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Russell's solitary wave in 21st century Scotland

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Introduction

At the end of the 19th century, Scotland's relatively new canals were abuzz with activity. Canal boats were transporting bulk cargo and people, stimulating a flourishing economy. Darrigol [1] recants the well-known fable of the discovery of the solitary wave by John Scott Russel when a horse pulling a boat was frightened into gallop. To everyone's surprise, the boat offered less resistance than at low speeds. Exploiting that discovery, businesses began offering high-speed boat services from Glasgow to Edinburgh along the Forth and Clyde Canal. This paper aims to investigate the occurrence of solitary waves on Scotland's canals.

Motivation

The first author has collected accounts of small, quasi two-dimensional waves in several locations along Scotland's canal network. These waves are typically described by the Scottish boating community as unaccompanied by a vessel, spanning the entire width of the canal, and consisting of a single wave crest with no wave trough; a description which matches the properties of solitary waves.

For example, when running canal boat cruises, the Linlithgow Canal Society, located between Glasgow and Edinburgh, use the presence of such a wave is a reliable indicator that their canal boat returning from a cruise.

Methods

The first author is collecting accounts of solitary waves from canal societies and the public in Scotland's central belt. The currently collected accounts indicate the most common experience in the boating community is that of a single fore-aft movement of lightly moored (or unmoored) craft in the absence of other vessels or otherwise visible disturbances. The first author joined canal society members on cruises along the canal network to observe the hydrodynamics of the canal boats and explore the likelihood of solitary waves being emitted from a canal boat.

The Linlithgow Canal Society's vessel Saint Michael is taken as a case study in the observations reported subsequently. The vessel has a length of 16.8m, a beam of 3m, a draft of 0.5m, and a displacement of 24t with a capacity to carry 40 passengers.

Outcomes

First-hand observations of the wave patterns and boat-induced disturbance indicated that canal boats create a significantly stronger disturbance that would be expected at speeds of between 1 and 2 knots. The disturbance comprised the acceleration of unconsolidated sediment, causing a visibly turbulent boundary layer on the canal bottom. At the aforementioned cruising speed range, a breaking wave emanates from the stern shoulder of the vessel, creating a danger of erosion of the canal bank.

The vessel becomes difficult to steer, accelerate or decelerate, and the rudder is subject to significant vibrations. These observations indicate that the critical speed, a combination of the ratio of vessel and canal cross-sectional area in addition to the speed is likely reached. The St Michael did not have sufficient installed power to overcome the trans-critical barrier. However, the likely proximity to the trans-critical range of the blockage-speed curve indicates the possibility of such vessels emitting solitary waves.

Future and ongoing work

Subsequent investigations will focus on abrupt reductions in canal cross-section along the track of the vessel. It is hypothesised that such reductions could temporarily push the operational condition past the trans-critical boundary, where solitary wave generation is expected. Such a scenario entails a reduction in vessel speed due to the additional blockage while energy builds at the bow. The chief question is whether that energy, in the form of a wave elevation at the bow, is able to escape upstream. That would explain the collected observations. These may also be produced under the same conditions without crossing the trans-critical boundary, by analogy to the *mini-tsunamis* observed in Norwegian fjords. Mini-tsunamis are generated when a high-speed vessel passes over an abrupt reduction in water depth. If that is the mechanism responsible for generating such waves, then the authors suggest the term *micro-tsunamis*.

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Reference

[1] O. Darrigol, "The spirited horse, the engineer, and the mathematician: Water waves in nineteenth-century hydrodynamics," *Arch. Hist. Exact Sci.*, vol. 58, no. 1, pp. 21–95, 2003, doi: 10.1007/s00407-003-0070-5.