# Hammerhead Flood Control System CFD

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| Project ID: | Garrison-1123-01 |
| Document Name: | Garrison-1123-01 Hammerhead Flood Control System CFD |
| Date Issued: | November 14, 2023 |

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| Rev | Description of Change | Date Issued | By |
|---|---|---|---|
| 0 | Engineering Report Released | 11/14/2023 | CSH |

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## 1. OBJECTIVE

Flood control barriers are required to withstand an inrush of water at a velocity of 2 ft/s. Garrison Flood Control is interested in evaluating dynamic loads on their Hammerhead Flood Control System, specifically the 40-inch-wide configuration consisting of 14 planks. The analysis will employ Computational Fluid Dynamics (CFD) to evaluate the 40-inch-wide flood control barrier from Garrison, Figure 1. The CFD analysis uses a multiphase VOF method to simulate a flow inrush at 2 ft/s. The peak pressures from this flow inrush are mapped to the static FEA model for analysis.

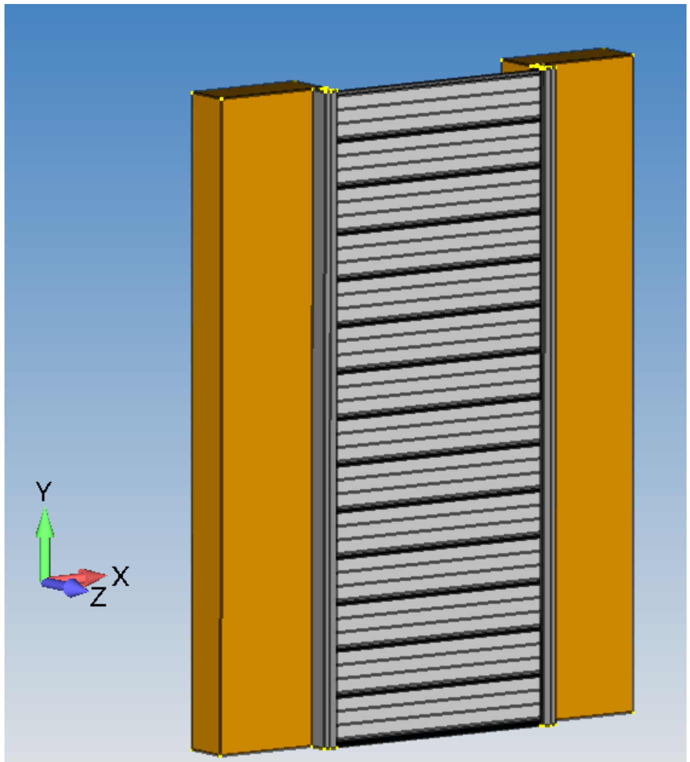



**Figure 1:** Garrison's Hammerhead Flood Control System

## 2. EXECUTIVE SUMMARY

This report presents the results of a comprehensive analysis aimed at assessing the structural integrity of a flood barrier subjected to a flood impact scenario with a velocity of 2 ft/s. The analysis focuses on a 14-plank-tall flood barrier installation, assuming that the top pressure of the system provides a sufficient ground seal. The primary objective was to determine whether the flood impact at this velocity has any adverse effects on the barrier's structural performance.

The analysis includes two critical time points: the initial impact at 1.84 seconds and the scenario when the water has risen at 3.53 seconds. Due to gravity pulling the water down in the simulation, the leading edge of the water initially impacting the barrier accelerated to 27 ft/s. The maximum von Mises stress values obtained during these two phases were found to be 17.1 MPa and 28.3 MPa, respectively. Importantly, these stress levels remained well within the safety margins for the structural integrity of the flood barrier. Figure 2 illustrates the pressure map on the bottom plank at the initial impact.

