COASTAL PROCESSES

Sedimentary micro-surgery at Napier

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A new system of instruments is providing first-hand evidence of the mechanisms that result in either erosion or deposition of sand on our beaches.

DELICATE MICRO-SURGERY is about to be performed as a highly technical optical glass probe is quietly moved into place by a computer. As it moves closer to its target, images suddenly come into focus on a high-resolution television screen. These allow the "surgeon" to complete the exact positioning of the instruments. Once this is done, a button is pressed and sonic beams ring out to complete the dissection.

Strangely enough, the above scene is not from an operating theatre in a hospital. It is a description of new micro-technology developed in the Centre of Excellence in Coastal Oceanography and Marine Geology, a joint educational and research centre at NIWA and the Department of Earth Sciences at the University of Waikato. The surgeons are sediment transport scientists dissecting the complex natural phenomenon of sand movement under the combined action of waves and currents. They are studying the inner space of single sand grains. The delicate micro-surgery is needed because, just as DNA is a basic component of living organisms, the movement and interactions of the grains form the building blocks for our beaches and coastal sedimentary systems. The combined movement of sand grains ultimately determines the state of our beaches and controls matters as diverse as the impacts of sand extraction or the best coastal protection solutions.

The sedimentary instruments are collectively known as the sediment micro-probe system (see panel opposite for a technical description). Such technology has previously been the reserve of surgeons or industry but, with some careful research and development, a system customised for the marine environment has been developed for beach research.

Field application

The system was the cornerstone of experiments conducted at Westshore Beach in Napier in November 1997. Napier was chosen for its suitable medium-intensity wave climate and mobile beach sediments.

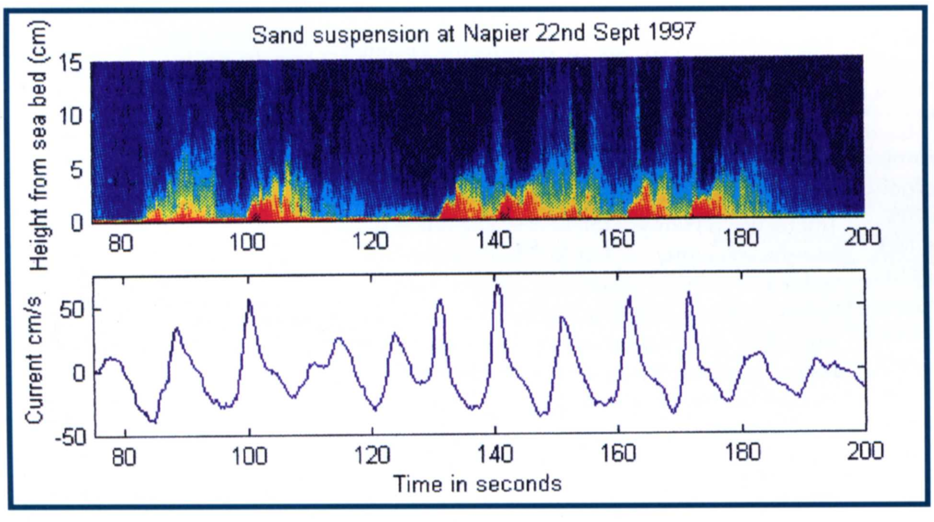
We were rewarded with a range of unprecedented measurements. The instruments provided world-first views of the micro-scale dynamics at the sea bed under natural waves. But we were additionally fortunate that the sea bed went through all of its motions, from planar sheet flow at low energy where the bed is smooth, through rippled where the bed is undulating and back to smooth under energetic wave conditions. In each case, the way in which sediment is lifted above the sea bed is different, and in each case we were able to watch and record its intricate behaviour.

Initial analysis of the data has shown sand grains of all different shapes rolling over their neighbours and breaking free of the sea bed to be ejected into the water column. We then observed that the boundary layer in the bottom few centimetres above the sea bed simply "collapses" after each wave crest passes (see diagram below left). This collapse raises the turbulence levels and changes the complex mechanisms that cause sediment from the bed to be forced upwards. The timing of the collapse during a single wave is critical. If the sand comes up around the crest of the wave, then it will be carried shorewards and may be deposited on the beach. But if the sand rises in the trough of the wave, then the offshore currents at this time will ultimately lead to beach erosion.

