RESCON 2 Analysis

Rapid assessment of sediment management alternatives

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Objectives

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Rapid assessment of sediment management alternatives

- Screening of state-of-the-art techniques
- Ranking of most promising for further studies
- Consideration of intergenerational value of storage through incorporated declining discount rate
- Sediment management as adaptation to climate change

Limitations

- The RESCON 2 model is a computer program designed for use in **pre-feasibility studies** with limited and **readily available site specific data**.
- The RESCON 2 analysis is based on empirical methods.
  It is **not a substitute for more detailed studies** with numerical and/or physical models based on data collected during field measurement campaigns.
- **Sound engineering judgment** is required for interpretation of the results.
- Synergies developed in reservoir **cascades are not considered**.
- It’s not possible to analyse sediment management strategies involving different techniques applied simultaneously

Timeline of development

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1999-2003

Development and release of first version of RESCON

2003-2015

- Extensive worldwide application of RESCON
- Stronger need for storage preservation
- Impact of Climate Change on reservoir sustainability
- Scientific advances in sediment management and economic analysis

2015-2017

Revision and upgrade of RESCON

RESCON 2 beta

2019 – 2020

Global sediment management study

Design guidelines

Technical toolkit including RESCON2 and numerical model

Download

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Sediment management

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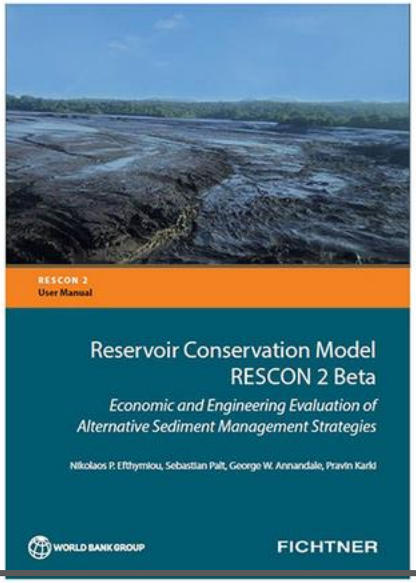
Hydropower Sustainability Guidelines
Hydropower Sustainability Assessment Protocol
HESG Tool
Pumped Storage Tool
Sediment Management Hub
G-res Tool

Tool: Reservoir Conservation Model RESCON 2 Beta



Nikolaos P. Efthymiou, Sebastian Palt, George W. Annandale, Pravin Karki. *Reservoir Conservation Mo* *Economic and Engineering Evaluation of Alternative Sediment Management Strategies. User Manua* W Bank. License: Creative Commons Attribution CC BY 3.0 IGO

The *Reservoir Conservation Model RESCON 2 Beta* tool presents the most advanced economic and engineering evaluation of alternative sediment management strategies. It builds on the Reservoir Conservation Model (RESCON) Approach published in 2003 which helps hydropower developers to carry out a preliminary screening analysis of viable sediment management alternatives. The upgrade to the RESCON 2 beta tool takes into consideration sustainability factors and hydrological uncertainties associated with climate change.

Download the tool.

https://www.hydropower.org/sediment-management/resources/tool-reservoir-conservation-model-rescon-2-beta

https://www.hydropower.org/tools

Questions answered by RESCON 2

What is the lifetime of the reservoir if no sediment management is applied (No action scenario)

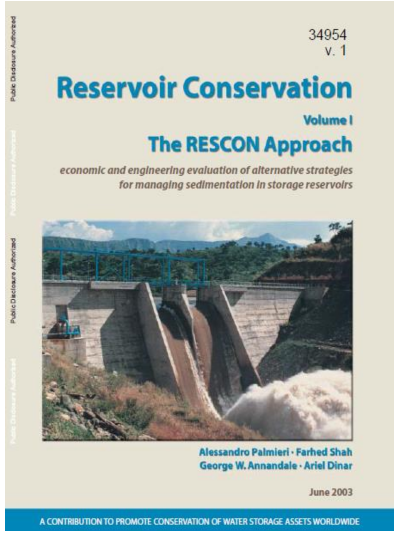
Is sediment management technically feasible?

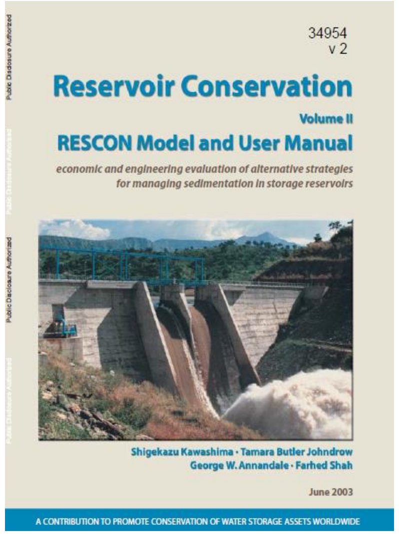
What sediment management strategy converts a reservoir from a non-sustainable to a sustainable resource?

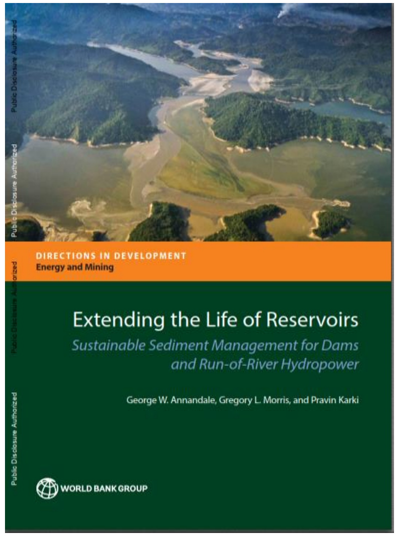
- Does sediment management improve the economic performance of the reservoir?

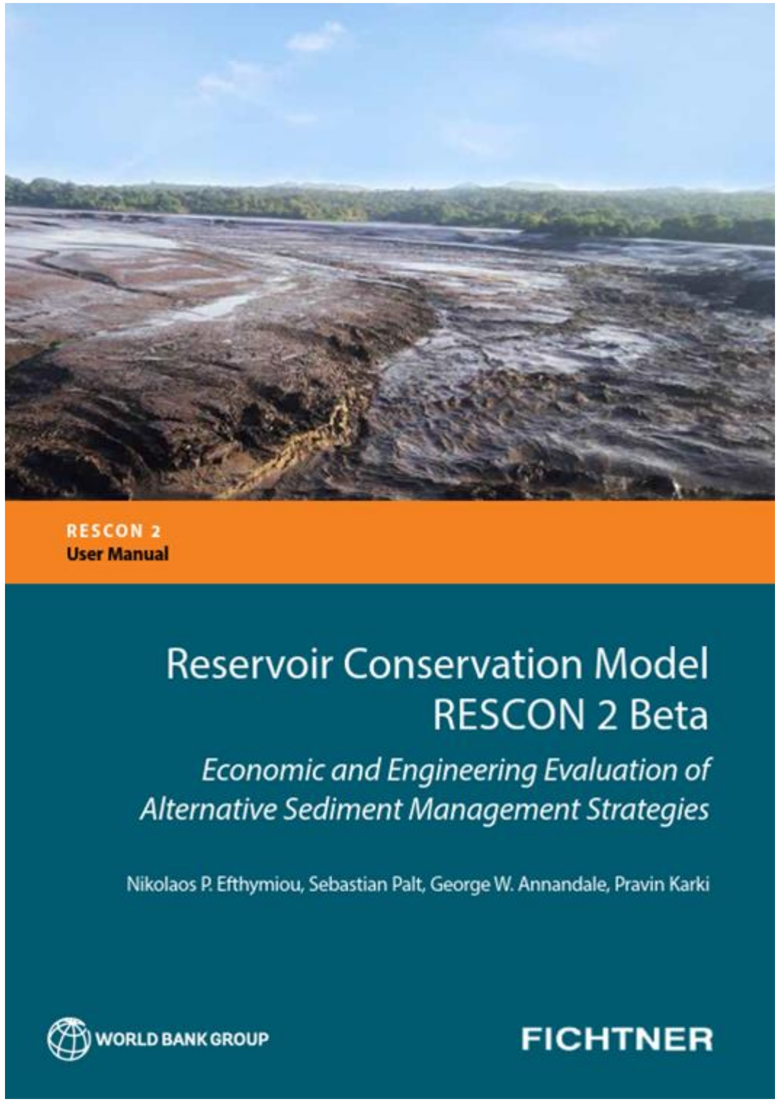
- Can sediment management increase resilience of water infrastructure to climate change?

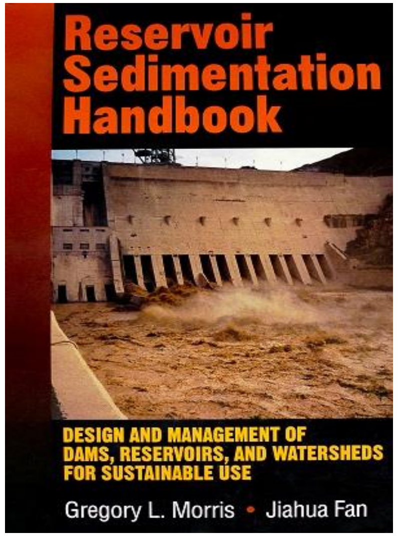
Theoretical background

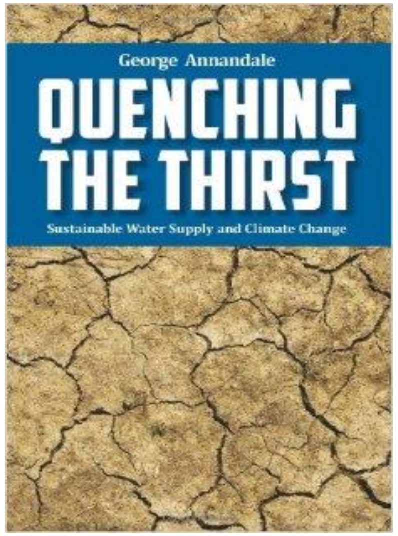












Capabilities

Sedimentation prediction

- Time Path
- Spatial pattern - Allocation of deposits in active and inactive storage

Evaluation of sediment management techniques

- Catchment management
- Sediment routing
- Deposit removal
- Multiple management techniques

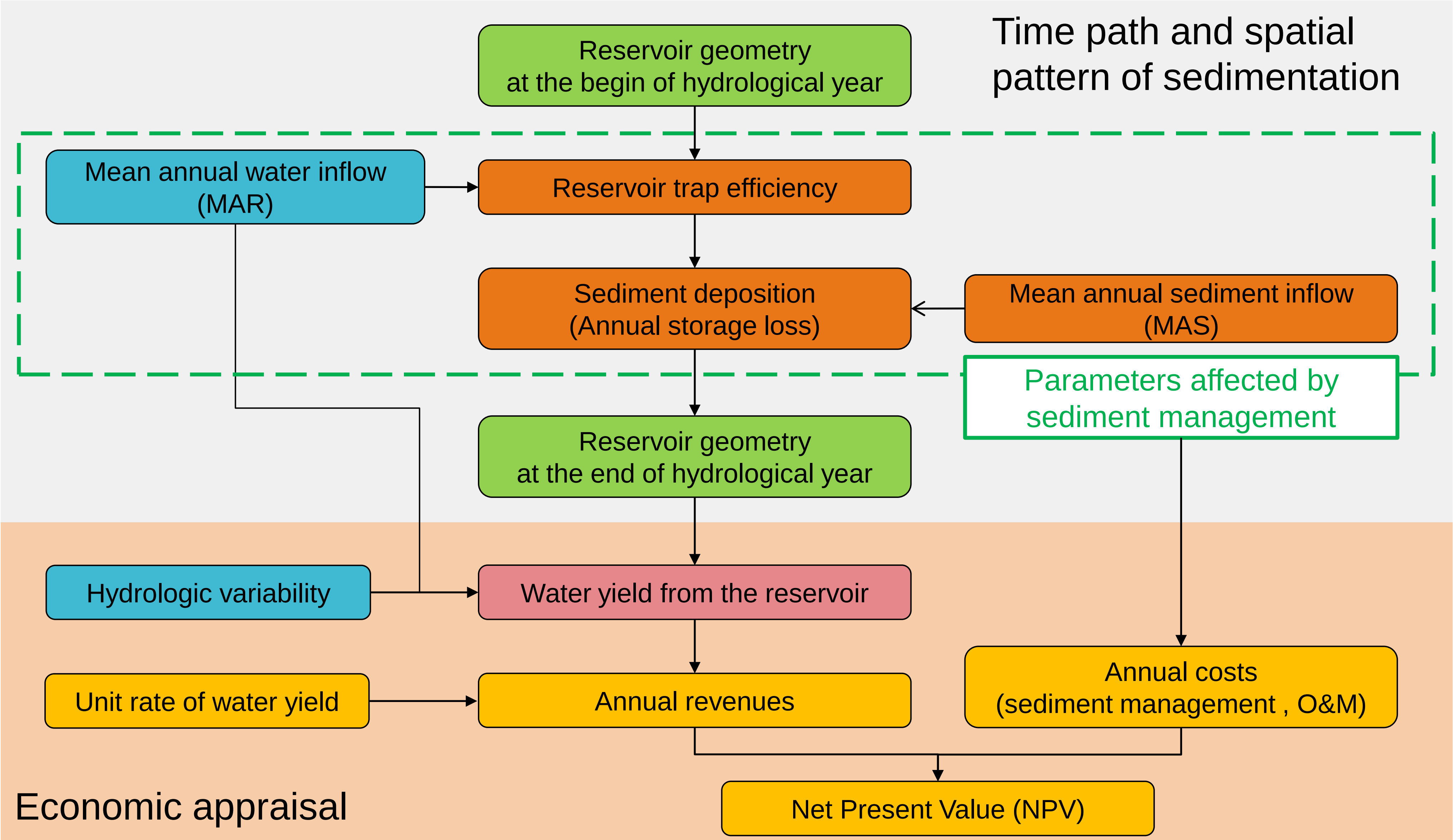
Economic appraisal

- Firm water yield
- virtues of intergenerational equity and sustainable development

