Article, Published Version

Efthymiou, Nikolaos P.; Palt, Sebastian; W. Annandale, George; Karki, Pravin

Rescon 2: A Tool for rapid assessment of alternative options for managing sedimentation in reservoirs

Hydrolink

RESCON 2: A TOOL FOR RAPID ASSESSMENT OF ALTERNATIVE OPTIONS FOR MANAGING SEDIMENATION IN RESERVOIRS

BY NIKOLAOS P. EFTHYMIOU, SEBASTIAN PALT, GEORGE W. ANNANDALE AND PRAVIN KARKI

There is a paucity of suitable locations for construction of new dams in watersheds where reservoirs have already been impounded in the past. Policy makers and engineers are focusing in-creasingly on the preservation of reservoir storage and prompting of sustainable dam projects. A plethora of sediment management strategies has been developed and successfully applied to counter reservoir sedimentation. REServoir CONservation (RESCON) 2 beta provides a tool for rapid assessment of expected reservoir sedimentation and screening of technically feasible and economically optimal sediment management techniques, based on easily accessible data.

From RESCON to RESCON 2 beta

The RESCON approach was originally published by the World Bank in 2003[1] to help selecting a sediment management strategy that is technically feasible, while maximizing net economic bene-fits. The RESCON approach is applicable to proposed or existing reservoirs and accounts for all major benefits and costs over the complete project life-cycle (*i.e.* intergen-erational equity concept). The impact of climate change on infrastructure in the water sector and the importance of reservoir sustainability are now better understood and new methodological tools for economic analysis of renewable resources have been developed[2,3]. The RESCON tool was tested against data from numerous dams around the world (*e.g.* Morocco, Sri Lanka, Kenya) and was shown to yield results in agreement with observations and field data and proven detailed mathematical models[1]. These reasons have prompted the World Bank to update the computer model of the RESCON approach. Fichtner Consulting Engineers has developed recently the beta version of the upgraded RESCON 2[4], which is a freeware tool to download at www.hydropower.org/sediment-management/resources/tool-reservoir-conser-vation-model-rescon-2-beta.

The RESCON 2 software provides a rapid evaluation of the state-of-the-art for sediment management alternatives, addressed to both engineering industry and decision-making communities. The purpose is to identify, based on readily available data, the optimum sediment management alternative able to convert a reservoir with a finite service life time to a sustainable one. The analysis is based on empirical approaches, and therefore it is not intended to replace detailed planning sup-ported by numerical and/or physical modelling.

Selection of optimum sediment management alternative

The RESCON 2 methodology comprises the following steps (Figure 1):

- Assessment of the technical feasibility of sediment management strategies,
- Prognosis of the change in time of the usable reservoir storage capacity and the corresponding firm water yield,

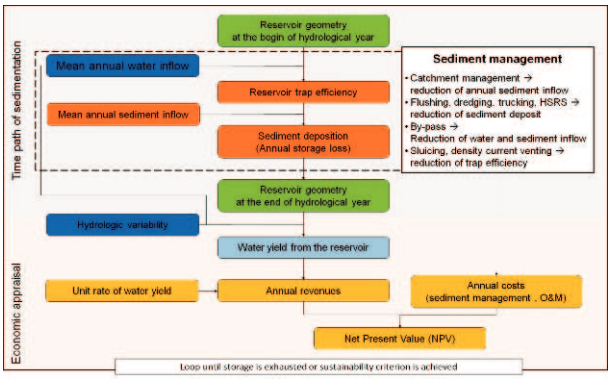

Figure 1: Flow chart of RESCON 2 analysis for the assessment of reservoir performance. O&M: Operation & Maintenance

- Estimation of the annual reservoir benefits, which are determined according to the revenue obtained by the firm water supply and cost for reservoir operation and maintenance, and sedi-ment management. The annual benefits are discounted to calculate the corresponding Net Present Value (NPV),
- Selection of the sediment management technique that maximizes the economic performance of the reservoir. The latter is quantified as the Aggregate NPV of benefits over the life of the res-ervoir.

The following sediment management techniques can be assessed with RESCON2:

- Reduction of sediment inflow into the reservoir through watershed management,
- Sediment routing (*i.e.* sluicing, by-pass, density current venting),
- Removal of sediment from the reservoir (*i.e.* flushing, dredging, trucking, Hydro-Suction Remov-al Systems (HSRS)),
- User-defined strategy combining a sequence of up to five different techniques,
- No Action Scenario (*i.e.* no sediment management intervention), which can be the baseline approach to which other sediment management alternatives are compared.

