HYDRO

SEDIMENT MANAGEMENT

ANALISI PREDITTIVA DEGLI EFFETTI DELL'EROSIONE E OTTIMIZZAZIONE DEL PROCESSO DI RILASCIO ATTRAVERSO IL SISTEMA INTEGRATO

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ANDRITZ

ENGINEERED SUCCESS

SEDIMENT MANAGEMENT

Intro

„Whereas the last century was concerned with reservoir development, the 21st century will need to focus on sediment management; the objective will be convert today´s inventory of non-sustainable infrastructure for future generations.“

Third World Water Forum, Kyoto 2003

SEDIMENT MANAGEMENT

Intro

SEDIMENT MANAGEMENT

Intro

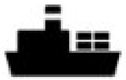
Trapped sediments in world's reservoirs

Global yearly reservoir sedimentation rate:

57 billion m³ sediment per year

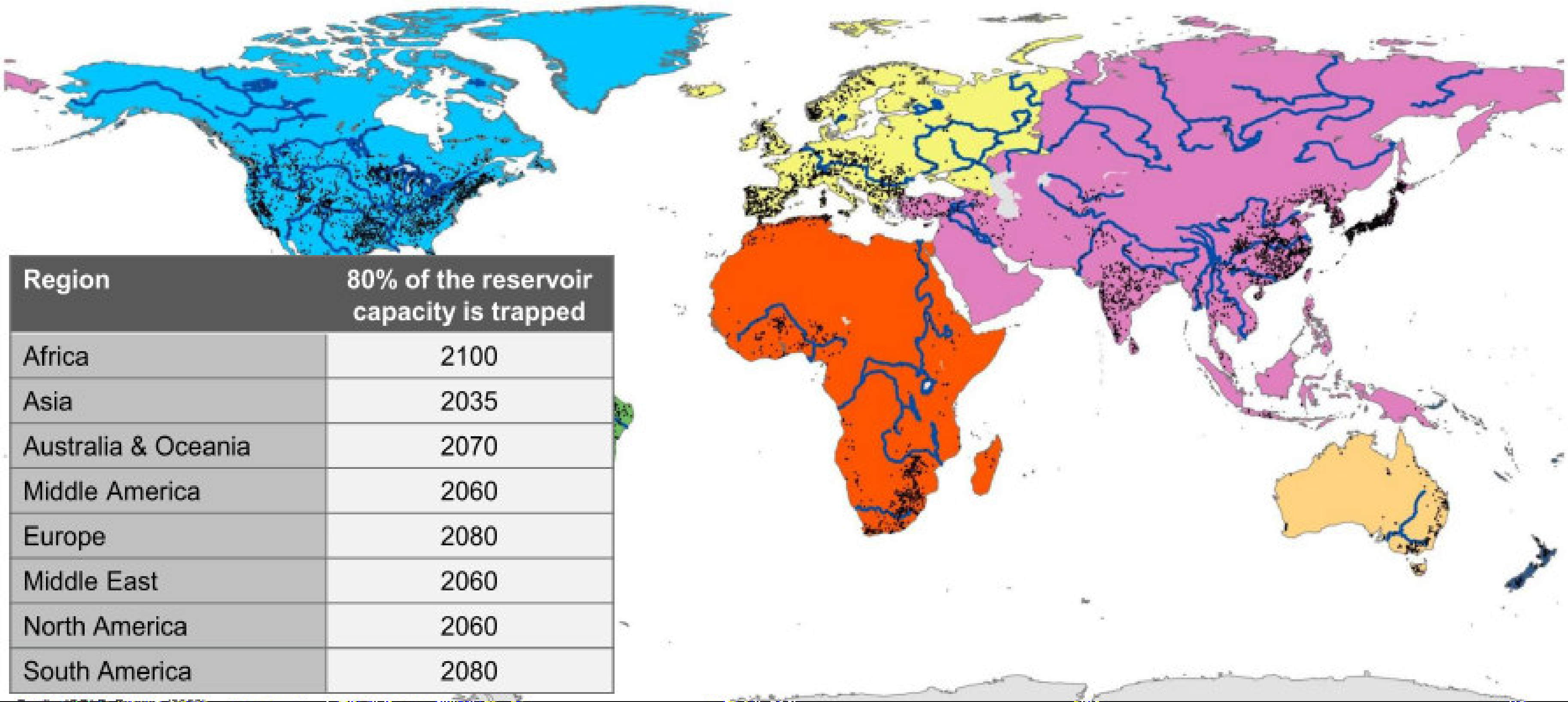
Shipping container (ISO)

MSC Oscar (19200 containers)

= 40 000  per year

SEDIMENT MANAGEMENT

Global view



Region	80% of the reservoir capacity is trapped
Africa	2100
Asia	2035
Australia & Oceania	2070
Middle America	2060
Europe	2080
Middle East	2060
North America	2060
South America	2080

[redacted]

