RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Research Update

S&T Program Project ID 4495

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Bottom Line

This research project developed and demonstrated a state-of-the-art three-dimensional modeling tool to predict complex flows through large woody structures so that the tool may contribute to the design in the field.

Better, Faster, Cheaper

Developing a numerical model that can predict risk, safety, and morphological impacts will allow Reclamation to use this river restoration technique responsibly and effectively, as well as allowing it to be used for a wide range of other Reclamation projects (e.g., design guidelines for instream structures and fish habitat studies).

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Complex Flows Through Large Woody Structures

Developing semi-automated, three-dimensional modeling tools for predicting complex flows through large woody structures

Problem

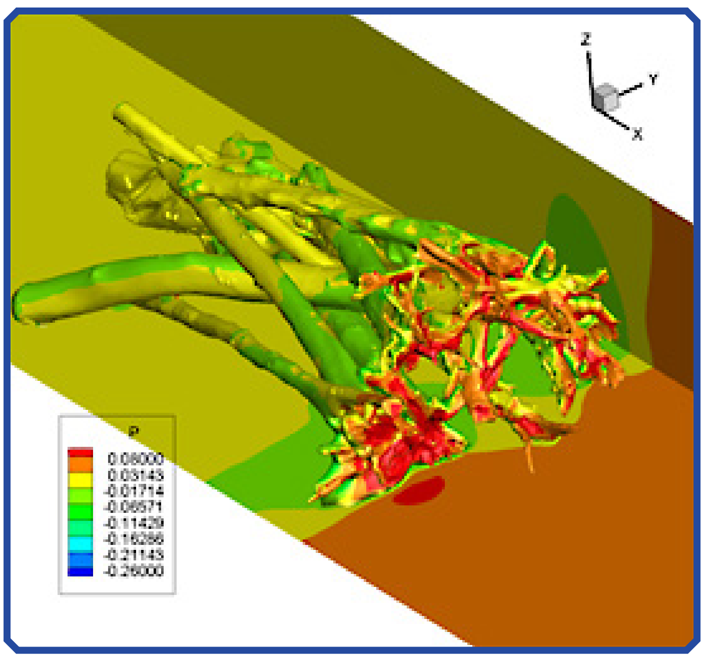
Providing large woody structures in a stream can help restore rivers and recover endangered species by re-establishing flow patterns and enhancing habitat. However, these large woody structures may cause scour and change the shape of the river—and these processes and risks are not well studied or understood. Methods and guidelines for determining risk, designing structures that effectively provide habitat and restore rivers, and predicting a river's response to large woody structures are not available. Traditional methods to measure and predict scour mostly rely on data from flumes, which suffer from scale problems. Field data for scour are scarce and expensive to obtain.

A major challenge of high-resolution large woody simulation is the representation of complex large woody geometry. It is well known that three-dimensional (3D) mesh development for complex geometry can be very tedious and time consuming. Inadequate meshing practices can leave cells highly distorted, causing numerical diffusion, solution instability, and convergence issues. Another challenge is the computational fluid dynamics (CFD) solver itself. Many existing 3D CFD models assume fixed shapes of mesh cells, which may impose severe constraints on the kind of mesh generation tools that can be used.

Solution

This Reclamation Science and Technology Program research project tackled both challenges. The objectives were to:

- Develop a semi-automated 3D mesh generator that may represent complex shapes of engineered logjams (ELJ) adequately and efficiently.
- Develop an integrated 3D flow and mobile bed model that can handle flexible mesh cell shapes, but is still robust and practical to use.



Predicted pressure distribution on the large woody structure, bottom and side walls (pressure unit in Pascal).

Thus, the summarized solution includes:

1. **Stream Representation.** An initial background mesh is generated first that represents the stream bathymetry and topography, but without the large woody structure.

2. **Large Woody Geometry Acquisition.** The ELJ is scanned using the latest available commercial scanners and geometry is then acquired.

3. **Large Woody Surface Representation.** The scanned ELJ surface geometry is integrated into seamless point clouds, which are then processed into a 3D solid model (stereolithography [STL] file format).

4. **Large Woody Placement.** The large woody structure represented by the STL format is added to the background mesh.

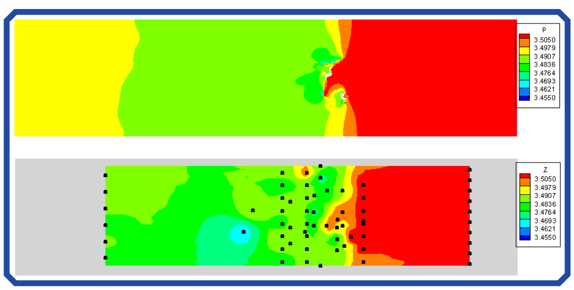
5. **Semi-Automatic Mesh Generation.** A suitable 3D mesh is generated automatically given the background mesh, the STL format surface representation of the large woody structure, and a user input file.

6. **Flow Simulation.** A specially developed 3D CFD solver is used to carry out the flow and morphological analysis.

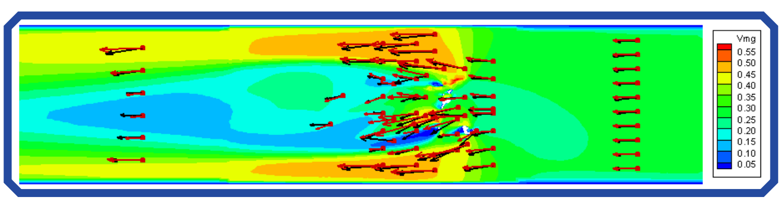
7. **Results Analysis.** The 3D results are analyzed, interpreted, and applied.

Application and Results

A large woody structure consisting of six pieces was used to demonstrate the modeling procedure and the modeling tools. The same structure was also constructed and placed in a flume so that experiment measurements could be conducted for model verification. A comparison between the model results and the measured data were made.



Comparison of predicted (top plot) and measured (bottom plot) water surface elevation. The measured zone is a smaller subset of the CFD modeling zone.



Comparison of predicted (red) and measured (black) velocity vector near water surface (background contours are the CFD predicted surface velocity).

Future Plans

Further research is planned for:

- Developing a new sediment transport module into the 3D CFD solver so that scour and morphological impacts of large woody structures may also be simulated.

- Developing a new immersed boundary method into the existing flow solver so that the complex geometry of large woody structures can be more easily handled by the flow solver instead of the mesh generation.

"State-of-the-art computational fluid dynamics modeling could help us understand how large wood structures work and interact in a river environment."

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Collaborators

- **Bay-Delta Office in Reclamation's Mid-Pacific Region**
- **U.S. Army Corps of Engineers-Engineering Research and Development Center, Vicksburg, Mississippi**
- **Yurok Tribe, Weaverville, California**
- **California Department of Water Resources, Sacramento, California**
- **Pennsylvania State University**
- **University of Arizona, Tucson**

More Information

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