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Redesign of the Tutong River Training Walls

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ABSTRACT

The Tutong River entrance located on the central part of the Brunei coastline is causing navigational problems due to the existence of a sandbar obstructing the majority of the channel's opening. Training walls are constructed on both sides of the river entrance to direct and confine the river flow. The existing western training wall is damaged and the eastern one is filled to capacity by the westward littoral drift of sand. The sand is now bypassing the eastern training wall and causing the sandbar formation. The area down drift of the river entrance has suffered erosion due to the interruption of sediment supply from the eastern area up-drift of the entrance.

The Water Research Laboratory (WRL) of the University of New South Wales has provided specialist advice in the redesign of the Tutong River training walls to provide a better stabilization of the river mouth. In order to determine the location and length of the new training walls, several studies were completed. Wave modelling, littoral drift modelling and a sand bypassing model was implemented to determine the seaward extent and sand bypassing of the new walls. Hydrodynamic modelling was used to test several entrance configurations and dredging scenarios. Physical modelling was used to determine sizing of materials for the training walls and layout optimisation.

This paper will discuss the existing training wall issues and the modelling used by the WRL to help configure the new training wall configuration.

INTRODUCTION

The Tutong River is one of Brunei's main rivers with its estuary centrally located on the Brunei coastline. The existing training walls located at the mouth of the river have various problems associated with them. The interruption of the natural littoral drift by the eastern training wall has caused the formation of a sandbar that is extending across the river mouth entrance. The eastern training wall is filled to capacity and the sandbar continues to grow because the sand is now by-passing the training wall. This sand bar is causing navigational problems for anyone trying to enter. Due to the interruption of the littoral drift, the area down-drift of the river entrance is suffering erosion. The western training wall has also been damaged. The Water Research Laboratory (WRL) has provided specialist advice on how to redesign the training walls to alleviate these problems. They have various types of modelling to determine the new design which will be discussed in this report.