climate change analysis

- Vulnerability - Resilience analysis - adaptation strategy to climate change

Analysis flowchart



Sedimentation assessment

Allocation of deposits in active and dead storage

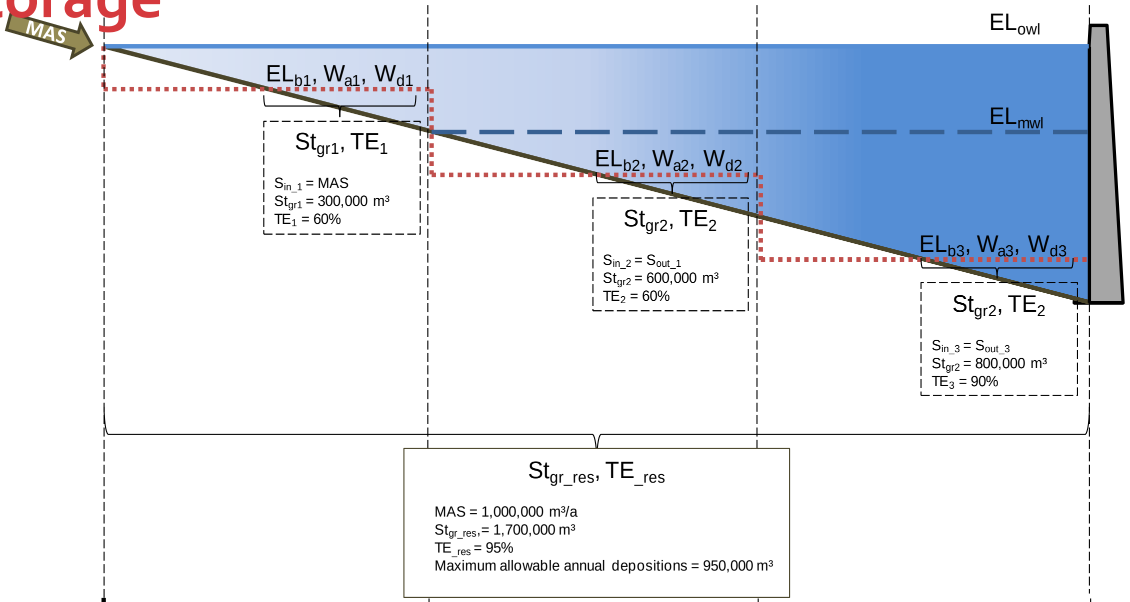
Method

Van Rijn (2013)

- Schematization of reservoir geometry in compartments
- Wide applicability

Trap Efficiency

- Bedload: 100%
- Suspended load
    - Brune
    - Churchill
    - Borland

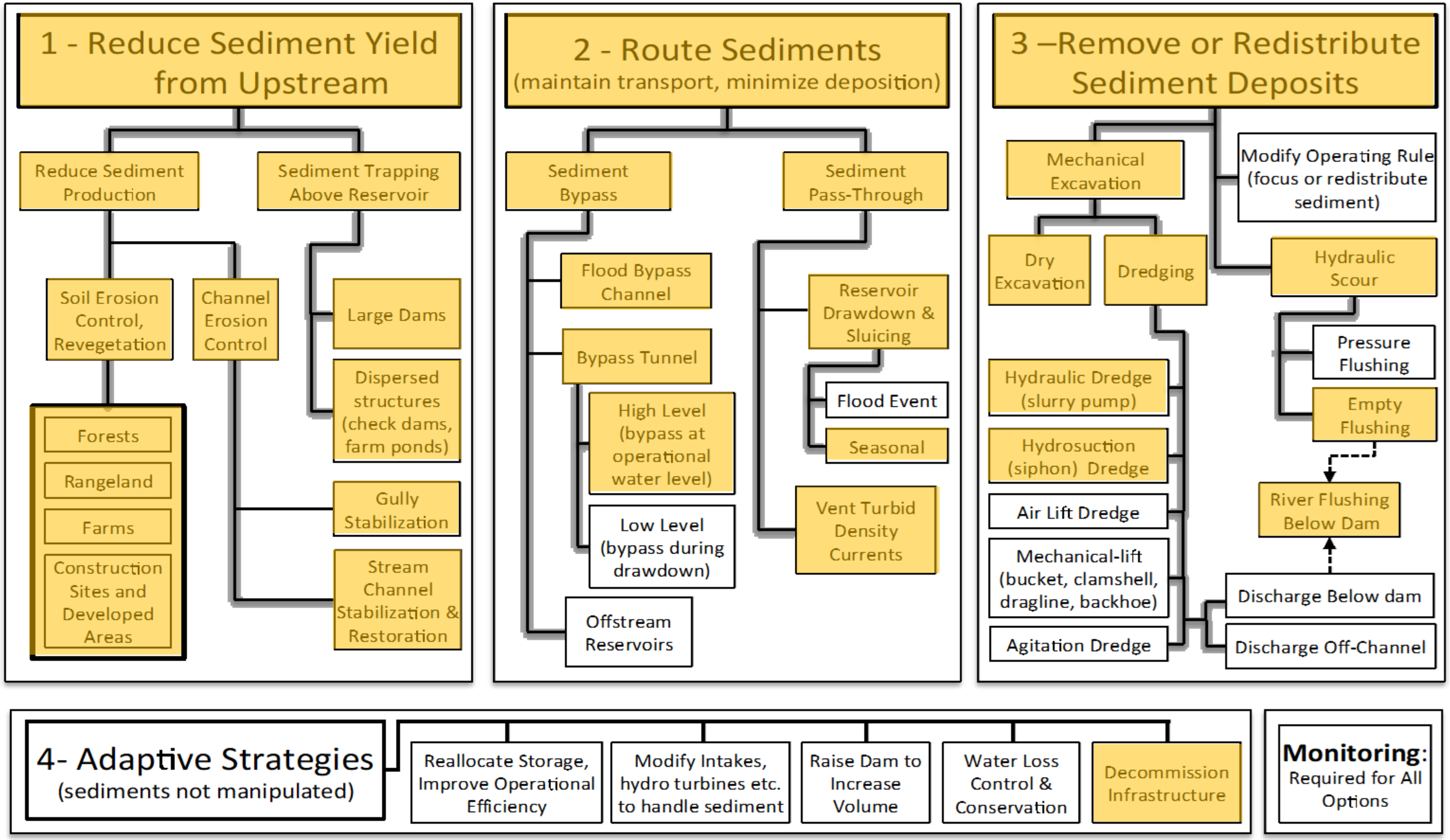


Compartment		1	2	3	
Sediment Inflow in Compartment	S_{in_i}	1,000,000 m³ (Mean Annual Sediment inflow in reservoir)	700,000 m³ (Sediment release from compartment 1)	210,000 m³ (Sediment release from compartment 2)	
Compartment's Trap Efficiency	$TE_{\_i}$	60%	70%	90%	
Potential deposits in the compartment	$Dep_{\_pot\_i}$	600,000 m³ (S_{in_1} x $TE_{\_1}$)	490,000 m³ (S_{in_2} x $TE_{\_2}$)	189,000 m³ (S_{in_3} x $TE_{\_3}$)	
Total deposits limitation	$Dep_{\_max\_i}$	950,000 m³ ($TE_{\_res}$ x MAS)	650,000 m³ ($TE_{\_res}$ x MAS-$dep_{\_1}$)	160,000 m³ ($TE_{\_res}$ x MAS-$dep_{\_1}$-$dep_{\_2}$)	
Compartment Storage limitation	St_{gr_i}	300,000 m³ (available compartment storage St_{gr1})	500,000 m³ (available compartment storage St_{gr2})	800,000 m³ (available compartment storage St_{gr3})	
Deposits in compartment i	$Dep_{\_i}$	300,000 m³ Min {$Dep_{\_pot\_i}$, $Dep_{\_max\_i}$, St_{gr_i}}	490,000 m³ Min {$Dep_{\_pot\_i}$, $Dep_{\_max\_i}$, St_{gr_i}}	160,000 m³ Min {$Dep_{\_pot\_i}$, $Dep_{\_max\_i}$, St_{gr_i}}	950,000 $\Sigma Dep_{\_i}$
Sediment Release from compartment i	S_{out_i}	700,000 m³ ($S_{in\_i} - S_{out\_i}$)	210,000 m³ ($S_{in\_i} - S_{out\_i}$)	50,000 m³ ($S_{in\_i} - S_{out\_i}$)	50,000 (Sediment release from reservoir)

Calibration of the model is possible

Sediment management assessment

Palette of assessed sediment management techniques



Source: Morris (2015)

Economic appraisal

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Annual revenues

Firm water yield **x** **Unit Rate**

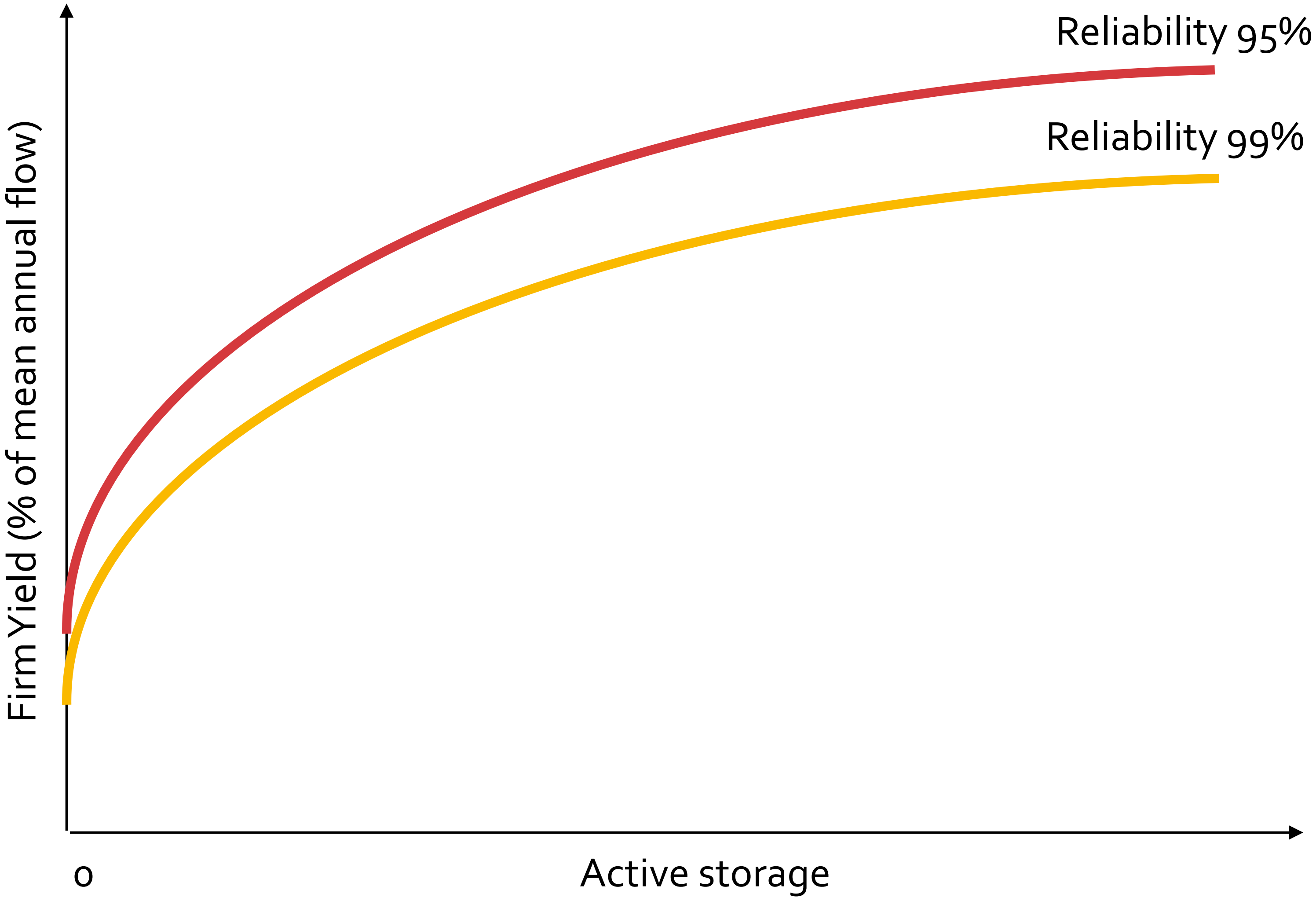
[m³/a] **[$/m³]**

Gould-Dincer method User defined

Function describing relationship between:

- dimensionless yield *
- Reliability
- hydrologic variability (Cv)
- reservoir active storage.

