PANAMA TIDAL DIFFERENCES

by

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(Extract from *The Military Engineer*, Washington, May-June 1932) (*).

Panama is a land of paradoxes. One marvels, when first he sees it, that the morning sun goes to his work from a dip in the Pacific; and the stranger is utterly convinced of the topsyturvyness of things that evening when Old Sol knocks off for the day to the Atlanticward of him. Reassurance as to the sun's regularity of habits can only be established by orienting a map of Panama. We find then that the Pacific end of the Canal is about 25 miles East (as well as about 32 South) of the Atlantic end. Later one finds that, when doing some geodetic work, he must have star charts of both hemispheres, as he is nearly sure to want a star across the equator. Again Panama has her best weather in the winter, while the United States freezes and the West Coast has rains (if any).

Panama's tides are queer too. In the matter of tides the Canal Zoner finds his area an oddity; he can swim in either ocean every 20 minutes (travelling by seaplane); now the 45 miles across makes an infinitesimal difference in the effect of the usually assigned forces of the tide-generating sun and moon. Yet we find that the Pacific annual mean sea level averages about 8 1/2 inches (215 $^{m}/_{m}$) above the Atlantic's; they are about equal in February and are over 1 foot (0 m. 305) apart in October.

The ranges of tide vary greatly also. Pacific spring ranges are as much as 22 feet (6 m. 705) and the neap ranges are as little as 6 feet (1 m. 830), averaging about 12 feet (3 m. 657). On the Atlantic entrance the ranges vary all the way from 2 inches (0 m. 051) to 3 feet (0 m. 915), averaging about 10 inches (0 m. 254).

The Pacific sedately has its two highs and two lows each 24 hours and 50 minutes. The Atlantic varies between two highs and two lows, two highs and one low, and one high and one low. When each side of the Canal is having the semidiurnal type, any given tide phase at Cristobal usually comes about 3 hours the earlier.

It is no wonder that the earlier magazines, discussing the effects of the Panama tides, gave the two sea levels as 10 feet (3 m. 048) and even 20 feet (6 m. 096) apart. At high or low tide springs the Pacific side level does actually grade about 10 feet (3 m. 048) above (or below) the Atlantic. And how the argument waxed hot over the effects of a resulting (and of course reversing) current in a sea-level canal!

The perplexing phenomena can be partially explained by the following discussion. Though the two canal entrances are a paltry 45 miles apart, they are, oceanically speaking, separated by at least 10,600 nautical miles. Hence the astronomical tide-generating causes (the rotation of the earth and the sun and the moon, in their various pro- and contra-gravitational positions) get seriously modified in their effects by the other physical causes of variations in tides. Among these causes are winds, land forms, ocean currents, sea densities, variations in air pressures and ocean temperatures, and sloping or shelving of the ocean bottoms.

Looked at from these angles the two canal entrances might as well be different parts of the world. In fact it is world-wide oceanic conditions that cause the peculiarities of tides here. The Atlantic system is subject to the modifying effects of the chain of islands from Yucatan, through Cuba and Porto Rico, to the eastern shores of the Guianas. The trades blow nearly steadily onshore to Panama. Except in the north western Caribbean there are no particularly noticeable sloping bottoms. The ocean currents, both the near-land and the counter out-at-sea, carry waters of approximately the same density and temperature. At the Pacific end the trades become off-shore winds but, during perhaps one-fourth of the wet season, they give way to variable winds that are more or less on-shore. To the west no land exists of any importance nearer than Asia. The mouth of Panama Bay has submarine palisades, north of which the Bay is relatively shallow, with sloping bottoms toward the land. The Bay itself is a re-entrant angle of the Pacific 100 miles long. There are two ocean currents, the Japa-