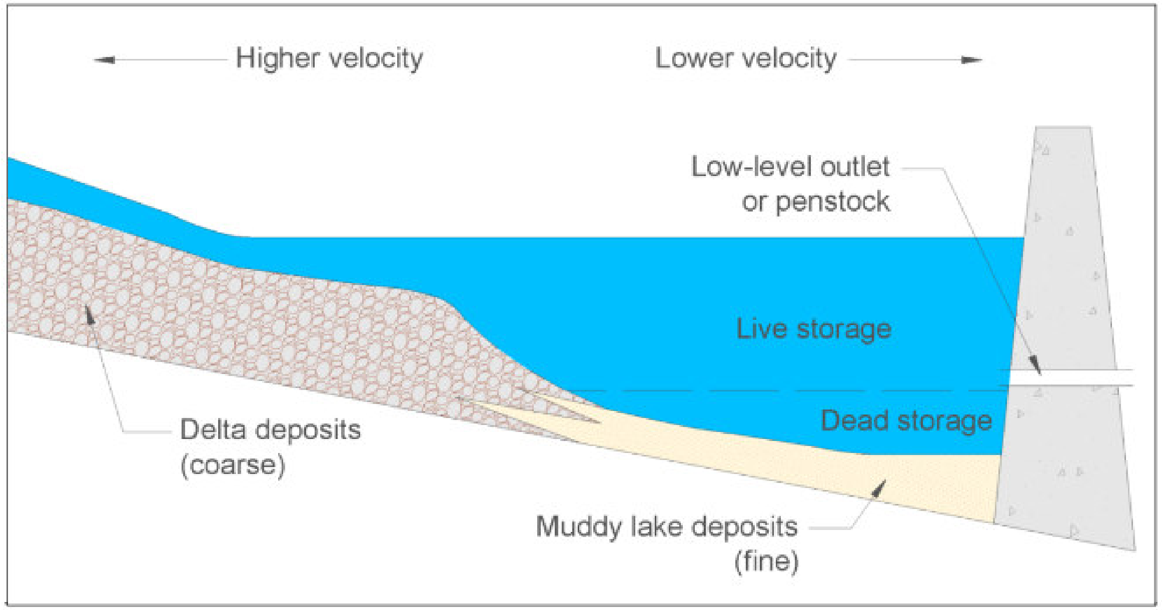
ICOLD BULLETIN

SEDIMENT MANAGEMENT

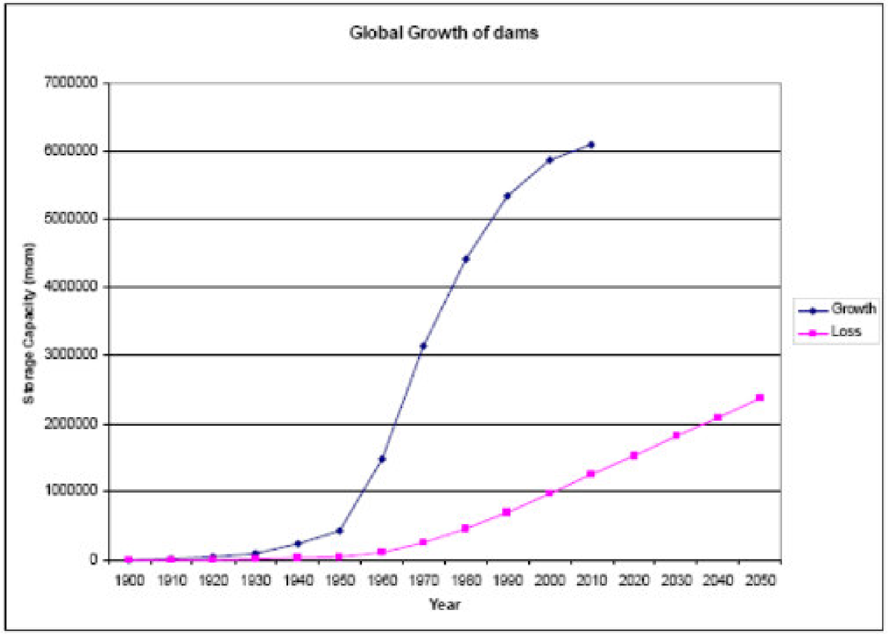
Background

The causes and processes for movement of sediment into reservoirs are well documented in available literature

Sedimentation is a processes of erosion, entrainment, transportation, deposition, and compaction of particulate materials .



Typical reservoir sediment profile



SEDIMENT MANAGEMENT

Background

There are three stages in a reservoir's life:

- The **first stage** the ***continuous sediment trapping*** stage in which sediment **accumulation occurs rapidly**.
- During the **second stage** of the sedimentation process, ***partial sediment balance***, occurs. During this stage the reservoir experiences a **mixture of sediment deposition and removal**, often with fine sediments reaching sediment balance but coarse sediments continuing to accumulate.
- In the **third and final stage *full sediment balance***, occurs with **sediment inflow and outflow** equal for all particle sizes. Complete sediment balance can only be reached if the incoming sediment load can be transferred downstream of the impoundment or otherwise removed from the reservoir.

"The objective of sediment management is to manipulate the river-reservoir system to achieve sediment balance while retaining as much beneficial storage as possible and minimizing environmental impacts and socioeconomic costs".

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Sediment Management Solutions

Bypassing

On-stream ***sediment bypassing*** diverts part of the sediment-laden water **around the reservoir and back into the river downstream of the dam**.

Sluicing

A common method of sediment management is routing the inflows through the facility by means of a combination of dam infrastructure and hydrological management. Sediments that would otherwise be deposited behind a dam can be sluiced **through gates designed to pass water** at a velocity sufficient to **maintain the sediments in suspension**

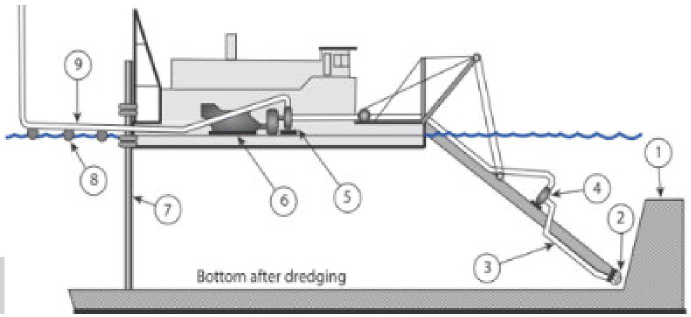
Dredging and flushing

The third most common method of sediment management is the removal or rearrangement of sediment that has already been deposited within a reservoir **in order to recover storage volume**. Sediment removal can be further classified into two sub-categories:

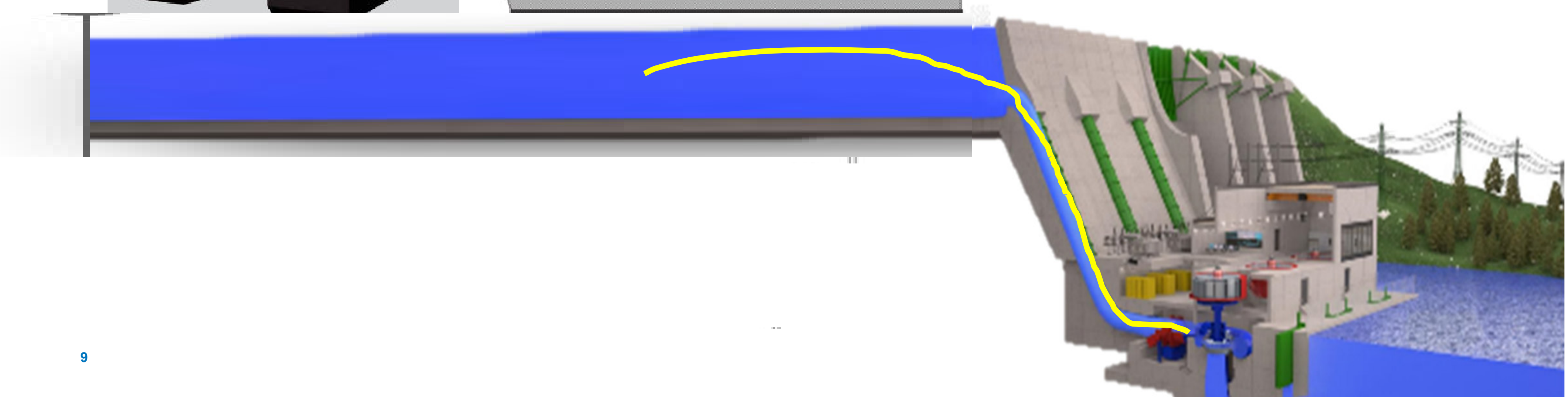
- ***Dredging*** is only a viable sediment management technique if it continues indefinitely; ***Tactical dredging*** used in some reservoirs to remove sediment from a specific area (i.e. near intakes) and depositing it either outside the reservoir or elsewhere within it.
- ***Hydraulic flushing*** involves completely emptying the reservoir by opening bottom outlets and then allowing the incoming streamflow to scour deposited sediment and pass it through the down stream side of the dam

SEDIMENT MANAGEMENT

Dredging system using Turbines as sediment transport outlet

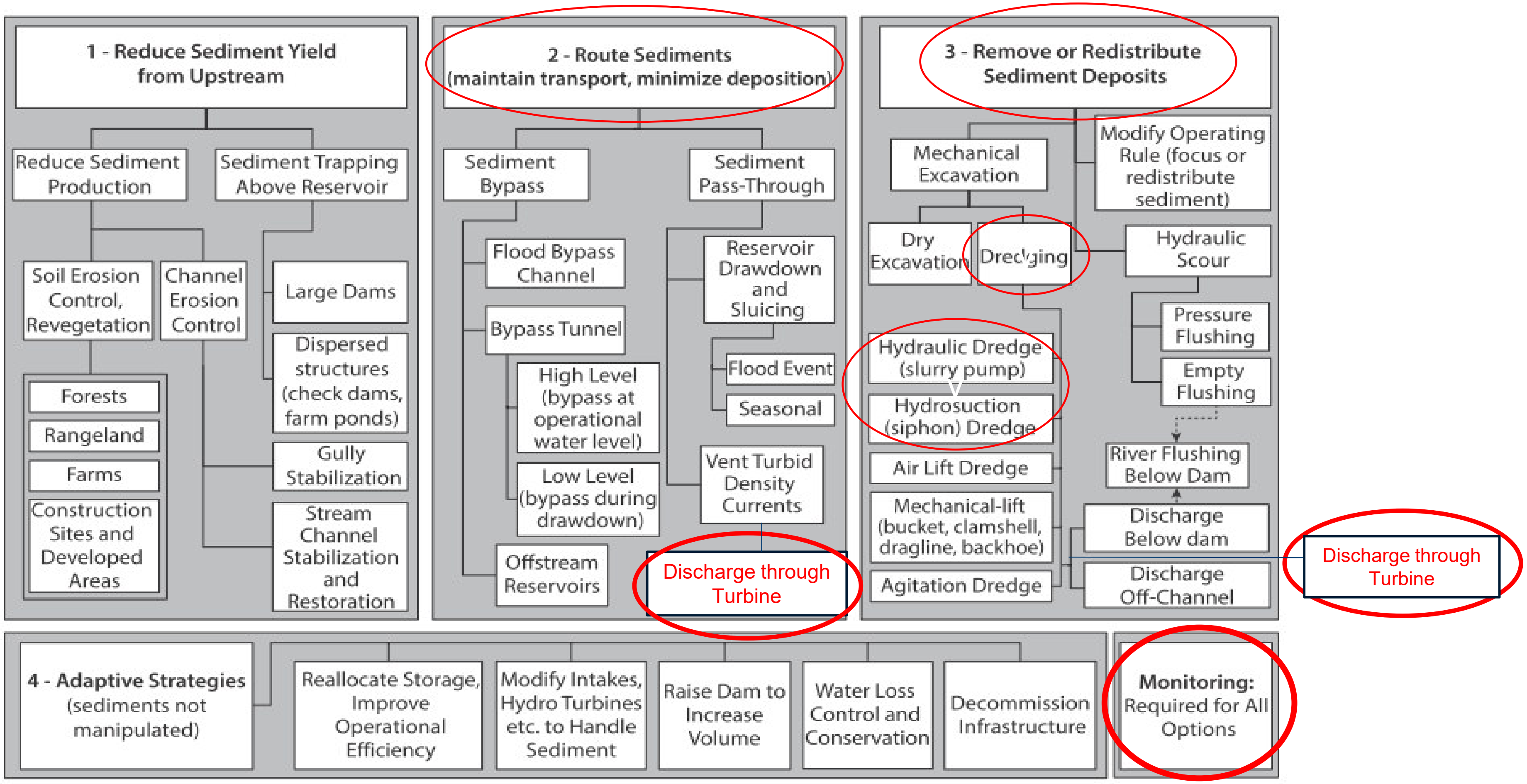


The idea is to do a flushing of the sediments and convey them through the turbines



SEDIMENT MANAGEMENT

Figure 7.1 Classification of Sediment Management Alternatives



Source: Morris 2015.