* **Dimensionless yield:** the amount of water that can be annually supplied from a reservoir with a given storage at a specified reliability normalised by the mean annual flow in the river.



Catchment management assessment

Input

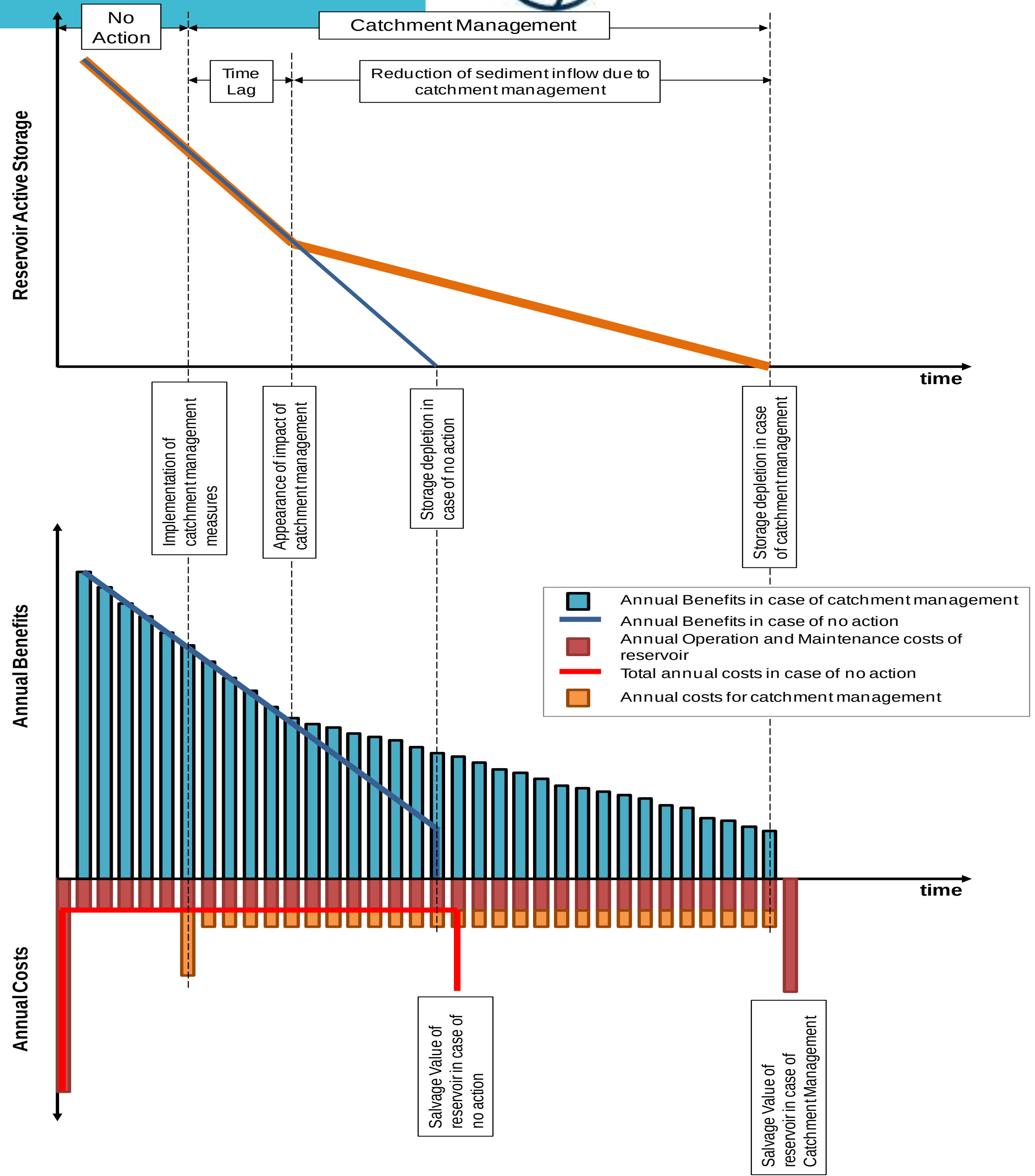
- Reduction of sediment inflow due to catchment management (bedload & suspended load)
- Timing
- Cost (implementation and maintenance)

Phases

1st: No action

2nd: Catchment management is implemented but its impact on sediment inflow is not yet apparent

3rd : Reduced sediment inflow due to catchment management



Optimized Parameters

- Timing of implementation year (duration of 1st phase)

Economic appraisal

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1. Annual revenues

Firm water yield x Unit Rate

[m³/a] [$/m³]

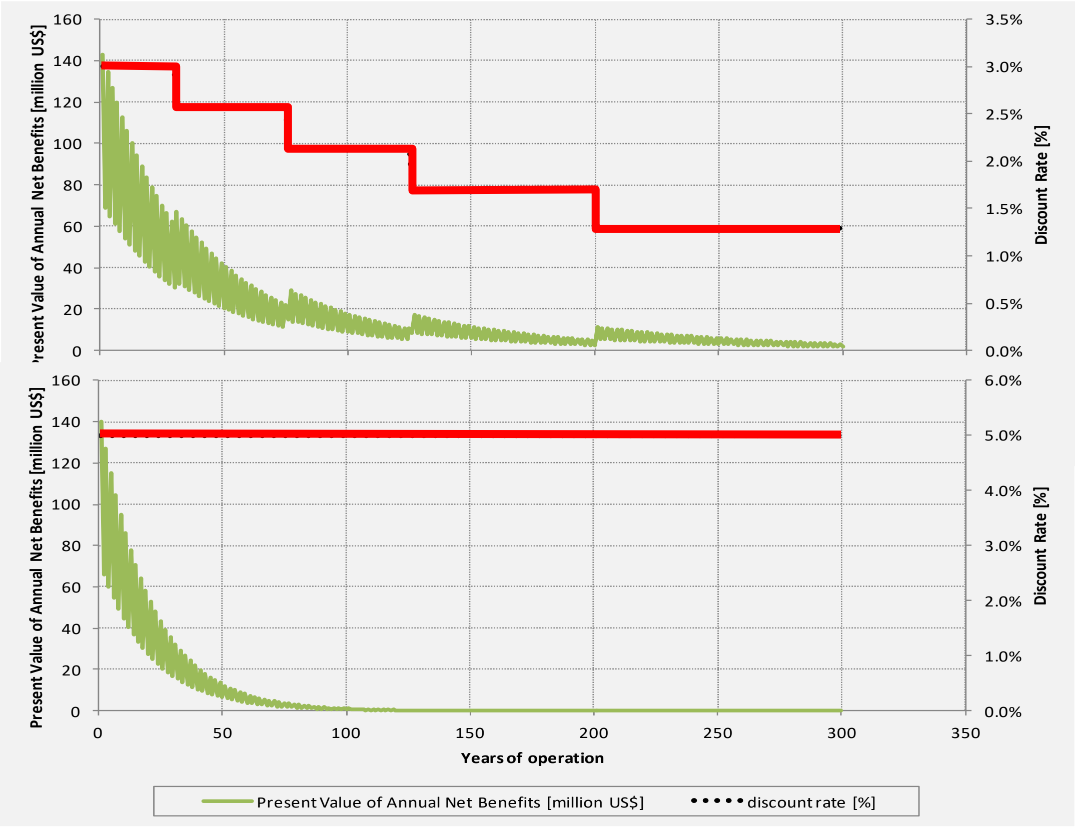
Gould-Dincer method User defined

2. Costs

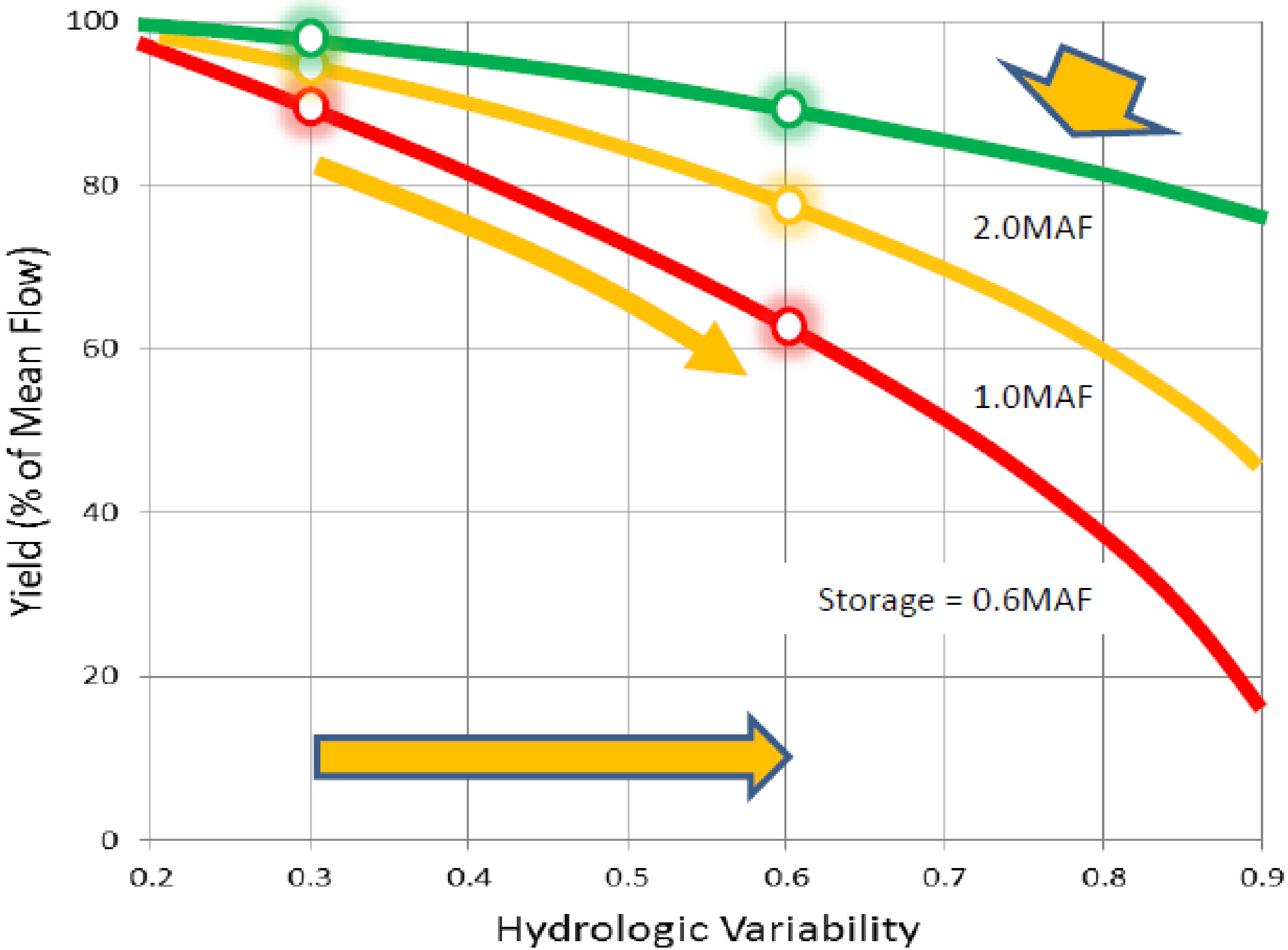
- CAPEX
- Regular annual O&M costs
- Sed. management implementation costs
- O&M costs for sed. Management
- Decommissioning cost

3. Net Present Value

- Fixed discount rate.
- Declining discount rate



Climate Change Analysis



Source: Annandale, G. (2015)

Climate Change Analysis

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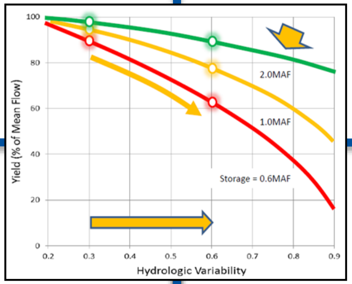
Climate Change

MAR
(Availability)

Cv
(Variability)

MAS
(Storage Loss Rate)



Source: Annandale, G. (2015)

