IMPLICATIONS OF CORAL REEF MINING PITS ON 2D HYDRODYNAMICS

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INTRODUCTION

Small Island Developing States (SIDS) are among the most vulnerable areas to the impact of natural hazards and climate change. Flooding due to storm surges and extreme waves, coastal erosion, and salinization of freshwater lenses are already a serious threat and could lead to irreversible consequences in the coming decades. On the other hand, reef flat mining is one of the most common practices to source the required material for the implementation of coastal protection measures on SIDS. There are strong concerns about this practice, because partial removal of the protective reef could increase wave impacts on the islands. However, the available data and knowledge on the effects of these mining pits are currently very limited.

Klaver et al. (2019) studied the effects that pits may have on nearshore hydrodynamics and wave runup. Results obtained via numerical modeling indicate that excavation pits cause a decrease in infragravity wave energy around the fundamental mode of the reef, which is partly caused by reduced wave transmission. Similarly, changes in sea and swell (SS) wave energy are attributed to reduced transmission, as well as a decrease in wave dissipation and (triad) wave-wave interaction. Earlier studies by Ford et al. (2013) and Yao et al. (2016) point out that mining pits may lead to additional two-dimensional effects.

In this presentation, we present the potential 2D effects of reef flat excavation pits on nearshore hydrodynamics. More specifically, we aim to assess the impact of excavation pits on nearshore circulation patterns, which could be an indicator of coastal morphological changes.

METHODOLOGY

The open-source numerical model XBeach non-hydrostatic+ (XBnh+) was used to simulate the nearshore hydrodynamic processes. The non-hydrostatic model (XBnh) solves the equations of horizontal momentum and mass conservation which resolve both motions in the SS and IG band. An extra virtual pressure layer in the vertical improves the frequency dispersion relation (XBnh+). This allows for steeper bathymetric gradients, such as fore reef slopes and excavation pit walls.

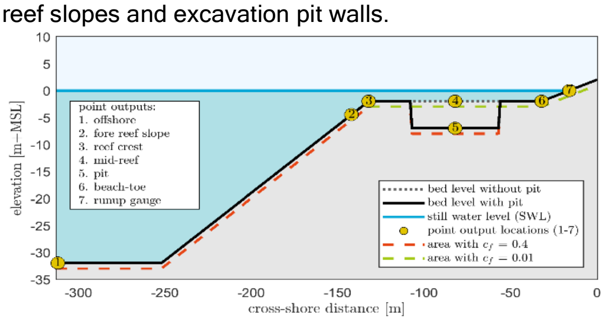

Figure 1 Reef schematization and model setup (with and without the presence of the pit). The numbers indicate the locations of the output points.

The model was set up based on a schematic cross-shore fringing reef (see Figure 1). A distinction is made between the hydrodynamic roughness of the fore reef and reef flat, due to characteristic differences in coral reef structure. The depth of the excavation pits was based on measurements by Ford et al. (2013). The wall slope was chosen as 5:1. A minimum grid size of $\Delta x = 0.25$ m was used to give reliable wave runup results. The bathymetry of the cross-shore transect is uniformly extended in the longshore direction to obtain the 2D model. The boundary is forced by a JONSWAP spectrum with daily swell waves and includes directional spreading.

PRELIMINARY RESULTS

The results of this 2D model show that there is a spatial variation of significant wave height around the excavation pit (Figure 2a) and a variation in mean surface elevation (Figure 2b). The changes (decrease) in significant wave height at the onshore side of the excavation pit result in a longshore varying wave-induced setup. Shoreward of the excavation pit, the resulting (longshore) mean water level gradients generate a mean depth-averaged current (Figure 2b). These currents result in a net offshore directed depth-averaged flow over the pit. This flow pattern may have a direct effect on the sediment dynamics over the reef flat, with the pit acting as a sediment trap for the alongshore sediment transport. 1D model results suggest that this is a generic effect, as pits cause a decrease in mean water level at the beach-toe in nearly all reefs (Klaver et al., 2019). Moreover, model results indicate that the alongshore impact of the pit may be significantly larger than the extension of the pit itself.

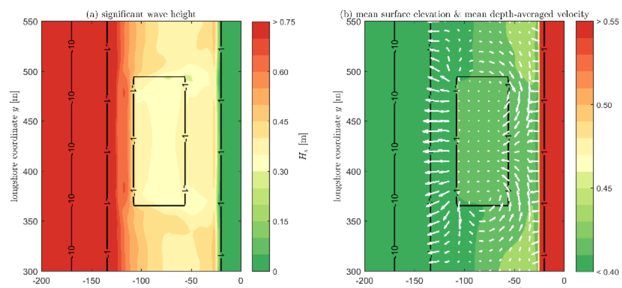

Figure 2 - Variation of (a) significant wave height and (b) mean water level and currents over an excavated reef flat

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