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Cross-shore and longshore transport of tracer pebbles on a macrotidal mixed sediment beach, Somme Estuary, France.

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Despite much current research, the available formulae for predicting pebble transport on shingle and mixed sediment beaches still provide generally poor results unless they are calibrated against field data from the site in question. This is due mainly to the number of parameters that are site specific, such as grain size or beach width. In order to improve the predictive formulae, the current study has attempted to collect accurate data on the transport behaviour of pebbles on a mixed-sediment beach in a macrotidal environment at Cayeux-sur-Mer in northern France (Figure 1).

Cayeux-sur-Mer beach experiences strong longshore transport in an overall northerly direction. It is part of a 40 to 50 million m^3 mixed sand and shingle spit that extends from chalk cliffs at its southern end 16 km northwards into the River Somme. To combat shingle loss and possible flooding of the land behind, groynes have been built northwards from Ault and now extend to just south of Cayeux-sur-Mer where at the moment the beach is still wide enough to prevent any flooding. At Cayeux-sur-Mer the beach is aligned N20-30º and the tidal range is 6.6-11.2 m. The shingle has an average D_{50} of 30-40 mm, with sand beneath the shingle comprising about 20% of the beach volume. The most frequent and also the highest and strongest incident waves occur between October and March and are from W to SW, comprising 50% of the annual wave spectrum. Incident waves from N to NE are less frequent, and form 15-20% of the annual spectrum. About 70% of the significant wave heights (Hs) are less than 1 m, 95% of the Hs are less than 2 m, and only 0.3% exceed 3 m (these total 25 hours/year).

The study area was selected because it offered a simple morphology and bathymetry, an absence of groynes, and an abundance of flint shingle, thus conforming to the recommendations of Van Wellen (1997). Sediment transport measurements were obtained from pebble tracing experiments and GPS surface surveys beyond the most northerly groyne. This groyne largely prevents material influx from the south so that the only source of additional shingle in the system comes from artificial recharge placed at the top of the beach.

Tracer pebbles 6-7 cm long were made of an epoxy resin with a copper core allowing their recovery down to a depth of 30 cm using a metal detector. Deployment normally occurred in three locations: on the upper, middle and lower part of the beach, down to depths of up to 40 cm. The tracers were collected over a neap-spring tide cycle during every other low tide following deployment at the preceding low tide. The wave conditions were recorded with an S4 directional wave recorder located directly on the sandy lower foreshore.

Over the 15 day study period, the tidal range varied between 4.5 m and 8.2 m, and a large spectrum of wave heights (0.6 m to 2.2 m) and periods (8 and 12 s) was observed. The wave direction stayed approximately constant at about 275° or 58° to the beach. In total, 550 tracers were deployed. The recovery rate after fifteen days was on average 37%, but sometimes exceeded 60% after a single tidal cycle. Significant longshore transport was observed, up to a maximum of 145 m. A clear relationship was identified between the pebble movement and wave height. However, the relationship was non-linear, with pebbles travelling furthest under moderate wave conditions. This highlights the importance of parameters other than wave height, such as pebble size, tidal range and beach slope. The pattern in pebble behaviour on the lower, middle and upper parts of the beach seemed to be consistent when deployments were conducted in these three locations (Figure 1). Pebbles injected on the lower and middle beach showed a clear longshore displacement whereas pebbles injected at the top of the beach were affected by a large seaward (cross shore) component. On the particular day illustrated in Figure 1, pebble recovery after 1 tide was 65.3% (98 pebbles). Of the pebbles from the top of the beach 64.1% were displaced down beach (23.1% of these showed an angle of displacement >45°), while this kind of movement only affected 51.4% of the pebbles from the middle of the beach (12.4% showing a displacement >45°) and 29.2% of the pebbles from the bottom of the beach (with none showing a displacement >45°). The pebbles at the top of the beach travelled furthest from their injection point: 31.2 m on average as against 23.8 m for the pebbles on the lower beach, and only 12.4 m for the pebbles injected in the middle part of the beach.

These differential movements will need to be taken into account in the predictive formulae. The challenge will be to include the data in a universal model.

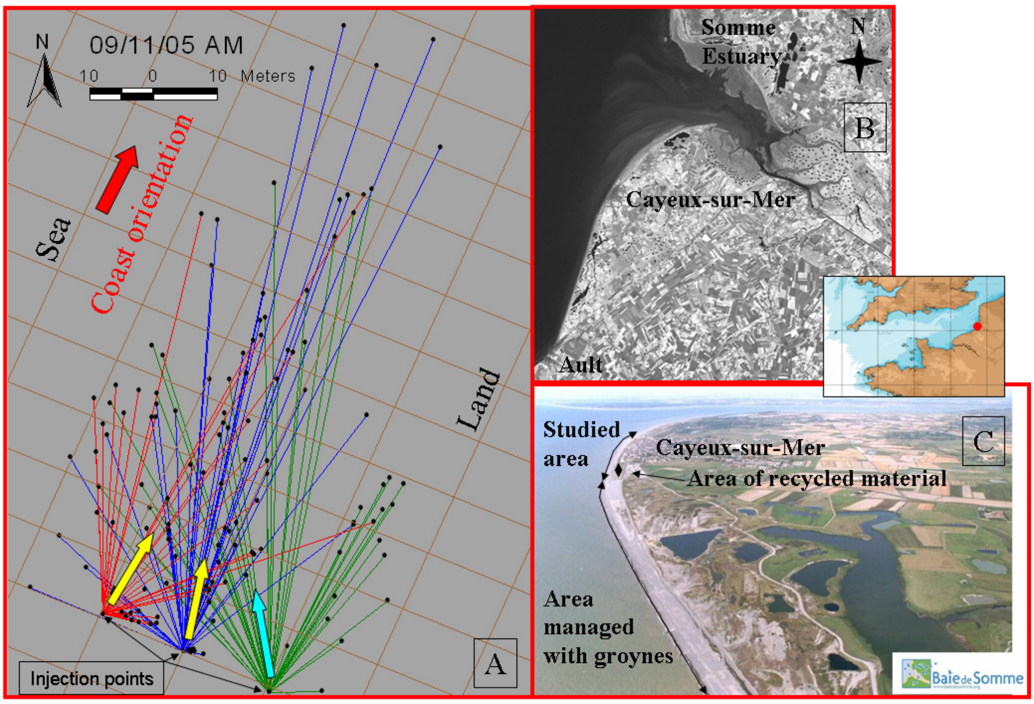

Figure 1: A- Example of pebble scattering on the 09/11/05 AM, each pebble is represented by a black point, B-Satellite view of the site, C-Picture of the studied area.

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