SEDIMENT MANAGEMENT

Sediment through Turbines

Benefits

- Cost saving related to dredging
- Potential increased generation due to use of turbines for SMART dredging

Remark

- "SMART dredging" through turbines to be controlled/monitored as well as intake dredging

Question marks/doubts

- Potential lack of knowledge **about impact of sediment** through turbines
- To be considered a new/different major maintenance plan and related frequency (with new parts, site activities, repairs…)

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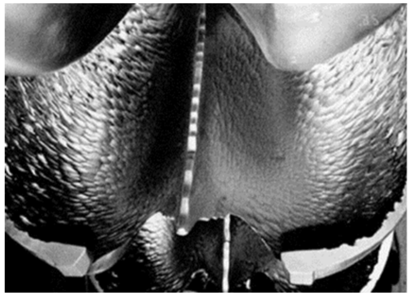
Sediment through Turbines



Hydro-abrasive erosion

- Leads to efficiency loss → production loss
- Destroys mechanical integrity of components → safety risk
- Is a trigger for maintenance → condition based maintenance

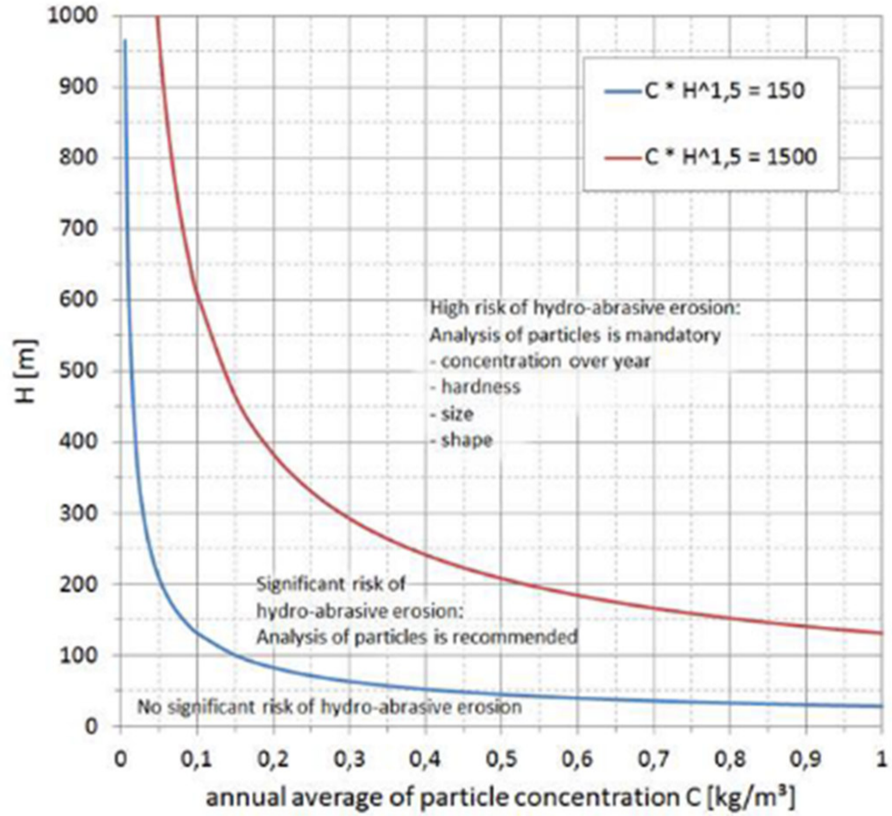
What can be done to prevent erosion/damages or high efficiency drop:

- Apply a coating layer of a hard material to runner

Monitor sediment content and adapt **operation** to avoid operating points that lead to more erosion

Monitor sediment content and adapt **maintenance** based on amount of sediments passing through turbine

Simplified model for first assessment of risk for hydro-abrasive erosion



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Sediment through Turbines

Monitor sediment content and adapt **operation** to avoid operating points that lead to more erosion

Monitor sediment content and adapt **maintenance** based on amount of sediments passing through turbine

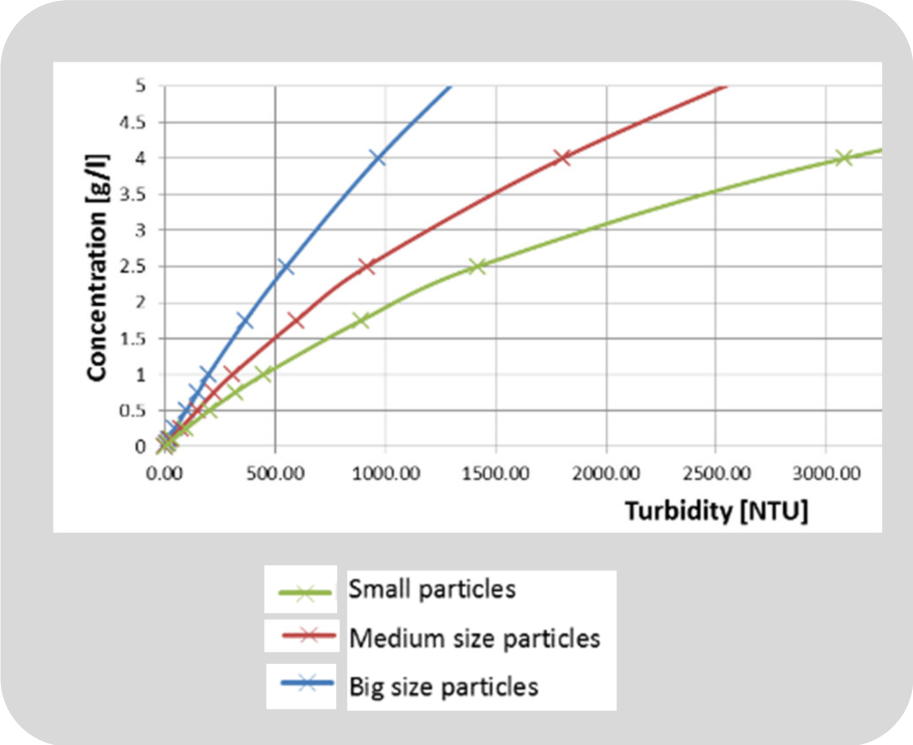
Intelligent combination of two sensors:

Turbidimeter:

- Measures the transparency (i.e. **turbidity**) of water continuously
- Light beam is scattered by particles in water volume
- Turbidity not only depends on concentration but also on particle size, particle type

CFDM:

- Flow of water with particles through two bent oscillating measuring tubes
- Measures density, flow rate and temperatures continuously
- Concentration is a function of density and temperature



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Sediment through Turbines

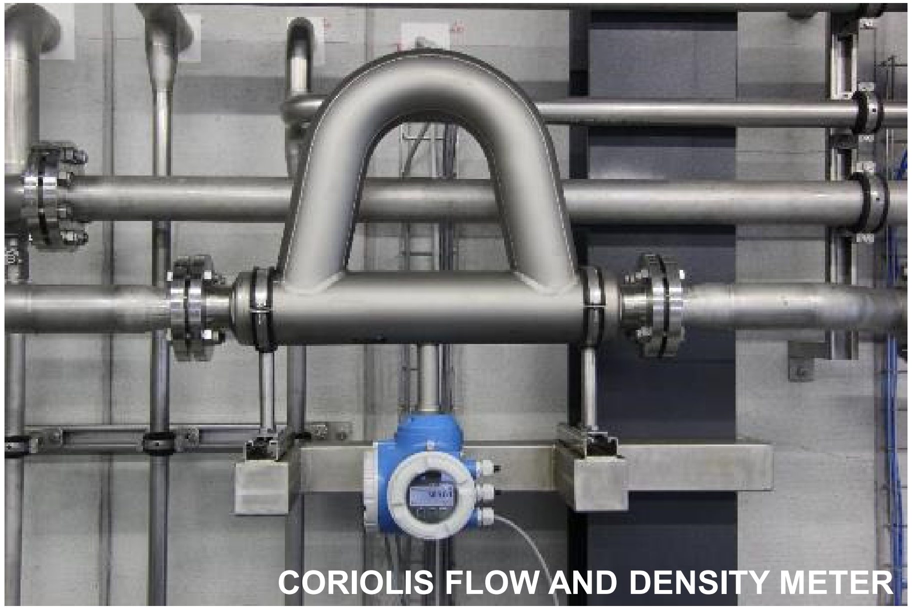
Particle concentration computed from a **combination of turbidity sensor & Coriolis flow and density meter:**

- Concentration directly obtained from measured values of **Coriolis Flow and Density Meter** (CFDM)
- CFDM is accurate for medium and large concentration (> 0.5 g/l)
- **Turbidimeters** resolve very accurately small changes in the concentration but it has to be recalibrated regularly depending on the sediment composition.

→ Combined method for large range of concentration values and high precision

→ Small changes in turbidity used to capture small changes in concentration

TURBIDIMETER



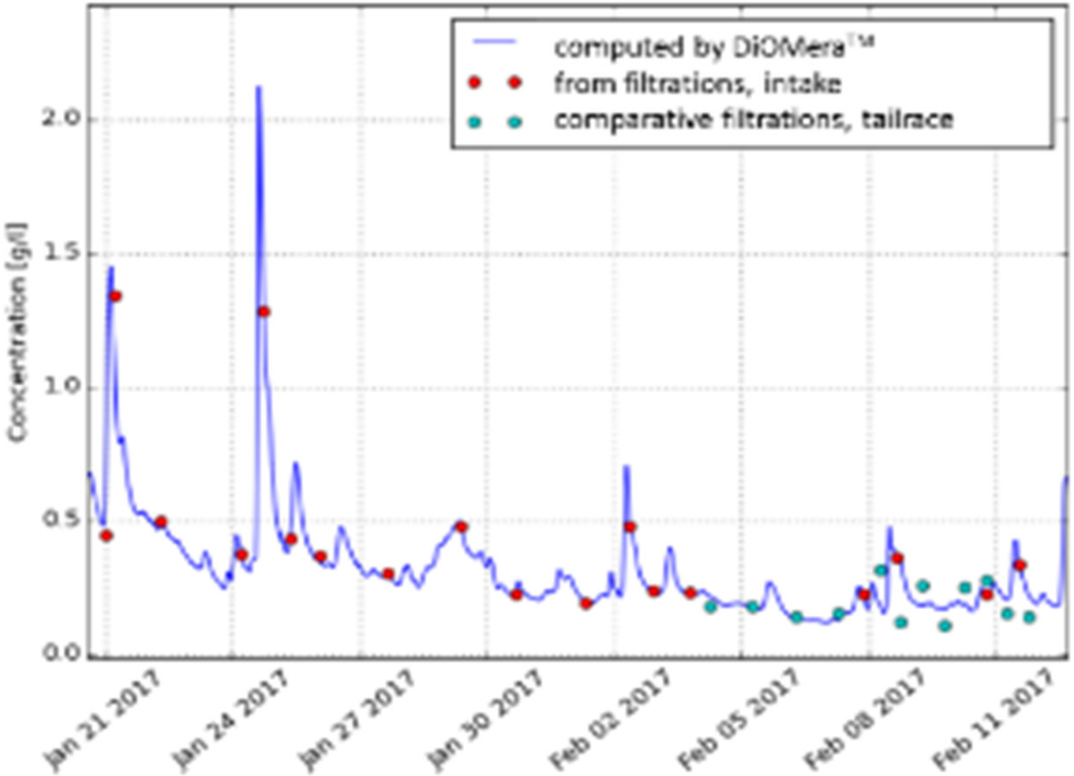
CORIOLIS FLOW AND DENSITY METER

SEDIMENT MANAGEMENT

Sediment through Turbines

automatic sediment monitoring

- Continuous measurement and calculation of concentration of silt by using two turbidity and Coriolis Flow Density sensors (or more) connected to SCADA (at a position being defined)
- The sediment monitoring set comes with a small tank and a pump feeding the Coriolis sensor