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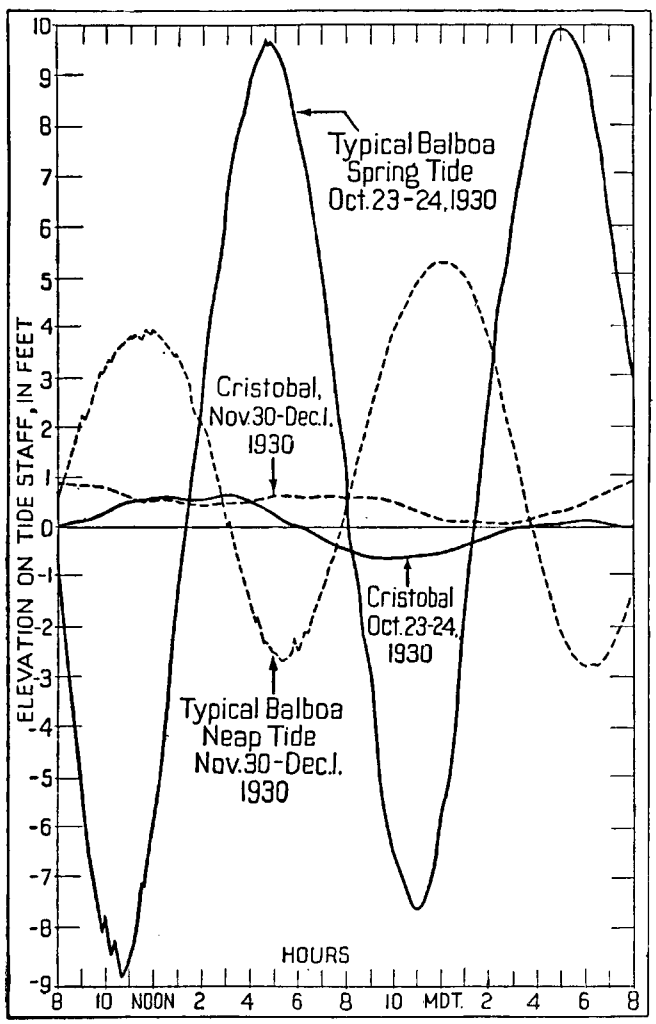
(*) *See* Hydrographic Review, *Vol. VIII, N° 1, May* 1931, *page* 270.

nese or Mexican (of warm water) and the Peruvian or Antarctic (a heavy, cold, and usually under surface water), variably meeting each other in the general neighborhood of the mouth of Panama Bay. It is readily seen that the resultant effects of all these discordancies are not subject to careful analysis of the various component causes; certainly not until much more is known of the meteorology and oceanology of both the Atlantic and Pacific.

AMERICAN TIDAL RECORDS.

The Americans have kept fair tidal records at both entrances of the canal since 1905; early harbor construction caused the staffs to be changed several times, but excellent records exist for the period since 1909. Furthermore the staffs have been intertied twice by trans-isthmian precise levels. For two years (1905-1906) the tide station in the Pacific was at Naos Island, 3 miles out in the Bay. At that time Balboa had one steel dock in the tidal mouth of the Grande River. Later a real harbor was developed and the tide station was moved in, though with misgivings as to the effects of the river flow. After making records through two dry seasons and one wet season, Pacific tide levels were calculated. The engineer found that his wet season record was nearly 1 foot (305 m/m) higher than the dry record, so he charged it to the effects of river flow and threw it out. Not until some time later, when the canal made this river lose its identity and its effect, and when precise levels via the new Naos Island Breakwater to the old station showed the same characteristics, were the wet season sea levels understood. It has likewise been proven from a two-year record run at Taboga Island, several miles out in the Bay, that its sea level checked those of Balboa and Naos Island, regardless of the Grande River's flow (which was never large anyhow).



As already stated, Balboa has the semidiurnal (two highs and two lows) type of tides daily. Cristobal's vary: semidiurnal, diurnal and intermediate types occur monthly. Figure shows that during the twenty-four hours between 8 a. m., November 30, to 8 a. m., December 1, 1930, Cristobal had virtually no tide; at spring tide, October 23-24, 1930, she had two highs and one low, with a near synchronization of the times of low tides on the two sides of the canal at just about midnight.

On account of the regularity of the tides at Balboa the Panama Canal's records are used by the Coast and Geodetic Survey as a basis for their tidal predictions between California and Ecuador. That is, Balboa is Standard Port for tidal predictions for all intermediate ports on that long coast. Until 1932 the nonconsequence and irregularity of Cristobal's tides have prevented tidal data or predictions to be published. However, the

Coast Survey has published such tables this year. The writer predicts greater inaccuracies in predictions (as the practical sea captain will look at it) than is now had on the Balboa side. An unusually strong on-shore wind can easily offset a relatively weak ebb tide, for instance.

Inter-independent calculations for sea-level canals 500 feet (152 m. 400) and 1000 feet (304 m. 800) wide in the Canal Zone indicate that the spring tides (of course the worst case) would give currents of 3.75 and 3 knots respectively. As the current would reverse direction four times a day, it would undoubtedly require a tidal lock. Such currents can not be tolerated at canal bends, docks, close clearances, et cetera. The present locks and lakes of course make the currents innocuous with the exception of the relatively small effects of the tidal prisms of water in the harbors themselves.