Available Reservoir Storage

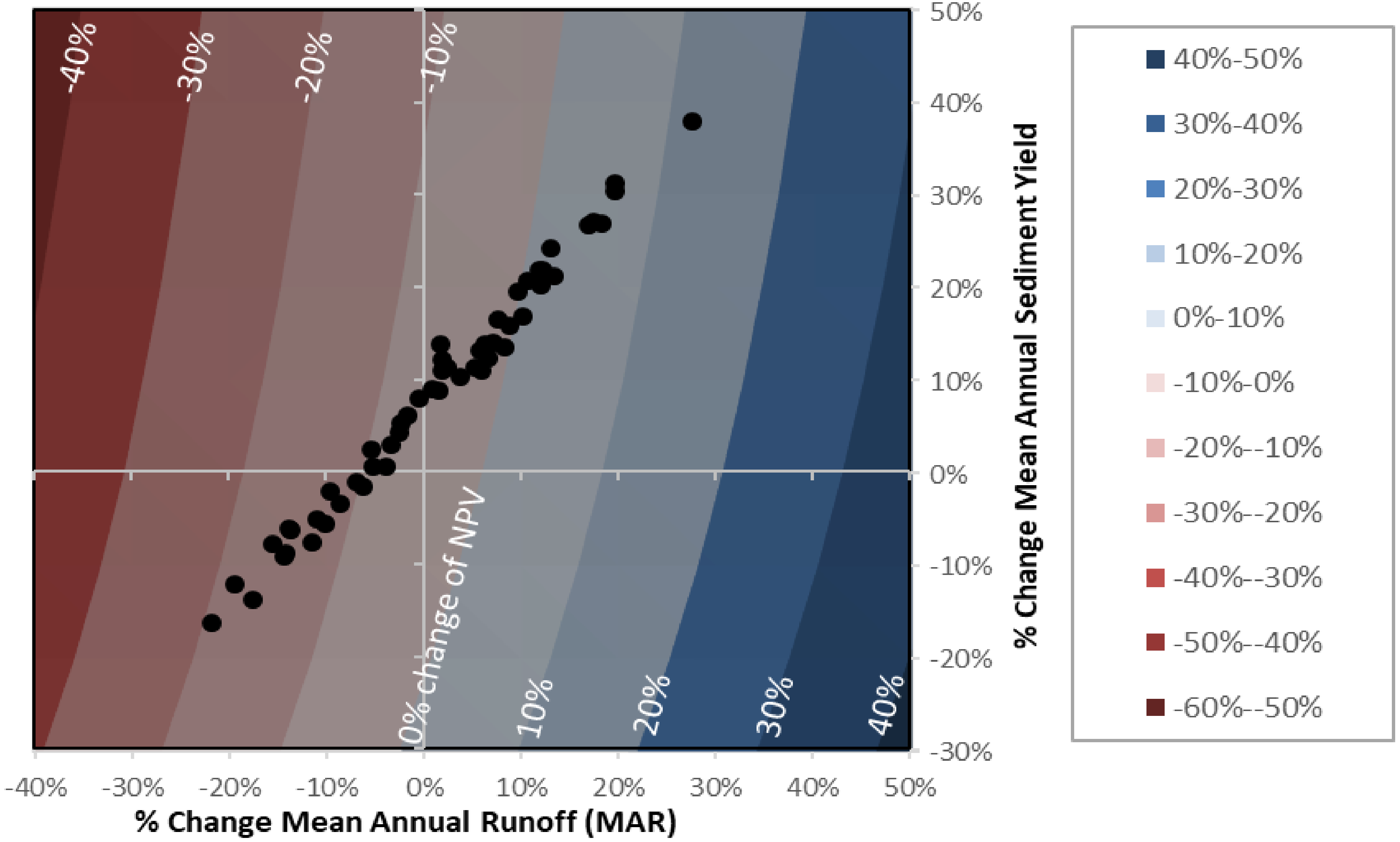
Storage adaptation strategies
- Sediment management
- Increase storage capacity

Supply of Water
(with a given reliability)

Supply adaptation strategies
- Adjust power generation capacity
- Improve Efficiency of Irrigation network
- etc

Economic Performance of infrastructure

Climate Change Analysis



Source: Efthymiou et al. (2019)

Summary

- Assessment of **reservoir sedimentation** process (timepath, allocation of deposits in active and dead storage, partitioning between bedload and suspended load)

- RESCON 2 evaluates the performance of the **state-of-the-art sediment management techniques**.

- The declining discount rate incorporates the **intergenerational value of storage** in the analysis.

- Assessment of sediment management as **adaptation strategy to climate change**

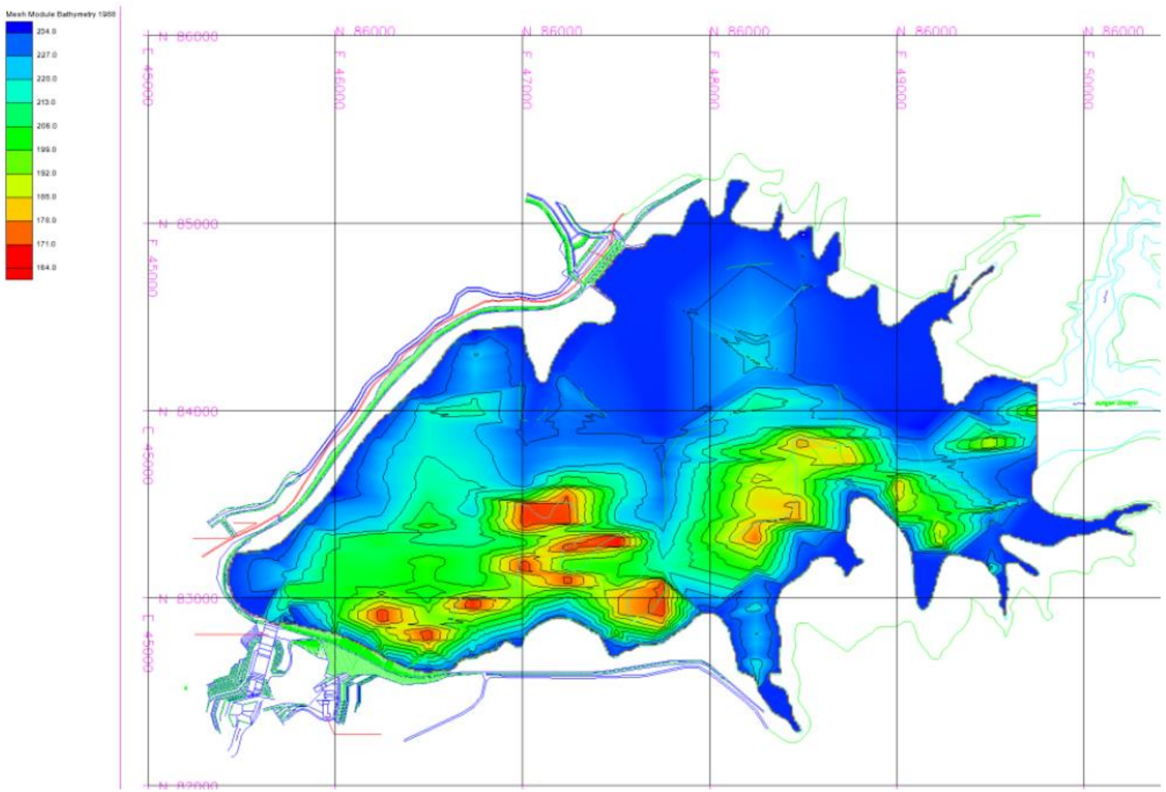
RESCON 2 Analysis

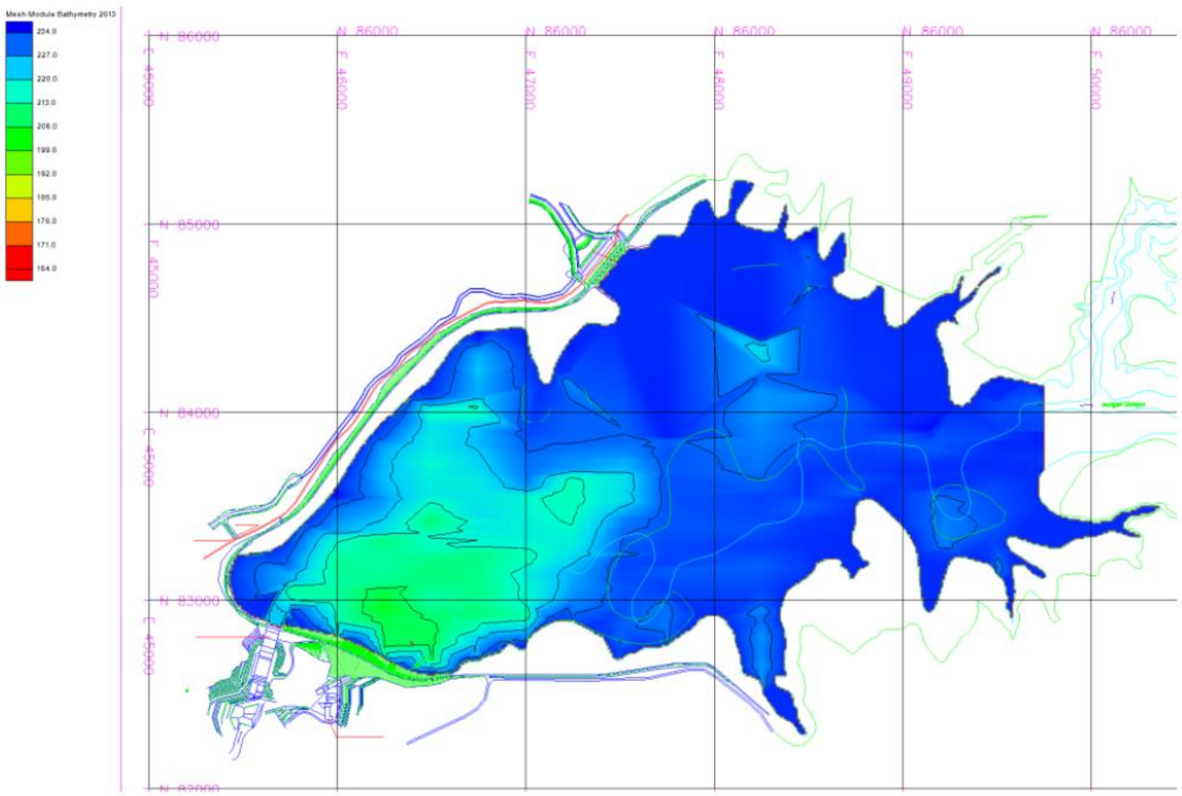
Application Example

Measured sedimentation

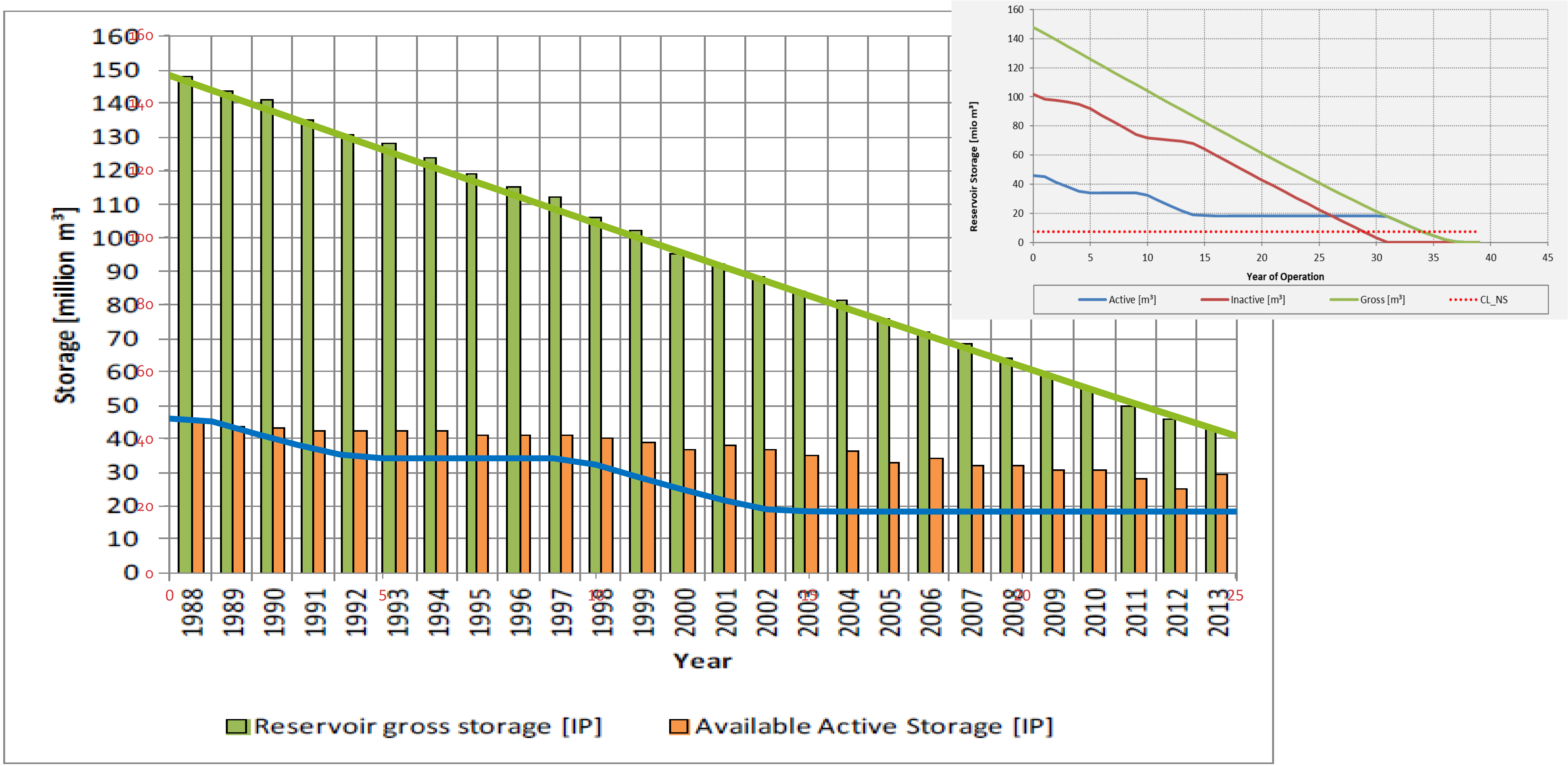
Trajectory of storage development

	1988	2013
Active Storage	46 million m³	20 million m³
Dead Storage	102 million m³	23 million m³





Comparison prediction - measurement



Questions

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What will happen if no sediment management is applied?