Turbidimeter sensor

Coriolis Flow Density Sensor

Sediment Tank

SEDIMENT MANAGEMENT

Installation at site / Example from Peru and India

Sediment monitoring station

Plant SCADA

Ethernet
IEC 104

CFMD
Water intake

Sensor
Water supply

Ethernet
IEC 104

Water
outlet

River

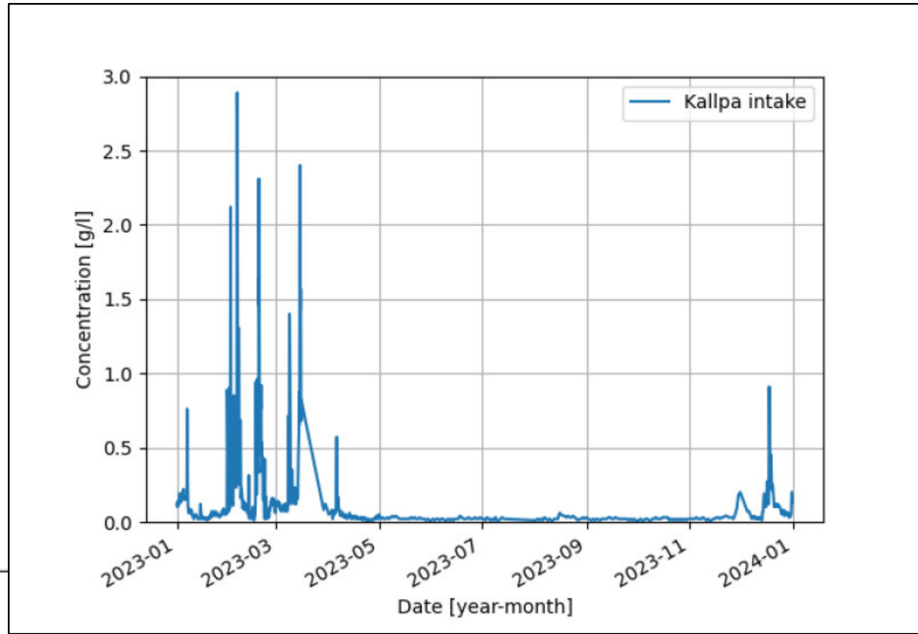
<u>Requirements:</u>

- Continuous water intake at penstock or turbine water inlet.
- Turbidity senor installed in a tank supplied by water from CFMD system.
- CMFD system and optic sensor to be connected to plant SCADA.
- Electric supply 100-230VAC/24VDC.

SEDIMENT MANAGEMENT

Example of monitoring and evaluation (Perù)

5.4.6 WEAR – SEDIMENTS CORRELATION



The amount of sediment per unit is shown in Figure 5A. These values are calculated by multiplying the sediment concentration by the flow rate of each unit. The differences in sediment loads are due to the different flow rates of the units. It can be seen that the loads are similar between the units for 2023.

Figure 5B compares the sediment loads in recent years. The difference in sediment loads over the years shows the climate variability in the region. Very high sediment loads were recorded in 2019, which can be associated to the “El Niño” climate phenomenon in the region that year.

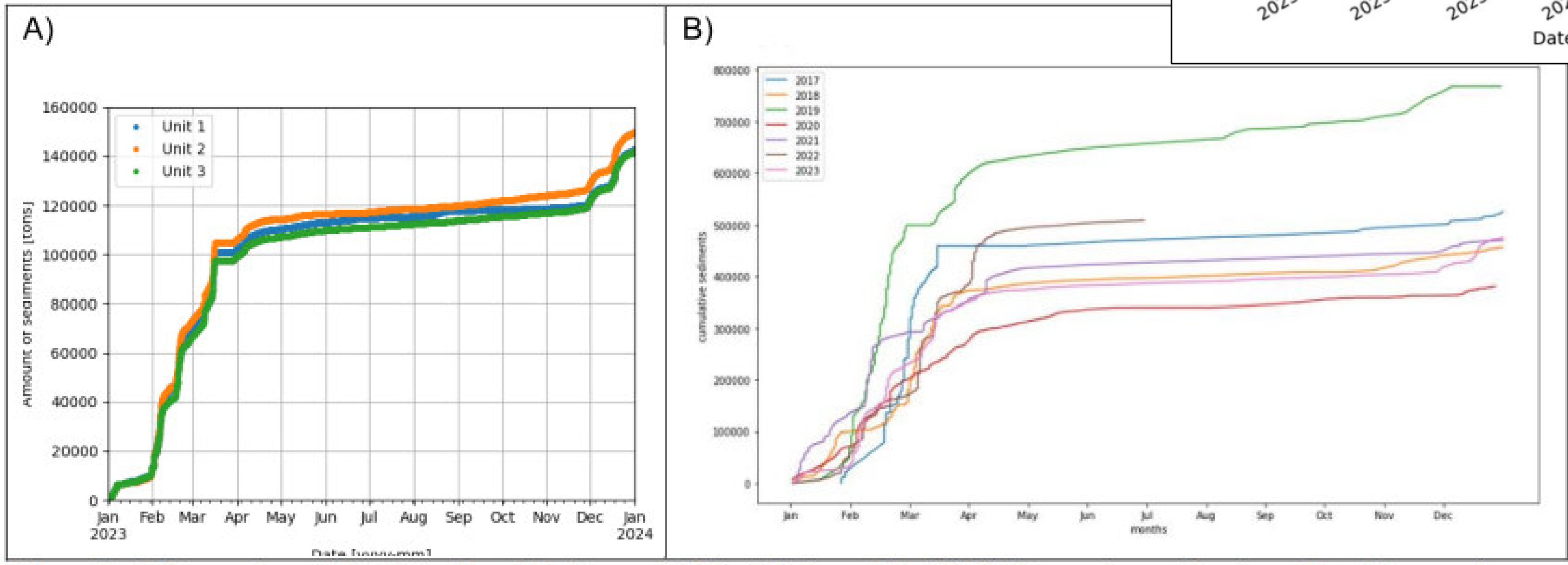


Figure 5. A) Comparison of sediment loads between Unit 1, Unit 2, and Unit 3. B) Comparison of sediment load in recent years.