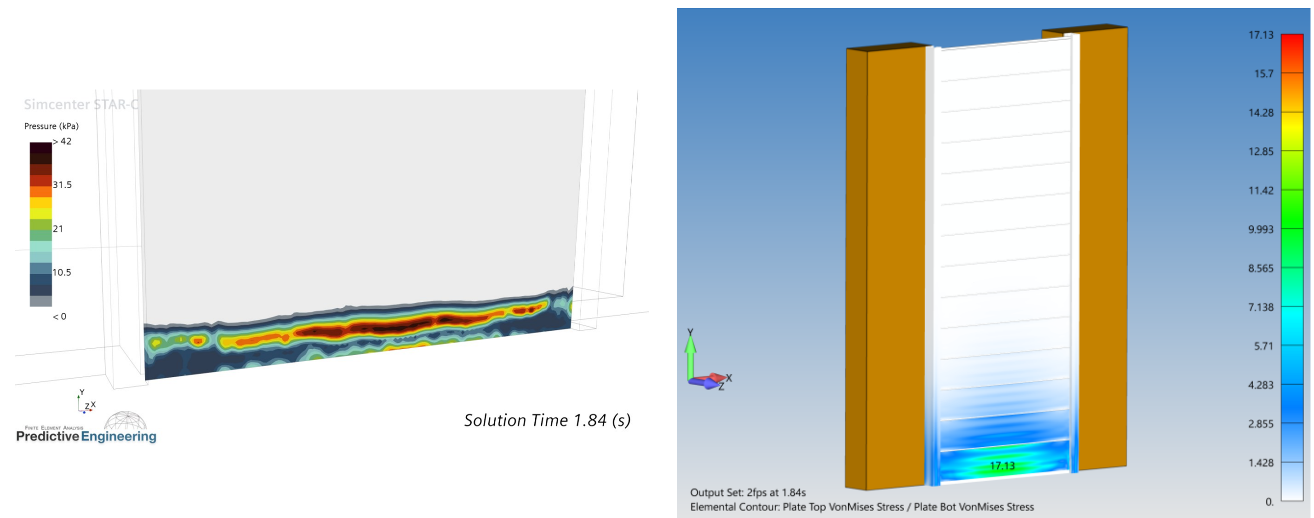



**Figure 2:** Plank pressure map and stresses at the initial impact

# 3. MODELING

## 3.1 ENGINEERING UNITS AND SOFTWARE

The CFD analysis is performed in Simcenter STAR-CCM+ with standard SI system of m, kg, K.

The structural FEM analysis is based on the metric system with length as mm's, force as N's, mass as Tonne (kg), time as seconds and temperature as C. In this unit system, the nominal mass density of aluminum is 2.710E-9 Tonne/mm3 with deflections in mm's and stress in MPa. The FE model was built with Femap v2301 MP1 and analyzed with Simcenter Nastran.

## 3.2 SIGNIFICANCE UNITS

Analysis results are reported to three significant digits and analysis inputs are likewise rounded to three significant digits. Fundamental physical constants are set to four significant digits (e.g., gravity is 9,807 mm/s$^2$). The imposed limitation on the number of significant digits implies, at best, a relative numerical precision of 1%.

## 3.3 GEOMETRY

This analysis is based on the 40-in wide X 104-in high barrier, which was analyzed in the previous report, Garrison-0923-01. The mesh from this analysis is imported into STAR-CCM+ for pressure mapping.

For the CFD analysis, we assume the barrier is situated within a test-trough that is 2 m wide and as high as the barrier, as shown below in Figure 3. The length of the trough from the barrier to the inlet is 10 m. A wall of water is fed into the trough at a velocity of 2 ft/s (0.6096 m/s) for a time of 16.4 s to fully fill the trough. The gray barriers are solid to contain the water. Above the trough is air space with an outlet pressure condition.

