THE "SEICHES" OF LAKES.

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I have just received a brilliant verification of the formula relating to Seiches which I established in 1876. In order to make the interest in this subject understood I must first of all give some general explanation about the phenomenon.

The dwellers on the shores of Lake Leman have known for ages singular variations in the level of the water of the lake, which they call "Seiches;" without apparent cause they see the water rise several centimetres, some times several decimetres, with a slow movement which lasts sometimes five minutes, sometimes a quarter of an hour, or sometimes half an hour, then retire with the same slowness below its original level, then rise again, and so on. One might call it a small tide of low amplitude and short duration.

Attentive observation shows similar movements in all lakes and ponds, whatever may be their dimensions.

I demonstrated in 1873 that these seiches are due to a balancing of oscillatory waves of water, which oscillate from one extremity of the lake to the other with a movement rhythmic, isochronous, and of decreasing amptitude, otherwise called a "Pendular" movement.

These seiches are of very frequent occurrence. With the aid of sufficiently delicate registering apparatus we may observe

them constantly; we can scarcely find in a year several consecutive hours, never an entire day when the level of the lake does not show some signs of these rhythmical phenomena.

The amplitude, or the height of seiches is very variable. It varies with the situation; certain places situated at the end of funnel-shaped bays, Geneva for instance, have seiches very much bigger than other stations situated on a projecting cape. The amplitude varies also from one day to another; some times then are no seiches, or almost none, some times their development reaches a maximum. The biggest seiches known were those of October 3rd, 1841, observed at Geneva when the change of water level from the highest to the lowest was more than 1.90 metres. This instance is very rare; during the nine years that we have had continuous graphic recorders at Lake Leman we have not observed any seiches at Morges with an amplitude exceeding 20 centimetres.

The study of the amplitude and development of seiches have shown us their relations with the movements of the atmosphere; their beginning coincides with a rupture of the equilibrium of the air over the lake. A storm which strikes the lake causes a local change of water level, a first impulse, which is followed by a series of oscillations of decreasing amplitude until a state of equilibrium is again attained, or what more frequently happens, until a new series of seiches is developed effacing the traces of the preceding series. I have observed on the tracings of the register an nnbroken succession of such pendular oscillations, caused by a single impulse and continuing for three, four, or five days.

I distinguish two principal system of seiches in a lake:

(1). Longitudinal seiches which oscillate along the greatest length of the lake: in Lake Leman this is from Chillon to Geneva.

(2). Transversal seiches which oscillate along the greatest breadth of the lake: in Lake Leman this is from the Swiss to the Savoyard coast, from Morges to Evian.

In each of these systems I recognise three principal types of seiches, namely :—

(1). Seiches of the first order, or uni-nodal seiches with a single node and two ventral segments of oscillation. The water is raised at one end of the lake while it is lowered at the other; at the middle of the length of the basin is a dead point, the node of oscillation, where the height of the water does not vary.

(2). Seiches of the second order, or bi-nodal seiches, with two nodes and three ventral segments. The water is raised simultaneously at the two ends of the lake, while it is lowered in the middle, and *vice versâ*; between these three ventral segments there are two nodes of oscillation where the level of the water remains stationary.

(3). Compound seiches (or seiches dicrotes) in which there is a superposition of seiches of the first and second order, which gives, according to the station of observation different types of curves of changes of water level, very complicated at the ends of the lake where the ventral segments of the uni-nodal and bi-nodal seiches mutually interfere.

I will here give, according to our observations on Lake Leman, the duration of these different types of seiches, calling the duration the space of time between two maxima of the height of the water, or crests of the seiches :—

Longitudinal uni-nodal seiche ..... 73 minutes.
Longitudinal bi-nodal seiche..... 35 minutes.
Transverse uni-nodal seiche..... 10 minntes.

The duration of a seiche varies from one lake to another according to the dimensions of the basin. In 1876 I succeeded, relying on a theoretical equation of Rodolphe Merian of Bale, in giving in a practical and very simple manner, a formula for uni-nodal seiches, namely :—

$$t = \frac{l}{\sqrt{gh}}$$

which expresses to the time of oscillation of a demi-seiche in

seconds, a function of l the length in metres of the section of the lake in the direction in which the seiche oscillates (the greatest length, or greatest breadth) of h the mean depth of that section, g being the co-efficient of gravity 9.8088.

According to this formula, the longer a lake is the longer the duration of the seiche. But this duration is greatly influenced by the depth of water; when the lake is shallow the duration of the seiche is prolonged; we may assume that the friction of the bottom is the cause of this retardation. The examples which I had at hand of the seiches of Swiss lakes permitted me to verify directly this formula, and I found that it applied very well on the one hand to the known dimensions of these lakes, or on the other hand to the duration of such seiches as I had measured. But all these lakes have very deep basins, of 100, 200, 300 metres, or more, and I never had an opportunity to verify the formula in the case of shallow lakes, or ponds, where the retarding influence of the friction would be exaggerated to the extreme. I am happy to find this verification in an observation which comes to us from a continent situated at our antipodes.

The President of the Royal Society of New South Wales, Mr. H. C. Russell, of Sydney, in Austalia, has studied, with the aid of a graphic recorder, the seiches of Lake George, a mountain lake situated behind the Gourock Range, in the Murray district. Here are the position and dimensions :—

Longitude	149° 25′ E. Greenrich.
Latitude	35° 7′ S.
Altitude, approximate	600 metres.
Length, 18 English miles	2,8962 metres.
Breadth, 5 English miles	8,045 metres.
Depth, 15 to 20 English feet	4·5 to 6·1 metres.

Mr. Russell gives the duration of longitudinal uni-nodal seiches as being 131 minutes.

This duration is very great, it reaches very nearly double that of the corresponding seiches of Lake Leman, which is only 73 minutes, and nevertheless the length of Lake Leman,

73.2 kilometres, is more than double that of Lake George, 29 kilometres. This is an effect of the retardation due to the the shallow depth of Lake George, which is not more than from 5 to 6 metres, while Lake Leman has a maximum depth of 334 metres and a mean depth of 114 metres.

Applying our seiche formula to Lake George :—

$$t = \frac{l}{\sqrt{gh}}$$

From which we get—

$$h = \frac{l^2}{gt^2}$$

If in this formula $l = 28962$ metres and t the duration of a demi-seiche $= 3930$ we find for the mean depth ; $h = 5{\cdot}536$ metres or 18.1 English feet.

Mr. Russell tells us that the depth of Lake George is from 15 to 20 feet : the seiche formula gives me 18 feet.

The verification, in this case of extreme variation of the very important factor, the depth, is as satisfactory as we could desire.

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