1. What is the lifetime of reservoir?
2. How does trap efficiency develop over time?
3. What is the Net Present Value of the No Action Scenario?
4. What are the risks associated with storage elimination?

Questions

2. Assessment of sediment management countermeasures

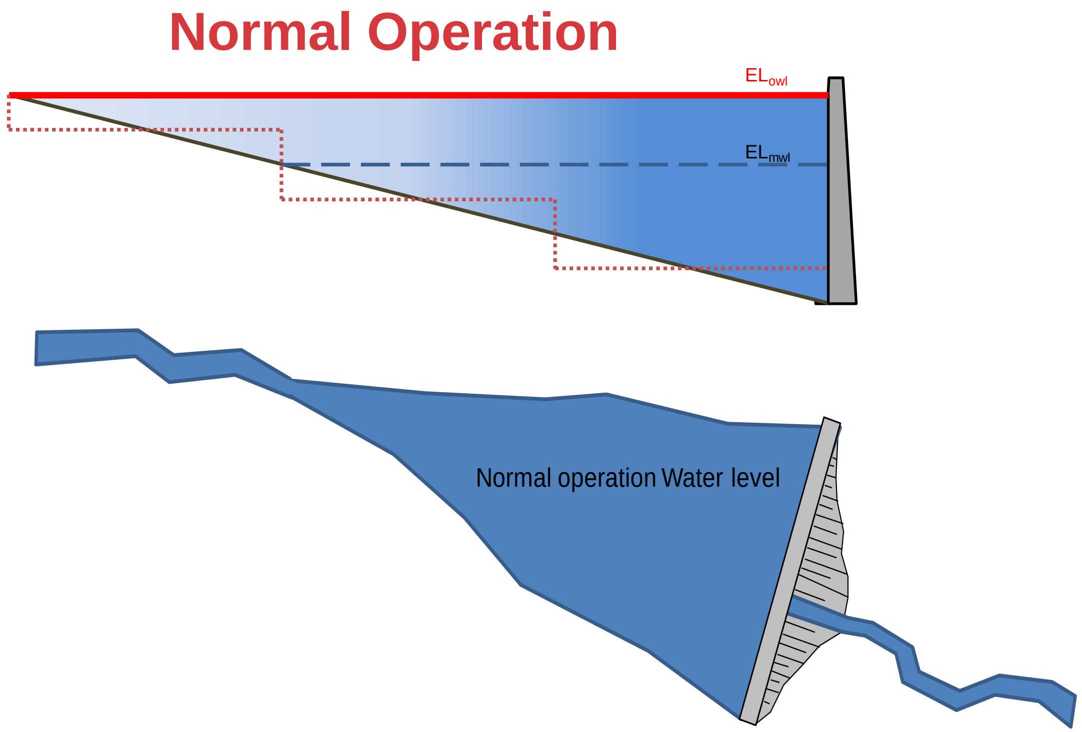
1. What is the development of reservoir storage?
2. Is the reservoir sustainable?
3. What is its long term capacity
4. What is the Net Present Value for the selected strategy?
5. Can the economic performance of the reservoir be optimized?
6. What is the sensitivity of the economic performance on discounting concept?

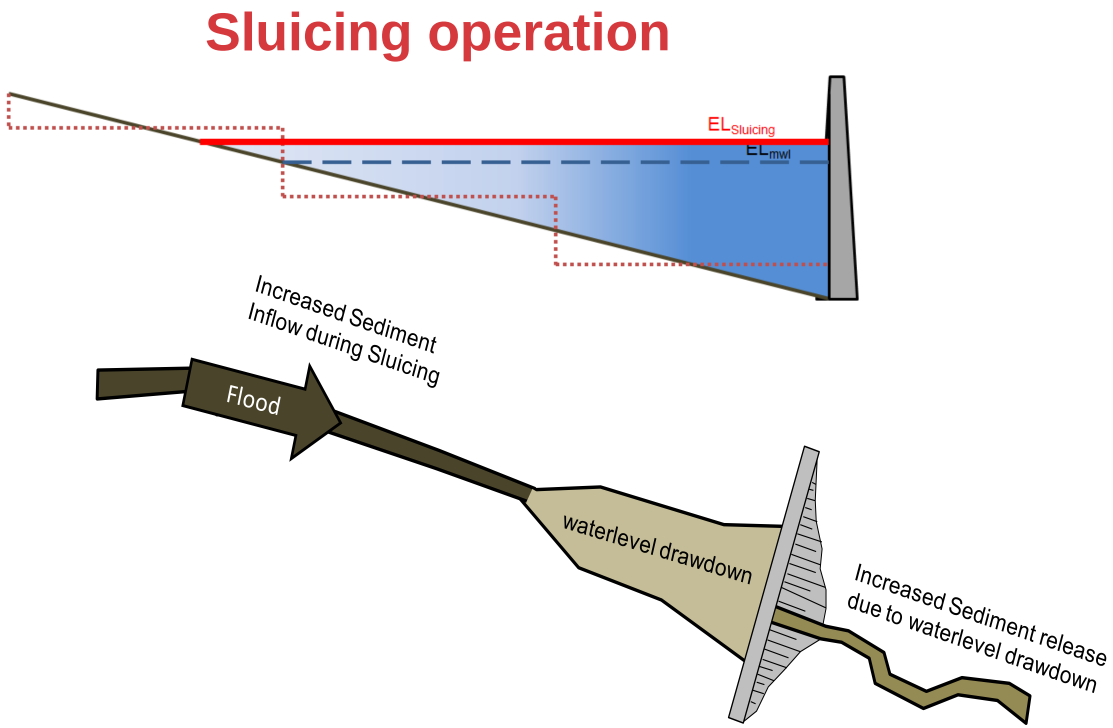
3. What is the impact of climate change on performance of reservoir

1. What is the full range of possible future climates, which representative future climates would you select?
2. What is the vulnerability of the reservoir for the case of no action
3. What is the performance of the reservoir for the representative climate futures if the selected sediment management strategies are applied
4. What sediment management method leads to the most robust reservoir behavior?

Back-Up

Sluicing assessment

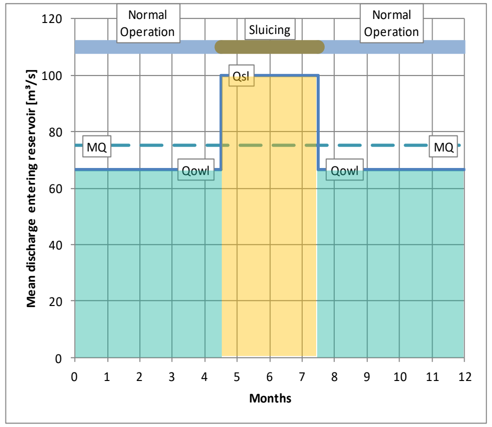


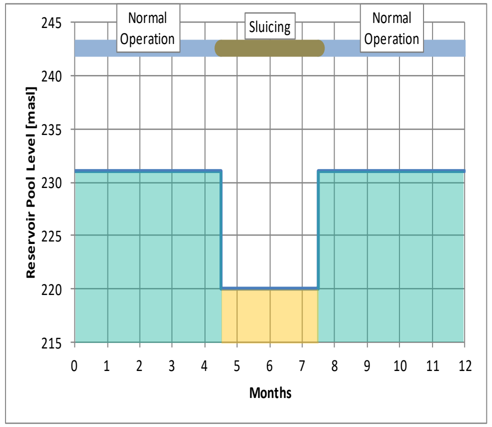


The hydrological year is partitioned into two periods

- Normal operation
- Sluicing (Water level drawdown)

- The waterlevel drawdown determines the reduction of trap efficiency during sluicing (Efficiency)



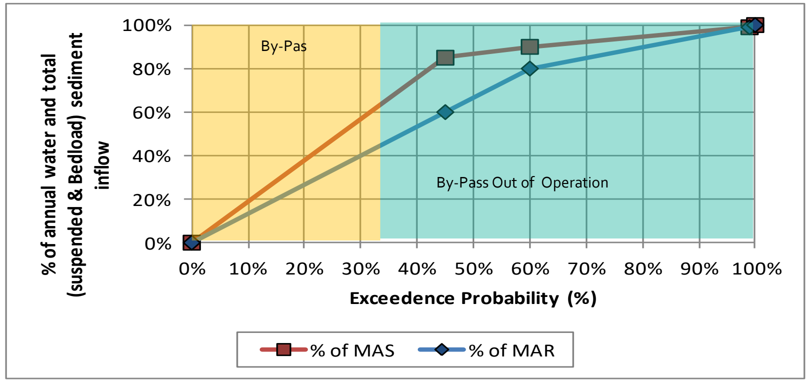


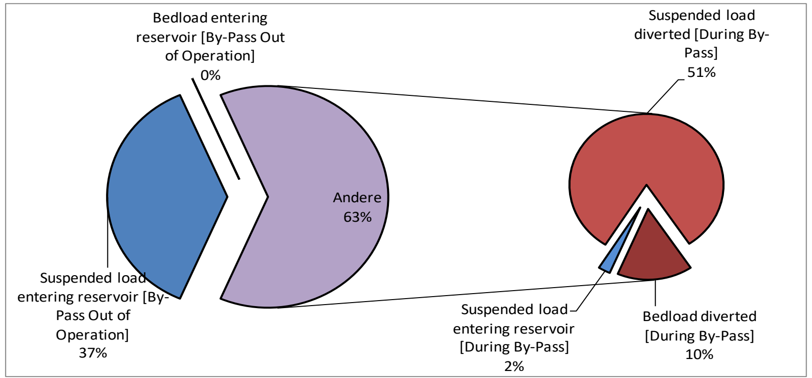
By-Pass assessment

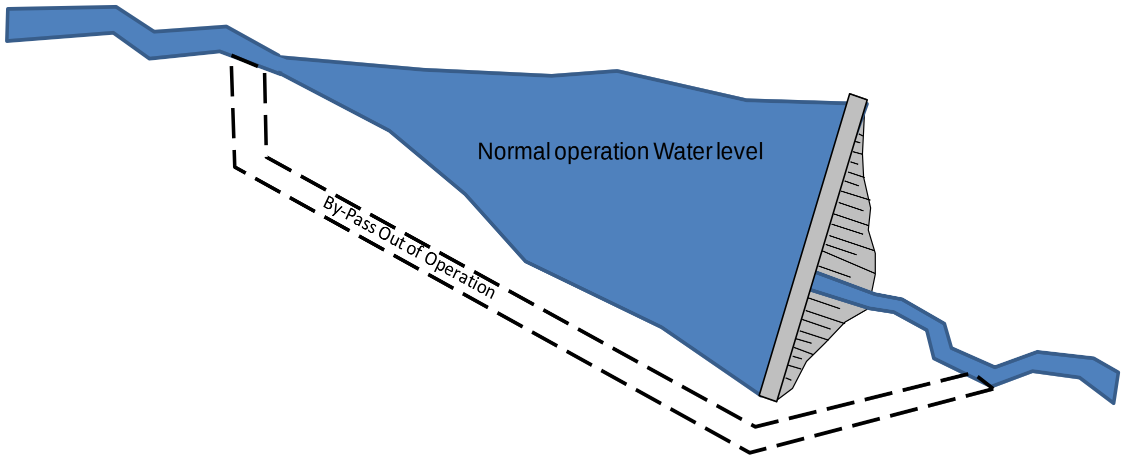
Description

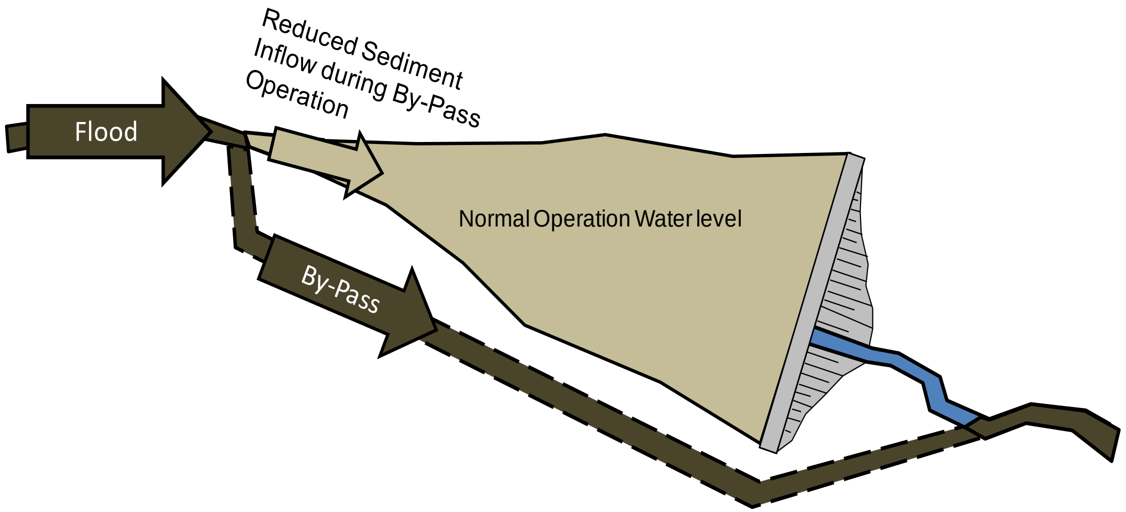
The hydrological year is partitioned into two periods

