Suspended Sediment Discharge on a Non-Tidal Coast

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Abstract

A field study was conducted on a non-tidal sand beach to measure the relationship between wave energy and the longshore transport of suspended sediment. The range of suspended sediment concentrations was similar to that reported elsewhere. The relation between longshore transport and longshore energy flux derived from this data set is about half that amount predicted by such widely quoted sources as Komar and Inman (1970).

Introduction

In recent times an increasing effort has been directed toward finding a universal mathematical expression for the rate of sand transport on beaches. Although the basic concepts of this phenomenon are well known, the problem still remains largely unsolved. For instance, it is well known that large volumes of sediment are displaced and transported along coasts through the action of currents which are induced when waves break in shallow water. It is also well known that the sand particles making up this longshore transport are moved either as bed load (i.e. material sliding or rolling while supported by, or in contact with, other grains on the bottom) or suspended load (i.e. material totally supported by the flow medium). Given these concepts as starting points, various relationships have been proposed to provide quantitative values for sand transport alongshore, based on variables related to the forces released when waves break on a beach (see, for example, Galvin and Vitale (1976)). However, for a variety of reasons, not the least of which is the complexity of the physical situation where turbulence and the variable nature of the bottom materials and geometry usually defy generalization, the goal of a generally-accepted universal relationship for longshore sediment transport has still not been achieved.

It is recognized, however, that, to be credible, such a relationship must be founded upon an adequate data base involving field measurements of those aspects of the physical situation that are most relevant, namely incident wave energy and the resulting longshore sediment transport. Because accurate measurement of the total transport (suspended and bed-load) still remains practically impossible on non-tidal beaches, it was decided that the longshore flux of suspended particles in the surf zone could serve as a reasonable estimate for the total transport in such cases. Furthermore, this is a parameter that is more amenable to direct measurement.

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The goal of this report is to describe the relationships obtained for a site in Lake Ontario between the suspended sediment flux under moderate to intense wave conditions and breaker zone wave energy calculated from concurrent wave measurements. It is also meant to provide a realistic indication of the scale of littoral processes on non-tidal coasts such as the Laurentian Great Lakes compared with that of marine and tidal areas.

Study Site Description

The site at which the measurements described here were taken is located at the extreme western end of Lake Ontario on a large bay-mouth bar separating Burlington Bay from the main body of the lake (Fig. 1). The shoreline is regular and trends approximately NNW, or perpendicular to the direction of maximum fetch (ENE, fetch - 400 km) for Lake Ontario. Waves reaching the site therefore can attain heights of more than 3 m and tend to approach the shore at close to right angles.

The local bottom topography in the inner nearshore zone (<3 m depth and <70 m from shore) is characterized by rhythmic sets of crescentic longshore bars (about 120 m long and 1 m high). Systematic monitoring of bathymetric profiles at the site since 1976 indicates that these structures are very sensitive to wave conditions, while, on the other hand, the bottom topography further offshore shows relatively minor changes during this period.

The nearshore bottom is composed of well-sorted sand, with grain sizes within the 5 m contour averaging 2.0ϕ (0.25 mm diameter). Coarser material (up to gravel size) often occurs in the vicinity of the beach step (<1 m depth) and on the subaerial beach face. Bottom slopes in the area range from 0.05 to 0.02 in the inner nearshore zone. The overall slope out to 300 m averages 0.017.

Methodology

The field measurement program was initiated in the fall of 1977. The methodology has been described in previous publications (Coakley and others, 1978, Coakley 1980). Briefly, the method entailed the collection at three vertical elevations (10, 30 and 100 cm above the bed) of 45 second averages of suspended sediment concentration, based on 2ℓ pumped samples of water/sediment suspensions; water depth values; and current velocity records (two orthogonal horizontal components) along a fixed nearshore transect, during periods of moderate to high wave activity. The transect extended approximately 100 m over water, terminating at a water depth of about 3.5 m. The instrument platform was a robust, open-work sled, equipped with a vertically-articulated boom protruding 1.5 m into the oncoming wave field, to which the suspended sediment sample intake, as well as the current sensors, were attached. The sled was manipulated from shore along the transect, stopping at up to ten regularly-spaced stations. A complete run took exactly 1 hour to complete, thus allowing replicate runs of the same storm to be carried out. A schematic illustration of the field layout is presented in Fig. 1.