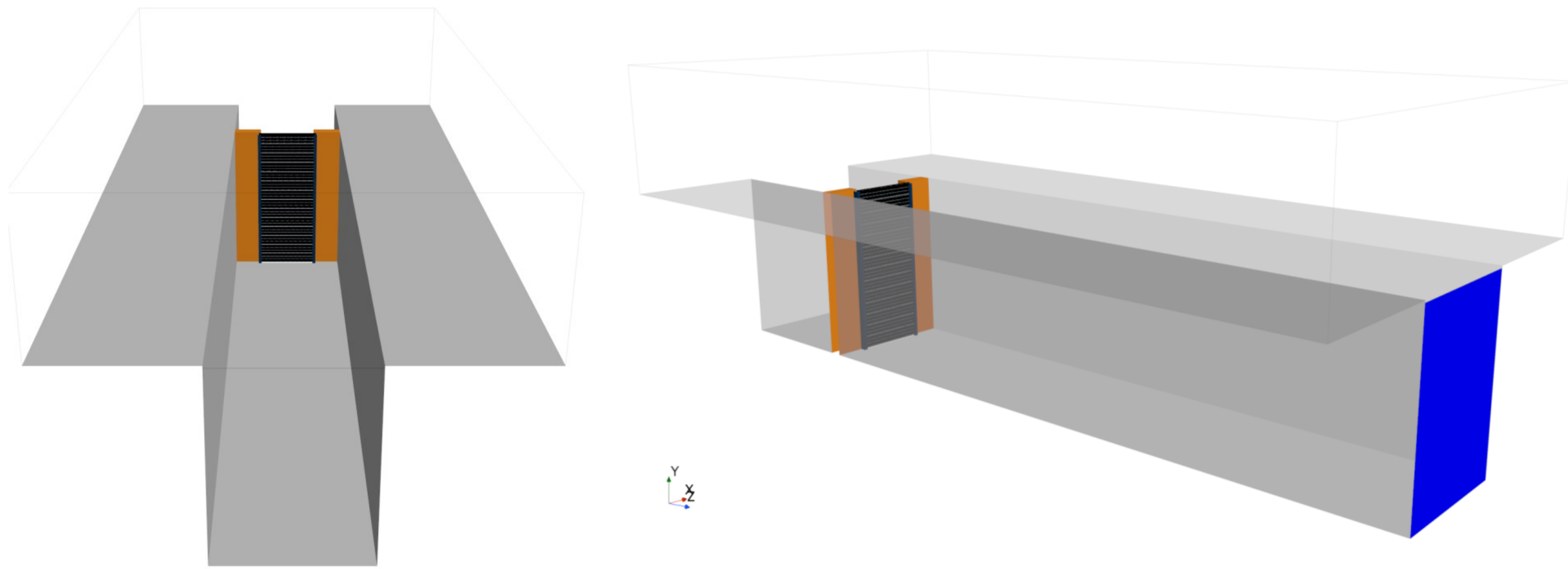
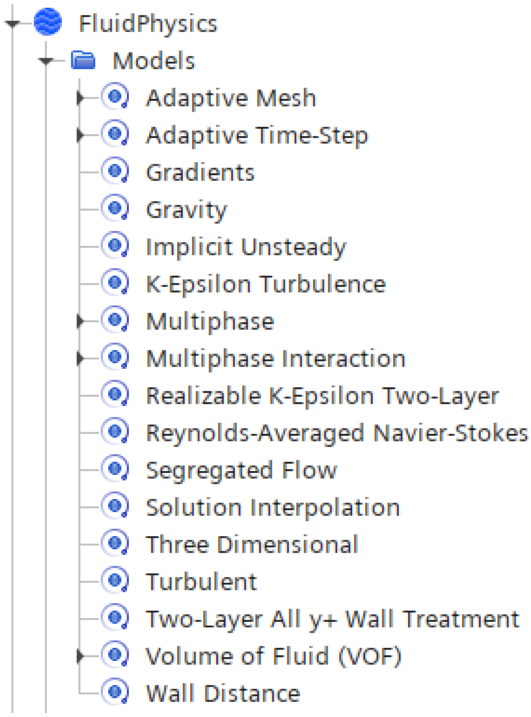



**Figure 3:** Test trough for CFD inrush analysis

## 3.4 CFD Model Assumptions and Physics

The CFD analysis is a multiphase solution relying on the volume of fluid method to capture the sharp immiscible interface between water and air, Figure 4. Both phases, water and air, are modeled as constant density fluids. The model uses an adaptive mesh to better refine the interface between air and water as it moves through the trough.




| | Water | Air |
|---|---|---|
| Density [kg/m^3] | 998 | 1.20 |
| Viscosity [Pa-s] | 8.90e-4 | 1.86e-5 |

**Figure 4:** CFD model physics conditions

### 3.5 CFD Mesh

The CFD analyses uses a trim-cell mesh with an initial cell count of 2.1 million cells. Near the barrier, the cell size is refined to 6.3 mm to nearly match the initial size of the structural mesh. As the model runs, the mesh is locally refined at the fluid-air interface, as shown in Figure 5.

