D5.3c Survival Test Report

Focused report compiling tank test data and numerical models, encompassing input conditions and resulting mitigation data for each finalist concept.

This “survival test report” summarizes the key tank test data, numerical model results, input test conditions (both numerical and tank testing), and crosses these items with three designs of the APEX wave energy converter. The baseline design of APEX is included, in addition to a minimalistic caisson design (aka “the skeleton”), and variations of the APEX design where elevation off of the seabed is achieved. In general, sediment transport mitigation is a trade-off with other design factors, for example: while a minimalistic caisson helps reduce local scour for many wave conditions, it comes at a cost for bag connection failure/weakening.

Input conditions:

Various design concepts (includes baseline APEX; skeleton caisson; tapered/ravioli shaped caisson; spherical caisson; skeleton framed APEX; stilts providing elevation; suction piles providing elevation. Note, only three designs (APEX, skeleton, and “stilts”) made it to the final round of larger scale physical testing.

WEC orientation relative to incoming waves. Numerical modeling included 0, 30, 45, 60 and 90 degrees, while tank testing only included 0, 30 and 60 degrees.

WEC elevation relative to seabed. Many tests were done with the WEC sitting on the sandy bottom, but some were done at elevations of 1, 5, 10, 15 and 20cm.

Wave condition / climate. Generally, waves were explored that were relevant to the 2014 deployment wave climate. Four wave regimes were selected. The following are the scaled down version for testing at the Hinsdale Wave lab:

wave	H (cm)	T (s)	U_m (cm/s)	KC (D = 5cm)	Representative conditions
1	30	3.6	21	15	2014 typical operation
2	30	5.8	25	30	2014 deployment, “regime IV”
3	60	3.6	41	29	local storm
4	60	5.8	45	57	winter storm

Table 1. Four wave regimes tested in physical tests at HWRL.

Design concepts:

Early on, as a part of this project, many design concepts were sketched, and discussed between M3 Wave, and our collaborators from Sandia and NREL. The most promising “WEC alteration/ improvement” designs were culled to create the following three key designs:

1. *APEX baseline*. This was not novel, but served as a scaled replica of the 2014 ocean deployed WEC, and provided the “typical” sediment transport baseline data.

2. *Skeleton*. This WEC was similar to the APEX WEC in all manners except the completeness of the caisson. The caisson was reduced to a minimalistic set of structures that could contain the bags in the vertical direction, but offered very little bag protection or restraint in the x-y plane. One obvious advantage of this design is that it allows water to pass through the WEC with less redirection near WEC surfaces.

3. *Stilts*. This WEC is very similar to the baseline APEX WEC. However, there are two methods that this was implemented: one used integral suction pile threaded fittings at the corners of the WEC frame; the other used a lift frame that sat above the WEC, and allowed it to be lifted from above—thus, allowing the team to separate WEC elevation effects on scour from the effects of the stilts.

Results: tank scour results side by side with numerical modeling predictions:

- Waves 1-4, APEX (baseline, 0cm, 0°)

