Attenuation of Waves Across Living Shoreline Sills

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INTRODUCTION

Through a combination of human development, sea-level rise (SLR), and increased frequency and intensity of storm events, coastal change has been exacerbated, threatening the stability of shoreline environments and their associated ecosystem services world-wide. Shoreline stabilization has, in turn, become increasingly important, and many are now looking to "living shorelines" as an erosion-mitigation strategy. Typical living shoreline installments include aquatic vegetation and a submerged breakwater or sill made of hard structures such as oyster reefs or rock material. Sills attenuate wave energy before the wave ever reaches the shore by inducing breaking and through dissipation due to friction.

Here, the validity of a model of wave energy dissipation based on the conservation of energy flux has been analyzed, using data from three living shorelines (denoted PKS, JR, and ML) located along the coast of North Carolina with varying sill structures. This study evaluated and optimized representations of wave breaking and friction within the model to improve the representation of sill features in the model given different incident wave characteristics. The results of this study will ideally aid in the evaluation and design of living shorelines and direct future research of wave energy dissipation across bottom topography.

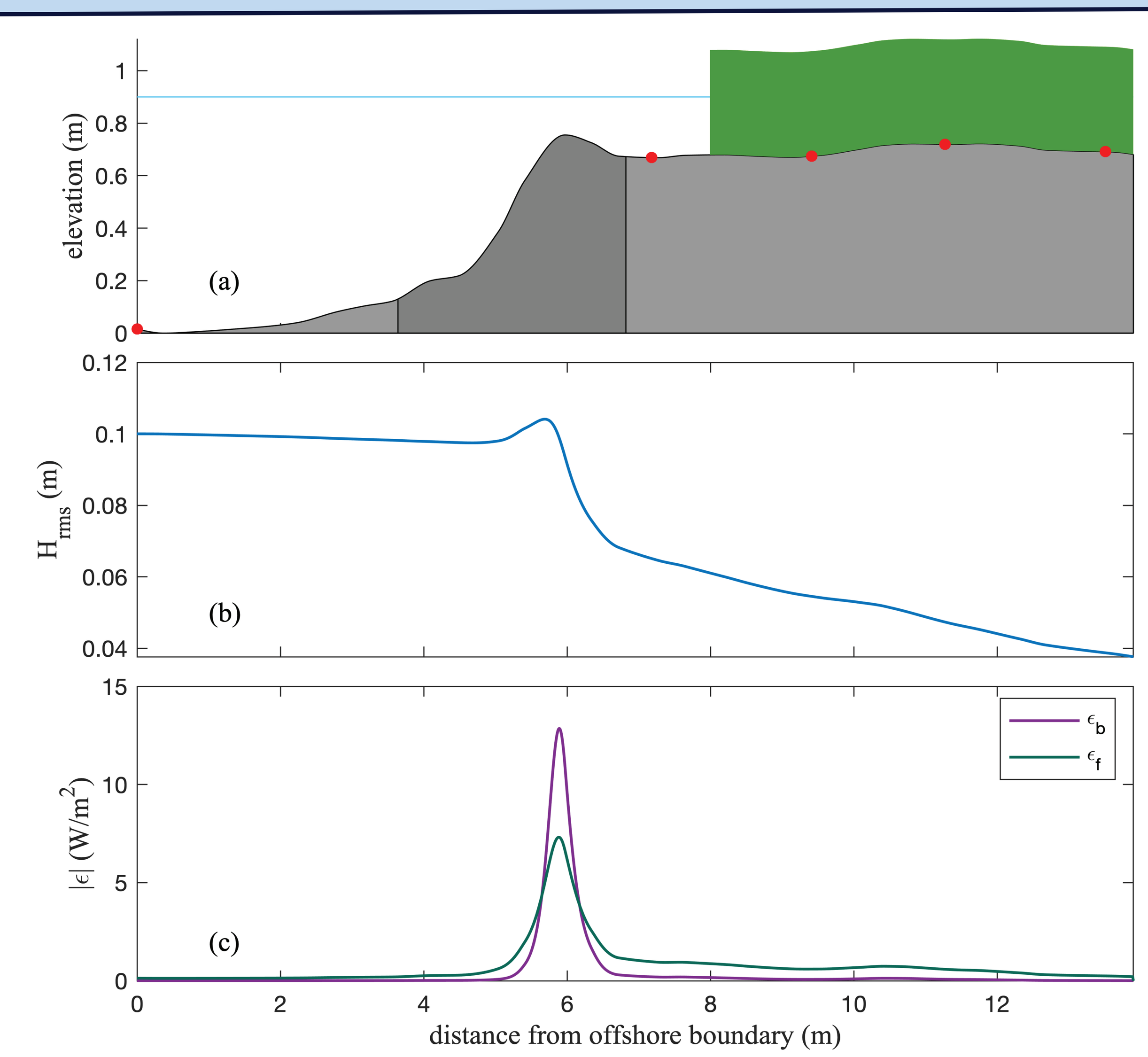

Figure 1: The elevation profile (a), the model-predicted wave height evolution (b), and the magnitude of dissipation by wave breaking (purple) and bottom friction (green) (c) for a sample run of the model. The blue line in the top panel depicts the water depth used in the model run. Pressure sensors are denoted as red points. The location of the sill has been shaded. Green shading is used to indicate the vegetated portion of the living shoreline.