The calculation of reservoir storage loss is based on empirical trap efficiency predictors and partitioning the sediment inflow into bedload and suspended load. The spatial pattern of reservoir sed-imentation is assessed by schematizing the reservoir geometry into compartments and calculating the corresponding deposits and invert elevation. This allows the allocation of sediment deposits in active and inactive storage pools, respectively. Several calibration possibilities are available to tailor the analysis onto the site-specific conditions. RESCON 2 can determine through economic optimization the parameters affecting the sediment management technique efficiency, and conse-quently the change of the reservoir storage over time. In addition, it is possible to specify explicitly these parameters, such as the implementation time schedule, in case of project specific con-straints.

The model has been validated using a large number of existing and green-field projects, showing an overall good agreement between the predicted and measured (or numerically simulated) evolu-tion of the reservoir storage capacity over time (Figure 2).

Water storage can be either an exhaustible resource, if the reservoir is non-sustainable, or renew-able, if the reservoir is sustainable by effective sediment management. The virtues of sustainable development and intergenerational equity are accounted for in the economic appraisal performed by RESCON 2 in two manners:

- Optional calculation of sinking fund in case of

Nikolaos Efthymiou is a consulting engineer at Fichtner GmbH & Co. KG, specialized in hydraulics, sediment transport and reservoir sedimentation. He is involved in sediment management studies, due diligences, prefeasibility and feasibility for small and large hydropower projects, in Europe, Asia and Africa. He was responsible for the development of RESCON2 software.

Sebastian Palt is the Executive Director of the Hydropower Department of Fichtner, Germany, in charge of all type of studies from reconnaissance level to feasibility and due diligences. He has worldwide experience in hydropower and development of reservoir sedimentation management approaches to ensure sustainable development. He was the principal in charge for development of the RESCON2 software.

George Annandale is a consulting engineer and the Principal of the firm George W. Annandale, Inc. He is recognized as a global leader in Reservoir Sediment Management, specializing in sus-tainable development of water resource infrastructure. He was the technical lead for the develop-ment of RESCON. He conceptualized and supervised the RESCON2 project.

Pravin Karki is leading the World Bank's work on sediment management and climate change resili-ence in the hydropower and dam sector. He has over 25 years of professional experience relating to hydropower, mainly in engineering, international policy and academic research. He managed the RESCON2 project on behalf of the World Bank.

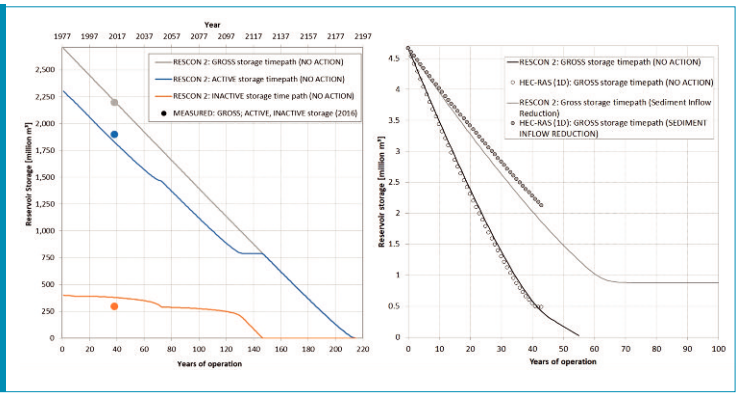

Figure 2: Comparison between predicted and measured or simulated devel-opment of storage over time for the Fierza Reservoir, Albania (left) and Moragolla Reservoir, Sri Lanka (right) Intergenerational equity

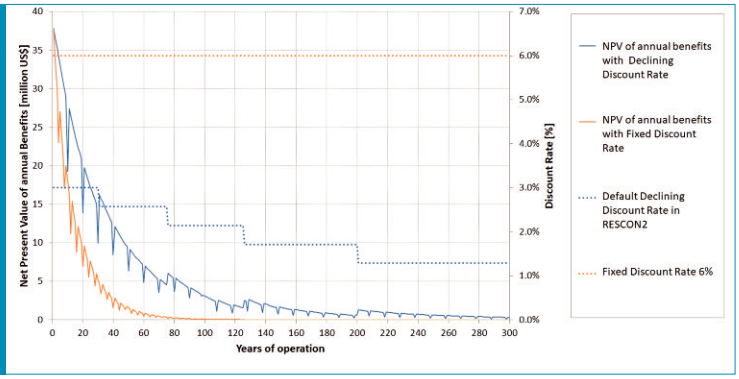

Figure 3: Calculated NPV of annual benefits with fixed discount rate (6%) and with time-declining discount rate for a large storage reservoir where the sediment flushing alter-native is applied Climate change

non-sustainable storage development that allows placing the burden of dam decommis-sioning on the current generation benefiting from the in-frastructure,

