Journal of Coastal Research	16	3	iii–x	West Palm Beach, Florida	Summer 2000

EDITORIAL

Red Flags on the Beach, Part II

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ABSTRACT

BALSILLIE, J.H. AND TANNER, W.F., 2000. Red flags on the beach, part II. *Journal of Coastal Research*, 16(3), iii–x. West Palm Beach (Florida), ISSN 0749-0208.

In a former treatment TANNER (1998) listed seven red flags. By "red flags" it was meant common uncertainties or errors in coastal work. It was not thought at that time that the list was complete, but in fact selected from a longer list compiled over the years. We here present six additional items as follows:

(8) Wave data description and definition.
(9) Is the wave period really conserved?
(10) The significant wave height—putting it in perspective.
(11) Where or when does shore-breaking occur?
(12) Reassessment of wave energy content.
(13) Misuse of tidal datum reference planes.

Again, this does not constitute an exhaustive list. Moreover, editorials by their very nature are generalized. Certain issues are probably well deserved of greater detail and justification; some for which future in depth treatments are underway. But, one must start somewhere.

ADDITIONAL INDEX WORDS: *Wave period, wave height; shore-breaking, tidal datum reference planes.*

INTRODUCTION

During the early part of this century when the exodus from cities to U.S. coastal environs was realized, coastal erosion problems along the coast of New Jersey caused concern. SHARP (1927) stated:

> *Conditions vary so widely from place to place that rule-of-thumb methods are sure to give a large percentage of failures, and a structure successful at one place may be a dismal failure at another. On the other hand, the engineer who wishes to attack his problem scientifically finds that science has done very little to help him. He is almost without trustworthy facts, and must work up his data from hasty studies of his own.*

But coastal practitioners (*i.e.,* scientists, and engineers who are gifted with practicing the scientific method), have certainly made advancements. Is there more work to be accomplished? Of course! Even so, it is appropriate to be kind to ourselves and restate:

> *Scientific work in the coastal community spans so many different disciplines that it is exceedingly difficult to keep up with everything, and even to know all the basics that one needs in order to be able to juggle the different demands and claims that must be dealt with.* (TANNER, 1998).

In the present note, six additional items are presented in addition to the red flags published earlier (TANNER, 1998). We should like to state that our selection of topics may not be all that well organized. We have addressed them as they have come to our attention. Nor do we apologize. Despite the advances that have been made, our approach serves to indicate just how disorganized collective coastal perceptions as yet remain. The number of coastal practitioners and the volume of literature concerning coastal matters has exponentially increased during the past 30 years and, yet, we have not sought to organize our field of study. If coastal science and engineering is to become a consolidated discipline, attaining the status of the other sciences with concerted engineering applications, we must seek, at some point, to organize. Perhaps one way in which we can proceed is to attempt to sift through our understanding of the store of knowledge and look for inconsistencies, oddities, apparent inadequately defined or unsubstantiated assertions, and then make inquisitive journeys into matters that we find troubling. Following are some more examples, suggesting such a need.

WAVE DATA DESCRIPTION AND DEFINITION

We describe *single wave trains* by using terms such as monochromatic, regular, or periodic waves. We also recognize

00026 received and accepted 12 March 2000.

scribed in terms of harmonics (*e.g.,* DRISCOLL and others, 1992; ISOBE and others, 1996; ELDEBERKY and BATTJES, 1994; LOSADA and others, 1997), solitons (*e.g.,* ZABUSKY and GALVIN, 1971; GALVIN, 1990), Miche wavelets (*e.g.,* SMITH, 1994; SMITH and JACKSON, 1995), Bragg scattering (*e.g.,* ZHANG and others, 1999), wave decomposition, (*e.g.,* OHYAMA and NADAOKA, 1992; BEJI and others, 1992), *etc.* In fact, while water depths over such obstacles as reefs and bars may be relatively shallow, breaking does not need to occur for the wave height and period to be affected.

We raise this "red flag" because it constitutes an issue of significant importance confronting us, and requires quantification.