OBJECTIVES

1) Analyze various sill designs' ability to dissipate wave energy
2) Evaluate a 1-D model's ability to characterize wave attenuation across sill features
3) Optimize the model to aid in the evaluation and design of living shorelines

MODEL

$$\frac{\partial(Ec_g)}{\partial x} = -(\varepsilon_o+\varepsilon_b+\varepsilon_f)$$

ε_o : dissipation by obstacles

ε_b : dissipation by wave breaking

ε_f : dissipation by bottom friction

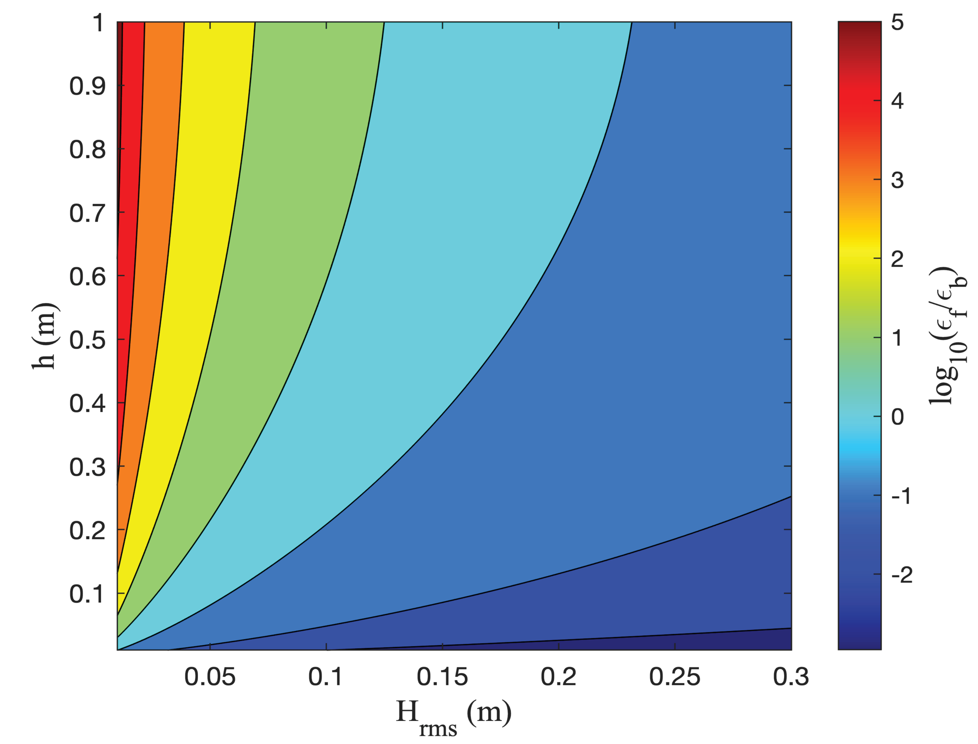

Figure 2: Model-predicted ratio of dissipation due to bottom friction to dissipation due to breaking for different wave height and water depth combinations. Waves in this study primarily fall in the range Hrms 0.004 – 0.16, h 0.05 – 0.6.

RESULTS

The model captures wave attenuation across sills with a mean average error (MAE) less than 1 cm at all sample sites (Fig. 3).

The model predicts wave breaking to dominate dissipation for nearly all wave conditions (Fig. 2). In order to increase the influence of friction for small waves, a new version of the model was created to treat the sill as an obstacle in the water column rather than just inducing friction along the bottom (model version 2).

Dissipation is under represented for small waves and over represented for large waves for both model versions (Fig. 4 b, e, h). Model version 2 increased agreement for large wave height to water depth ratios (where friction would be expected to play a larger role) but did not remove the general trend in error.

Removing trends in error will likely require parameters with dependency on wave conditions and sill characteristics that provide a more physically-realistic representation of dissipation occurring across the sill.