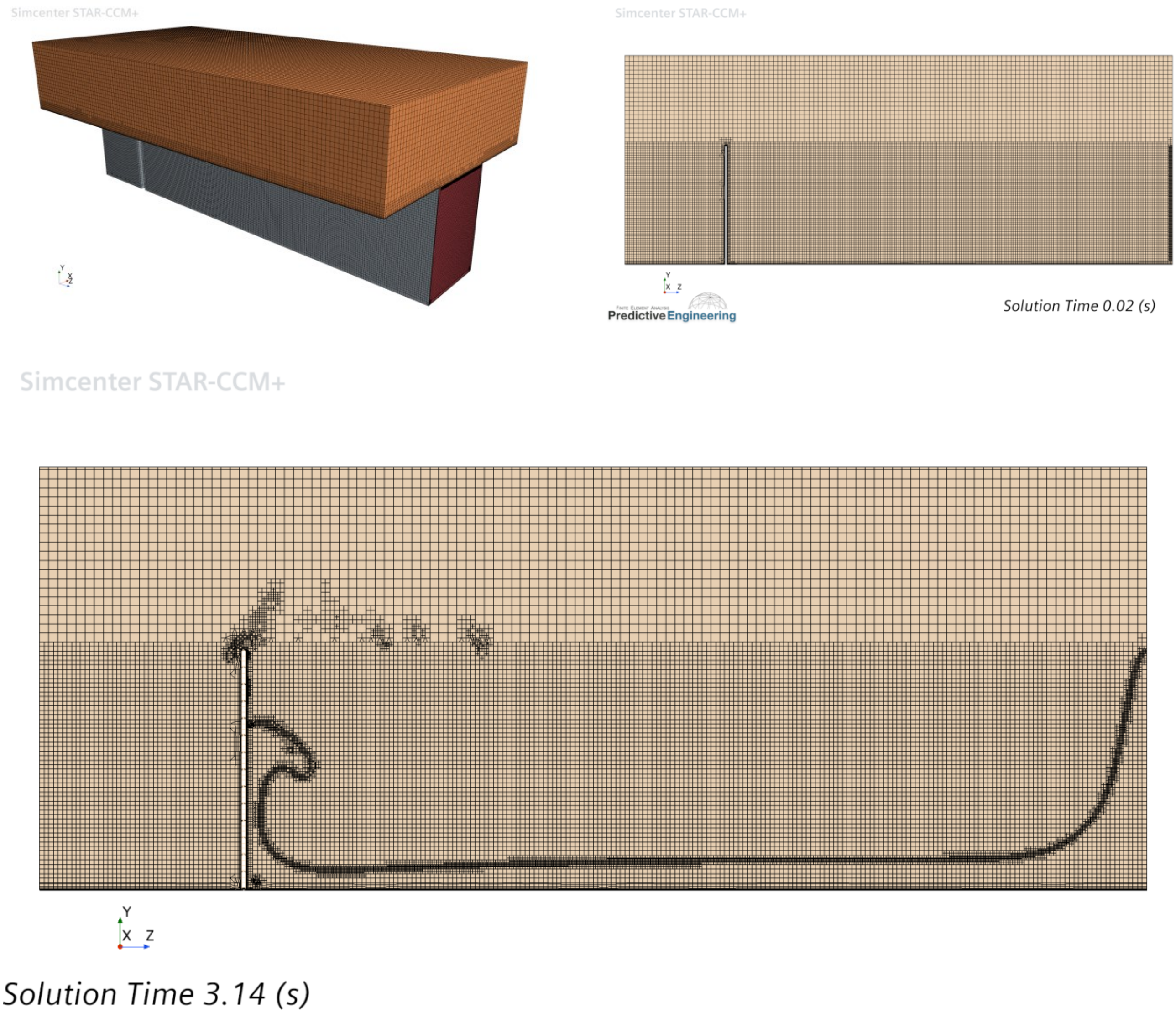



**Figure 5:** CFD mesh detail with adaptive refinement

### 3.6 FEA MATERIALS

Table 1 contains a list of the materials used within the structural model.