THE SIGNIFICANT WAVE HEIGHT—PUTTING IT IN PERSPECTIVE

Waves have been studied for centuries largely in terms of theoretical work, beginning, perhaps, in the late 1700's and early 1800's (BEACH EROSION BOARD, 1941). Interest in shore-breaking waves accelerated during World War II when landing craft operations became of serious concern. The U.S. Government initiated a program of research through the Joint Army-Navy Intelligence Service (JANIS) with the U.S. Army, Beach Erosion Board (BEB) assigned as the lead agency (QUINN, 1977). While the BEB conducted much of its own research, it also contracted with such institutions as Wood's Hole Oceanographic Institution and Scripps Institution of Oceanography (SCRIPPS INSTITUTION OF OCEANOGRAPHY, 1945). A considerable number of confidential works were completed. They remained virtually unknown to the public until the summer of 1976 when one author (JHB), then on the staff of the U.S. Army, Coastal Engineering Research Center (CERC, successor to the Beach Erosion Board), found them in a secured section of the agency and had them released (ironically, these documents had been declassified in the summer of 1950, but were apparently forgotten and not made available to the public). One of these documents (MUNK, 1944) is the *original source* for the significant wave height.

Both non-breaking and shore-breaking waves were studied by MUNK (1944). He found that when the wave height was estimated by an experienced observer, the result corresponded to the average of the highest ⅓ of the measured wave record (although, he reported it to correspond to the highest 30% of the record). BALSILLIE and CARTER (1984a, 1984b) compared visually observed and measured shore-breaker heights from 30 field experiments (900 individual waves were measured). They found that if (following MUNK's analytical approach) the mean value of $\bar{H}_{bo}/\bar{H}_{bm}$ (where $\bar{H}_{bo}$ is the mean of the visually observed breaker height for an experiment, and $\bar{H}_{bm}$ is the mean of the measured breaker height for an experiment) were determined for many experiments, MUNK's results were duplicated. However, if one used linear regression techniques, it was found (BALSILLIE and CARTER, 1984a, 1984b) that experienced observers generally reported the measured mean breaker height (*i.e.,* $\bar{H}_{bo} = \bar{H}_{bm}$). Moreover, the linear regression approach is a more robust method than taking the average of the quotient of averages. Linear regression, however, may have not been an option to MUNK in the early 1940's, due to short time constraints associated with the war effort.

The significant wave height has, however, a continuing history. Surface profiling gauges (*e.g.,* step-resistance relay and continuous wave staff gauges) and pressure sensitive devices used during the late 1940's, 1950's and 1960's were resource intensive because they required tedious physical interpretation and analysis. About 1970, however, a new method for analyzing wave data . . . spectral analysis, the ground rules of which had been defined years earlier (*e.g.,* LONGUET-HIGGINS, 1952; PIERSON and others, 1958), allowed for more automated analysis of measured wave records.

If we solve for $\bar{H}$ in the last equation of equations (1) we obtain $\bar{H} = 2.5\sigma$; when this result is substituted into the second equation of equations (1) then:

$$H_s = 4\sigma \tag{3}$$

LONGUET-HIGGINS (1952) asserted that if the wave spectrum is sufficiently narrow, wave heights will be approximated by a Rayleigh distribution and demonstrated that the variance of the continuously measured sea surface height record, m_o, conformed to $\sigma = m_o^{1/2}$. Moreover, m_o was found to be proportional to the potential energy, E_p, of the waves (KINSMAN, 1965; HARRIS, 1970). The significant wave height was given the international notation of H_{m_o} (PIANC, 1973) where:

$$H_{m_o} = H_s = 4m_o^{1/2} = 4\sqrt{\frac{E_p}{\rho_f g}} \tag{4}$$

in which ρ_f is the fluid mass density, and g is the acceleration of gravity. Equation (4), a standard used for some 30 years in spectral analysis, has been subject to considerable criticism. For instance, we concur with the basic findings of FORRISTAL (1978) that the value represented by 4 varies. VINCENT (1981) and THOMPSON and VINCENT (1985) clearly state that by using m_o and E_p, *estimates* only of H_{m_o} result, and that equations (3) and (4) produce results in the laboratory that differ from each other by over 40% in some cases. The authors have undertaken an extensive study of the subject (BALSILLIE and TANNER, in manuscript) and have found serious problems with the approach as offered by equation (4). We have found that the coefficient does, indeed, vary depending on the degree of vertical wave distortion occurring during the shoaling process. Moreover, we have found that to proliferate the notion that H_s is a fundamental quantity (U.S. ARMY, 1984, p. 3–11) is to promote either naivete or agendadriven numerical legerdemain.

