A BRIEF HISTORY OF EXPRESS CANAL BOATS

Around 1830, when the canal passage boat services were well established, a proprietor of such a service in Scotland had an amazing experience. He was William Houston, who became the acknowledged expert in what was a “leading edge” technology of the day.

The source of his future prosperity occurred by accident, when his horse took fright whilst towing an empty boat, and bolted. He decided to hang on, expecting the resistance of the boat to quickly tire the horse. Imagine his alarm when the boat rose up onto its bow wave and shot off along the canal at high speed. John Scott Russell, in his account given to the Edinburgh Royal Society, described how “Mr Houston had the tact to perceive the mercantile advantage”.

He also described Houston’s astonishment when he observed “that the foaming stern surge, which used to devastate the banks, had ceased”. It was this unexpected drop in the boat’s resistance that allowed the horse to continue so far. At 10 mph, return day trips over the 8 miles from Paisley to Glasgow became very popular. By 1835, his accounts showed 323,290 passenger trips in one year. The “Illustrated History of British Canals” by Charles Hadfield shows a tenfold increase in these five years with the number of boat trips tripled to 12 a day each way. Hadfield quotes the typical speed as 10 m.p.h, regularly maintained, at fares no higher than those for the previous 4 m.p.h. service. It was a wonder of the times.

So how did they do that? The difficulties encountered by others who endeavoured to copy Houston’s success led to the appointment of the young scientific prodigy, John Scott Russell, to investigate. At least 4 experimental boats were built and tested, and their details recorded in “Mr Russell’s Researches in Hydrodynamics”, a paper read to the society in 1837, and published in 1840 (Transactions of the Edinburgh Royal Society XIV, pp47-109) with 62 pages of text plus illustrations.

By that time the competition from the railways had already sounded the death knell of the technology. The enthusiasm for suitable new boat designs faded, as it became clear that the railways would win. However, this did not occur before the Scottish expertise had been exported to many other countries. A.I. Bowman, in “Swifts & Queens”, an account of “passenger transport on the Forth & Clyde canal”, described the boat “Swallow”, built in 1832. It was a “65ft long light iron passage boat” modelled on a racing gig shape. Renamed the “Grahame-Houston”, it was sent to England, where it was used for the time trials at Paddington in 1833. Hadfield details the results of these trials, including a run over 12 mph with 27 passengers, pulled by two horses.

Meanwhile, four new design boats had been made to replace it. A notice “To Canal Proprietors and Traders”, dated 1833, was circulated to “enable Canal Proprietors to follow the latest improvements”. It compares “Old boat Swallow” with the new design, built with “broader bearings behind”. This improved the clearly critical trim when riding the wave. It seems likely that these boats formed the basis of the “Swift” class, named after, but not a replica of, an earlier twin hull design. The first “Swift” was made by Thomas Grahame, who experimentally fitted it with a steam driven paddle wheel. However, when this proved ineffective, it was once again pulled by two horses.

The organisation difficulties associated with the swift boat services led to a system which gave them priority over normal traffic. They carried a bow scythe or knife to cut the traces of the opposing boat if necessary. Fig 29 in “Swifts & Queens” shows a swift boat in action, with the postilion cracking his whip whilst riding the rear horse. Even so regular services on the Forth & Clyde were operated at night, leading to the sobriquet “Hoolets” (owlets), describing the noise of their warning horn. This was a sleeper service, showing how smooth a ride they achieved. John Scott Russell was again involved to design special focussed multi-burner lights to act as “headlights” to reduce the hazards.

In England, the “swift boats” were called “fly boats”. In “English Canals” by Gladwin & White they say that “fly boats and pottery boats” were the lightest designs, other than the “fly packets”. They give a detailed description of boats built for the Shropshire Union Railway & Canal Co sometime after 1847, with “very fine lines to the fore-end and a clean run aft”. This description matches the recommendations given by Russell. They claimed they could tow their maximum load of 22 tons at 10 mph even with a single horse.

Although by no means all operators were fully successful, those who could make it work did well. However, on the Royal Canal in Ireland, they eventually gave up after trying with three horses and suffering from bad erosion of the banks. Where the boats rode on the wave, erosion does not seem to have been a difficulty, with the absence of the stern surge giving a smooth quiet ride.

The wave

Russell's researches soon led him to consider the nature of the wave on which the swift boats rode. He famously observed that when a boat on which he was travelling stopped, a wave arose and rushed forward leaving the boat behind. He disembarked, but found that he could not follow on foot, so pursued it on horseback. He noted that this unusual solitary wave was about 30ft long , 12–18" high and moved rapidly but smoothly, visible for well over a mile.