Continuous records of wave parameters at the study site were also collected using a fixed, linear array of three surface-piercing wave gauges installed approximately 225 m from the shoreline in about 5 m of water (outside the breaker zone for all waves encountered). Wave measurements were made either immediately prior to, or during a sled experiment.

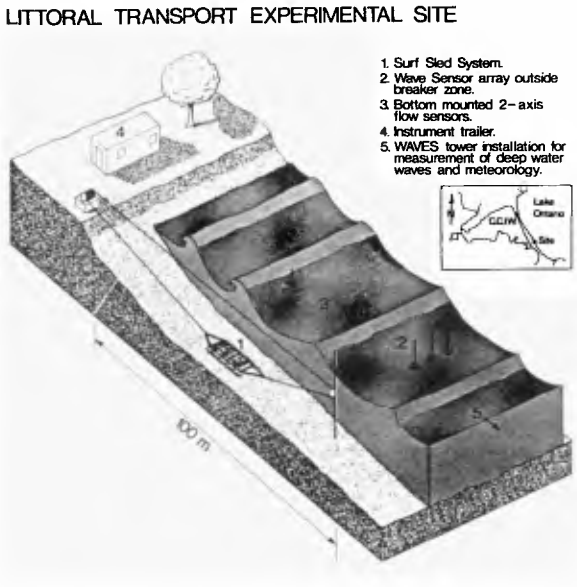

Figure 1 Perspective view of the experimental site, showing sled cableway, sled, wave sensor array and other instruments.

Description of the Data Set

1. Wave Data

The time series of instantaneous water elevations at the wave gauges were analyzed to obtain variance spectral densities, using the fast Fourier transform technique. Characteristic (significant) wave heights and peak periods were calculated for each experiment. Covariance spectral calculations allowed the determination of phase angle of the waves between wave gauge pairs as a function of frequency, and from this the direction of the peak of the spectrum was found. For each experiment, this latter value was used to characterize the wave direction at the location of the gauges.

The wave data at the gauges are summarized in Table 1. The characteristic or significant wave height is H_c, the period of the peak of the spectrum is T_p and the angle the waves make with the shore normal is α. (The wave parameters for experiment 7-1 were manually estimated from the time series.)

The bathymetric charts prepared from monitor surveys done after major storms at the experiment site were examined to determine the best way of transferring the wave information from the location of the gauges to the breaker zone. The nearshore bathymetry, as described previously, was irregular, with both small-and large-scale structures. Furthermore, the waves were "sea" as opposed to "swell" and, for this reason, a distinct breaker line was not always readily apparent.

Detailed wave ray calculations were done, but due to the irregular nearshore bathymetry, the resulting ray patterns did not give a consistent description of the waves inshore the wave gauge site. Several of the more common breaking criteria (such as the depth of breaking being equal to 1.28 times the breaking wave height) were tried in conjunction with the ray computations. These criteria were found to be ineffective in defining the surf zone as observed in the field. In the end, the method that gave the most consistent results and that was used here is as follows:

The bathymetry between the wave gauges and the shore was assumed to have straight contours parallel to the water's edge. The location and water depth of the breaker line was determined based on visual observations in combination with the position of normal breaker-line indicators, namely longshore bars. Snell's law was used to calculate the wave direction at the breaker line, and the shoaling and refraction coefficients were evaluated to get the breaking wave height.

The breaker line wave conditions, derived from the gauge data, are shown in Table 3. The depth at breaking is d_b, and the characteristic wave height at breaking is H_b; the other parameters have the same definitions as in Table 1, or as defined later.

2. Suspended Sediment Discharge

The data retrieved by the sled consisted of the following:

TABLE 1. Wave Conditions at the Wave Gauge Array
(approximately 225 m offshore)

Exp/Run	T_p s	H_c m	α degrees	Water Depth m
2-2	4.9	0.9	1.1	5.1
3-1	6.1	1.0	-3.5	5.2
3-2	6.1	0.9	-2.7	5.2
4-1	3.6	0.6	-19.4	5.1
4-2	4.1	0.6	-6.5	5.1
6-1	6.1	1.9	1.1	4.6
9-1	4.9	0.8	-1.8	4.3
9-2	4.9	0.7	0.0	4.3
10-1	6.1	1.0	-5.8	4.3
11-1	6.1	0.9	0.1	4.3
13-1	4.9	0.8	4.2	4.8
15-1	4.9	0.8	2.3	4.9
16-1	3.6	0.6	-2.0	4.8
2-1†	4.9	0.8	3.8	5.1
7-1†	5.6	2.1	-	4.3
16-2†	4.9	0.9	2.2	4.8
16-3†	4.9	0.8	1.0	4.8

* Negative angle implies northward currents (wave ray on south side of shore normal)

† Partial data set, not used for discharge calculations.