We already knew that both processes occur but our measurements showed the variability and complexity of one of nature's delicate balances. This balance between opposed processes, some causing erosion and some causing deposition, results in the coastal geomorphology that we have all seen but have never fully understood.

With the combined power of the different components of the sediment micro-probe system, the sedimentary micro-surgeons were able to probe the inner space of sediment transport and watch it in action at high resolution on a natural beach. With these insights, the computer takes over and accurate computer models of the micro-scale processes are used to predict the sediment suspension. An

below: *Output from the sediment micro-probe system during the measurements at Napier. The upper panel shows the vertical suspension of sand close to the sea bed. The suspended sand concentration scale is logarithmic extending from 0.001 g/l (dark blue) to 10 g/l (dark red). The lower panel shows measured currents at 7 mm above the bed (lower panel) at Napier. The sand is lifted upwards as each wave passes, as shown by the complex patterns which evolve through time.*



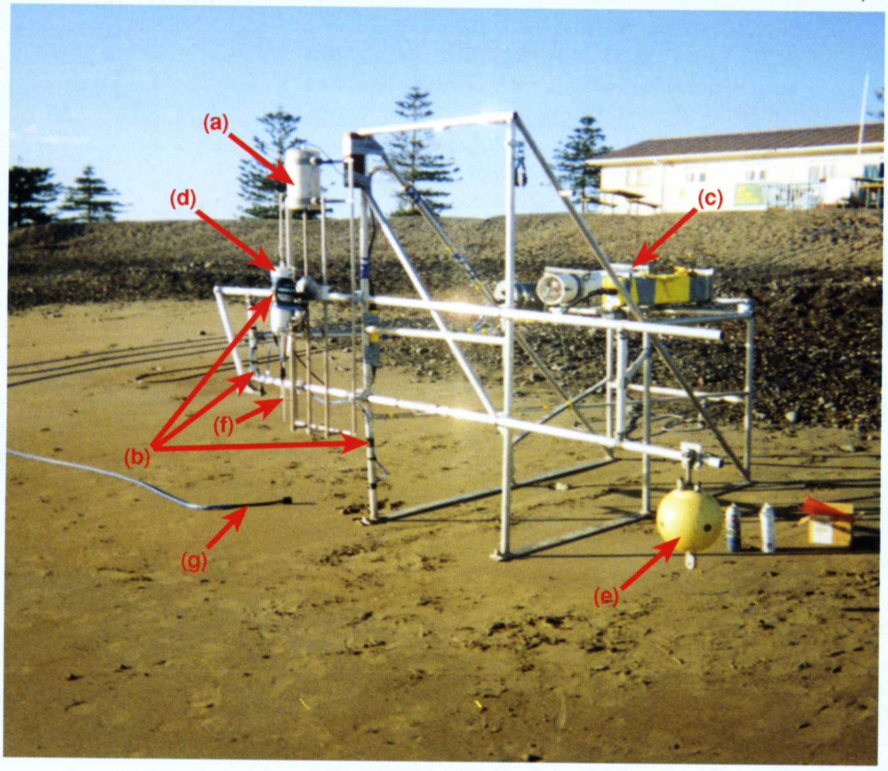
Sediment micro-probe system: technical description

The sediment micro-probe consists of a 600-mm long stainless steel rod filled with optical glass fibres. The rod is attached to a small video camera which receives the images passing up the optical fibres. The images from the camera are relayed to the beach via a cable with low electrical impedance and which can also withstand the considerable force of the waves in the surf zone. A high-intensity light source is fed into the optical fibres and travels down the fibres to illuminate the images. The reflected light then returns along the same route and into the camera. At the base of the optical rod, a mirror reflects the light at 90° so that the instrument looks sideways across the sea bed, giving a better perspective. The field of view is about the size of a 10 cent coin (22 mm diameter) and a single sand grain is about 5 mm diameter on the television screen, giving high resolution images of each grain.