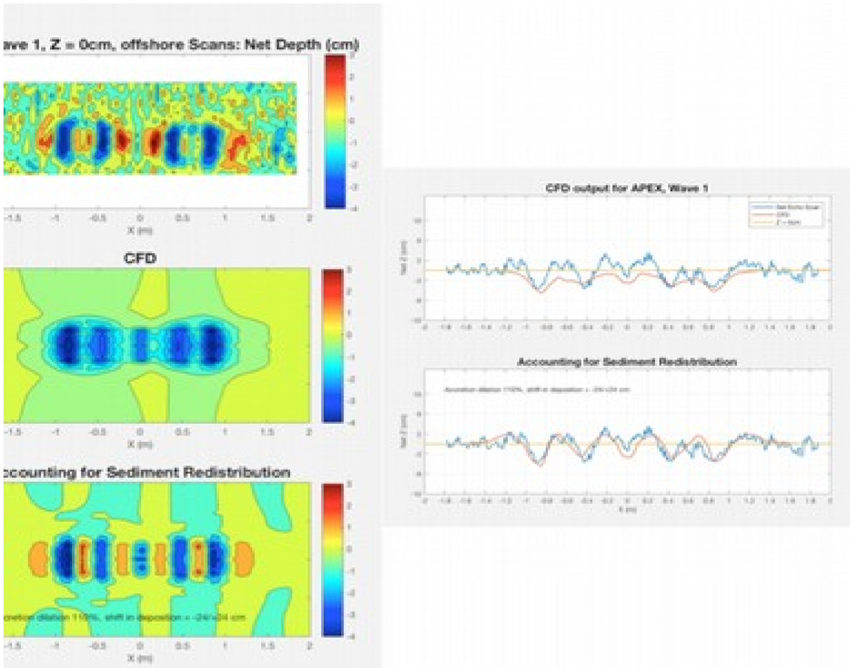

FIGURE 1. WAVE 1 CONDITIONS. CFD SIMULATION OF APEX (BASELINE), RAISED 0CM AND ORIENTED AT 0 DEGREES.

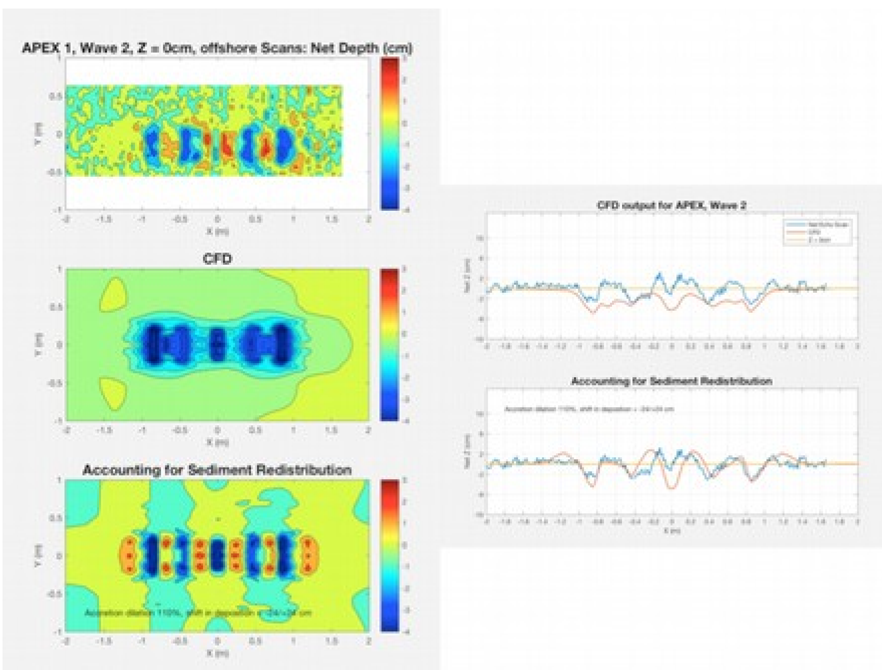

FIGURE 2. WAVE 2 CONDITIONS. CFD SIMULATION OF APEX (BASELINE), RAISED 0CM AND ORIENTED AT 0 DEGREES.