TABLE 2. Longshore Suspended Sediment Discharge per Unit Width of Surf-Zone Transect Measured at Each Transect Station (Discharge expressed in mg/s.cm)

Exp/Run	Inner Transect <35 m			Mid-Transect 35-70 m				Outer Transect 70-115 m			Total Longshore Discharge over Transect (kg/h)
	1	2	3	4	5	6	7	8	9	10	
2/2	58†	-70	-416	-1516	-276	-242	-134	-137	-190	42*	-10,265
3/1	30†	-165†	-541	-566	-395	-487	-651	-435	-191	-436	-12,734
3/2	15†	-54†	-3995	-1577	-1334†	-734	-213	-80	-111	-80	-29,106
4/1	-30†	-171	-363†	-146†	-347	-38	15	-32	-19	-10	-3,889
4/2	-21†	-17†	-307	-179	-194	3	-106	-58	-26	-16	-3,230
6/1	-108	-47†	-343†	-991	-3629	10,170	-4067	-2371*	-2059	-2909	-88,614
9/1	-46	-453	44	-405		-31	-184	-1	-41	0	-4,026
9/2	-59	-35	-95	-151		-217	-115	-54	-18	-12†	-2,351
10/1	-225	-725	-3291*	-7767†	-4489*	2,062	-908	-188†*	-274	-145†	-55,034
11/1	-492†	-371†	-235†	-53†	-422	-341	-1206	-148	-20	-181	-12,314
13/1	-417†*	-298†	-240	-97	-80	163	-110	170	45	99†	-1,838
15/1	743	349	348	-20	-63	-34	-15	-21	1	-9	+4,612
16/1	61	113	-174	-71	-104	-75	-39	-43	-27	-29†	-1,479

* Interpolation or extrapolation used to replace anomalously high value of concentration.

† Interpolation or extrpaolation used to replace missing value(s) of concentration or current.

Negative values indicate transport toward the north, positive toward the south.

TABLE 3. Summary of Breaking Wave and Suspended Sediment Transport Conditions at Van Wagners Beach, Lake Ontario (waves refracted into break-point)

Exp/ Run	H_b	T_p	α	Breaker Type	Breaker Depth d_b	Surf-Zone Width λ_b	ξ_b**	I_ℓ	P_ℓ
	m	s	degrees		m	m		N/s	N/s
2/2*	0.93	4.9	0.8	S	2.2	51	0.27	-17	+29
3/1	1.15	6.1	-2.4	S, P	2.2	51	0.31	-22	-139
3/2	0.99	6.1	-1.8	P	2.2	51	0.33	-49	-79
4/1†	0.60	3.6	-16.7†	S	1.9	43	0.26	-7	-194
4/2	0.63	4.1	-4.6	S	1.9	43	0.29	-9	-66
6/1*	1.98	6.1	0.9	P, S	3.7	200	0.10	-150	+181
9/1	0.96	4.9	-1.1	P, S	1.4	50	0.17	-7	-37
9/2*	0.85	4.9	0.0	P, S	1.4	50	0.19	+4	0
10/1	1.27	6.1	-3.5	S	1.4	50	0.19	-9.3	-206
11/1*	1.10	6.1	0.1	P, S	1.4	50	0.20	-21	+2
13/1*	0.85	4.9	3.1	S	1.9	65	0.19	-3	+93
15/1	0.90	4.9	1.6	(n.r.)	2.3	70	0.21	+8	+51
16/1	0.61	3.6	-1.5	S, P	2.1	60	0.20	-3	-18

* Sign of wave angle, α, indicates longshore current opposite in direction to measured by the surf-sled, or α=0. Confused breaker pattern noted in field.

† Wave angle anomalously high.