SEDIMENT MANAGEMENT

Example of monitoring and evaluation (Perù)

6.1.2 ANALYSIS OF EFFICIENCY DEGRADATION

U2

*Figure 11. Results of the indicator **Drop of index efficiency** for Unit 2. It compares the index efficiency computed from the recorded signals and the one predicted from the meta-model.*

SEDIMENT MONITORING

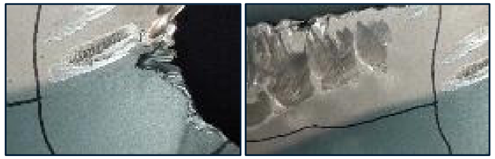
Correlate operation data with sediment data for improved maintenance

Already ca. **5000** operating hours on Unit #1 but no sediment or operation data available

Example Bucket #2

Inspection 04.09.18
6642 operating hours

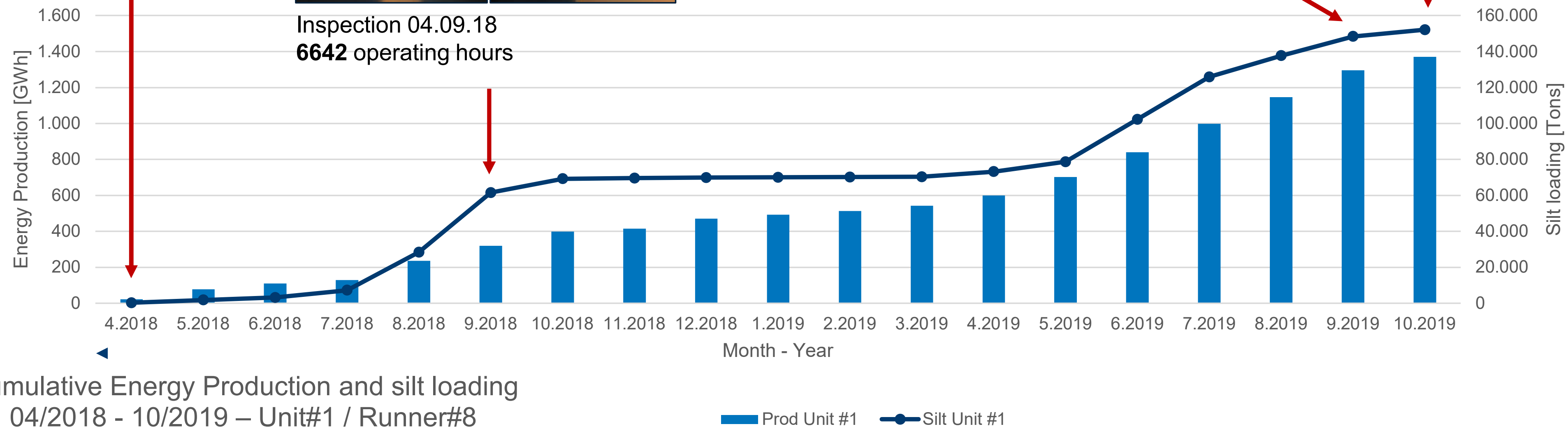
Example Bucket #2



Inspection 18.09.19
11952 operating hours

Example Bucket #2

Inspection 07.10.19
12389 operating hours



Cumulative Energy Production and silt loading
04/2018 - 10/2019 – Unit#1 / Runner#8

SEDIMENT MANAGEMENT

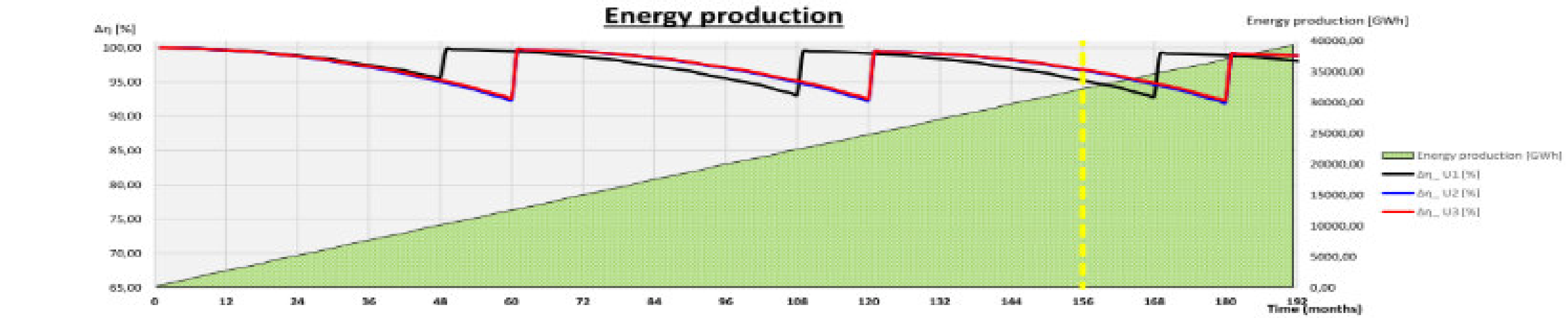
Sediment through Turbines

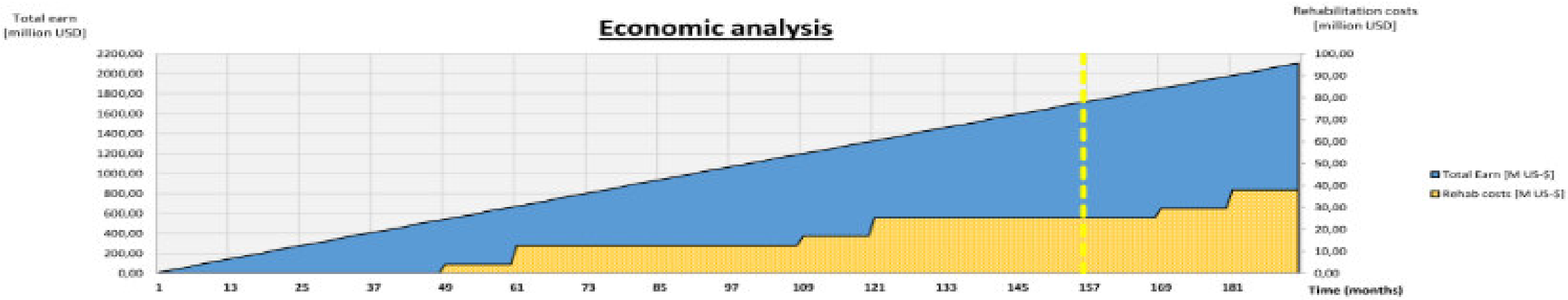
✓ Simulation and forecasting of the best major maintenance plan, considering the efficiency dropping due to wear+erosion and the HPP generation