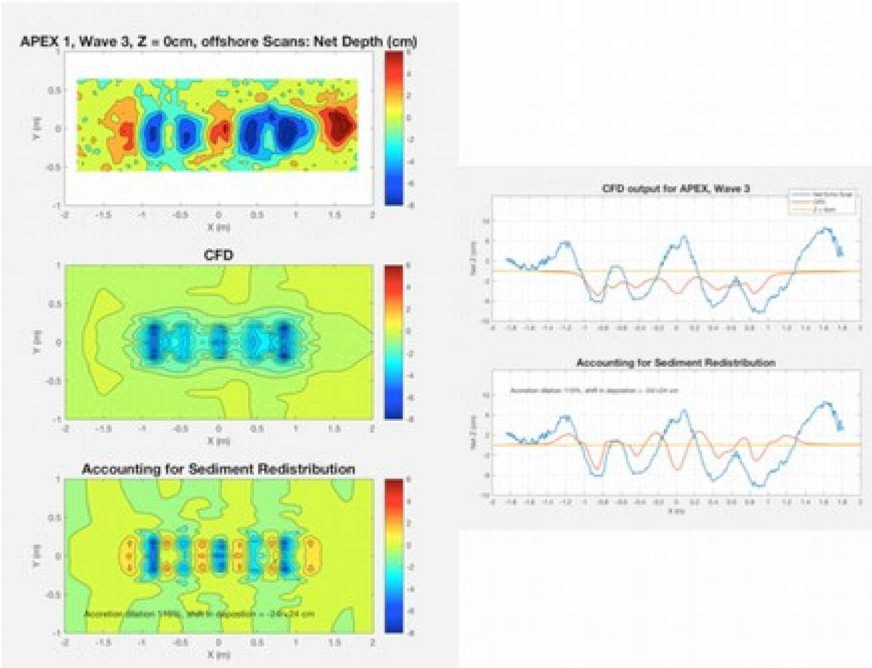

FIGURE 3. WAVE 3 CONDITIONS. CFD SIMULATION OF APEX (BASELINE), RAISED 0CM AND ORIENTED AT 0 DEGREES.

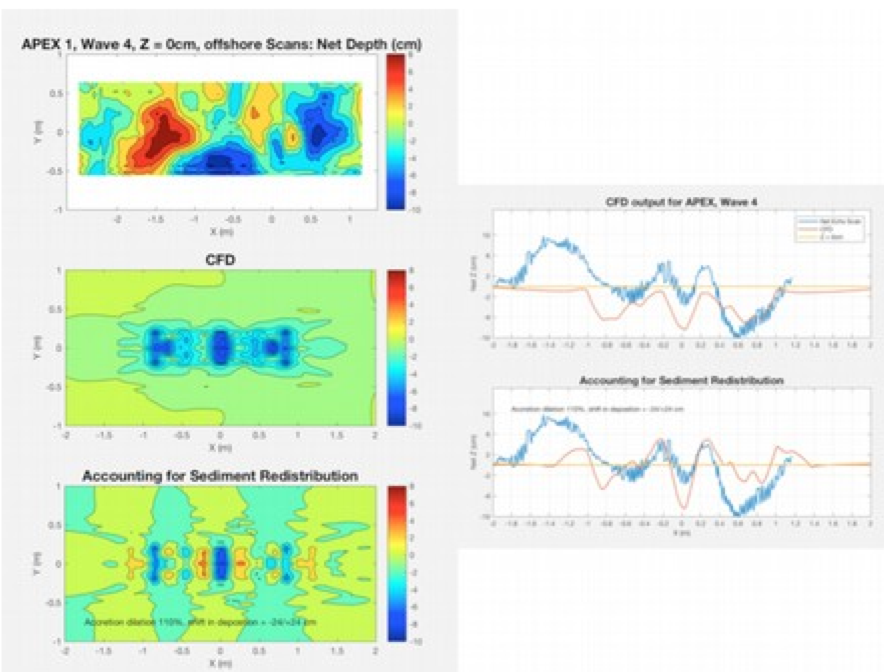

FIGURE 4. WAVE 4 CONDITIONS. CFD SIMULATION OF APEX (BASELINE), RAISED 0CM AND ORIENTED AT 0 DEGREES. NOTE IN TOP LEFT PANE THAT WAVE-INDUCED SHIFTING OF DEVICE AWAY FROM CENTERLINE ORIENTATION OCCURRED DURING EXPERIMENTAL TEST.

- Waves 1 and 3 (APEX default, 0cm, 0^{o})

