THE EFFECT OF REEF GEOMETRY ON BREAKING WAVE SHAPE. COMPUTATIONAL AND FIELD DATA COMPARATIVE STUDY.

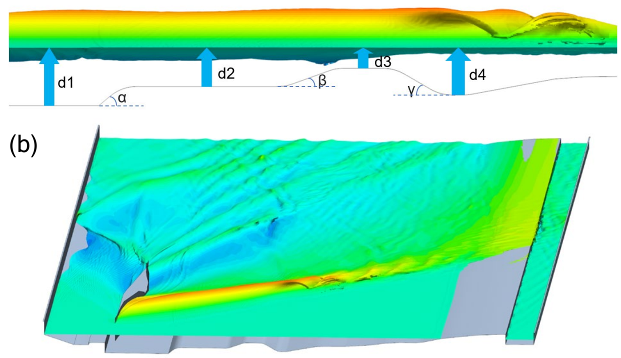
Adam Fincham, Kelly Slater Wave Company, World Surf League, University of Southern California, adam@kswaveco.com
Michal Pieszka, Kelly Slater Wave Company, World Surf League, michal@kswaveco.com

ABSTRACT
Detailed investigation, accurate Computational Fluid Dynamics (CFD) modeling and understanding of surf-zone processes are essential for recreating world-class surfing wave conditions. Parametric studies of different reef shapes have been carried out to analyze the effects on the barrel vortex ratio for a solitary-type wave. The computational models are based on the Volume of Fluid (VOF) method and are compared against field data from the WSL Surf Ranch facility in Lemoore, CA. Results from these studies highlight the importance of reef shape and have implications to the quality of surfing experiences in both coastal regions and artificial wave environments.

1. INTRODUCTION
With growing demand for inland surfing and interest in artificial surf reefs, CFD methods supplemented with field data constitute an effective tool that allows for analysis, optimization, and verification of the design performance of surfing waves. Bringing surfing to non-coastal areas provides big opportunities for a new market. This led to formation of a new sub-genre of hydrodynamics engineering, where one is looking at transformation of shallow-water waves through a slightly different lens. In classical coastal engineering, wave characteristics can affect various design conditions of certain structures - however, in the following case, one is looking specifically into analysis, optimization, and verification of design performance of the surf-zone wave itself, i.e. its *surfability aspect*. This presentation provides a high-level overview of the scientific process behind the creation of the Kelly Slater's Wave Pool in Lemoore, CA.

2. RESEARCH METHODOLOGY
The concept was founded on formal scientific investigation. The research was conducted using analytics, laboratory-scale and CFD models. Series of tests have been carried out to identify the most optimum wave generation mechanism that produces a solitary-type wave with the largest amplitude for a given water depth and offers direct transfer of energy to a propagating wave with minimum energy loss. A CFD Finite Volume Unsteady Turbulent Moving-Mesh model with Adaptive Mesh Refinement was used. The model was based on Reynolds-Averaged Navier-Stokes equations, using K-Epsilon turbulence model, which provides a good compromise between robustness, computational cost and accuracy. To model the free-surface, the Volume of Fluid (VOF) model was used - a well-known multiphase model based on an interface-capturing method. For better quality of the free-surface results, the VOF model was coupled with a Higher Order Differencing Scheme to get better fidelity of the results at the free surface. Some of the fundamental CFD research cases were computed in collaboration with the University of Southern California, Advanced Research Computing Center. Parametric studies of different reef shapes have been carried out to analyze the effects on significant surfing wave quality aspects for the solitary-type wave, e.g.: barrel vortex ratio, rotation angle of the overturn, wave height at the breaking point, wave peel angle, wave steepness, skewness, asymmetry, wave shoulder width, and downline velocity.

(a)



(b)

Figure 1 - Example CFD Moving-Mesh model results: effect of a reef geometry with high non-linearity on breaking wave shape. (a) Front view of the wave (looking at the wave straight offshore), parallel projection. (b) Trimetric view of the wave, parallel projection. Still water level (SWL) at first shelf *d1*, reef gradient *α*, SWL at second shelf *d2*, reef gradient *β*, SWL at third shelf *d3*, reef gradient *γ*, SWL at fourth shelf *d4*.

High confidence in the research findings on the effect of reef geometry on breaking wave shape based on high correlation between analytics, laboratory-scale and CFD models led to the final design and implementation of the full-size facility in Lemoore.

3. RESULTS AND DISCUSSION
After implementation of the full-size facility, a strong qualitative and quantitative correlation was observed between the field measurements and the laboratory and CFD studies. The CFD results are in excellent agreement not only when it comes to simulating the wave breaking and splash-up of the overturning jet, but also wave damping and energy dissipation in the basin. The parameters that control the wave were optimized in-situ for the ultimate surfing experience. For each bathymetry section, the shape of the CFD breaking wave is in good agreement with the full-scale prototype data. This provides confidence that this model constitutes an effective tool, allowing for analysis, optimization, and verification of the design performance of surfing wave systems.