S: Spilling. P: Plunging. n.r.: not recorded.

** $\xi = \dfrac{d_b/\lambda_b}{(H_b/L_o)^{1/2}}$ the surf similarity parameter, where L_o is the deep water wavelength.

(i) Up to 30-2ℓ samples of suspension collected at 10 stations along the surf-zone transect; at three fixed elevations for each station.

(ii) Depth profiles along the transect measured by a recording pressure transducer mounted on the sled.

(iii) 45-second time-records of flow velocities collected for each of the three vertical sampling elevations measured at each station.

Mass/volume concentrations were later obtained gravimetrically from the samples. These concentration values were combined with the calculated time-averaged longshore component of flow to provide point discharge values at each of the three elevations comprising each station.

In Coakley (1980), an integration was done using 10 cm spaced point values which were interpolated through a computerized procedure in which the three measured points were fitted to a theoretical (exponential) distribution. Further appraisal of this technique in the light of the small number of points on the curve (3), as well as the frequent apparent deviation of the points from the expected theoretical curve, led us to abandon this technique. To obtain the results presented here, the water column was simply divided into four compartments with the time-averaged concentration/longshore current data points assumed to be representative of the space halfway to adjacent data points. Values for concentration above the top compartment (165 cm above the bed) were arbitrarily set to zero. This appeared reasonable as concentration values even at the top position sampled (100 cm) were almost always very low (< 100 mg/ℓ). The product of concentration and flow for each block was then summed to obtain total discharge for that station.

The values predictably are slightly different from those previously reported (Coakley, 1980) based on the curve-lifting procedure, but the differences are less than 20 percent in most cases. However, several cases (exp. 3-1, 9-1, 9-2, 13-1) where redigitizing and recalculation were necessary, show larger discrepancies, and differ from previously published figures by up to a factor of 3.

The vertically summed discharge values for each station were then summed horizontally over the transect length, using a simple half-interval product summation. The discharge values for each station and for the entire transect (expressed in kg/hr) are presented in Table 2, for each experiment run.

Data Screening

From the above, it is seen that a complete data set for each station should ideally contain a depth record, three 45-second averages of onshore-offshore and alongshore currents and three values for concentration at the three different sample elevations. In addition, such complete stations should occur, if not at all stations occupied, at least at enough stations to provide adequate coverage of the transect length.

This was, as could be expected, not achieved in a considerable number of experiment traverses. The data set was prone to missing values in any of the four measured variables. Such lapses were due mainly to mechanical failure in the hostile environment of the surf zone, where suspended sand and algal debris

tended to clog the moving parts of sensors, and occasional freezing of sample tubing made pumping impossible.

Data evaluation and screening was therefore a necessary step. Several entire runs or stations had to be left out of the present analysis due to large-scale absence of essential data components. Lesser gaps could be filled mainly by interpolation and extrapolation. Other experiment runs were virtually gap-free. Table 2, therefore, shows only the 13 experiment runs which survived the screening process. Only these will be considered in the calculation of suspended sediment discharge. Not shown on Table 2 are four other partial data sets which will be used in a later section only in examining the sediment suspension/wave energy relationship (Fig. 3). These data sets had no flow records, but wave and concentration data were recorded. The wave data for these four experiments are shown at the bottom of Table 1.

The Combined Data Set

In Table 3, the measured and derived parameters associated with the incident wave field and suspended sediment discharge are presented. The parameter, I_ℓ, is defined as the total immersed weight of suspended sediment discharge over the transect length, and is expressed in Newtons per second (Komar and Inman, 1970). It was obtained by converting the discharge figures shown in Table 2 to immersed weight quantities. P_ℓ is the value calculated for the lateral thrust times the phase speed (Longuet-Higgins, 1972), also called the longshore component of wave energy density flux, expressed in Newtons per second. The relationship used to calculate P_ℓ is:

$$P_\ell = \frac{gH^2_{rms} c_g \cdot \sin\alpha \cos\alpha}{8.0}$$

where $H_{rms} = H_b/1.416$, c_g = wave group celerity, and α =the angle between the wave orthogonal and the beach normal (all values at breaking). Also shown on the table are subjective breaker descriptions and a calculation of surf-zone width based on the position of the calculated break-point with respect to the strand-line on the day of the experiment.