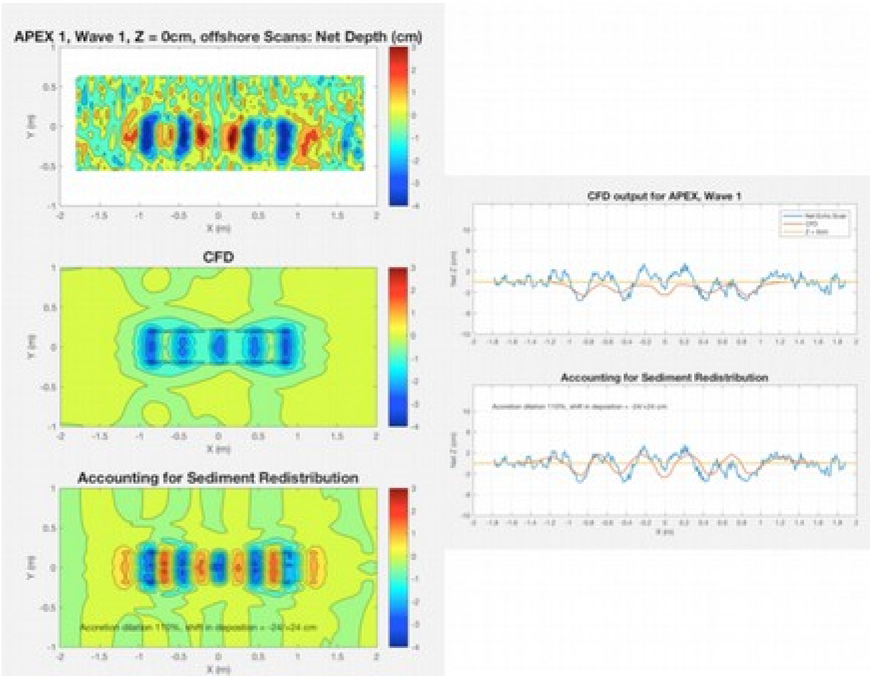

FIGURE 5. WAVE 1 CONDITIONS. CFD SIMULATION OF APEX (DEFAULT), RAISED 0CM AND ORIENTED AT 0 DEGREES.

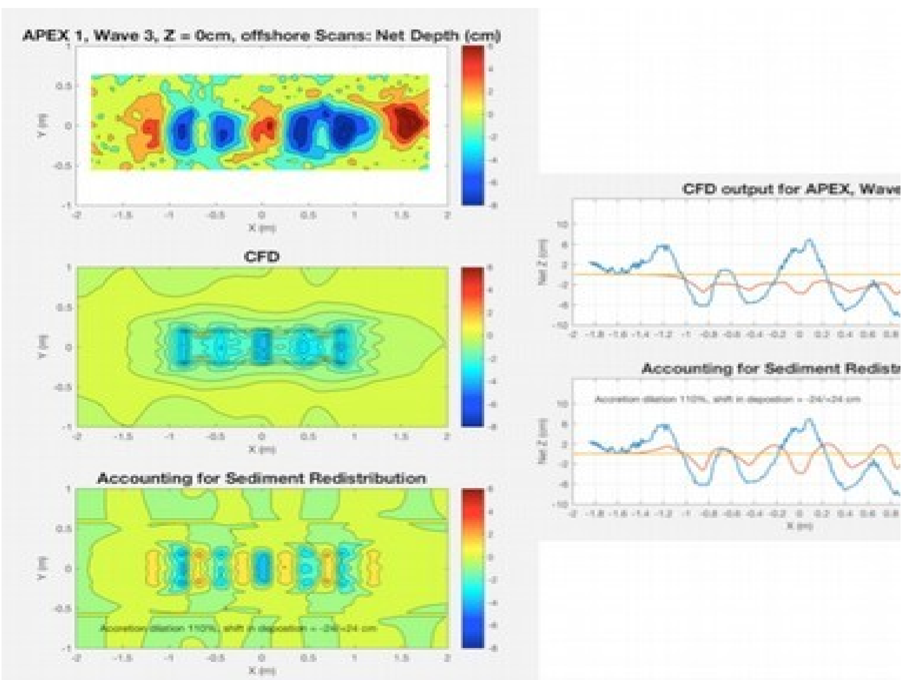

FIGURE 6. WAVE 3 CONDITIONS. APEX (BASELINE VERSION).

