# DEL114 - Improving an integrated operational tool to manage a river system with dams and reservoirs considering flow, sediment and ecology

## Introduction

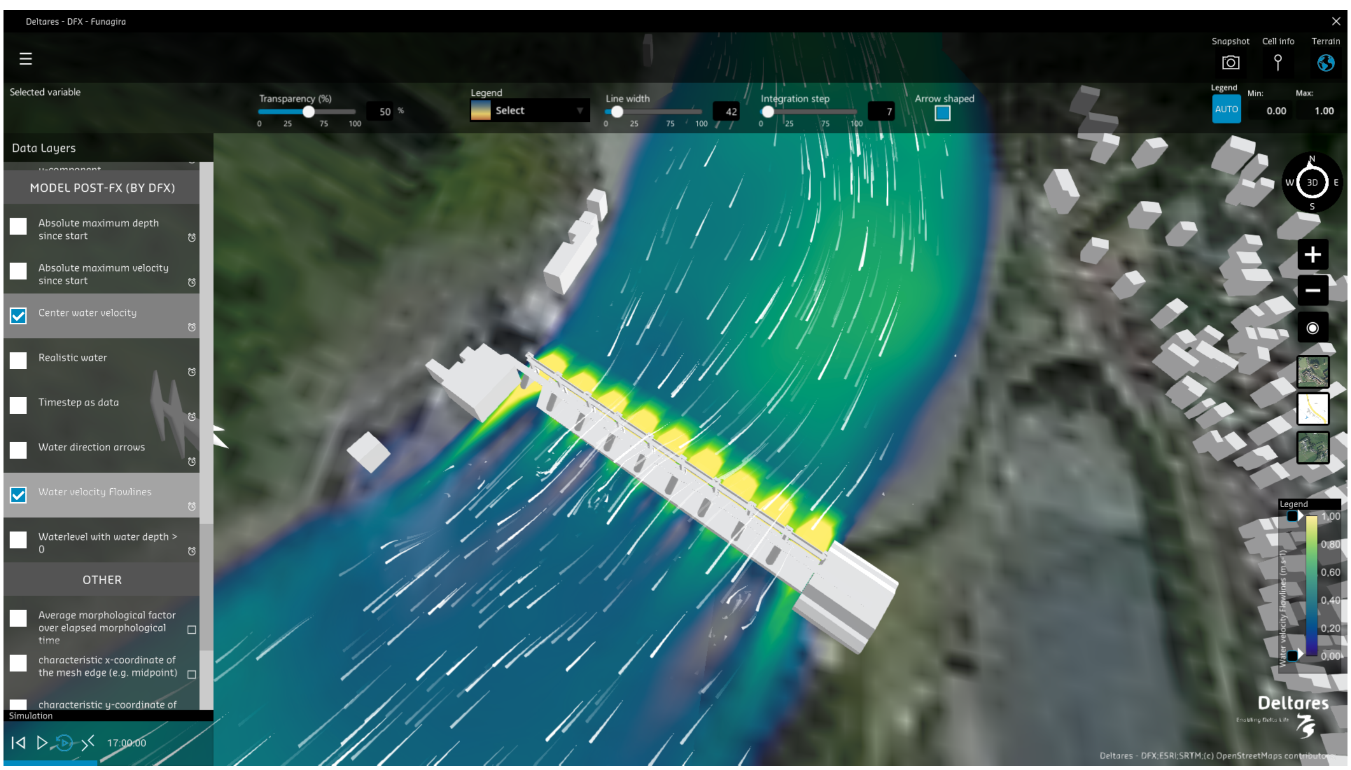
Dam and reservoirs are important for water storage, renewable energy generation as well as flood management, particularly in areas with strong seasonal variations in rainfall-runoff patterns along with ever-growing water and energy demand due to growth of economy and population. However, these dammed reservoirs intervene the natural system of rivers: they distort the natural environmental flow of the river. The natural environmental flow of a river is defined by the quantity, frequency, timing, predictability and duration of a river’s flow regime. Over hundreds of years, this natural flow regime has shaped the riverine functioning in terms of abiotic and biotic interactions. The degree of impact of dams on a river’s natural flow regime depends on the extent of the required water storage, the diversion of the water from the natural river bedding and the interruption of the lateral connectivity.

The major negative impact of dams in a river basin is the disturbance in natural flow dynamics and sediment transport, for example, shortage in downstream flow and sediment supply leading to micro- to large-scale morphological changes and changes in species habitats. These changes do not only impact riverbeds, floodplains and settlements, but also aquatic and riparian habitats (e.g. wetlands and fish spawning areas) and ecological processes (e.g. fish migration cues) and therefore socio-economic benefits, like providing food for local communities and profits for larger scale companies. It is vital to improve the ecosystem services of regulated rivers to minimize the hinderance to the natural processes.

Common impacts of changes of the natural environmental flow by river damming are deterioration of the natural riverine habitats as flow and sediment and erosion dynamics changed. Also, damming of rivers introduce the risk of calamity (e.g. dam break). Reservoirs behind dams may introduce emissions, enhance pollution (virtually stagnant water) and health challenges, especially in the tropical areas. Most of these impacts are associated not only directly with the interventions, but also due to mismanagement, poor planning, poor monitoring, inefficient operation and ageism. It is important to ensure that every river system with such interventions is resilient and capable to absorb the unexpected or expected event or strain.