As he subsequently showed, the speed of this special wave is almost entirely determined by the depth of the canal. He called it the "great wave of translation", and it is now known to follow the equations since determined for a solitary wave or "soliton". As he explained it, this wave speed is that which a falling body would acquire if dropped in air from a height half the depth of the canal. This wave motion is dominated by the effects of gravity. The acceleration due to gravity, or "g", is typically 9.81 m/s^2. For a canal depth "d" of 2m, the soliton wave speed is $\sqrt{(g*d)}$, that achieved by an object falling 1m, which is 4.43 m/s or about 10 mph.

When the boat speed is less than the wave speed, the bow wave and stern wave are separate, and as the speed is increased, so these waves grow larger. However, if the boat can be pulled up sharply onto the bow wave at the speed of the soliton, the resistance to motion falls and the stern wave is absorbed. Indeed, Russell described how this state could also be achieved by first creating a large stern wave, then slackening the line to allow it to pass forward under the boat. The time to pull hard is the moment it reaches the centre of the hull. The stern surge is then eliminated, and the water behind the boat subsides smoothly.

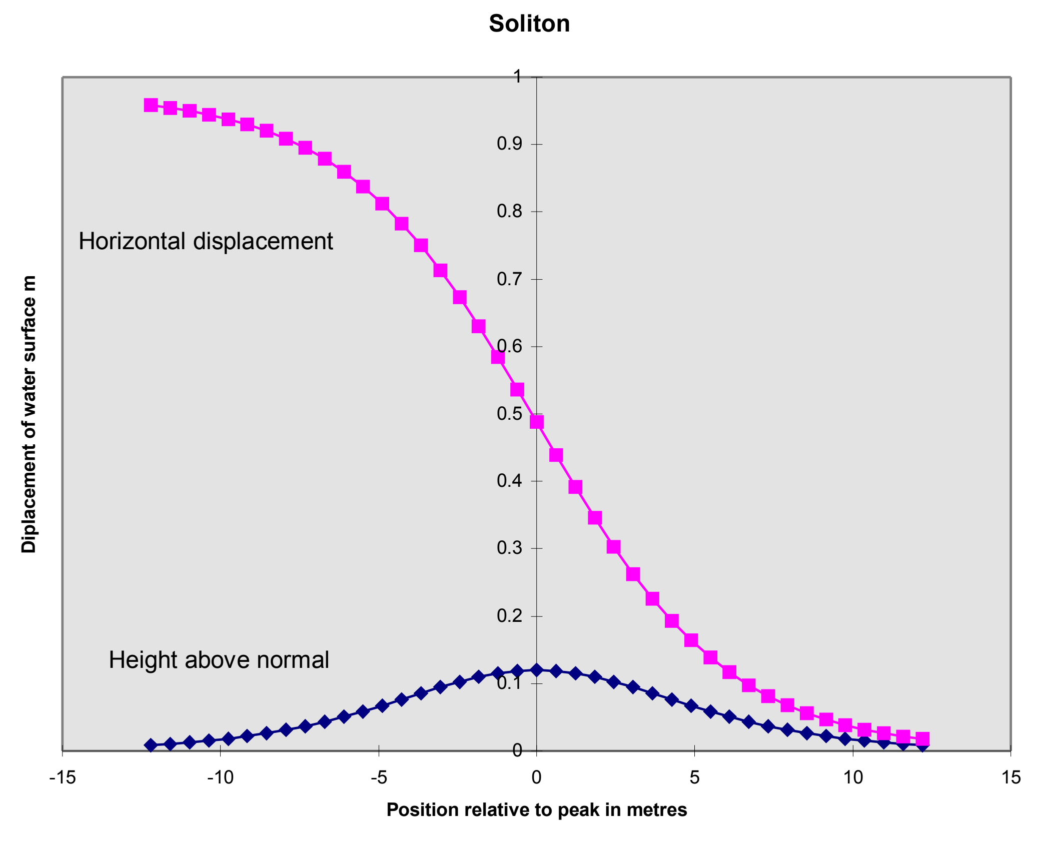
The mathematics of the wave fascinated many people over the next century. However, the full significance of Russell's observations became more clear in the 1960's when the soliton mathematics were solved and applied to many areas such as quantum mechanics and the propagation of signals through fibre optic cables. There are now many web sites dealing with solitons, of which that run by the Heriot Watt University is particularly related to canals. Professor Chris Eilbeck has provided several of the earlier references given here, as well as co-ordinating with the Edinburgh canal centre to make the wave on the Union canal for the BBC TV "Local Heroes" programme.

