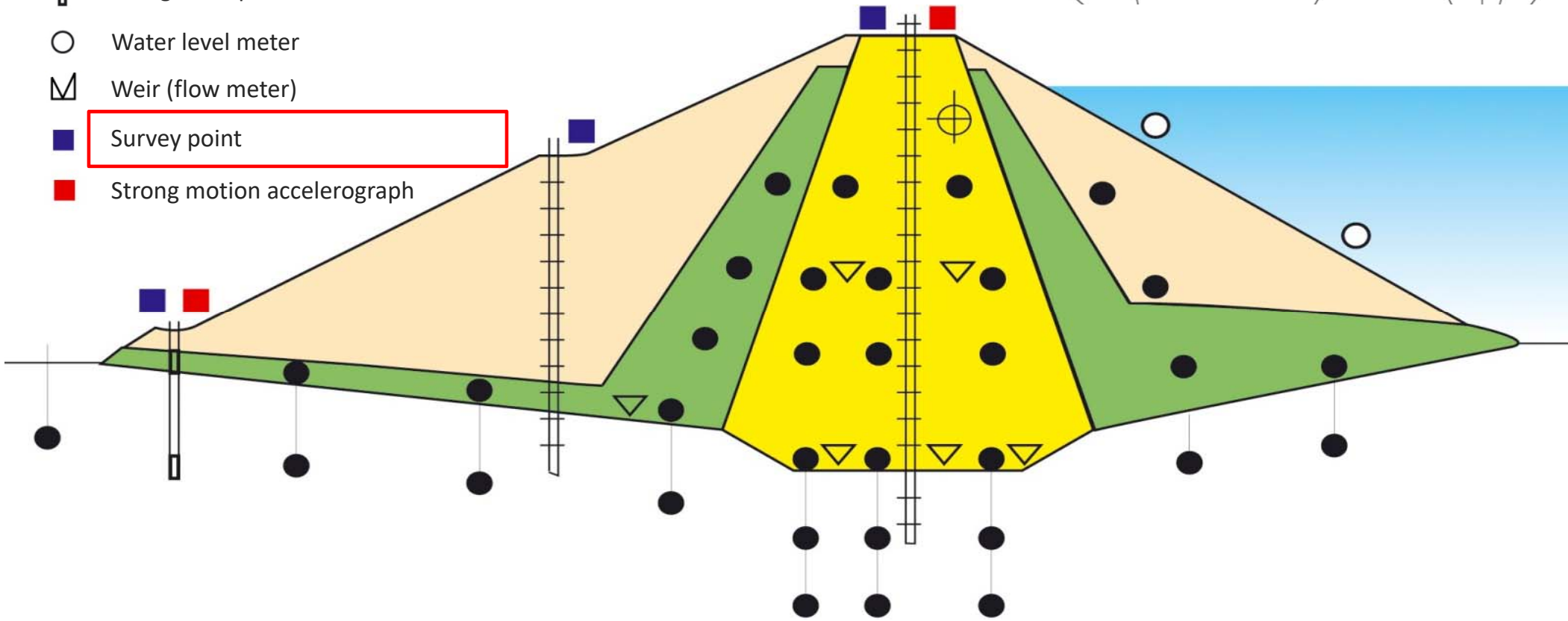

SURVEY POINTS (BENCHMARKS, PRISMS, ETC…)

SURVEY POINT

- Piezometer (pore pressure)
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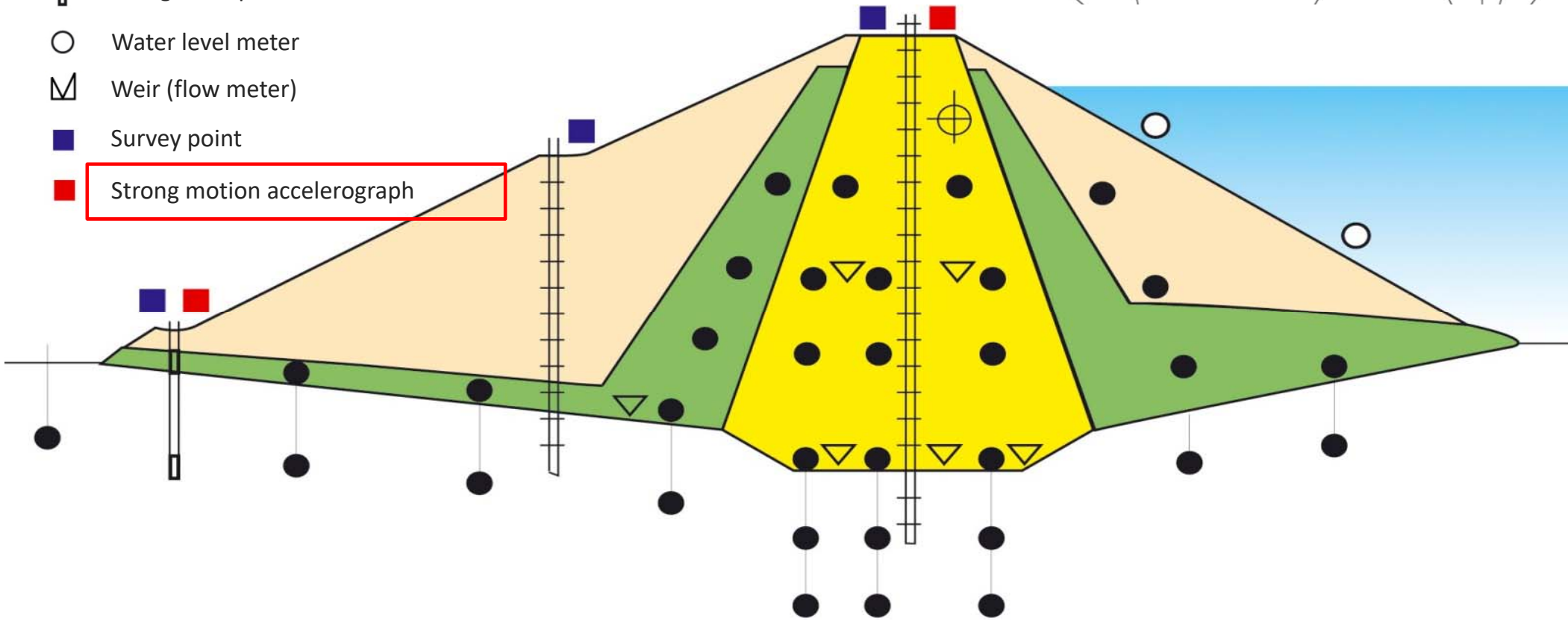

STRONG MOTION ACCELEROGRAPH

DAM MONITORING: DATA ACQUISITION SYSTEM

Instruments installed in the dam body provide automatic real-time monitoring by means of OMNIAlog datalogger.

With an internet 3G router, OMNIAlog can provide remote system management, data pushing on a server and alarms.

Wadi Daiqa DAM, OMAN

DAM MONITORING: DATA ACQUISITION SYSTEM

OMNIAlog Module

Wadi Daiqa DAM, OMAN

DAM MONITORING: DATA ACQUISITION SYSTEM

Wadi Daiqa DAM, OMAN

METEOROLOGICAL STATION

Typical meteorological parameters needed in dam monitoring include:

- *rain fall*
- *wind speed and direction*
- *atmospheric pressure*
- *air temperature and humidity*
- *evaporation*

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