The complexity and diversity of the processes in combination with such interventions require an integrated and optimized solutions. For instance, flow and sediment management, optimization of reservoir operation considering energy production, flood control as well as habitat suitability. This is even more important for a cascade system of interventions due to their larger (basin) scale impacts. Additionally, in present context, consideration of emissions and health has become important as well.

This requires dealing with challenges related to knowledge integration and application, and thus our effort in cooperation with J-Power is to continue improving the knowledge related to sediment management in rivers with reservoirs considering optimization of water use in complement with the ecosystem of the river basin. We aim at further improvement of our knowledge and tools to understand and address key processes, and problems. These efforts are of use to eventually seek for solutions to increase the resilience of the river system from basin to reach scales considering short- and long-term effectiveness.



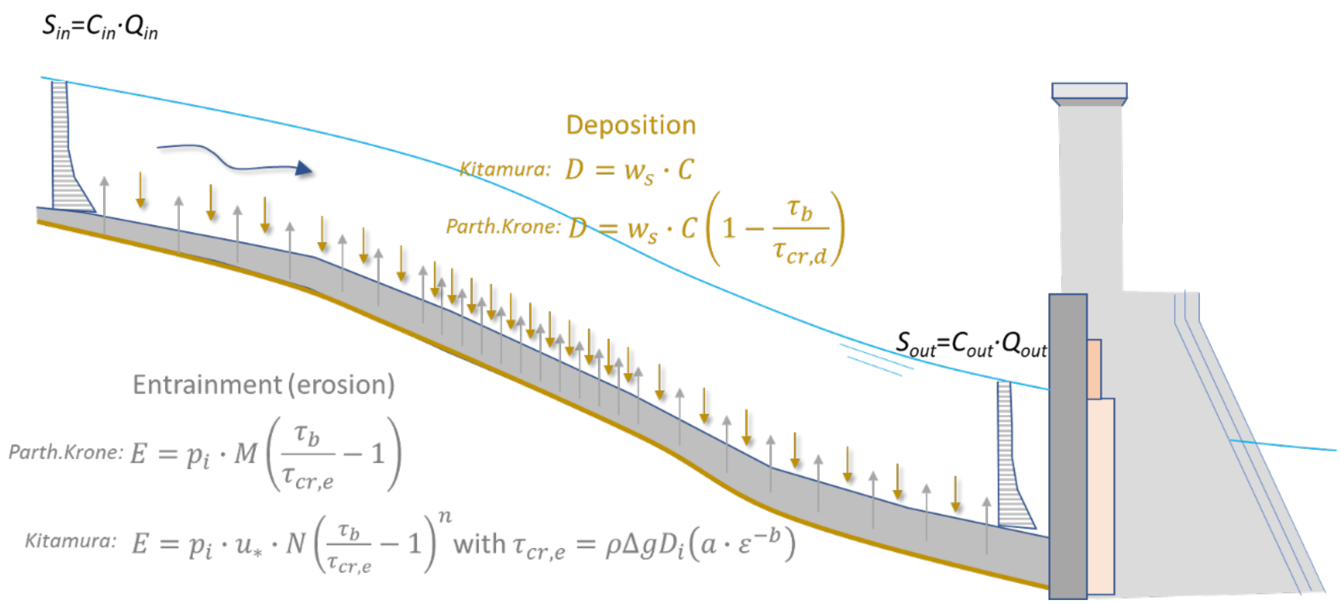

Funagira Dam and reservoir integrated model in DFX environment. (Click https://demos.deltares.nl/360dam/dfx/ to see the 360 degree visualization)

# Goals

The overall objective is to improve our knowledge base and tools to support the optimal management strategy for resilient river system with reservoirs considering large (e.g. catchment level) to detailed scale (e.g. reach level). Followings are some of the objectives of the proposed research activities:

1. To implement new functionalities in our 1D and 2D flexible mesh software to make it usable to provide a reliable prediction of dam operation, flow, sediment transport and ecology (Delft3D-FM+RTC under Delta-Shell platform).
2. To validate above mentioned functionalities in our modelling tools to improve the morphological replication and prediction with dam operation that could be more useful to assess river environment and habitats
3. Provide 1D and 2D modelling tools that are equipped with new functionalities needed for optimal sluicing and flushing operation of the system of reservoirs in a cascade.
4. To provide RTC tool with improved approach (a step ahead) for optimizing reservoir operation by integrating component related to environmental flow, sediment transport and habitat suitability models and tools:

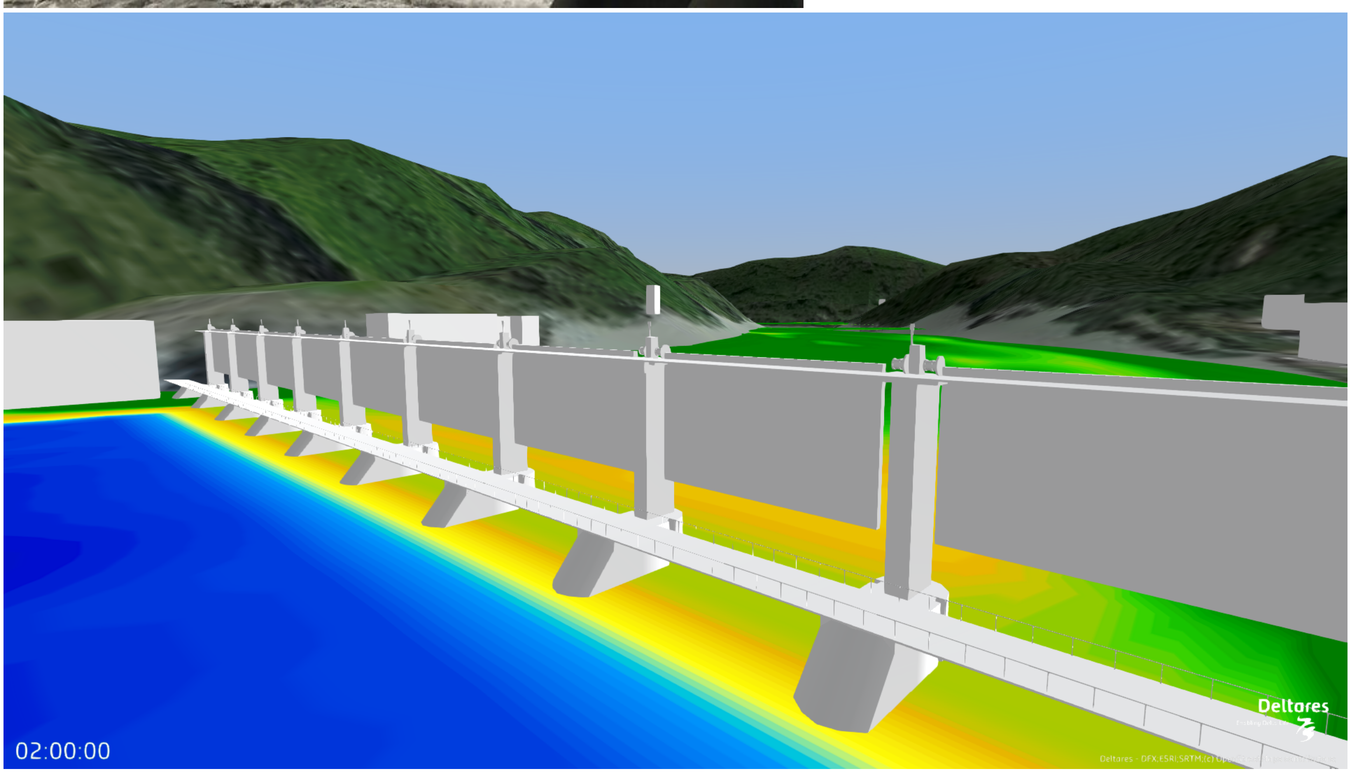
One and two-dimensional models, namely Delft3D4 and Delft3D-FM (1D and 2D), are coupled with RTC tool to mimic the real-time dam operation (standalone and synchronized). The coupling will be improved further in complement with water quality and habitat suitability tools. The tool will be also be improved and used to optimize the water use, environmental releases, sediment management and habitat suitability in an integrated manner.




The deposition and entrainment processes in reservoir for cohesive sediment

# Research activities

1. Implementing and testing new sediment transport formula in Delf3D- FM software .
2. Implementing the PID controller in Delft3D-FM 1D for gate operation as well as validating of the new development (e.g. the new cohesive sediment transport formula) in Delft3D4 morphological model with RTC.
3. Investigating and improving the implementation of Fluff layer of sediment to replicate deposition and erosion process of fine sediment/mud in reservoirs and downstream reach (relevant for fish).
4. Explore a better approach to connect HABITAT model database to Delta-Shell environment. The new approach “An adapter” is expected to be implemented and tested . The adapter is expected to be coupled with other models and read the files and produce HABITAT model ready to run within Delta-Shell.
5. Investigate the applicability of including the dynamic porosity calculations in the mud sediment transport calulcations. The new development /improvement is expected to be included in Delft3D4 kernel.
6. Application of the new functionality in Delft3D4 morphological model with RTC for a real-world case (Funagira Reservoir in Japan).
7. Real-world application of coupled model (morphology + habitat + RTC) in Delft3D-FM to Funagira reservoir morphological model with habitat assessment.
8. Application of the improved 1D-model in a cascade system of dams in Tenryu River.
9. Optimization of Funagira reservoir operation as standalone optimization using RTC tool.
10. Develop knowledge related to species traits (specific characteristics of species) as modelling entity instead of species in Habitat modelling.
11. Investigate how to consider sediment and HABITAT to optimize reservoir operation in RTC-toolbox with optimization.




Funagira Dam in Tenryuu River. The left image represents the dam picture, while the right image is the dam developed in DFX visualization tool.

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