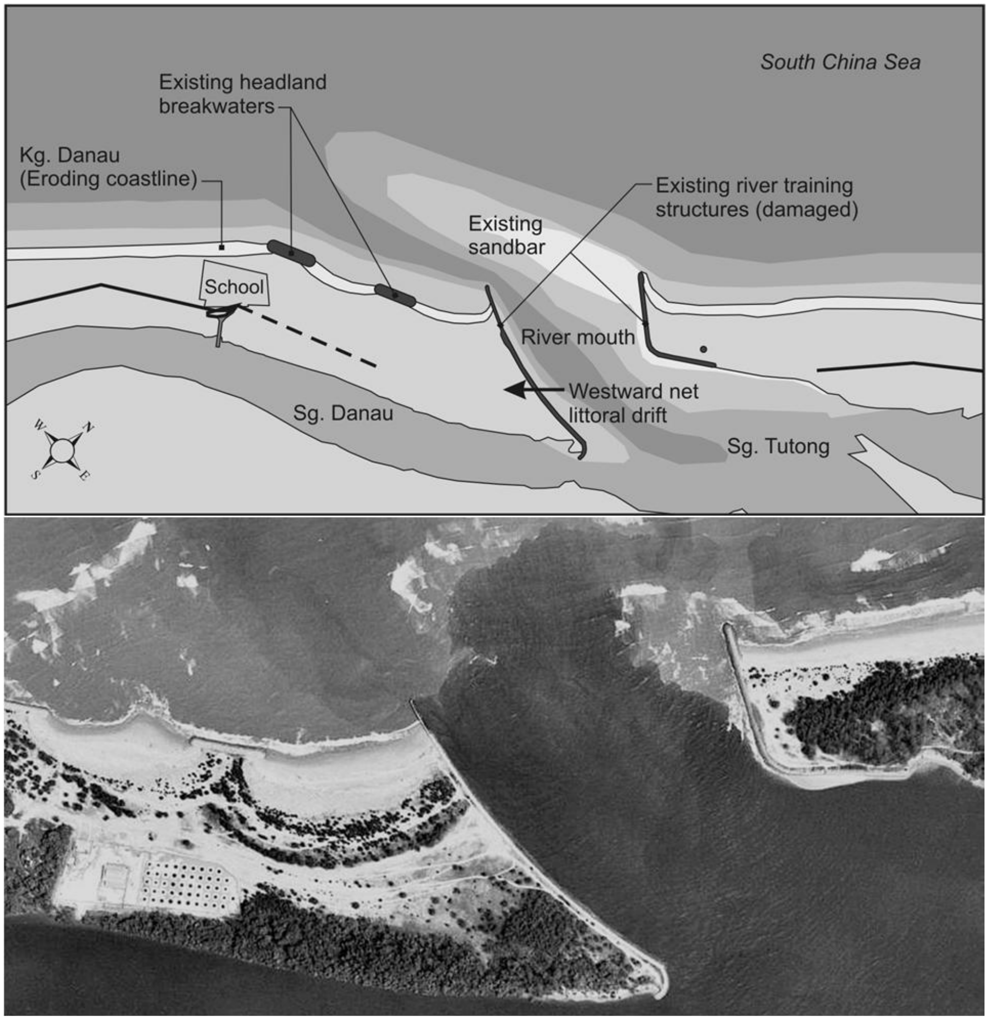

Figure 1 Aerial photo and schematic representation of Tutong River Entrance

WAVE TRANSFORMATION MODELLING

The WRL obtained a hind cast wave model from the National Oceanic and Atmospheric Administration of National Weather System. The modelling program they used to model this data was called Wave Watch- III. The dataset was for offshore waves over a period of twelve years. The data consisted of a time series of significant wave height, peak spectral wave period and mean wave direction at three hour intervals. The WRL analysed the data using a modelling program called SWAN to determine the near shore climate characteristic using the offshore water climate data. The near shore SWAN predictions were validated using wave measurements that were collected in several locations along the coastline. Figure 2 shown below shows the predicted significant wave height found using SWAN plotted against the measured values. The modelling allowed the WRL to generate wave roses which is a diagram showing the long-term distribution of wave height and direction. The diagrams that were generated can be seen in Figure 3. The diagrams show that the waves undergo reduction in wave heights and a general realignment parallel to the shores normal direction.