✓ Many simulation with different conditions have been checked. The best solution, in accordance also with the evidences out of physical site inspection (Jun2018) is the following (TBO = Time Between Overhaul of 5 years with about 5% of efficiency dropping)

	Month	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun
	Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Rehab type	Unit1	-	-	-	-	Major	-	-	-	-	Major	-	-	-	-	Major	-
	Unit2	-	-	-	-	-	Major	-	-	-	-	Major	-	-	-	-	Major
	Unit3	-	-	-	-	-	Major	-	-	-	-	Major	-	-	-	-	Major
Coating		No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No

CASE PERU





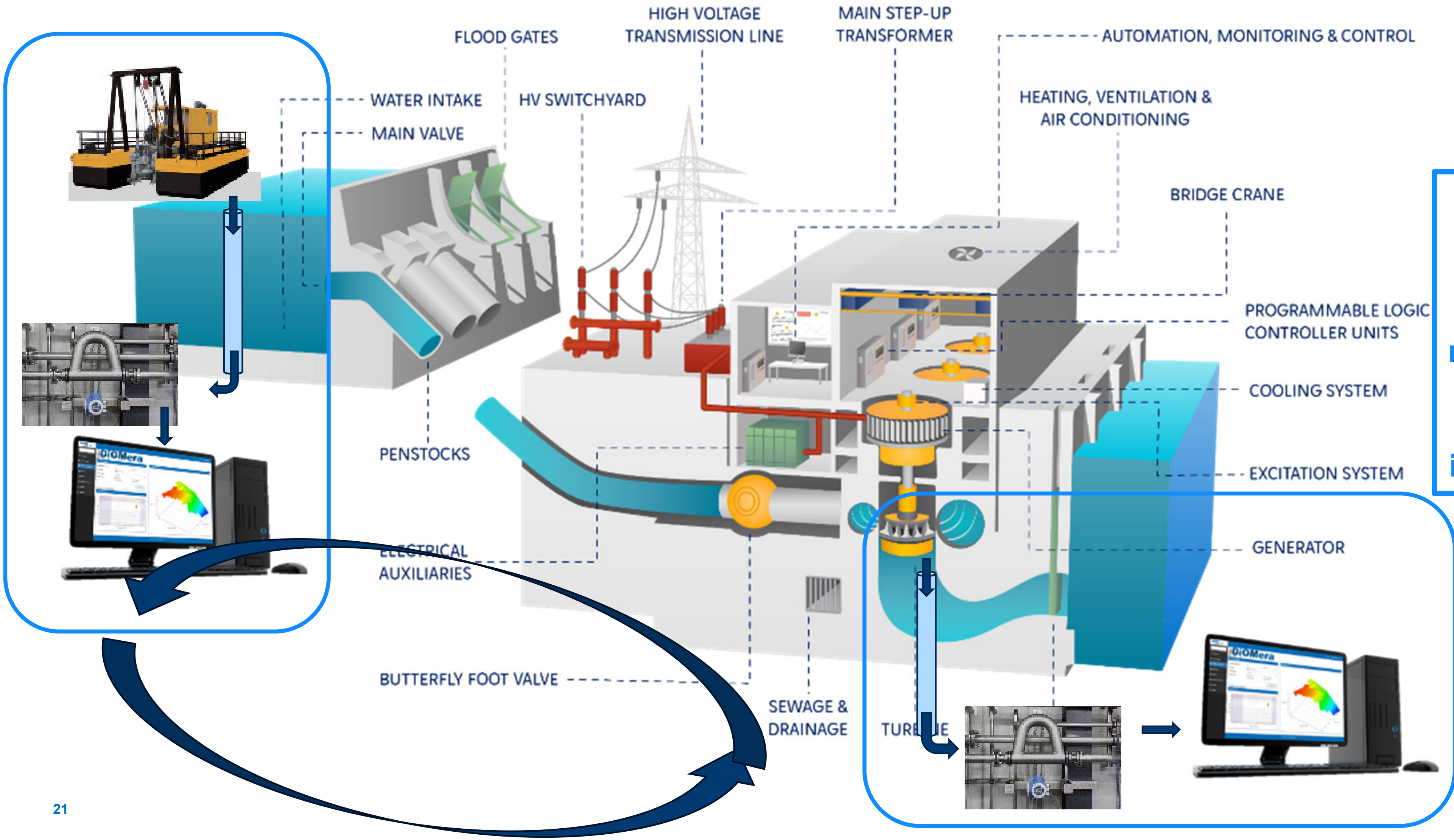
SIMULATION:

- BEST Maintenance Concept for the CLIENT
- Intervals for major maintenance defined to maximize earning, in cooperation with the Client
- Time Frame 10 yy (total 6 major maintenances)
- Maximization of Client's net earnings

AH REAL TIME MONITORING :

- Efficiency by DiOMera basic module
- Sediment concentration (DiOMera Erosion technology module)

SEDIMENT MONITORING



Full CONTROL of Sediment by reliable measurement and «intelligent» interpretation

SEDIMENT MANAGEMENT

Take Home Message

It is an integrated digital system to manage and reducing the sediments in reservoirs by combining dredging with turbine technologies and operation.

Economic assessment is only possible combining measurement technologies, algorithm prediction and maintenance cost

Forrest Kerr Hydroelectric Project, Canada

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