Several of the experiments showed discrepancies between the transport direction of suspended sediment measured by the sled (as denoted by the sign of the discharge quantities in Table 2) and the expected direction as indicated by the sign of the wave angle, α (Table 3). The cases where this occurs are Exp. 2-2, 6-1, 9-2, 11-1, and 13-1. In addition, one experiment (4-1) showed a wave angle of 19.4° which is anomalously higher than the range of values measured. While most of these discrepancies could be explained in view of the spatially varying conditions in a surf-zone characterized by an irregular bathymetry and low wave angles, they nonetheless present problems for further analysis and interpretation of the data set. These problems will be addressed to some degree in the Discussion section.

Correlation Between Suspended Sediment Transport and Longshore Wave Energy

The values shown in Table 3 were plotted on log/log paper (Fig. 2), after the method of Komar and Inman (1970). Only the seven data points remaining after exclusion of those showing discrepancies have been plotted. Also

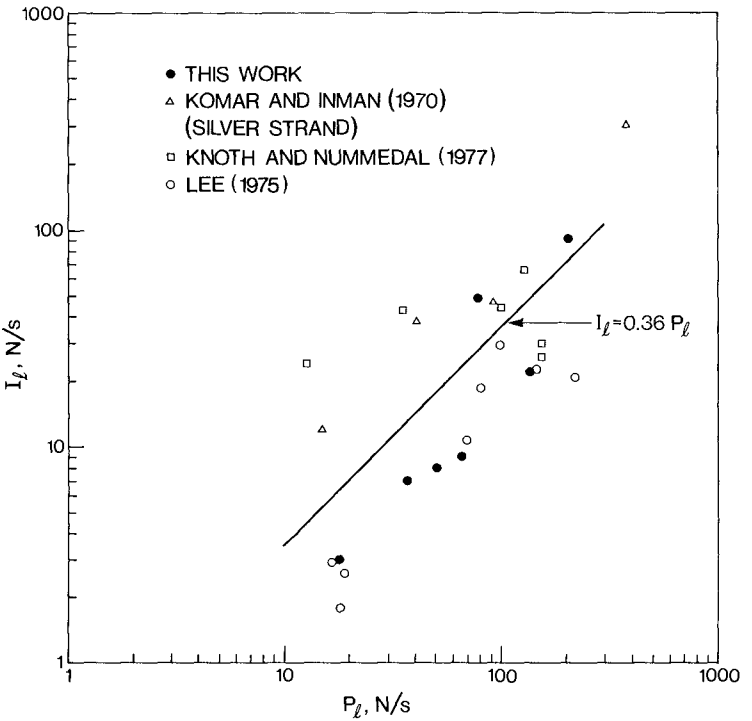

FIGURE 2. IMMERSED WEIGHT SUSPENDED SEDIMENT DISCHARGE vs LATERAL THRUST x PHASE SPEED.

shown for comparison are the data points for total transport listed in Komar and Inman (1970) for Silver Strand Beach, a beach of comparable slope to Van Wagners Beach, and those of Knoth and Nummedal (1977) for North Bull Island, South Carolina, and those of Lee (1975) for Lake Michigan.

The linear regression of I_ℓ against P_ℓ was calculated for the seven solid points, and was found to be:

$$I_\ell = 0.36\, P_\ell$$

and is plotted on Fig. 2.

This value of the coefficient of P_ℓ is therefore slightly less than one-half that calculated by Komar and Inman (1970) for the total transport of sand on marine beaches on the Pacific coast of North America (I_ℓ=0.77 P_ℓ). Our coefficient is, however, over twice the value of 0.15 that we obtained from the tabulated data of Lee (1975). The data of Knoth and Nummedal (1977) does not fit this type of model.

The correlation coefficient for the regression using the seven data points shown in the figure was calculated to be: r=0.84, compared to 0.99 (calculated by us) for the data tabulated by Komar and Inman (1970), p. 5921. The value of r=0.84 for the correlation coefficient is very significant, i.e. it exceeds the 99 percent confidence level (Fisher, 1970, p. 211).

Suspended Sediment Concentration vs. Wave Energy

The suspended sediment discharge figure calculated was based on the summed products of concentration and longshore velocity averaged over the sampling interval and integrated over the water depth and transect length. In view of the obvious difficulty in reconciling, with consistency, the calculated longshore flow direction with the measured flow especially in beaches with low wave angles and irregular bottom topography, it might be useful to examine the relationship between wave energy (total) and a non-directional parameter, such as mean concentration.