WHERE OR WHEN DOES BREAKING OCCUR?

Where (*i.e.,* at what water depth?) waves shore-break can significantly affect the magnitude of wave energy (BALSILLIE, 1999b). Please note that the authors are careful to use the terminology shore-breaking waves (including bar-breaking waves) which are produced due to nearshore shoaling conditions (*i.e.,* depth limitations), so named to distinguish them from fully forced waves breaking in deeper water (discussed earlier).

The breaking of ocean waves (*i.e.,* gravity waves) is defined to occur when the internal horizontal water particle velocities, u_b, in any part of the wave crest exceed the wave phase speed, c_b (*e.g.,* McCowan, 1894; Munk, 1949; Kinsman, 1965), or:

$$\frac{u_b}{c_b} > 1.0 \tag{5}$$

termed the *kinematic stability parameter* (Dean, 1968). There is also involved the *dynamic stability parameter* (Dean, 1968) which addresses vertical water particle accelerations necessary to conserve the integrity of the wave height form. One can, however, assume wave height integrity is maintained which, in reality, it is; that is, until breaking occurs.

For the bulk of the history (~1859 to present) in endeavors to determine the cause(s) of shore-breaking, technical means were not available to measure the criterion of equation (5). Nor are they available to many of us today. We have had to or do rely upon an approximating *surrogate* set of visual definitions, which more nearly identify *when* waves shore-break. By 1946, Dean M. P. O'Brien had identified and suggested conditions required to produce *spilling* and *plunging* type shore-breakers (Beach Erosion Board, 1949). Subsequent evaluations (*e.g.,* Galvin, 1968) led to a set of "standardized" visual definitions of shore-breakers in profile view. Principle shore-breaker types are *spilling, plunging, surging,* and *collapsing* for which definitions are given by Balsillie (1985; 1999b), as is a shore-breaking numerical continuum, and an history of the development of shore-breaking quantification.

Interest in where waves shore-break has been a subject of serious interest for well over a century. The first published formal account known to the authors was the theoretical work of McCowan (1894) resulting in:

$$d_b = 1.28\bar{H}_b \tag{6}$$

where d_b is the water depth of shore-breaking (measured as the vertical distance from the still water level (SWL) to the bed), and $\bar{H}_b$ is the mean shore-breaking wave height. Equation (6) simply states that waves are water-depth limited.

Through the ensuing years, however, investigators have conducted experiments to numerically quantify where shore-breaking occurs. In many cases, these studies were conducted by researchers apparently convinced that waves were simply not depth limited, but that the correct answer had to be more complicated. Variables and/or parameters, in addition to d_b and $\bar{H}_b$, such as the wave period T, bed slope at shore-breaking tan α_b, equivalent wave steepness $\bar{H}_b/(g\ T^2)$ where g is the acceleration of gravity, and the modified surf similarity parameter $\xi_b = \tan \alpha_b/[\bar{H}_b/(g\ T^2)]^{1/2}$, have been investigated by researchers hoping to increase predictive power. Indeed, some researchers claim to have increased predictive power using their own selected, often small, data sets (usually small laboratory wave tank waves). One author (Balsillie, 1983) conducted comparative analyses of these methods and found that McCowan's (1894) much simpler approach, in every case, does at least slightly better than the more complex predictive equations. Since 1983, additional data have become available (Balsillie, 1999b; Balsillie and Tanner, 1999). In addition to an updated comparative analysis of predictive methods, stepwise regression was employed to analyze sets of field and laboratory data for d_b, $\bar{H}_b$, T, tan α_b, $\bar{H}_b/(g\ T^2)$, and ξ_b. The more recent investigation (Balsillie, 1999b; Balsillie and Tanner, 1999) considered 771 data sets for these variables, forthcoming from 23 small wave laboratory studies, four laboratory investigations for prototypical waves, and five field investigations for large waves. These data represent a domain of close to 2.5 orders of magnitude (*i.e.,* from 0.02 m to 6 m for d_b, and from 0.02 m to 4 m for $\bar{H}_b$).

