UTM Faculty of Mechanical Engineering
UNIVERSITI TEKNOLOGI MALAYSIA

THE ENGINEER STORY

e-ISSN: 3009 - 0792 Volume 23, 2026, 8-11

FROM HULL TO RIVERBANK: DEVELOPING A SITE-SPECIFIC WAKE CRITERION FOR TOUR BOATS IN SUNGAI KILIM, LANGKAWI

Mohd Arif Ismail *
Department of Aeronautics, Automotive & Ocean Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.
* mohdarif.i@utm.my

ABSTRACT

Every tour boat in Sungai Kilim, Langkawi, leaves a wake that ends its journey on a mangrove riverbank. This story follows that wake from the hull to the bank. A pressure gauge on the main tour route recorded 286 boat wakes in one working day, with heights up to 175 mm and energy up to 528 J/m. Full-scale trials with the most common tour boat, an 8.23 m planing hull, showed that the wake is decided by how the hull is driven. Wakes stayed small below the 6.46-knot hull speed, peaked at 8.6 to 9.2 knots as the hull climbed its resistance hump, and dropped again once it planed. Water shallower than 2 m, a full load of ten passengers and two boats running together each made the wake much larger. Existing site data on bank retreat and bank strength were then used to set a wake the bank can tolerate: no higher than 45 mm and no more than 16 J/m at 12 m from the sailing line. For boat operators this means touring at high tide, holding about 6 knots on the critical stretch and never running side by side.

KEYWORD

Boat wake, planing hull, Froude number, wake criterion, mangrove riverbank

INTRODUCTION

Kilim Karst Geoforest Park, part of the Langkawi UNESCO Global Geopark, is one of the best-known mangrove tourism sites in Southeast Asia (Blanton et al., 2024). Visitors see it from small fibreglass boats that run from the Kilim jetty down the narrow, tidal Sungai Kilim (Figure 1). The banks along this route are eroding fast. Earlier field work at the same sites measured route banks retreating 22.8 to 45.5 mm per month, against 4.0 to 7.9 mm per month at control banks (Ismail, 2024).

For an engineer the questions are how much of that comes from the boats, and how the boats should be driven so that it stops. A moving hull pushes energy into the water as a train of waves. How much it pushes depends on its speed relative to its waterline length ($Fn_l = V/\sqrt{(gL)}$), to its displaced volume ($Fn_\nabla = V/\sqrt{(g\nabla^{1/3})}$) and to the water depth ($Fn_h = V/\sqrt{(gh)}$). Wakes grow sharply as Fn_h approaches 1 (Macfarlane, 2012). Waterways abroad therefore manage boats with wake limits (Bilkovic et al., 2019), such as $H_m < 75$ mm on the Gordon River (Bradbury, 2005) and $E < 60$ J/m on the Noosa River (Macfarlane and Cox, 2004). These were written for alluvial banks. None was written for a mangrove bank, and Kilim had no limit at all.



Figure 1: (a) Sungai Kilim study reach: critical route sites A to D and G (red), control sites E and F (green), wave gauge B1 (blue). (b) Tour boats at the Kilim jetty. (c) Undercut mangrove bank on the tour route.

MATERIAL AND METHODOLOGY

For a field wake record, an RBR pressure gauge installed at B1 (6.4061377°, 99.861705°) marked as the busiest straight route, logged the water surface at 2 Hz through one working day (21 May 2016). Each passing boat was logged with its length and passenger count. Single wakes were separated by zero up-crossing, and each gave a maximum height H_m, a period T and an energy per metre of crest, $E = \rho g^2 H^2 T^2 / 16\pi \approx 1961 H^2 T^2$ J/m.

Full-scale boat trial was the V-bottom planing hull used by 60% of the Kilim owner/operators. With length overall 8.23 m, waterline length 6.95 m, beam 2.12 m, draft 0.18 m, displacement 1,210 kg and hull speed 6.46 knots. It was run past two gauges, 8 m and 12 m from the sailing line, at 5 to 25 knots. Sandbags used in for resembling 2, 4 and 10 passengers of 65 kg each. Runs were repeated as the tide changed, giving 1.18 to 3.62 m of water at the gauge. Two boats were also run together in five relative positions. Wave basin tests of the same hull are reported in Ismail et al. (2022).

The criterion developed from the involved bank side, data from in-situ vane strengths τ_f of 16 to 54 kPa (Ismail, 2024) measurement and monitoring. These were converted to a critical shear stress with $\tau_c = 2.145 + 0.520 \ln \tau_f$ (Watts et al., 2003), giving 3.65 to 4.12 N/m^2. The weakest route bank, at the corner D, set the threshold of 3.73 N/m^2. For every recorded wake, a wave shear stress $\tau_w = \frac{1}{2}\rho f_w U_b^2$ was estimated from linear wave theory (Soulsby, 1997). The wake height and energy at which τ_w first reaches the threshold became the limit.