- **Normal operation period** (By-Pass out of operation)
- **By-Pass period** (Diversion of water and sediment inflow through by-pass structure)



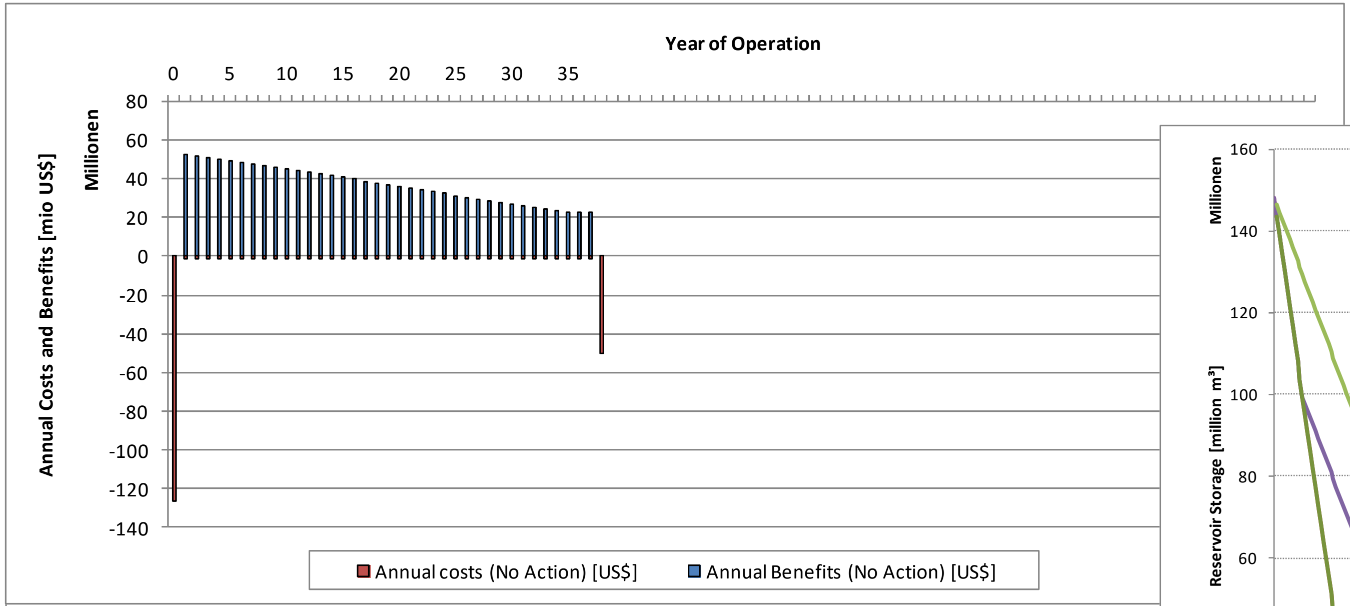




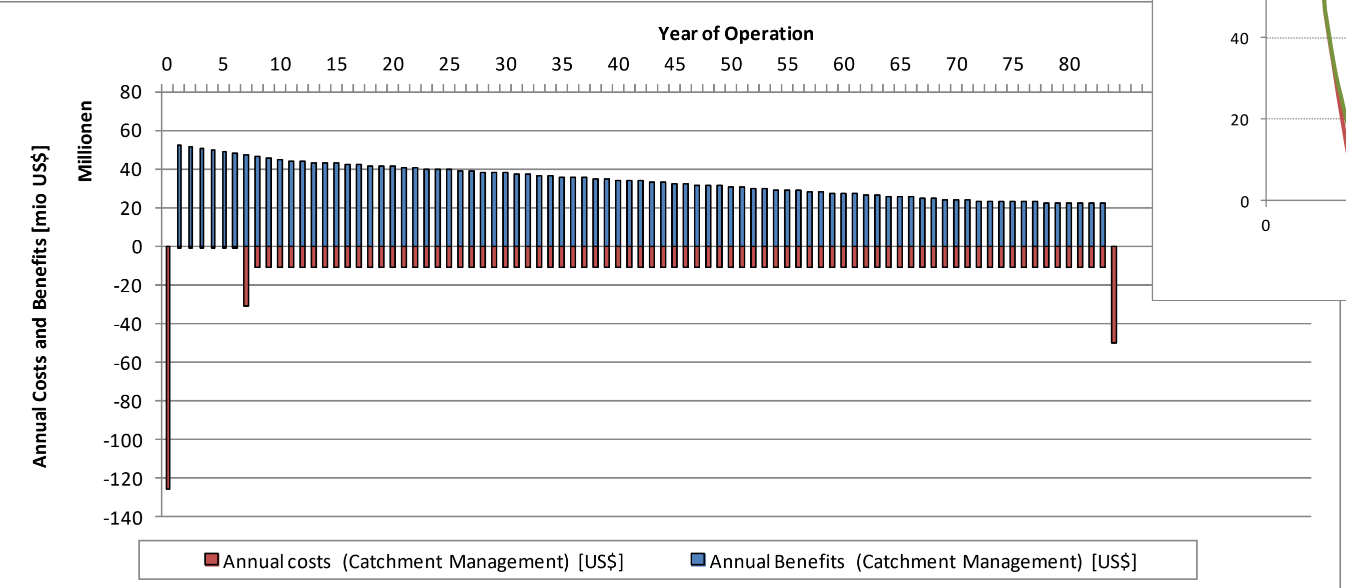


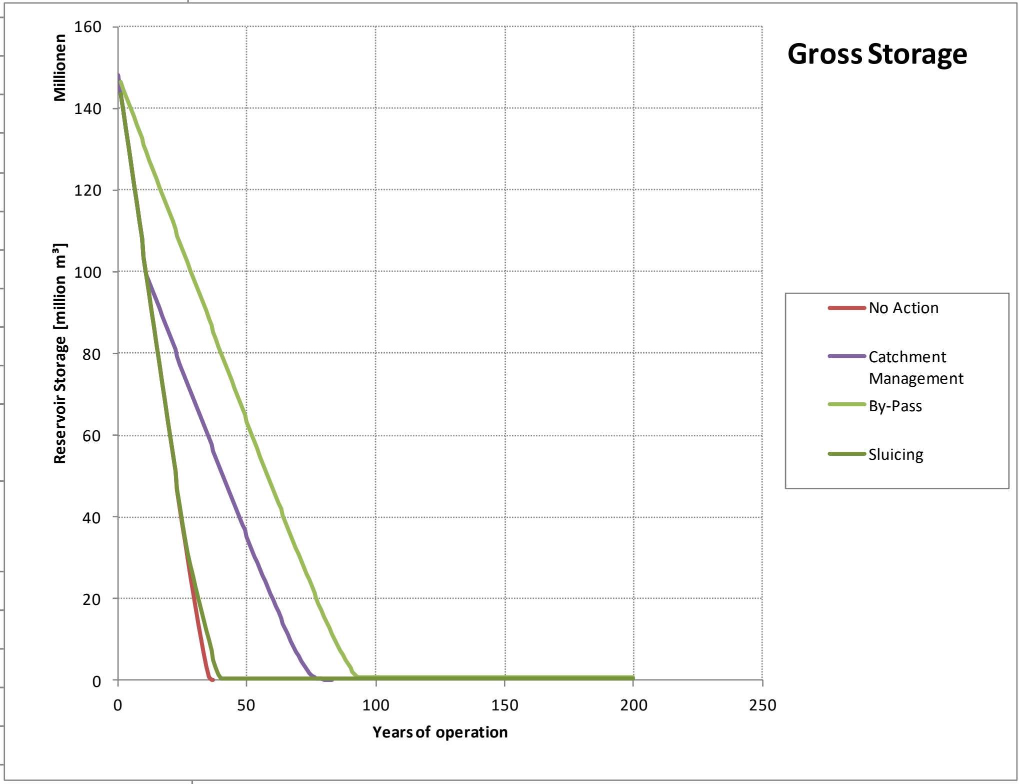
Indicative results

No Action



Catchment Management





Graphical User Interface

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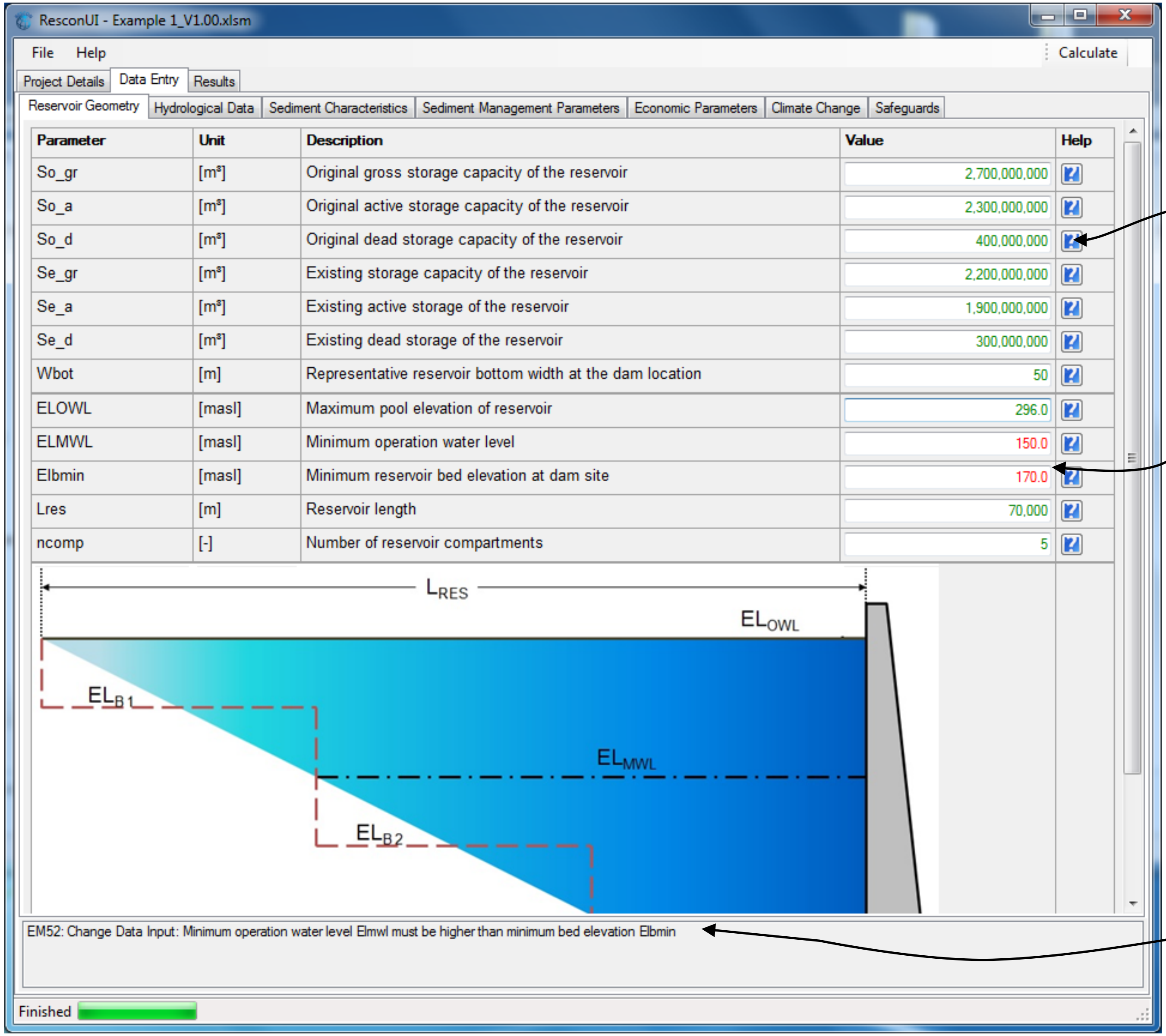
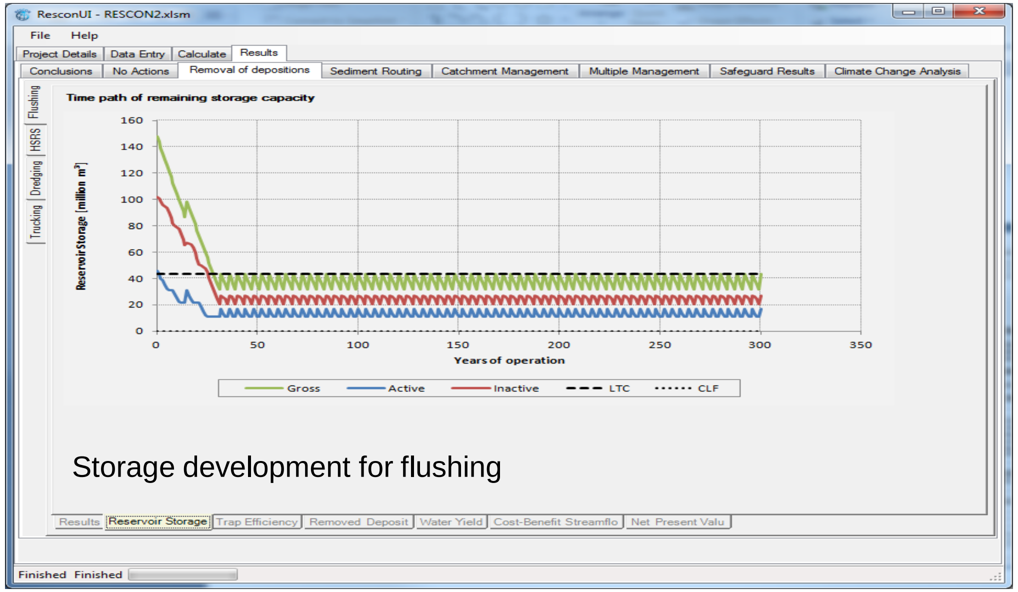