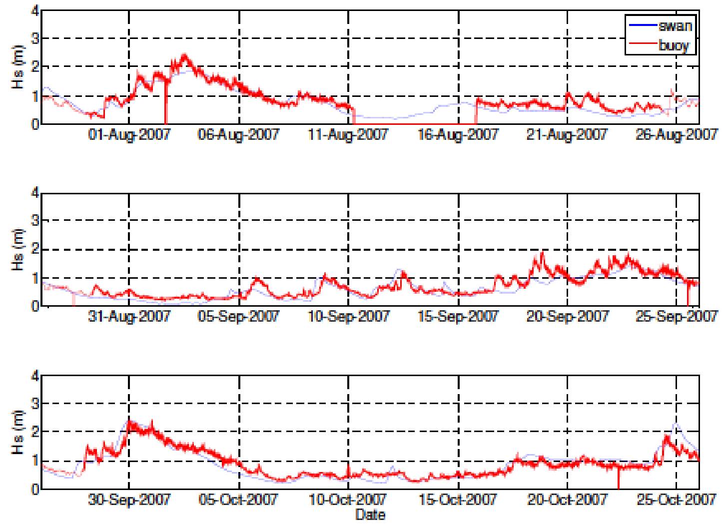

Figure 2 Predicted and Measured Hs at the Champion Shoals Location

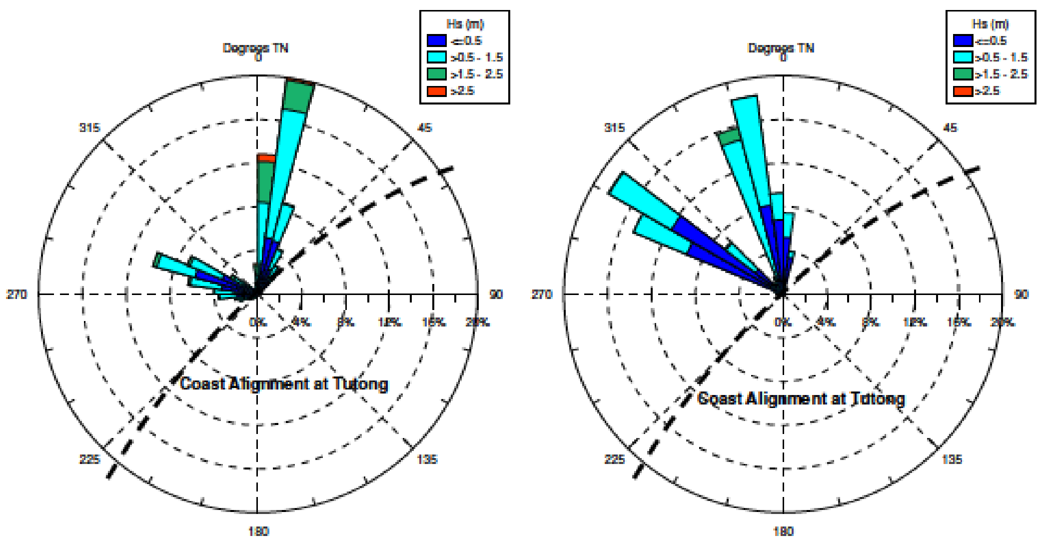

Figure 3 Offshore and Nearshore Wave Roses-Significant Wave Height

LITTORIAL SEDIMENT TRANSPORT

Littoral sediment transportation is a process by which waves and currents move sand cross shore and long shore in the surf zone. Long shore sediment transportation is responsible for the sand infilling and bypassing of structures. This process is described by annual or seasonal rates express in m^3 of sand moved per year. The long shore transport cannot be directly measured and is usually indirectly estimated through measures of sand impoundment at coastal structures and sand deposition in inlets and entrances when the data is available. The WRL did not use field measurements for determining the long shore transportation rates; instead they inferred the rates from the deep water wave data that was transferred to the near shore conditions. The WRL used the Kamphuis formula the wave heights, period and direction at three hour intervals that they obtained from the wave modelling and calculated the annual transportation rates. A mean net sediment transport towards the west of approximately 49,000 m^3/yr was estimated with 75,000 m^3 of sand being transported towards the west and 26,000m^3/yr towards the east. Previous studies that were based on field measurements estimated net littoral drift at the river entrance to be 30,000 to 50,000 m^3/yr westward which confirms the findings of the modelling.

SAND BYPASSING CURVES

The total sediment transport was then estimated by the WRL using the Kamphuis/Queens formula. Since sediment transport rates are not constant across the surf zones depending on the combined effect of wave breaking and long shore currents, the cross-shore distribution of the sediment transport rate was necessary. Bijker's sand transport model was used to obtain the cross-shore distribution of the sediment transport based on the total sediment transport rates determined from the Kamphuis/Queens formula. Bypass rates were then calculated for water depths from 0.5 to 3.5 m with 0.5m increments. The sand bypassing curves that were generated allowed the WRL to determine the required extension in length of the eastern and western training walls so that minimal sand would bypass the river entrance.

HYDRODYNAMIC MODELLING

In order to determine a conceptual design of the training walls, a hydrodynamic numerical model was established. The model was constructed and calibrated using site data that was collected during the WRL fieldwork campaign. The model is used to assess the potential impact the walls will have on scour, sedimentation and water levels. Several entrance configurations and dredging scenarios were tested using the calibrated model. The optimized design was to have the training walls perpendicular to the coastline as this minimised the training wall length and optimised the entrance navigability in relation to the winds, waves and currents.

This conceptual design showed though the hydrodynamic model that the entrance channel was predicted to consistently scour during ebb-tide. This would ensure channel accessibility and minimize dredging operations. Figure 5 seen below shows the two dimensional entrance flow paths during ebb and flood tide for the chosen training wall configuration.

Figure 4 Entrance flow paths during ebbing and flooding tide

PHYSICAL MODELLING

The WRL undertook the process of physical modelling to complete two objectives. They wanted to determine the sizing and configuration of the rock and concrete armour of the training walls; they also wanted to optimize the training wall layout in terms of wave penetration and navigability. Concrete and armoured stones where used in the quasi three dimensional testing. The hydraulic stability of the training walls head and trunk revetments were tested under oblique wave attack for the 1 in 100 year average recurrence interval (ARI) design event. For the Quasi three dimensional testing thirteen irregular wave tests were performed in the WRL three meter wave flume. Concrete units were used as the primary revetment instead of rocks due to the scarcity of rocks of suitable size on site. Head sections of the wall were tested using both antifer cube and hanbar options. The testing indicated that the wall heads should be armoured with 7.6t antifer cubes in order to meet the design criteria of less than 5% damage during the 1 in 100 yr ARI event. Although the hanbar units that were tested have a higher capacity and are less bulky than the antifer cubes they experienced excessive rocking motion during the testing. The rocking of the units could potentially cause breakage of individual units and overall loss of stability of the primary armour layer. A rigorous maintenance program would be needed in order to use the hanbar units.