Similar waves were created in 2001 to investigate some details of the water motion. It was confirmed that these waves can be characterised by a mass displacement, or translation in the words of Scott Russell. Calculations using the modern mathematics show that the famous wave described by him involved a displacement of over 30 tonnes. As the wave passes the observer on the bank, the water is moved along the canal. This movement is slower than the wave speed, and characterised by a translational movement of about 2 metres.

With the help of Ronnie Rusack, proprietor or the Bridge Inn at Ratho, a smaller wave was created in the Almondell aqueduct in May 2001. This only moved the water about 1 metre, corresponding to a 6 tonnes displacement of water. However, the displacement of the canal centre tender, driven by boatman Bill, which created it was less than 1 tonne, even with several additional volunteers as ballast. It was not possible to put this boat onto the wave, but the constriction provided by the aqueduct converted its bow wave into the correct form. This wave was not dramatic, except in its speed. The water rose and fell quite slowly , but the wave peak moved at running speed. It was barely noticeable after it left the constricted section. This behaviour fulfils the equations of a soliton, a solitary wave of translation, quite unlike the surface waves more commonly experienced.

The analysis shown below is for an idealised 6 tonne wave, moving the water 1metre.

Sech^2 shape (parameters as Drazin & Johnson)				Neglect surface tension	RAH 21/1/01
Channel dimensions		Wave ht m	0.12	Wavelength (between 42% heights) m	12.2
Depth m	1.5	Mass displaced tonnes	5.9	Speed of the wave m/s	3.99
Breadth m	4	Distance displaced m	0.98	Peak particle speed m/s	0.32
		Momentum tonnes.m/s	24	Kinetic energy kJ	2.5



The wave shape is a sech^2 function (with diamond symbols), travelling at 4 m/s (about 8 mph). The horizontal displacement is shown by square symbols, but plotted vertically. The peak water speed which occurs as the peak passes the observer is only 0.32 m/s, less than a tenth of the wave speed.

Surface waves do not move the water, except when they break. A bobbing cork on the surface is seen to describe a circular motion, returning to its start point, unless driven by the wind. The equations of such waves involve periodic sinusoidal functions, with a wavelength defined by the distance between peaks. A simple single frequency wave train gives a regular sequence of peaks and troughs passing the observer. However, their speed depends on their wavelength, and a solitary surface wave will rapidly be dispersed into many complicated periodic waves. This dispersion is a well known property of surface waves and leads to the chaotic motion typical of the sea.

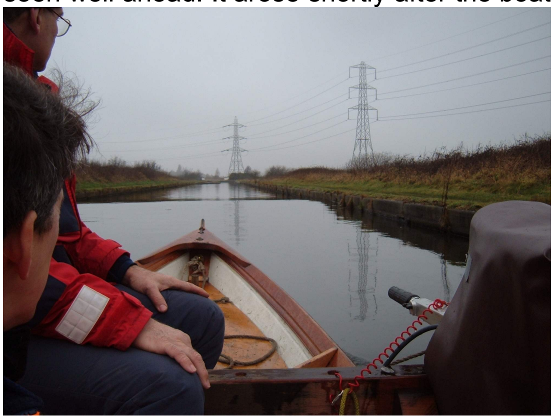
The solitary wave observed by Russell and recreated in Edinburgh were by contrast apparently simple. However, the mathematics eluded theoreticians for over a century, and it took a person of Russell's perception to see how remarkable it was. The same mathematics can be used to predict the performance of Tsunami waves, where the combination of a finite but slow water motion is combined with very high wave speeds. Tsunamis are typically only a few inches high in the deep ocean, but travel at hundreds of miles per hour. They are quite hard to detect at sea, yet contain sufficient momentum to destroy coastal cities.

R A Hazelwood Feb 2003

Walsall trial (2005)

This trial of Feb 2005 used the "Henry Williamson" a skiff owned by Mark Edwards, here seen holding the tiller at the stern. The work was initiated by Tom Chaplin, 4th from the right, and ideas were contributed by Richard White 5th from right. The boat was powered by an outboard on a forward mounted cross beam and the throttle controlled by Malcolm at the bows.

Whilst the engine created significant wash, the smooth soliton created by the boat can be seen well ahead. It arose shortly after the boat achieved the correct speed.



Solitary waves could be released by slowing down, and one was followed on bicycle for perhaps a kilometre before being bid farewell