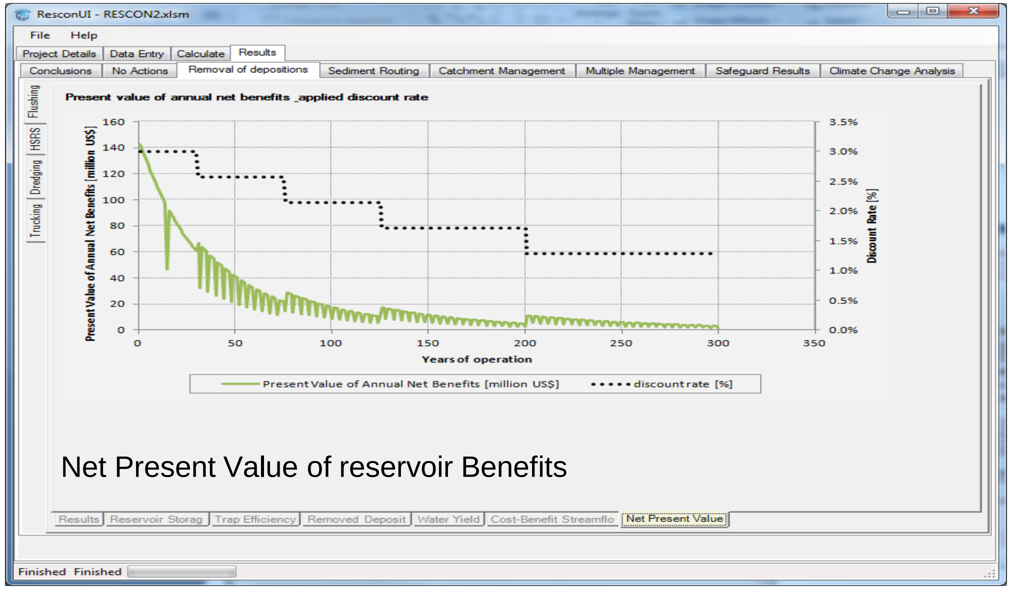
Direct access to help and validation of data input during model set-up

Messages indicating possible errors

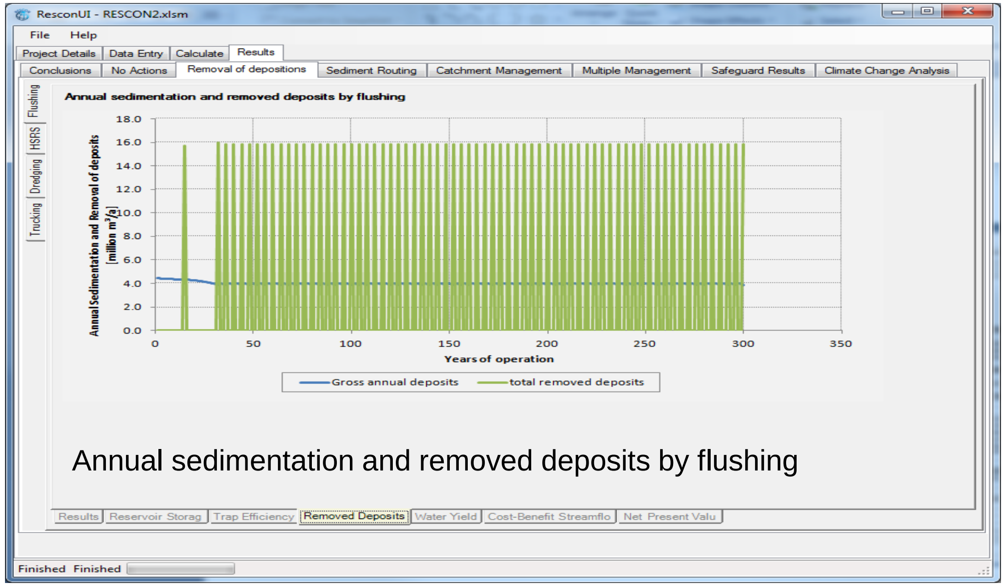
Graphical User Interface



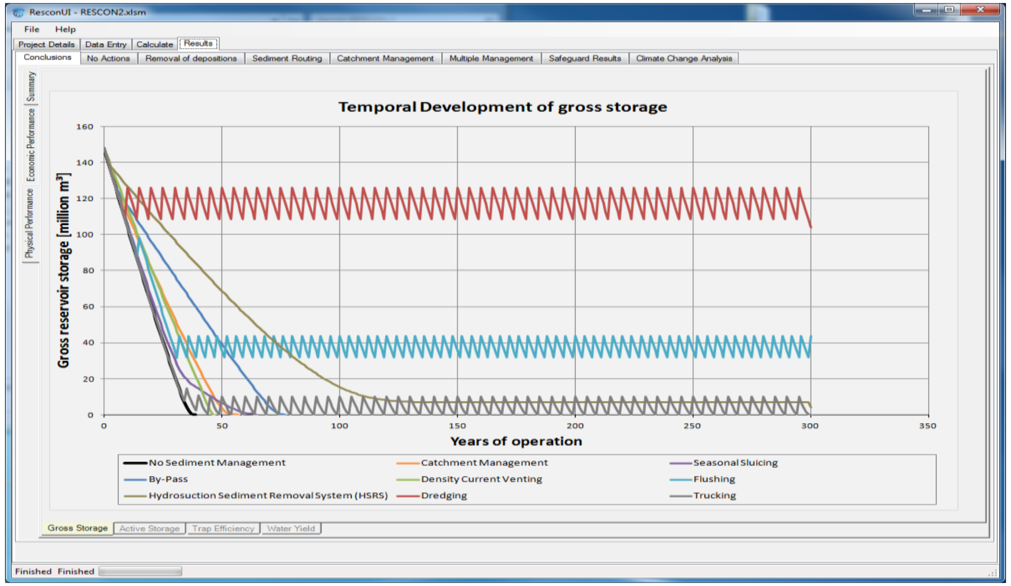
Storage development for flushing



Net Present Value of reservoir Benefits



Annual sedimentation and removed deposits by flushing



Comparison of sediment management techniques.

- Gross and active storage
- Trap efficiency
- Firm water yield
- Net Present Value of Benefits

Specification of reservoir geometry

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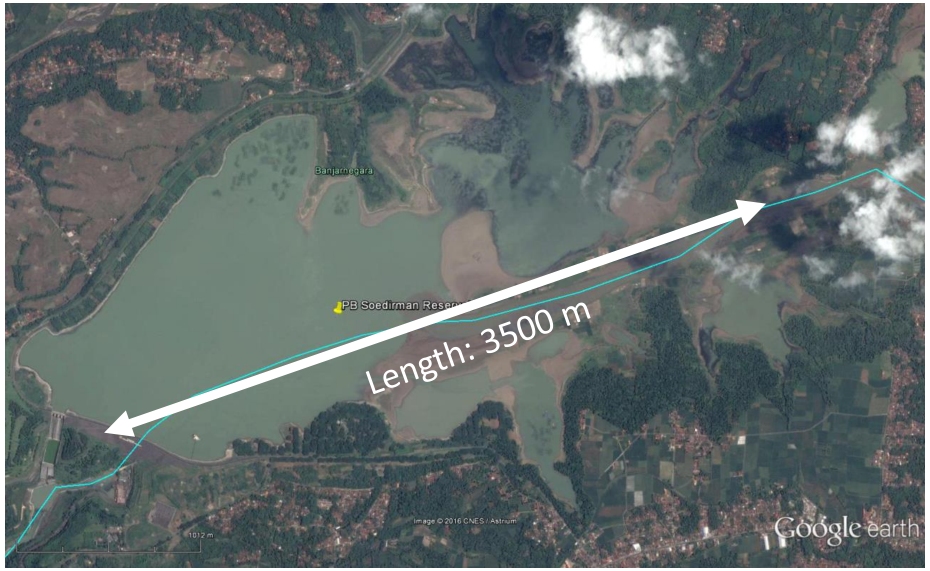
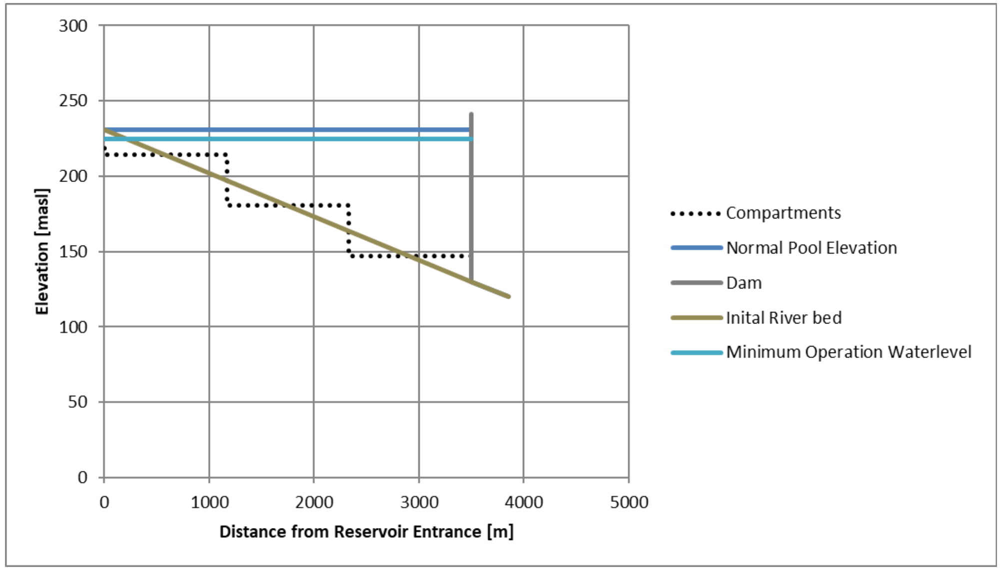
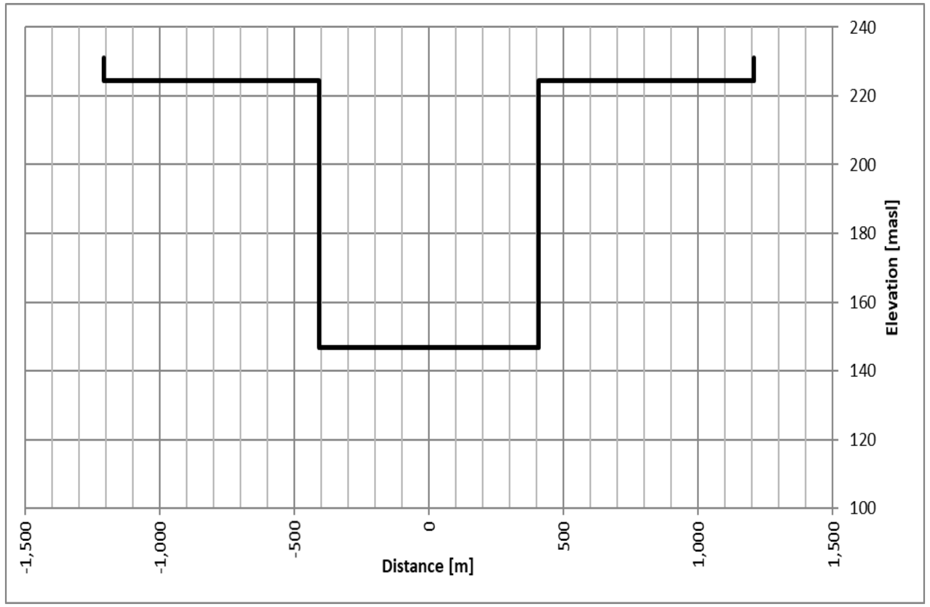
Basic geometrical features of reservoir