**Table 1:** Material definitions for structural analysis

| Usage | Material | E, MPa | Poisson's Ratio | Yield Strength, MPa | Ultimate Strength, MPa |
|---|---|---|---|---|---|
| Planks | 6063-T5 Aluminum | 70,000 | 0.33 | 145 | 186 |
| Posts | 6063-T5 Aluminum | 70,000 | 0.33 | 145 | 186 |
| Rubber Seals | Rubber EPDM | 16.50 | 0.49 | - | - |
| Brackets | 304 Stainless Steel | 200,000 | 0.29 | 215 | 505 |
| Leg Support | 304 Stainless Steel | 200,000 | 0.29 | 215 | 505 |

# 4. SIMULATION RESULTS

## 4.1 CFD Analysis Results at 2 ft/s In Rush

The first analysis evaluated the flow inrush at 2 ft/s. In this analysis, the water velocity at the inlet is set to 0.6096 m/s (2 ft/s). Although this inlet wall velocity is set at the specified value, as the water comes in, gravity pulls it down, and surface velocities reach 8.2 m/s (27 ft/s) when the water impacts the planks, as shown in Figure 6.

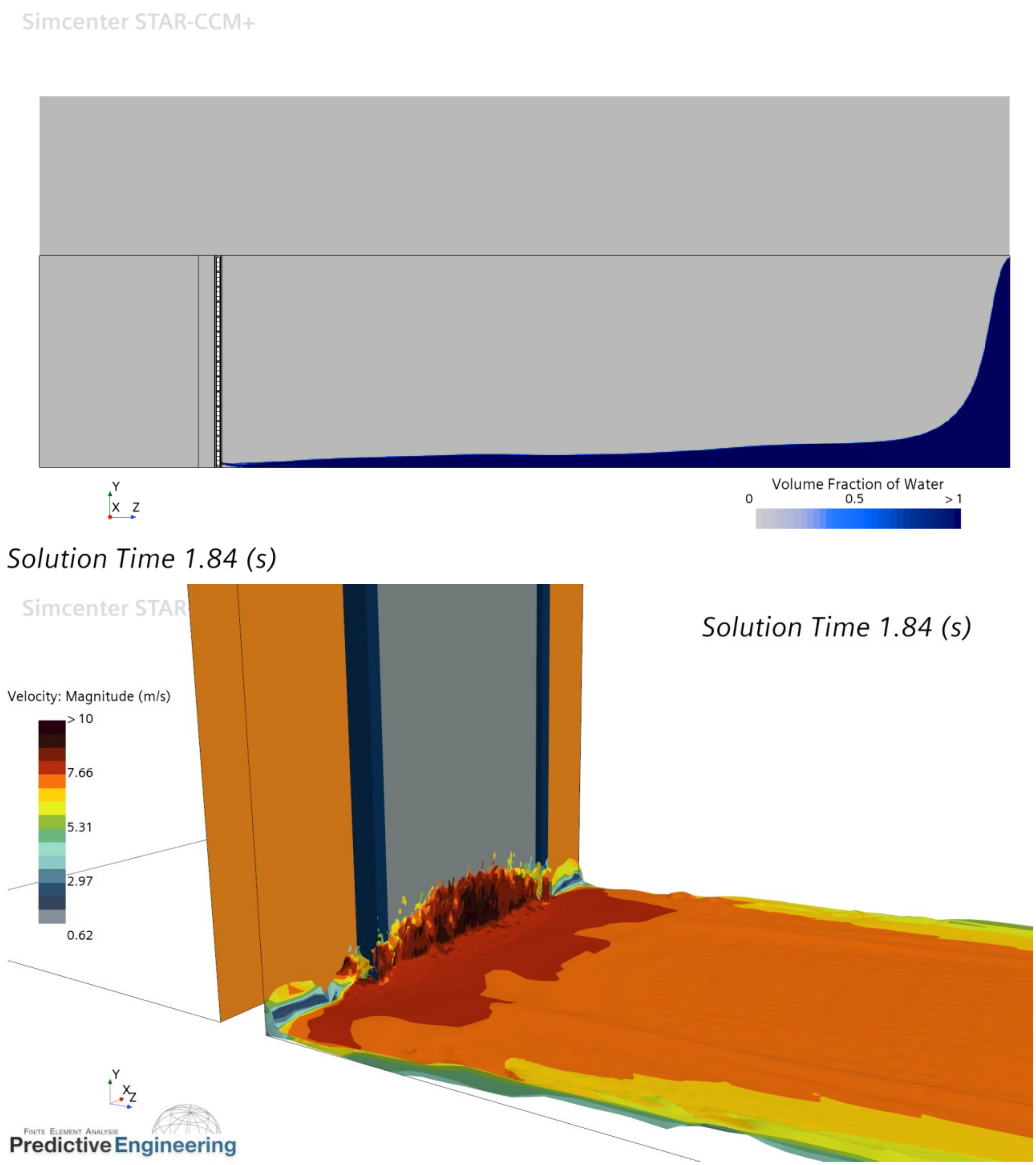



**Figure 6:** Midplane water volume and surface velocities at plank impact

The evaluation of results determined that the peak localized pressures experienced by the barrier occur right after the moment of initial impact with the water. The peak pressure of 38.8 kPa is near the bottom at the surface of the incoming water. Although the overall load on the barrier increases with rising water level, the local pressures dissipate. There is a local peak load on the barrier at 32.53 s due to an incoming wave.