The camera is suspended on a vertical profiler unit which was custom made for the micro-probe. The heavy duty profiler consists of a carriage for camera mounting, which is attached to a threaded rod. In response to commands from the "surgeon's" portable computer, the stepper motor rotates the thread by an exact number of revolutions, which causes the carriage to move up or down the rod by a precisely known distance. The mechanical components were built to the Centre of Excellence specifications by a specialist engineering company (Neil Precision) in Hamilton.

Also on the profiler unit is a highly sensitive current meter called an acoustic doppler velocimeter (ADV, Sontek Instruments Ltd.; see *Water & Atmosphere* 5(3):22–24 for more details about the ADV). It sends out sound wave pulses which reflect back off the tiny particles found in all water bodies and deciphers water currents in three directions up to 25 times per second.

Another technically advanced instrument on the profiler is the acoustic backscatter system or "ABS". The ABS sends a sound beam towards the sea bed and, the intensity of the returned signal reflected off the sand grains in suspension is used to determine the concentration of sand lifted off the sea bed by waves and currents. This instrument records the sand concentrations in thin bands, each only 5 mm thick. It does this in 60 bands above the sea bed 10 times every second. This sort of high-resolution technology has only recently become available for natural beaches. Three ABS's were brought to the Centre of Excellence by Dr Chris Vincent from the University of East Anglia (United Kingdom) for the experiments at Napier.



The system ready for deployment on Westshore Beach, Napier. The instruments consist of: (a) vertical profiler unit; (b) three acoustic backscatter sensors; (c) instrument housings; (d) micro-video unit; (e) S4 electromagnetic current meter; (f) acoustic doppler velocimeter; (g) umbilical cord to the shore.

The Napier experiments were conducted under the auspices of the research programme "Wave and Sediment Dynamics in Coastal and Estuarine Systems", funded by the Foundation for Research, Science and Technology. Wave and Sediment Dynamics underpins a range of applied studies and provides the framework for refinement of our comprehensive computer simulations which forecast outcomes for coastal management.

example is shown to the right. Only with this level of technology can the fundamental processes which cause either erosion or deposition on a beach be resolved and comprehended. ■

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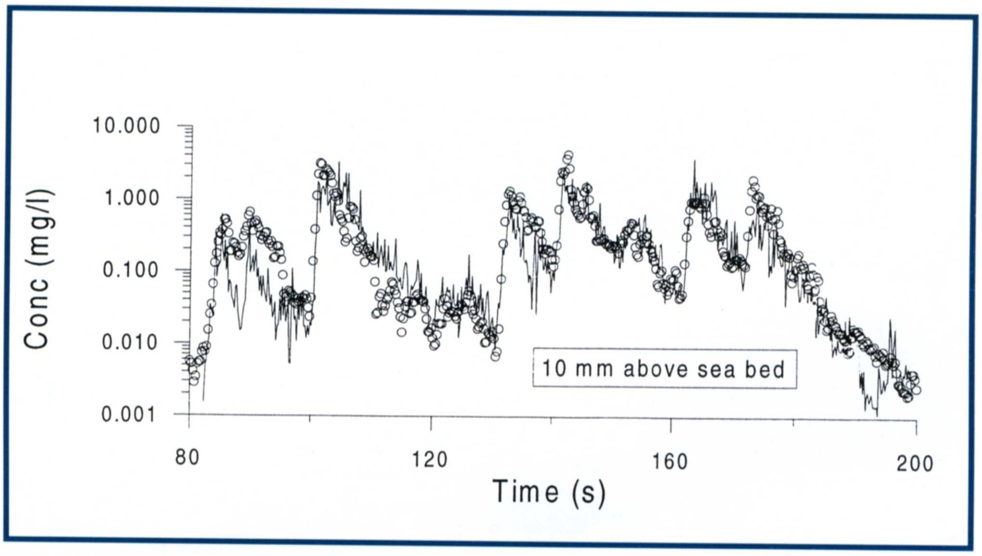

right: *The concentrations measured at 10 mm above the sea bed (circles) are closely predicted by the numerical computer models (solid line).*