Figure 3 shows a plot on semi-log paper of total incident wave energy density (E) versus the vertically and horizontally averaged suspended sediment concentration termed the global concentration, or $\bar{C}^*$. This plot was based on a total of 17 data points, which included the four experimental runs referred to earlier where the flow components were not recorded, due to sensor malfunction.

The plot shows an obvious correlation between the two parameters, and the linear regression of $\bar{C}^*$ on ln E was calculated to be:

$$\bar{C}^* = -903 + 206 \ln E$$

where $\bar{C}^*$is in mg/ℓ and E in N/m. The correlation coefficient is 0.85. The value of the correlation coefficient is very significant at the 99 percent confidence level, and thus indicates concentration of suspended sediment can be well predicted using wave data alone. It should be kept in mind, however, that such a relationship is also dependent on the grain size of the beach in question, and care should be taken in extrapolating it to other beaches.

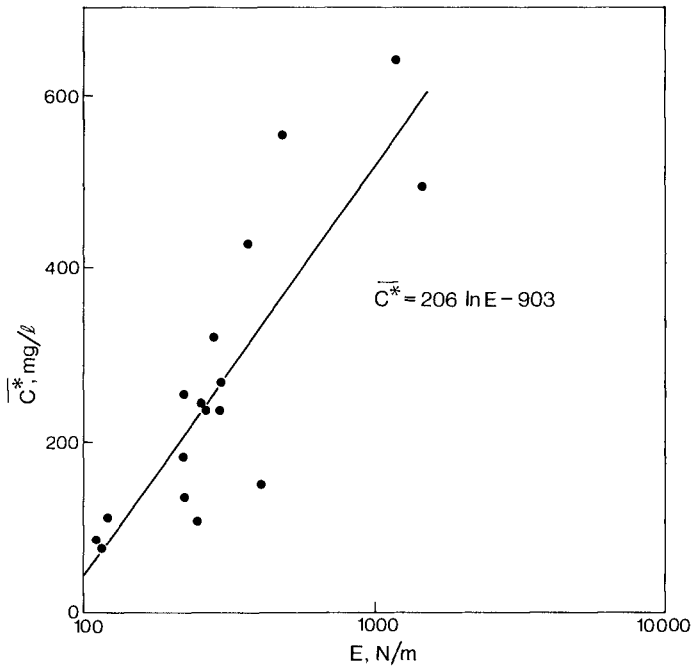

FIGURE 3. GLOBAL CONCENTRATION vs WAVE ENERGY DENSITY

Discussion

The results presented above were obtained using only screened data. Also, they were based on time-averaged point measurements of 45 s duration measured sequentially at three elevations (over a period of 3 min.), and were repeated at a series of stations across the surf-zone in succession; a process which took approximately one hour. There are several areas on which such an arrangement could be criticized, for instance:

- The discharge figures assume that the measurements are synoptic and that the transport has reached a steady-state condition, i.e. taking place at the same time across the entire zone and basically unchanging with time. The measurements covered a time-period of one hour while the vertical profile at each station took three minutes. From our knowledge of surf-zone dynamics, it is more likely that the process varies both in time and space even in a fully-developed storm and thus it should be sampled simultaneously over the zone for most accurate results.

- The time-duration of the sampling of sediment concentration and flow was only 45 s for operational reasons. The work of several researchers (Downing and others, 1981; Meadows, 1976, and Leonard and Brenninkmeyer 1978) indicated the presence of long-period events in surf-zone dynamics at time-scales ranging from fractions of the wave period to more than 120 s. This would imply that time series of 45 s, such as ours, might be subject to some inaccuracies.

These problems in experiment design, coupled with other complications introduced by irregular bottom topography, difficulty in defining accurately the wave angle at breaking, and in determining the width of the surf-zone with any accuracy, are probably all factors in the considerable variability which characterizes the data set. For this reason, the results presented above must be considered only as first-order approximations of a complicated and highly variable process, but which indicate, at least, the scale and overall trends in suspended sediment transport on beaches. Furthermore, the results must be considered as site-specific (to this particular Great Lakes beach) until more general insights into the influence of sediment grain-size, beach geometry and bottom topography can be included.