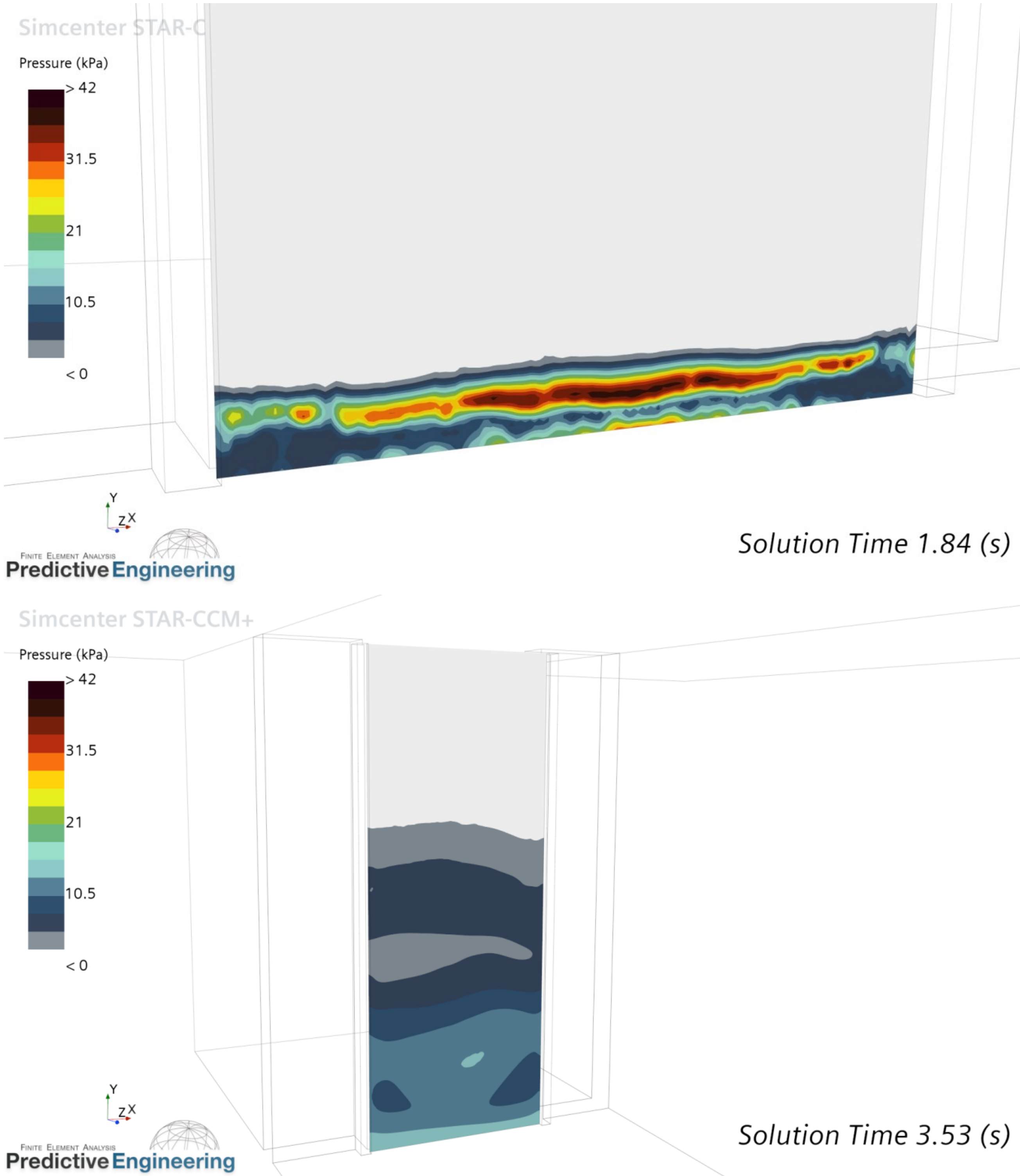



**Figure 7:** Plank pressures during 2 ft/s flow inrush

### 4.2 FEA Evaluation Results at 2 ft/s In Rush

At 1.84 seconds (Initial Impact), the FEA analysis evaluates the barrier's structural response to the initial impact pressure, with a maximum von Mises stress of 17.1 MPa, as shown in Figure 8.