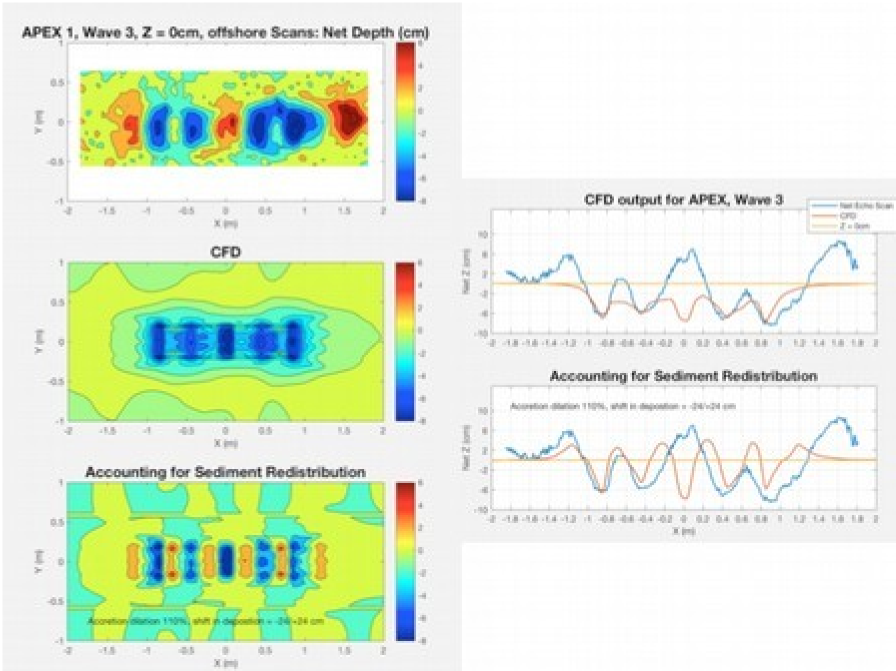

FIGURE 7. WAVE 3 CONDITIONS. CFD SIMULATION OF APEX (BASELINE), RAISED 0CM AND ORIENTED AT 0 DEGREES. CFD RESULTS SCALED UP BY A FACTOR OF 2.

B. Effects of Geometry

- Comparison of APEX with lift frame (left) and APEX baseline version (right), Wave 3 conditions, 0cm, 0°

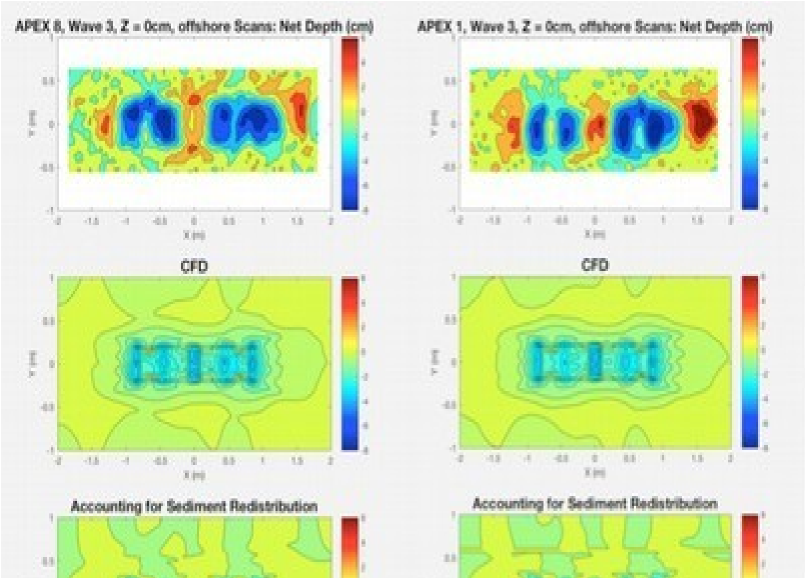

FIGURE 8. WAVE 3 CONDITIONS. LEFT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (LIFT FRAME). RIGHT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (BASELINE). FOR BOTH SIMULATIONS, DEVICE RAISED 0CM AND ORIENTED AT 0 DEGREES.