- Option to discount the future benefit streams using a time variant Declining Discount Rate. This allows attributing higher NPV for benefits associated with the utilization of infrastructure by the future generations. Figure 3 illustrates how applied discount rates impact the valuation of future reservoir benefits.

The continuous loss of reservoir storage due to sedimentation will reduce the resilience of the existing water sector infrastructure against the unavoidable increase of hydrologic variability driven by climate change[3]. Sediment management can provide therefore an effective adaptation strate-gy through preservation of the available storage capacity, protecting thus the reliability of water supply. RESCON 2 can perform an assessment of the effects of climate change on reservoir sus-tainability. Using data retrieved from the Climate Change Knowledge Portal of the World Bank[6], *i.e.* predicted changes in mean annual runoff and temper-ature[7], it is possible to assess the im-pact of climate change on the reliability of water and power supply from reservoirs with diminished volume. The climate change data represents the results of 22 GCMs and three climate change scenarios, provided on river basin level. It is also possible to empirically estimate changes in sedi-ment yield using the changes in average annual flow with application of the BQART equation[8]. Finally, the user is asked to specify the expected increase of hydrological variability. The latter can be assessed by statistical analysis of precipi-tation time series derived from open climate change data sources. This analysis performed by RESCON2 has the following objectives:

- Climate "stress test": assessment of how vulnerable different project configurations (*i.e.* different sediment management alternatives) might be across a sensible range of potential climate change effects.
- Robust Decision Making: identification of the robust sediment management configuration that minimizes the expected maximum regrets due to climate change on the economic performance of the reservoir.

Environmental safeguards

In addition to technical feasibility and economic viability, environmental and social impacts of sed-iment management play a decisive role in selecting the optimum alternative. RESCON 2 includes the safeguard rating method, which allows the differentiation between environmen-tally and socially constrained and unconstrained sediment management alternatives during the evaluation proce-dure.

Graphical User Interface

RESCON 2 has a Graphical User Interface (GUI), which facilitates a structured setting-up of the model and reading of results. The GUI allows for a real-time validation of the inserted data and easy access to text providing further explana-tions on the input parameters. The model output includes summary tables and graphical plots of the time evolution of the most important parame-ters (*e.g.* reservoir storage, trap efficiency, deposit removal, water yield, NPV of reservoir benefits). The results are saved in a MS Excel spreadsheet that can be easily processed by the User. ■

References

[1] Palmieri, A., Shah, F., Annandale, G.W., Dinar, A. (2003). Reservoir conservation: The RESCON ap-proach. Vol. I, Washington DC, The World Bank.
[2] Annandale, G.W., Morris, G.L., Karki, P. (2016). Extending the Life of Reservoirs: Sustainable Sediment Management for Dams and Run-of-River Hydropower, Washington DC, The World Bank
[3] Annandale, G.W. (2013). Quenching the Thirst: Sustainable Water Supply and Climate Change. Charles-ton SC, CreateSpace Independent Publishing Platform
[4] Efthymiou, N.P., Palt, S., Annandale, G.W., Karki, P. (2017). Reservoir Conservation Model RESCON 2 Beta - Economic and Engineering Evaluation of Alternative Sediment Management Strategies, User Man-ual, The World Bank & Fichtner.
[5] www.hydropower.org/sediment-management/resources/tool-reservoir-conservation-model-rescon-2-beta.
[6] http://climateknowledgeportal.worldbank.org.
[7] Strzepek, K., McCluskey, A., Boehlert, B., Jacobsen, M., Fant IV, C. (2011). Climate Variability and Change: A Basin Scale Indicator Approach to Understanding the Risk to Water Resources Development and Management. The World Bank Group. Water Papers 67338
[8] Syvitski, J.P.M., Milliman, J.D. (2007). Geology, geography and humans battle for dominance over the delivery of sediment to the coastal ocean. J. Geology, 115, 1–19.