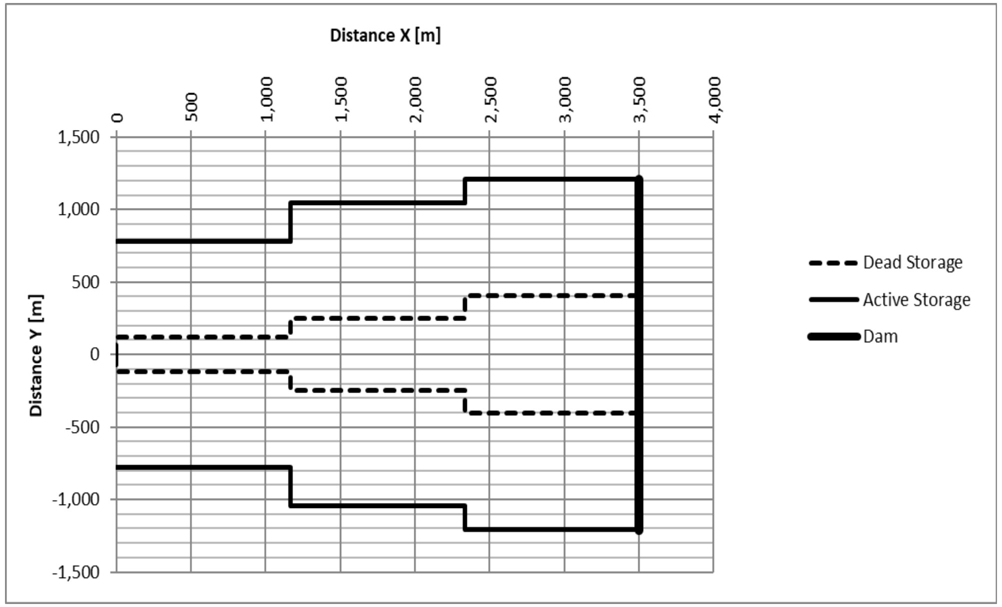
Reservoir Geometry			
User Input			
Parameter	**Units**	**Description**	**Value**
So_gr	[m³]	Original gross storage capacity of the reservoir	148,000,000
So_a	[m³]	Original active storage capacity of the reservoir	46,000,000
So_d	[m³]	Original dead storage capacity of the reservoir	102,000,000
Se_gr	[m³]	Existing storage capacity of the reservoir	
Se_a	[m³]	Existing active storage of the reservoir	
Se_d	[m³]	Existing dead storage of the reservoir	
Wbot	[m]	Representative bottom width of the reservoir	100
ELOWL	[masl]	Normal pool elevation of reservoir	231.0
ELMWL	[masl]	Minimum pool elevation	224.5
Elbmin	[masl]	Minimum bed elevation	100.0
Lres	[masl]	Reservoir length	3,500
ncomp	[-]	Number of reservoir compartments	4
		Automatic or manual discritization of reservoir in compartments	Automatic

Approximation of reservoir geometry









Specification of hydrological data

Water inflow

- Mean Annual Runoff (MAR)

  MAR = 2,950,000,000 m³/a:

  MAR = 75 m³/s

- Standard deviation of annual flows

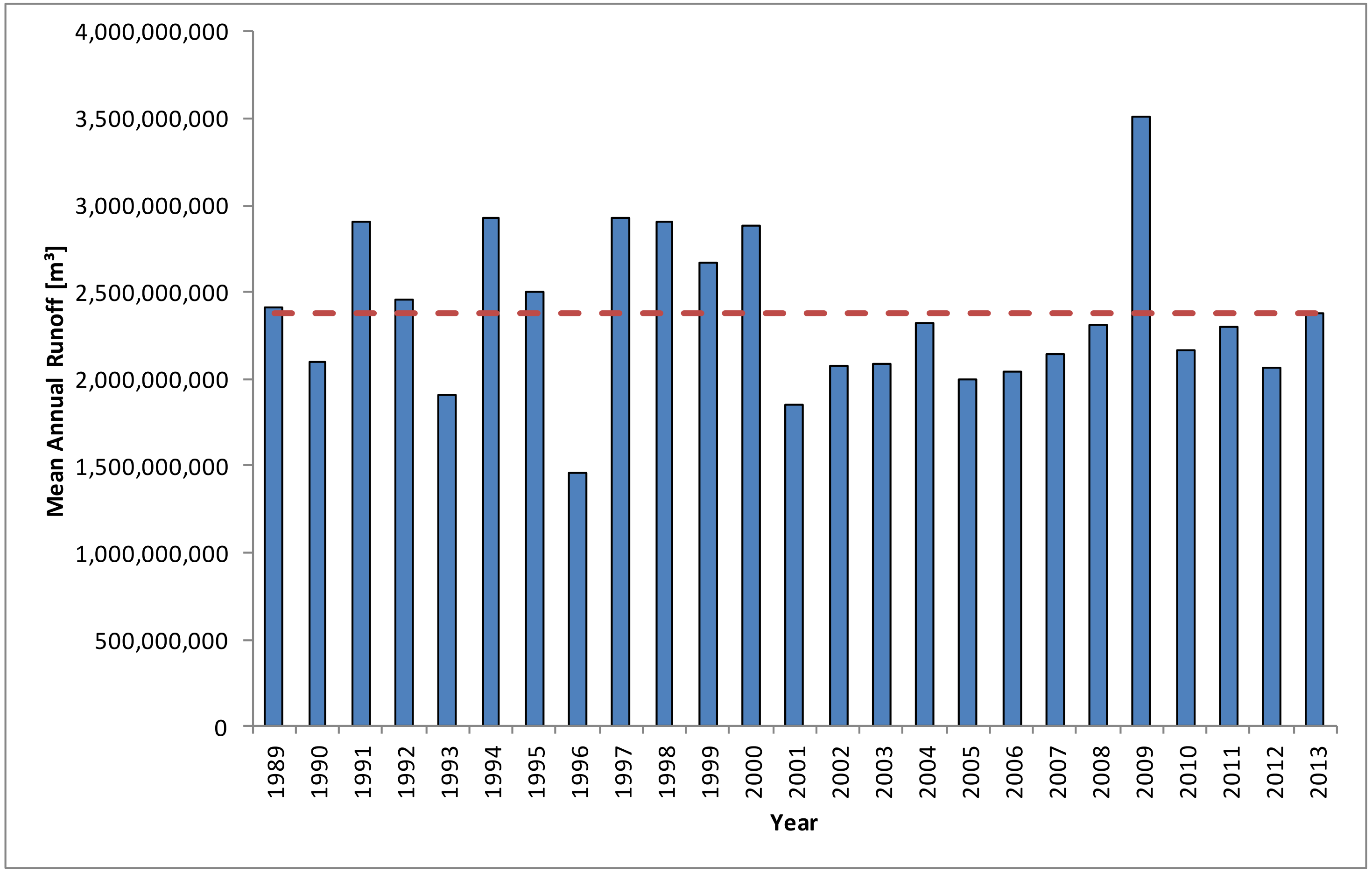
  sd = 450,000,000 m³

- Coefficient of variability

  Cv = MAR / sd

  Cv = 2,950,000,000 / 450,000,000

  Cv = 0.19



Specification of hydrological data

Sediment Inflow

- Total Sediment Inflow (MAS)

  Suspended & bedload

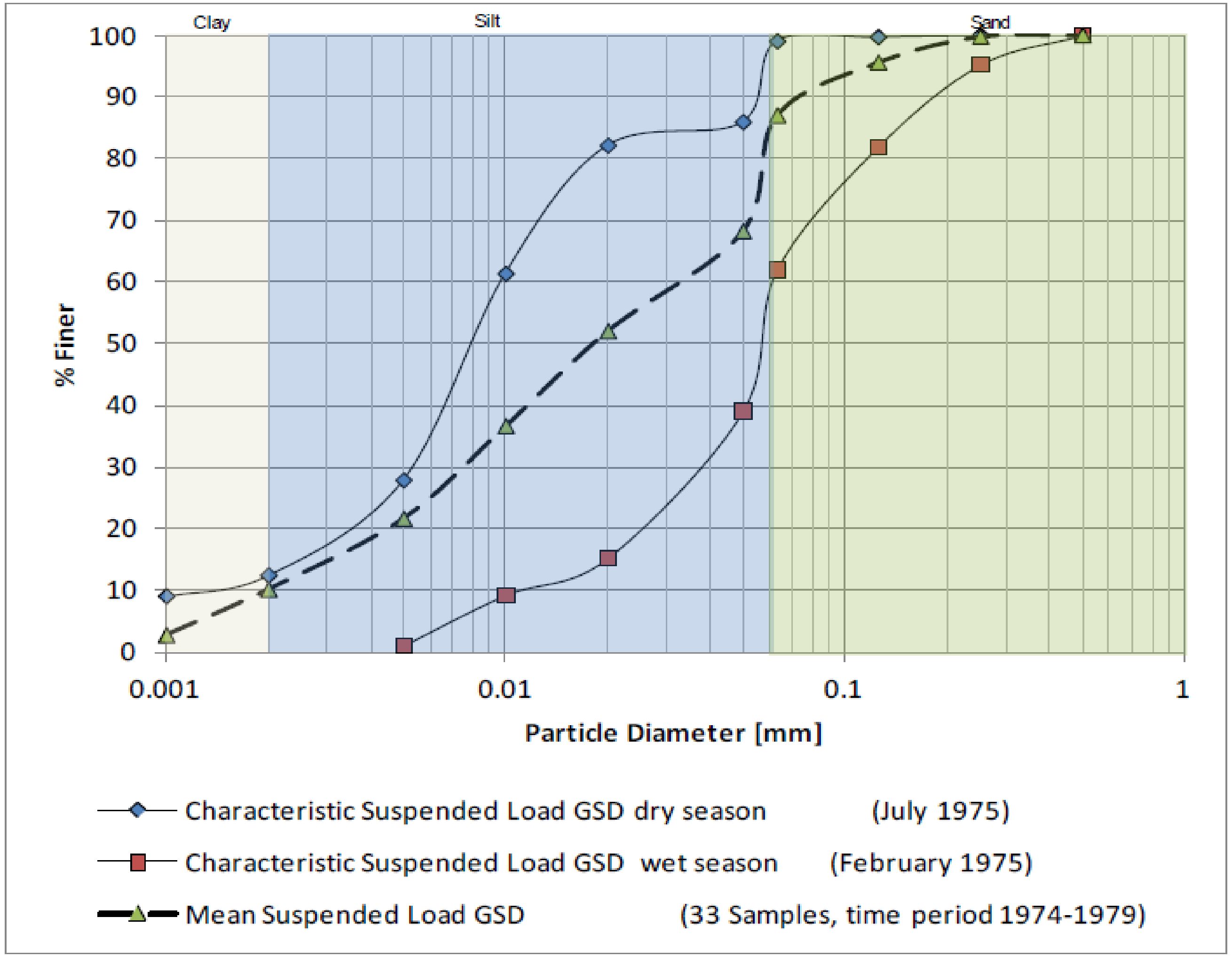
  MAS = 6.2 million t/a

- Composition of suspended load

  Silt & sand

- % of bedload in total load

  pb = 8%



pcl	[%]	Fractional content of clay in suspended sediment inflow	5.0%
psi	[%]	Fractional content of silt in suspended sediment inflow	63.0%
psa	[%]	Fractional content of sand in suspended sediment inflow	32%

Specification of hydrological data

Intrannual distribution of water & sediment inflow

- **Wet Season**: Mid. November – Mid April

  5 Months (40% of the year)
  - Sediment Inflow: 80% of MASs + bedload
  - Water inflow: 60% of MAR

- **Dry Season**: Mid April - Mid. November

  7 months (60% of the year)
  - Sediment Inflow: 20% of MASs
  - Water inflow: 40% of MAR