- Comparison of Skeleton (left) and APEX baseline version (right), Waves 1 and 3, 0cm, 0^{o}

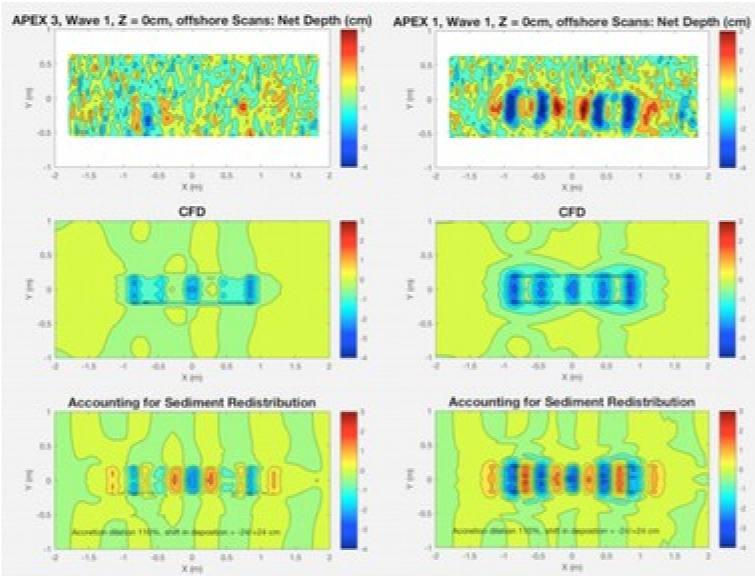

FIGURE 9. WAVE 1 CONDITIONS. LEFT PANELS : MEASURED DATA VS CFD SIMULATION OF SKELETON. RIGHT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (BASELINE). FOR BOTH SIMULATIONS, DEVICE RAISED 0CM AND ORIENTED AT 0 DEGREES.

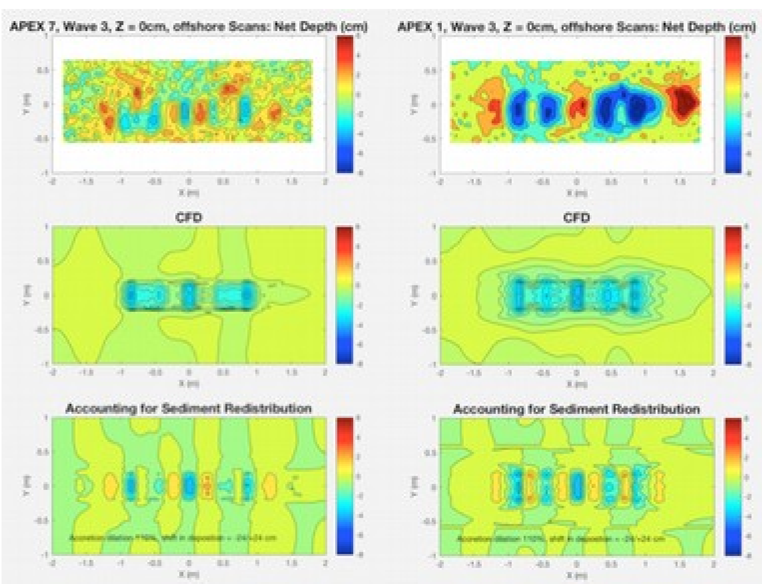

FIGURE 10. WAVE 3 CONDITIONS. LEFT PANELS : MEASURED DATA VS CFD SIMULATION OF SKELETON. RIGHT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (BASELINE). FOR BOTH SIMULATIONS, DEVICE RAISED 0CM AND ORIENTED AT 0 DEGREES.

C. Effects of elevation

- o Comparison measured vs model predictions for elevations of 0cm, 7cm, and 15cm. APEX with lift frame, Wave 1 conditions, 0°