There appears to be no justification, therefore, for a more sophisticated treatment of the data than the conservative screening and empirical analysis featured in the previous section. Still, some pertinent and useful comments can be made on the results.

The data confirm that a statistically significant relationship exists between suspended sediment transport and the longshore component of wave energy density flux. We have also shown that a considerable quantity of sediment can be moved as suspended sediment (up to 88,600 kg/h (Table 2)) during intense Lake Ontario storms. We are, however, no closer to determining how large a proportion of the total littoral transport at the site this figure represents, since no reliable estimate of the bedload transport or the total drift at the site was possible. There is a danger in trying to obtain such a total drift estimate by applying empirical relationships, such as that of Komar and Inman (1970), since their base data were collected on marine coasts having no proven process-related affinity to beaches in the Great Lakes. Assuming that the total

transport is adequately represented by suspended transport (Kana, 1977), then the longshore sediment transport at Van Wagner's Beach is approximately half of the total transport on ocean beaches studied by Komar and Inman (1970). Furthermore, if the latter value is only regarded as an order of magnitude estimate, as suggested by Greer and Madsen (1978), then the results of this paper are in excellent agreement to that degree of accuracy.

Examination of the magnitude of the suspended sediment concentration and transport measurements reported by others (Kana, 1977 and 1978; Fairchild, 1977; Downing and others, 1981) provides an interesting comparison. Table 4 lists comparable statistics from these sources, along with values obtained in this study. In spite of the fact that procedures differed greatly, the statistics all include either average concentrations and/or suspended sediment discharge. The average concentrations are all of similar magnitude. Fairchild (1977) is larger because it is a measure of concentration very near the bed. The ranges of discharge measurements are all overlapping. The wave conditions reported by the various authors are quite different from the ones in this study. The wave heights in this study as a group form the high end of the range of all wave heights reported elsewhere. The waves are also relatively steep, because they were locally generated storm waves. The longshore energy flux values, on the other hand, are of the same order as those reported by Komar and Inman (1970). The difference is accounted for by the relatively small wave angles reported here.

Kana (1977) reported a marked difference in suspended sediment concentration depending on breaker type: "plunging waves entrain almost one order more sediment than spilling type breakers". Examination of Table 3 reveals that in our study there was only one case of clearly plunging breakers: the majority are a combination and a few are spilling only. Spilling waves entraining less sediment and the fact that waves reported here tended to be at least partly spilling would suggest that less transport is to be expected and thus is supportive of the lower value of the coefficient (0.36) found in this study. In a recent paper, Hallermeier (1982) points out that more effective transport apparently occurs for high values of ξ, the surf similarity parameter (Battjies, 1975). High ξ corresponds to swell conditions, and since the values of ξ were small for our experiments as shown in Table 3, correspondingly smaller measured transport rates are to be expected. It would appear, as more evidence is gathered, that the characterization of the beach and breaking conditions using the surf similarity parameter might lead to better prediction of transport rates. This approach is discussed in a paper in these Proceedings by Sayao and Kamphuis (1982).

Concluding Remarks

Suspended sediment, longshore current, and wave data have been collected during moderate to severe early winter storms at Van Wagner's Beach, Lake Ontario. This data set is distinguished from others in that the site is a non-tidal beach characterized by offshore bars; the wave heights were some of the largest encountered during experiments of this type; the angles of wave approach were relatively small.

The range of suspended sediment concentrations and the range of transport rates encountered are similar to those reported elsewhere. However, the relation between longshore transport and longshore energy flux derived from this data set suggests that about half the amount of sediment is moved in suspension for a comparable energy flux as was reported for total transport by

TABLE 4. Representative Suspended Sediment Transport Values from Several Published Sources