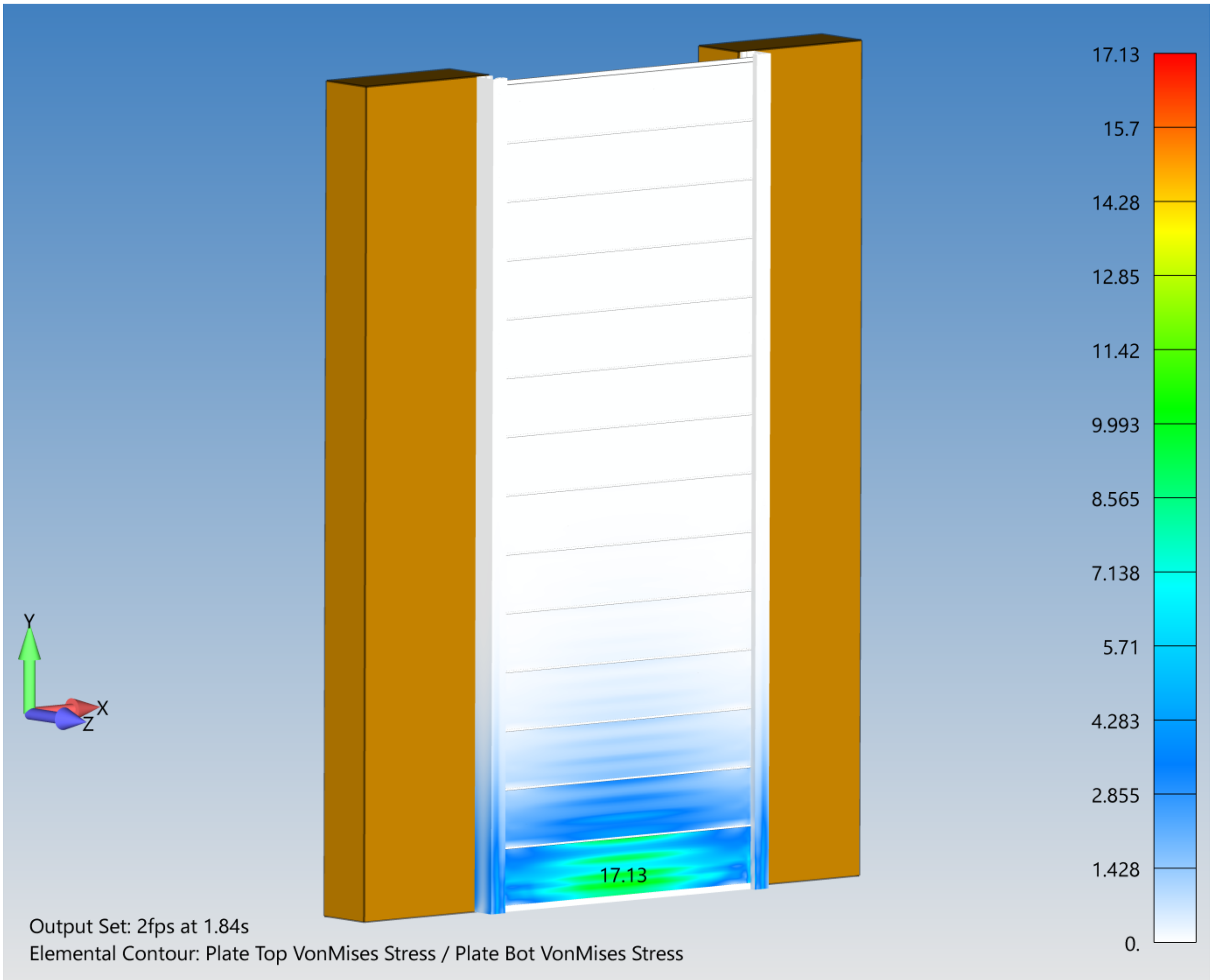



**Figure 8:** Maximum von Mises at the initial impact

At 3.53 seconds (water risen), the maximum von Mises stress of 28.3 MPa, influenced by the elevated water pressure, is shown in Figure 9. This stress is about 20% of the material yield strength for 6063-T6 aluminum.