RESULT AND DISCUSSION

The 286 wakes that reaches the bank came in three categories. Type A (162 wakes) is one tight packet, made by boats running near the critical depth Froude number (Fn_h 0.75 to 1). Type B (113) is a long train of small, near-equal waves from slower boats. Type C (11) is overlapping packets from boats passing close together. Of the 286, 38 exceed the Gordon River height limit and 40 exceed the Noosa energy limit, and the largest carried nine times the Noosa limit. The worst wakes came in the morning, when the tide was low and traffic was heaviest. Because the shape of the record shows how a boat was driven, a single gauge can flag fast running without a speed gun.

Figure 2(a) shows the wake against speed. Below the hull speed of 6.46 knots ($Fn_l < 0.4$), the boat pushes through the water and the wake stayed under 20 mm. Above it, the hull climbs its resistance hump. The wake peaked at 8.6 to 9.2 knots ($Fn_l \approx 0.55$, $Fn_\nabla \approx 1.4$) at about 90 mm. Once fully planing above about 15 knots ($Fn_\nabla > 2.4$), the hull lifts out and displaces less water, and the wake fell back to about 40 mm. The most damaging habit is cruising between 7 and 15 knots, which is how many boats slow down for a bend or the jetty. Three other significant factors. In water shallower than 2 m the wake jumped, and many runs passed 60 J/m, while above 2.8 m depth hardly mattered. Ten passengers raised the displacement by about half and the wake by 27.5%. Two boats abreast or close astern produced nearly twice the wake of one boat (Figure 2(b)).

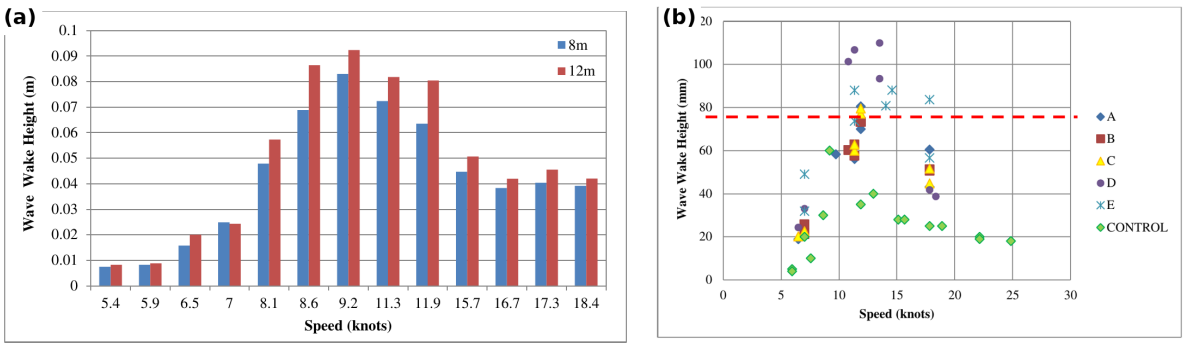


Figure 2: (a) Wake height against speed, 10 passengers, at 8 m and 12 m from the sailing line. (b) Wake height for two boats in five positions (A to E) and one boat (control); dashed line is the 75 mm Gordon River limit.

In developing the wake criterion, a limit the bank can take were analysed. Figure 3 plots the wave shear stress of every recorded wake against its height. The stress crosses the 3.73 N/m² threshold at H_m = 45 mm, which corresponds to E = 16 J/m. Table 1 shows this site limit is far stricter than the Australian ones: 102 of the 286 wakes (36%) broke it.

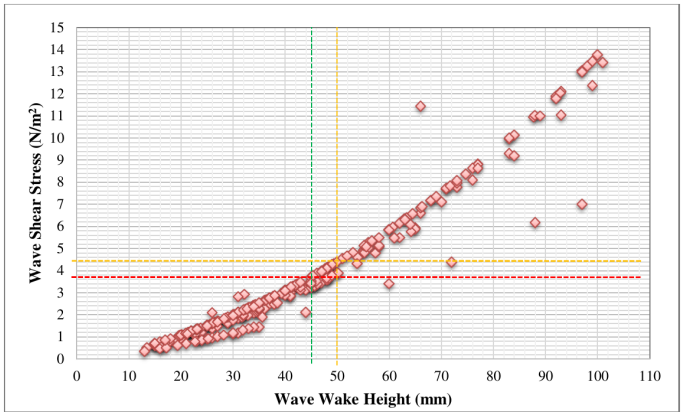


Figure 3: Wave shear stress of the 286 recorded wakes against wake height. Red dashed line: bank threshold at site D (3.73 N/m²); green dashed line: 45 mm.

Table 1: The 286 recorded wakes judged against each criterion.