Stepwise regression is a powerful and rigorous statistical method which allows one to assess the relative contributory importance of independent variables (Harrison and Krumbein, 1964; Krumbein and Graybill, 1965). Stepwise regression results (Balsillie, 1999b; Balsillie and Tanner, 1999) showed that $\bar{H}_b$ was overwhelmingly strong in its relationship to d_b. Net contributions of independent variables (in the presence of each other) predicting d_b were: $\bar{H}_b$: 94.26%, T: 0.01%, tan α_b: 0.00%, ξ_b: 0.01%, and $\bar{H}_b/(g\ T^2)$: 0.00%. The updated comparative analysis, once again, showed that McCowan's equation, in every case, performed better than the more complex predictive equations. This should, in fact, be expected from the stepwise regression results, since variables or parameters other than $\bar{H}_b$ had inconsequential net contributions. Functional regression resulted in an outcome (Balsillie, 1999b; Balsillie and Tanner, 1999) of:

$$d_b = 1.277\bar{H}_b \tag{7}$$

substantiating McCowan's equation. Isn't it nice to know that some things can remain simple. Moreover, it was demonstrated (Balsillie, 1999b, Appendix VII) that it would be futile to collect more data to "improve" any fit using surrogate data. If we wish to continue to pursue the subject, only the pursuit of the *kinematic stability parameter* would appear to provide conclusive results (only a minimal amount of data has thus far been collected on this parameter).

REASSESSMENT OF WAVE ENERGY CONTENT

Coastal practitioners have tenaciously persisted, without many questions, in applying wave energy densities that are, by definition, applicable across the entire wavelength. That is, we define the wave energy density, $\bar{E}$, as:

$$\bar{E} = \frac{E_T}{L} \tag{8}$$

where E_T is the total energy (*i.e.,* sum of the potential and kinetic energies) contained in one wavelength, and L is the wavelength.

It has not been made clear, however, just how energy might vary across the wavelength. Given the fact that potential wave energy is assessed relative to the height of the wave form (*i.e.,* free surface) about the still water level, one might suspect that total wave crest and wave trough energies are different. Not only are they different, but remarkably so.

Let us first take the simple case using Airy Waves (*i.e.,* Small Amplitude Wave Theory). These waves are symmetrical in both vertical and horizontal planes. Moreover, the theory is applicable in deep and most of transitional water depths, but not in shallower transitional water depths or in shallow water. For the moment, however, let us assume that Airy Waves can shore-break. It was found (BALSILLIE, 1997, 1999c) that wave crest total energies exceeded wave trough total energies by a factor of five. Wave crest energy densities also exceeded wave trough energy densities by a factor of five, because of the symmetrical nature of the waves.

At the shore-breaking position, however, the wave profile is not symmetrical. Rather, it is distorted in both the vertical and horizontal planes. Based on measured wave profile distortion data at the shore-breaker position, BALSILLIE (1997, 1999c) investigated wavelength, wave crest, and wave trough energy contents. Shore-breaking wave profile distortion was found to be related to the wave steepness and bed slope, expressed in terms of the modified surf similarity parameter stated earlier, and apply regardless of the type of shore-breaker. It was determined that total wave crest energies were five to 14 times total wave trough energies, increasing in value as the wave became longer (*i.e.,* as wave period increases, holding wave height constant). Moreover, for distorted shore-breakers, wave crest energy densities were constant at 14 times wave trough energy densities. These results are significant; a difference of almost 1.5 orders of magnitude is not trivial. The difference between crest and trough energy contents should greatly affect how we might apply destructive impact pressures where the elevation is of importance (*i.e.,* crest versus trough elevations), and where sediment transport is of concern (although, there are other factors which control sediment transport direction in addition to energy density differences).