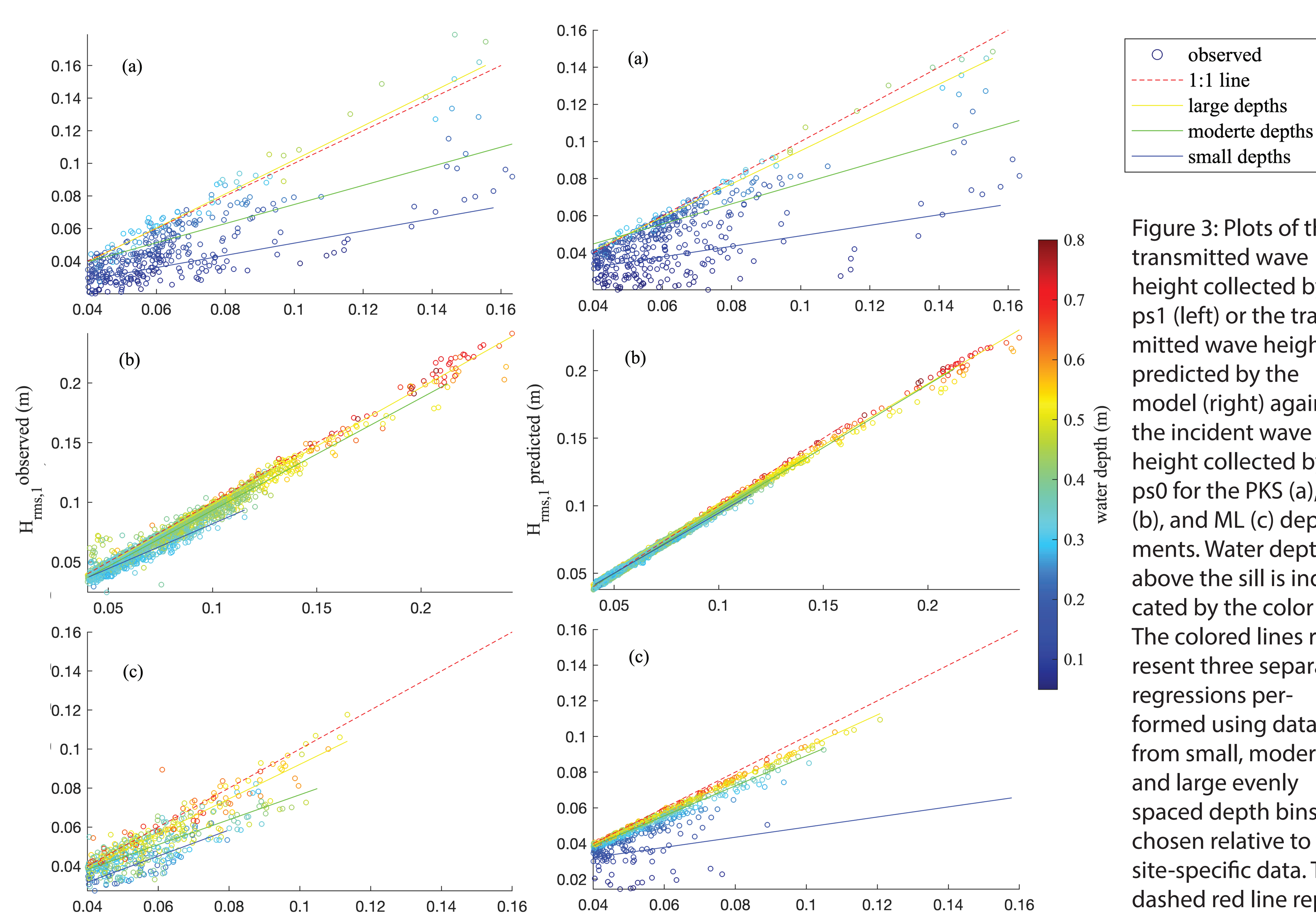

Figure 3: Plots of the transmitted wave height collected by ps1 (left) or the transmitted wave height predicted by the model (right) against the incident wave height collected by ps0 for the PKS (a), JR (b), and ML (c) deployments. Water depth above the sill is indicated by the color bar. The colored lines represent three separate regressions performed using data from small, moderate, and large evenly spaced depth bins chosen relative to the site-specific data. The dashed red line represents the 1:1 line.

METHODS

Five high-frequency pressure transducers (RBR Solo-Ds) were deployed along a single transect perpendicular to the shoreline with one offshore of the sill, one inshore of the sill, and three on the marsh platform (Fig. 1a).