Researcher (s)	Beach Location	$\bar{C}$* (avg. concentration across surf-zone	Discharge
Downing, et al. 1981	Twin Harbours Beach Washington, U.S.A.	(not calculated)	76.5 m^3/h
Kana (1977) (examples given in Table 2, p. 378)	Price Inlet S. Carolina, U.S.A.	0.7 g/ℓ	1.3 - 130 m^3/h (49-4908 tonnes/day)
Kana (1978) (extracted from Fig. 5, p. 1734)	Price Inlet S. Carolina, U.S.A.	0.33 g/ℓ	
Fairchild (1972) (extracted from Fig. 3, p. 1086)	Ventnor, N. J.; Nags Head, S.C., and Mission Bay, California, U.S.A.	(not calculated)	15.3 - 350 m^3/h (4.8×10^2 - 1.1×10^4 yd^3/d)
Fairchild (1977) p. 46	Ventnor, N.J., Nags Head, N.C.	2.7 g/ℓ (typical within 0.4 ft (0.12 m) of bottom)	0.9-55 m^3/h based on maximum flux values 2700 kg/m^3 solids density 0.60 void ratio
Coakley and Skafel (this report)	Van Wagners Beach	0.27 g/ℓ	3.8 - 230 m^3/h

Komar and Inman (1970). This difference is not unreasonable given the complexity of shore processes and the difficulty of obtaining true measures of transport.

The controversy over the question of bed load versus suspended load has not been addressed. It is clear, however, that at our site substantial volumes of material are moved by suspended load.

References

Coakley, J. P., H. A. Savile, M. Pedrosa, and M. Larocque, 1978. Sled System for profiling suspended littoral drift. Proc. 16th Int. Conf. on Coastal Eng., ASCE, Hamburg, pp. 1764-1775.

Coakley, J. P., 1980. Field measurements of suspended sediment transport in the littoral zone of Lake Ontario. Proc. Cdn. Coastal Conf. 1980, Burlington, pp. 31-46.

Downing, J. P., R. W. Sternberg, and C.R.B. Lister, 1981. New instrumentation for the investigation of suspended sediment processes in the shallow marine environment. Marine Geol. 42 (in press).

Fairchild, J. C., 1972. Longshore transport of suspended sediment. Proc. 13th Int. Conf. on Coastal Eng., ASCE, pp. 1069-1087.

Fairchild, J. C., 1977. Suspended sediment in the littoral zone at Ventnor, New Jersey, and Nags Head, North Carolina. U.S. Army Corps of Engineers, CERC, Tech. Paper 77-5, 97 p.

Fisher, R. A., 1970. Statistical methods for research workers. 14th ed., Hafner Pubc. Co., Darien, Conn.

Galvin, C. J., and P. Vitale, 1976. Longshore transport prediction - SPM 1973 Revision. Proc. 15th Int. Conf. on Coastal Eng., Vol. 2, pp. 1133-1148.

Greer, M. N., and O. S. Madsen, 1978. Longshore sediment transport data: A Review. Proc. 16th Int. Conf. on Coastal Eng., Vol. 2, pp. 1563-1576.

Hallermeier, R. J., 1982. Bedload and wave thrust computations of alongshore sand transport. J. Geophys. Res. 87 (C8), pp. 5741-5751.

Kana,T. W., 1977. Suspended sediment transport at Price Inlet, S.C. Coastal Sediments '77, an ASCE Symposium, Charleston, S. C., pp. 366-382.

Kana,T. W., 1978. Surf zone measurements of suspended sediment. Proc. 16th Int. Conf. on Coastal Eng., ASCE, Vol. 2, pp. 1725-1743.

Komar, P. D., and D. L. Inman, 1970. Longshore sand transport on beaches. J. Geophys. Res., 75 (30), pp. 5914-5927.

Knoth, J. S., and D. Nummedal, 1977. Longshore sediment transport using fluorescent tracer. Coastal Sediments '77, an ASCE Symposium, Charleston, S. C., pp. 383-398.

Lee, K. K., 1975. Longshore currents and sediment transport in west shore of Lake Michigan. Water Resources Research 11 (6), pp. 1029-1032.

Leonard, J. E., and B. M. Brenninkmeyer, 1978. Periodicity of suspended sand movement during a storm. Proc. 16th Int. Conf. on Coastal Eng., ASCE.

Longuet-Higgins, M. S., 1972. Recent progress in the study of longshore currents. In "Waves on Beaches", Ed. by Meyer, Academic Press.

Meadows, G. A., 1976. Time-dependent fluctuations in longshore currents. Proc. 15th Int. Conf. on Coastal Eng., ASCE.

Sayao, O.S.F.J. and J. W. Kamphuis, 1982. Model tests on littoral sand transport rates. These Proceedings.