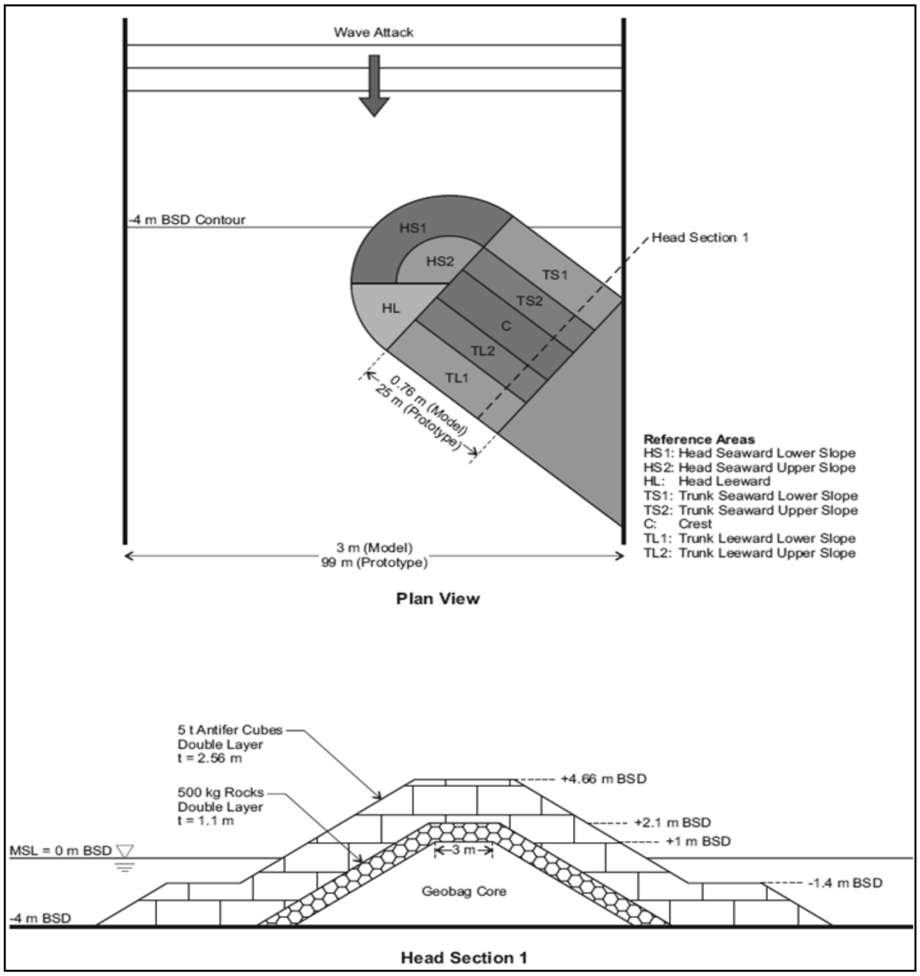

Figure 5 WRL Wave Flume Set up


Figure 6 An Example of Antifer Cubes (Left) and Hanbar units (Right)

The focus of the three dimensional testing was the characterisation of the wave climate within the entrance. The testing was completed in the WRL three dimensional wave basin. Wave height measurements were recorded at 11 locations offshore and within the entrance channel of the training walls. The walls were built protruding seaward perpendicularly to the shoreline with the eastern and western training walls measuring 600 and 230m long respectively and an entrance width of 280m (full scale dimensions). The tests showed that the proposed training wall alignment was considered optimised in terms of rubble mound structure lengths and navigability with prevailing winds, currents and waves. Wave penetrations showed that wave conditions inside the channel will remain mild during most of the operational conditions.

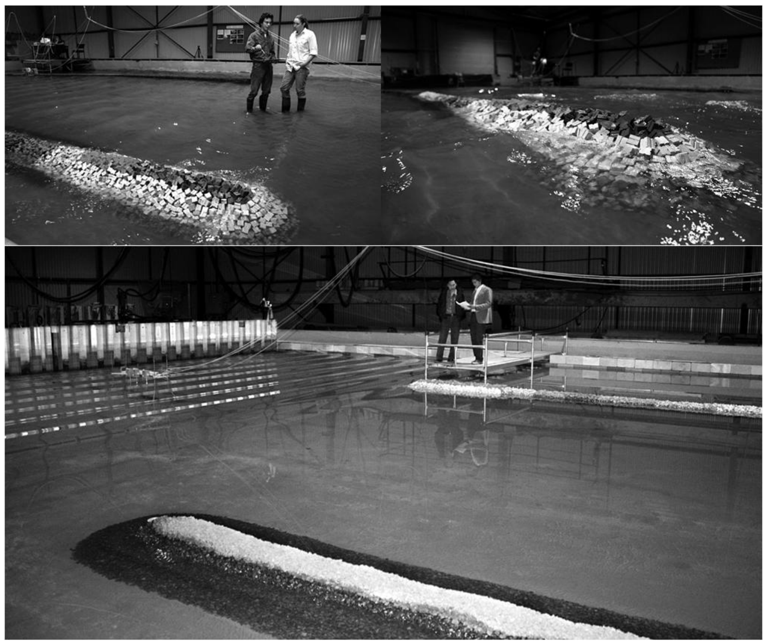

Figure 7 Three-dimensional testing of the Tutong training walls

CONCLUSIONS

The interruption of the natural sediment drift along the coast line caused the eastern training wall to fill to capacity with sand as well as cause the formation of a sandbar across the entrance. The WRL were asked to complete a conceptual design to replace the existing Tutong River entrance training walls. A methodology to estimate the littoral transport and sediment bypassing rates in the absence of field measurements was discussed in this case study. The WRL using state of the art coastal engineering methods along with field data collection, numerical and physical modelling were able to optimize the training wall design for minimum length, littoral sediment transport processes and flow conditions with the entrance.

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