Criterion	Limit	Pass	Fail
Gordon River (Bradbury, 2005)	H_m < 75 mm	248	38
Noosa River (Macfarlane and Cox, 2004)	E < 60 J/m	246	40
Sungai Kilim (this study)	$H_m \leq 45$ mm and E ≤ 16 J/m	184	102

The shear stress should be read as an index that ranks wakes, not as the true load. The Kilim banks stand at 80 to 85°. At low tide a wake breaks on the toe and slams or surges up the face, and the pressure it applies, of order ρgH or about 450 Pa for a 45 mm wake (Goda, 2010), is two orders larger than the shear. That explains why small wakes still matter (Figure 4). The tide slowly undercuts the toe until the root mat collapses (Thorne and Tovey, 1981). Wakes speed up this cycle by scouring the toe and clearing away the fallen blocks that would otherwise protect it. On banks already undercut, the number of passages matters as well as the size of each wake.

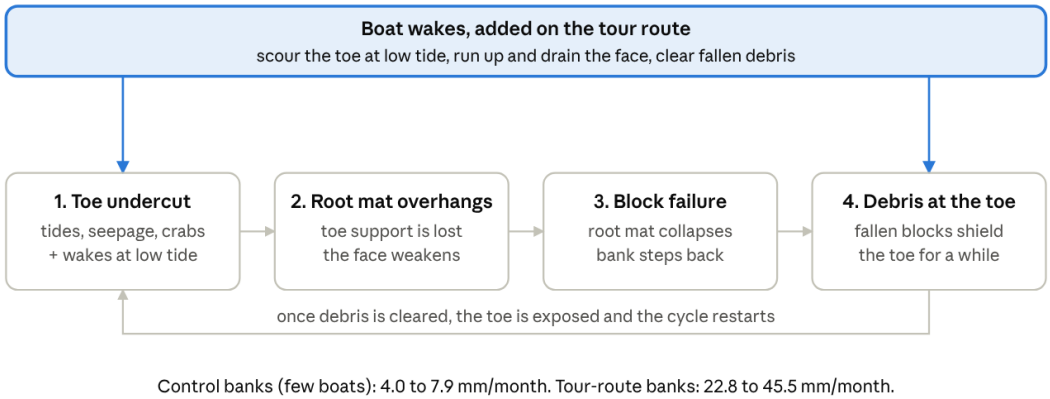


Figure 4: Bank-retreat cycle at Sungai Kilim and the two points where boat wakes act.

The findings become four rules an operator can follow without new equipment. Tour at high tide and avoid the critical stretch at low tide. Hold about 6 knots, just below hull speed, from the

jetty to open water, keeping the bow level (no planning at critical sites). Never run abreast or close astern. Cap the load on the critical stretch.

CONCLUSION

The wake that erodes the Kilim banks is a product of how the hull is driven, and it can be controlled at the boat throttle. Field records showed many tour-boat wakes exceed limits used elsewhere. Full-scale trials traced the worst wakes to the resistance hump at 8.6 to 9.2 knots, to shallow water and to boats running together. Combined with existing river bank data, they gave Kilim its first site-specific wake limit of 45 mm and 16 J/m. Next steps are pressure sensors on the bank face to measure wake impact directly, and continuous monitoring once the rules are in place.

ACKNOWLEDGEMENT

Special thanks to the Kilim Village Community Cooperative and the boat operators of Sungai Kilim.

REFERENCE

Bilkovic, D. M., et al. (2019). Defining boat wake impacts on shoreline stability toward management and policy solutions. Ocean and Coastal Management, 182, 104945.

Blanton, A., et al. (2024). Ecotourism and mangrove conservation in Southeast Asia: Current trends and perspectives. Journal of Environmental Management, 365, 121529.

Bradbury, J. (2005). Revised wave wake criteria for vessel operation on the lower Gordon River. Department of Primary Industries, Water and Environment, Tasmania.

Goda, Y. (2010). Random Seas and Design of Maritime Structures (3rd ed.). World Scientific.

Ismail, M. A. (2024). Boat wave wake characteristics and its impact on riverbank erosion in a restricted waterway. PhD thesis, Universiti Teknologi Malaysia.

Ismail, M. A., Shaharuddin, N. M. R., Yaakob, O., Jamal, M. H., Adnan, F. A., et al. (2022). Wake wash of a fast small boat in restricted waters: Model tests and full-scale measurements. Brodogradnja, 73(2), 93-119.

Macfarlane, G. J. (2012). Marine vessel wave wake: Focus on vessel operations within sheltered waterways. PhD thesis, University of Tasmania.

Macfarlane, G., & Cox, G. (2004). The development of vessel wave wake criteria for the Noosa and Brisbane Rivers in Southeast Queensland. WIT Transactions on Ecology and the Environment, 68.

Soulsby, R. (1997). Dynamics of Marine Sands. Thomas Telford.

Thorne, C. R., & Tovey, N. K. (1981). Stability of composite river banks. Earth Surface Processes and Landforms, 6(5), 469-484.

Watts, C. W., Tolhurst, T. J., Black, K. S., & Whitmore, A. P. (2003). In situ measurements of erosion shear stress and geotechnical shear strength of the intertidal sediments of the experimental managed realignment scheme at Tollesbury, Essex, UK. Estuarine, Coastal and Shelf Science, 58, 611-620.