Moreover, one can further assess the results for the distorted shore-breakers in terms of the relative dispersion (*i.e.,* standard deviation divided by the mean). Relative dispersions of less than 0.5 can be considered to represent "excellent homogeneity" for natural processes, 0.5 to 0.95 "good homogeneity", 0.95 to 1.35 "fair homogeneity", and greater than 1.35 "poor homogeneity". The latter corresponds to granulometric relative dispersions for sand-sized littoral sediments (BALSILLIE, 1995). We can take this as a clue to represent wave activity if we are serious about quantifying the relationship between wave energy and sediment transport. Energy density relative dispersions (R.D.s) for distorted shore-breakers across the entire wavelength were, in our experience, poor (ranging from 1.333 to 1.811). Energy density R.D.s were 0.768 for the wave crest and 0.87 for the wave trough; while not excellent, they are good. It is notable that when considering wave crest front and back, and wave trough front and back energy densities, R.D.s are not improved compared to crest and trough R.D.s.

MISUSE OF TIDAL DATUM REFERENCE PLANES

Tidal datum planes ". . . are planes of reference derived from the rise and fall of the oceanic tide" (SWANSON, 1974). There are numerous tidal datum planes. Commonly used datums in the United States include the planes of *mean higher high water* (MHHW), *mean high water* (MHW), *mean tide level* (MTL), *mean see level* (MSL), *mean low water* (MLW), and *mean lower low water* (MLLW). Each datum is defined for a specific purpose or to help describe some tidal phenomenon. For instance, MHW high water datums have been specified by cartographers in some states (*e.g.,* Florida) as a boundary of property ownership. Low water datum planes have been used as a chart datum because it is a conservative measure of water depth and, hence, provides a factor of safety in navigation. Not only do tidal datum specifications vary geographically based on local to regional conditions for purposes of boundary delineation, cartographic planes, design of coastal structures, and land use designations, *etc.,* but they have changed historically as well (BALSILLIE and others, 1998).

National Geodetic Vertical Datum of 1929 (NGVD29) and/or newer geodetic datums (*e.g., North American Vertical Datum* of 1988 or NAVD88) are not tidal datums but, rather, standard geodetic datums determined by taking the average of mean sea levels at open-ocean sites around the U.S. (NGVD29) or North America (NAVD88).

The criticism of this work is centered about the observation that there seems to be an increasing number of misapplications of tidal datums by coastal science and engineering practitioners.

Here, we wish to illustrate one important example concerning the misuse of tidal datums. Let us assume that two identical storms or hurricanes make landfall in the same manner, one along northern Amelia Island, Nassau Co., FL and the other along St. George Island, Franklin Co., FL where the nearshore, beach, and coastal profiles at both localities are assumed identical. Let us reference resulting erosion volumes to MHW. MHW along Amelia Island is +0.95 m MSL (or +1.02 m NGVD29), and +0.20 m MSL (or +0.27 m NGVD29) along St. George Island (BALSILLIE and others, 1998). For a peak combined storm tide elevation of +1.22 m MSL, the Amelia Island erosion volume will be 20.36 m^3/m above MHW, 33% less than the 30.22 m^3/m above MHW eroded along St. George Island (note: this example is graphically demonstrated in BALSILLIE (1999a, p 37, Fig. 4)). While it is true that both answers are correct, the fact remains that they are NOT comparable; that is, one cannot compare such outcomes from location to location. If, however, one calculates erosion volumes above NGVD29 or NAVD88, they would be identical. One should recognize, however, that NGVD29 and NAVD88 are geodetic planes and that local long-term average water levels do, in reality, depart somewhat from the geodetic datums and are, therefore, real. The answer is to reference erosion volumes to MSL. By using MSL, referenced outcomes are not only precise, but can be compared from locality to locality, thereby greatly increasing the usefulness of the data.

Other examples of the use and misuse of tidal datums in coastal applications are discussed and demonstrated in BALSILLIE (1999a).

CONCLUSION

We conclude by emphasizing that the list of "red flags" on the beach is by no means exhausted. However, the serious researcher now finds on this list, and the previously published list (TANNER, 1998), starting points for work at the thesis, dissertation, or professional level.

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