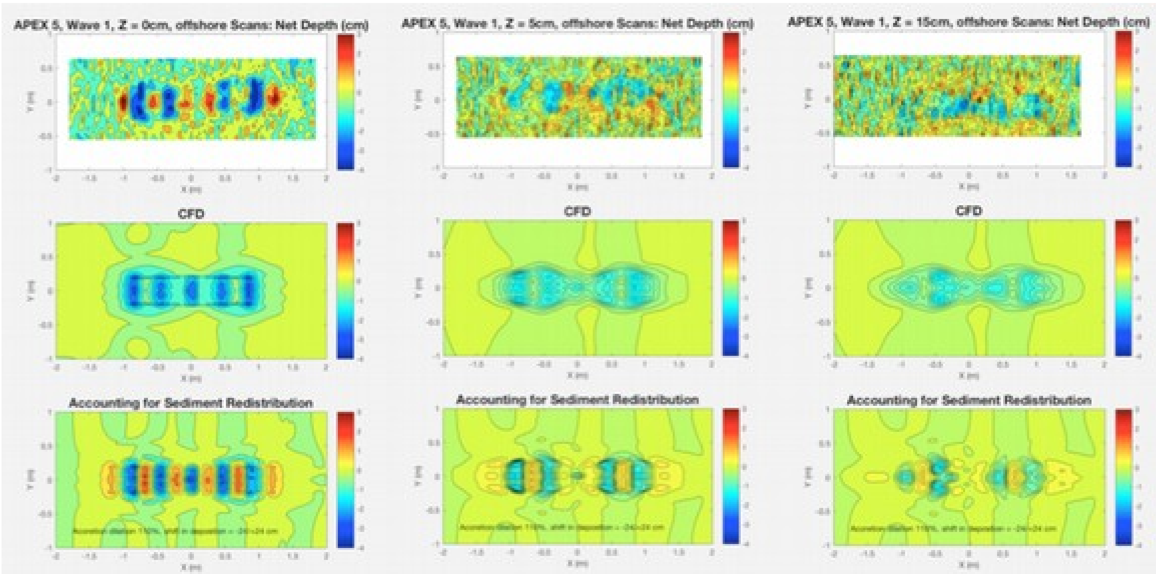

FIGURE 11. WAVE 1 CONDITIONS. LEFT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (BASELINE). CENTER PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (WITH LIFT FRAME) RAISED 7CM. RIGHT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (WITH LIFT FRAME) RAISED 15CM.

D. Effects of Orientation

- Comparison measured vs model predictions for 0, 30°, and 60° orientations. APEX (baseline), Wave 1 conditions, raised 0cm

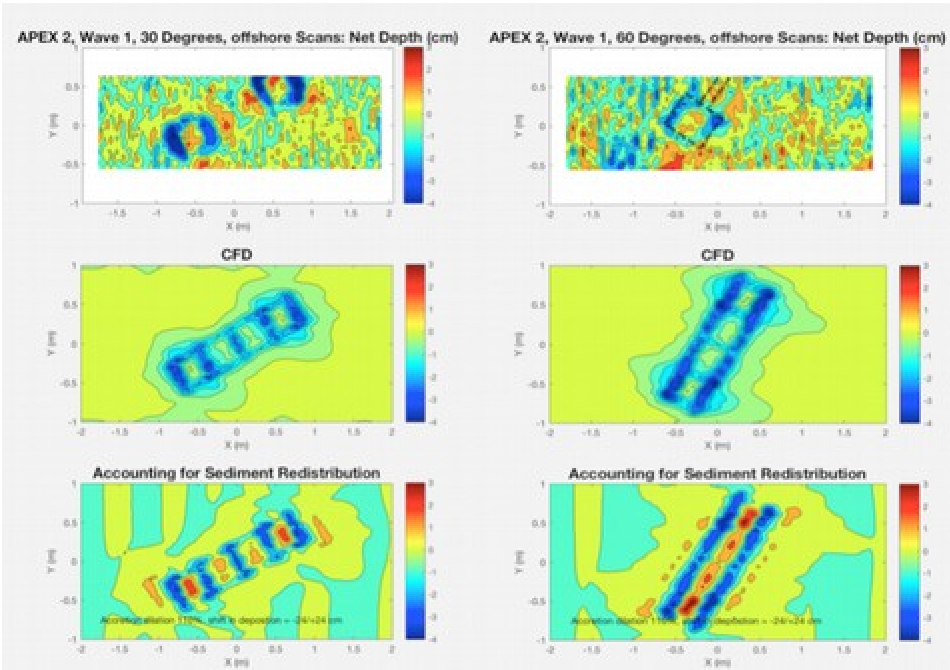

FIGURE 12. WAVE 1 CONDITIONS. LEFT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (BASELINE) RAISED 0CM, 30 DEGREES. RIGHT PANELS : MEASURED DATA VS CFD SIMULATION OF APEX (BASELINE) RAISED 0CM, 60 DEGREES.