In order to characterize wave attenuation across sill features, this analysis focused exclusively on the offshore pressure sensor (ps0) and the next sensor in the sequence, located landward of the sill (ps1). The wave height at ps0 therefore represents the incident (or initial) wave height, and the wave height at the location of ps1 represents the transmitted wave height.

By using the incident wave conditions collected by ps0 as the initial condition for the model and determining the predicted wave height at the location of ps1, direct comparisons can be made to evaluate model accuracy.

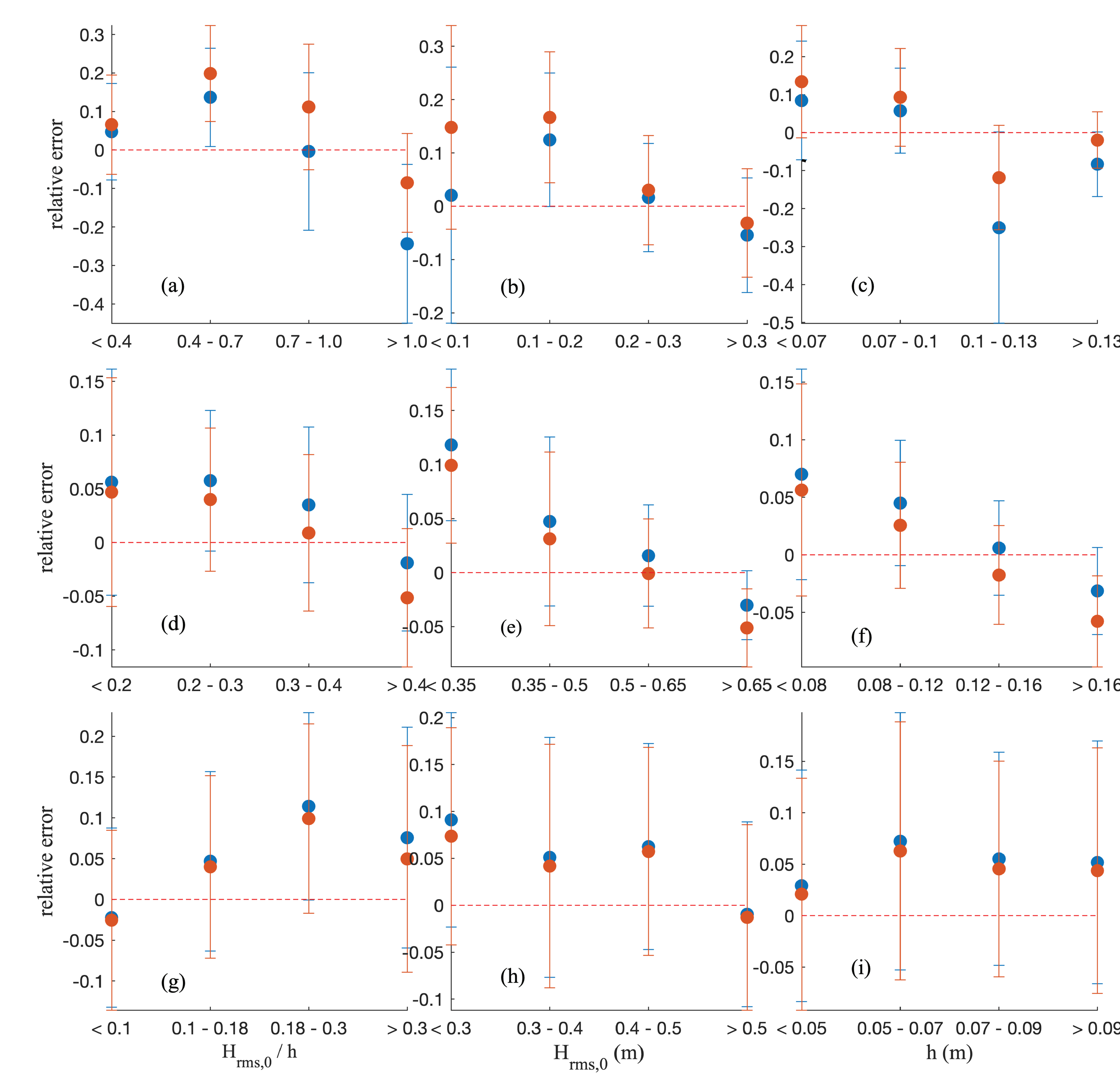

Figure 4 : Wave data was binned by wave height to water depth ratio (left), water depth (middle), and incident wave height (right) for the PKS (a, b, c), JR (d, e, f), and ML (g, h, i) deployments. For each bin, the average relative error was determined. The procedure was performed for both versions of the model. Version 1 is shown in blue and version 2 is shown in red. The red dashed line represents the line of zero error.

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