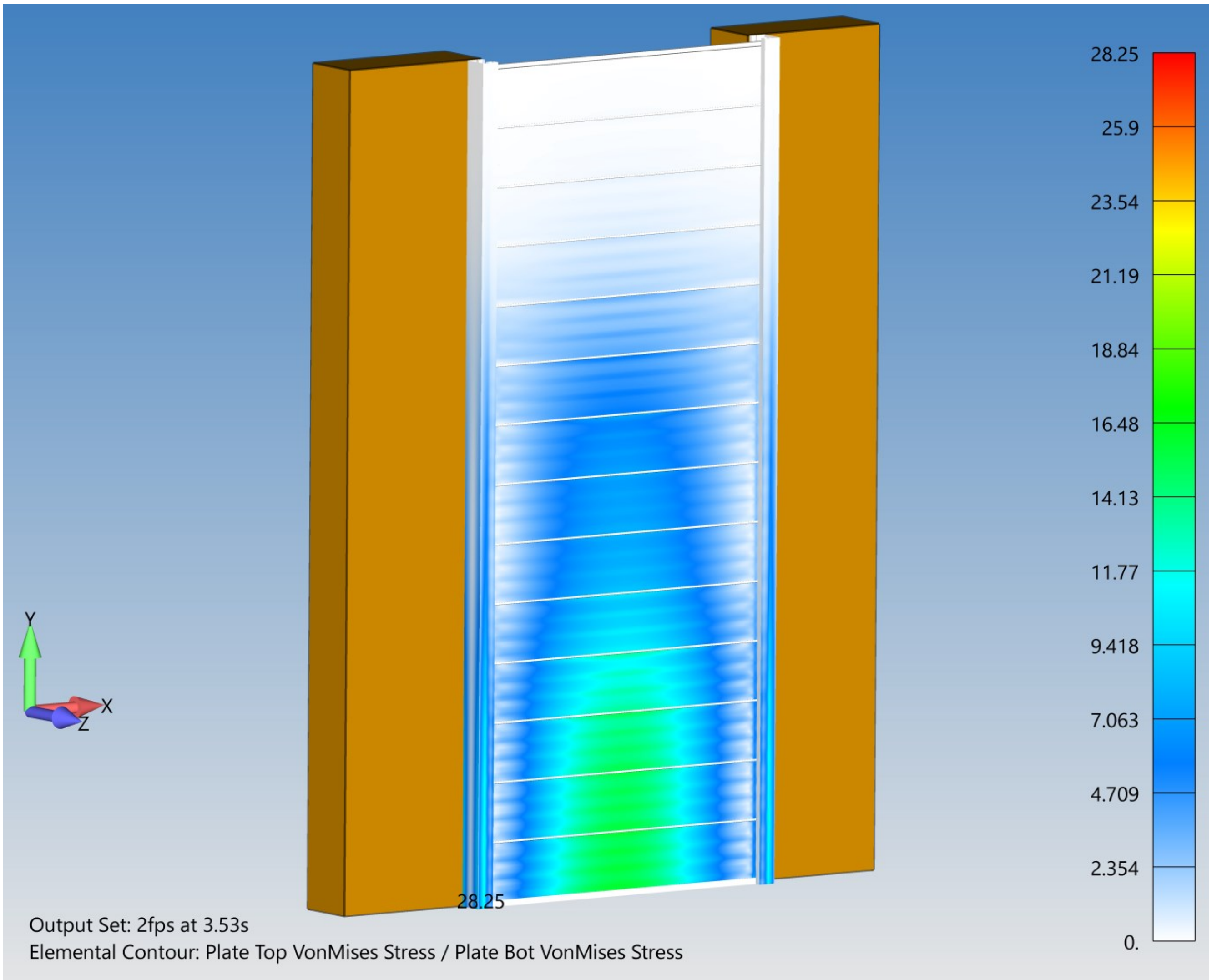



**Figure 9:** Maximum von Mises stress at 3.53 s.