Effect of borrow pit dredging on shoreline stability at Richards Bay

Photograph: A Theron

▶ ***Figure 1*** *Richards Bay Coal Terminal*

THE NATIONAL PORTS Authority of South Africa (NPA) has extended the coal terminal at the Port of Richards Bay by constructing Berth 306 (figure 1). This berth is adjacent to the existing coal berths of Richards Bay Coal Terminal. Approximately 1,3 million cubic metres of sand is required as fill behind the quay wall of Berth 306 and for extending the stacking areas for coal landwards of the quay. A borrow area for acquiring this sand has been identified by Marine GeoSolutions. This area is located about 7 km east-northeast of the port entrance in about 32 m of water.

A study was undertaken by WSP Coastal Africa (then Entech Consultants) for Ecoserv on behalf of NPA and the Richards Bay Coal Terminal to determine whether a significant physical impact on the shoreline (the northern beaches of Richards Bay) might result from the dredging of sand from the borrow area.

PREVIOUS STUDIES ON THE INFLUENCE OF A DREDGE PIT ON THE SHORELINE

The following conclusions were drawn from the literature survey:

- In general, the proposed sand borrow pit envisaged for Richards Bay will adhere to the European and Japanese regulations and guidelines
- Dredging sand can cause either erosion or accretion or both to the shoreline, depending on the sand regime
- For minimum impact on the shoreline, the layout of sand borrow area should follow these guidelines:
  - Remove sand over a larger area
  - Limit the depth of cut of the dredger (that is, make a shallow hole)
  - If possible, orientate the main axis of the borrow area parallel to the wave crests
  - The borrow area should be in deeper water

Clearly, practical aspects like being able to dredge economically in the specific water depth must also be considered.

LAYOUT OF THE DREDGE PIT

Volume computations confirmed that 1,3 million cubic metres of sand can be sourced by dredging the whole borrow area without exceeding a depth of cut of 2 m. At the same time, side slopes of 1: 10 were taken into account around the borrow pit. Dredging will be approximately 0,3 m above the rocky substrate to prevent damage to the dredger. The length over which the borrow pit can be trailed by a trailing suction hopper dredger is long enough to ensure that its hopper can be filled in one pass of the borrow pit.

ENVIRONMENTAL DATA

The average median grain size at the borrow pit (D50) is 0,30 mm (medium sand).

Directional wave measurements by the CSIR covering about 6,8 years were analysed to represent the average annual climate at the location of the wave buoy just outside the Port of Richards Bay. Wave conditions were schematised into a few conditions by conserving the energy flux of the individual wave conditions. These wave conditions were then converted to equivalent deep-sea wave conditions for the refraction.

The SWAN model was applied to simulate refraction with and without the borrow pit and to predict the nearshore wave conditions in the vicinity of the borrow pit and along the 5 m contour. Wave direction and wave height difference plots were prepared to visualise the effect of the borrow pit on the wave conditions (figure 2). The magnitude of the changes in wave conditions as a result of the borrow pit were extremely small, with the largest changes occurring in relatively deep water in the vicinity of the borrow pit. Maximum changes in wave direction near the borrow pit are less than 1°, while changes in wave height are less than 5 cm only.

Figure 3 illustrates the variation in the significant wave height along the 5 m contour for one of the representative wave conditions. In this figure the wave height variation is plotted without and with the borrow pit. The changes in wave direction that will be found along the 5 m contour were also plotted. Similar figures were produced for the other wave conditions. These figures clearly depict that virtually no change in the wave characteristics will be found along the 5 m contour. The situation will be the same along the breaker line, namely negligible changes in wave height and direction can be expected along the shore.

It was therefore concluded that the changes in wave height and in wave direction resulting from the borrow pit would be negligible along the northern beaches of Richards Bay. As such, no wave focusing on the shoreline is expected because of the borrow pit.

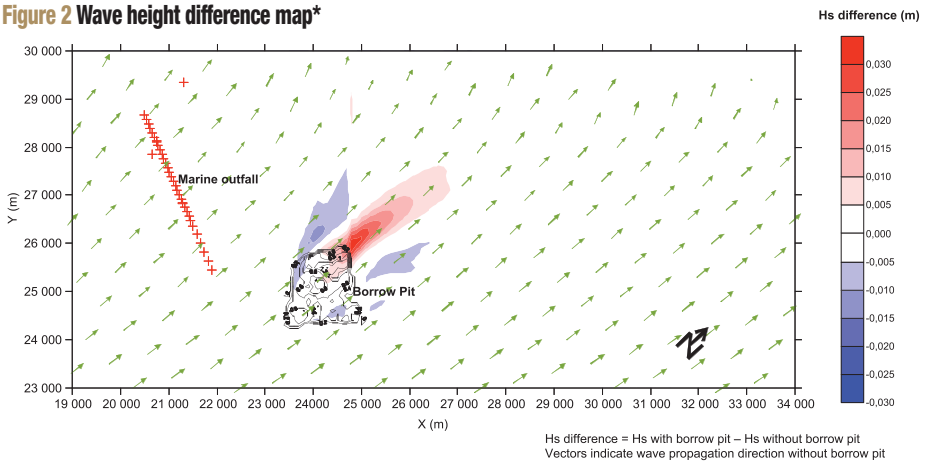
Based on current measurements 2 m above the seabed, the current regime at the borrow pit was schematised into a few current conditions. The combined wave and current climate at the borrow pit was compiled by assuming that the wave conditions are independent from the current conditions.

SEDIMENT TRANSPORT REGIME

Longshore sand transport

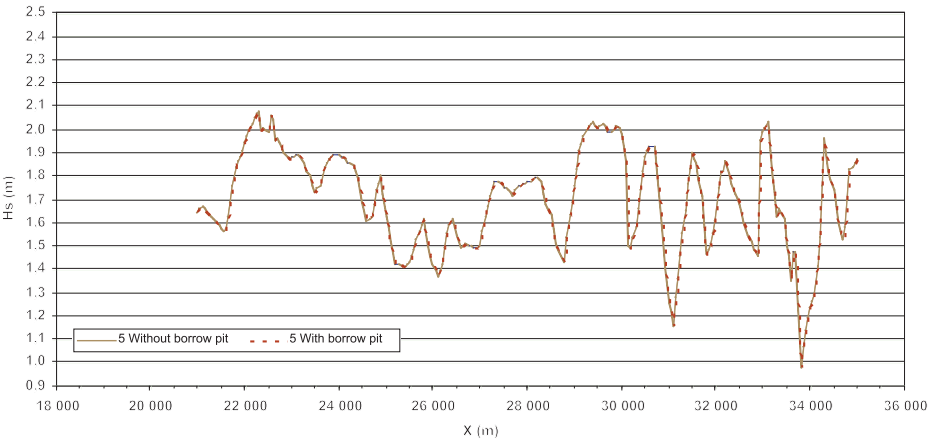
Waves are the dominant mechanism for generating currents in the surf zone. As shown in the refraction modelling, the impact of the borrow pit on the wave characteristics along the shoreline is negligible. The impact of the borrow pit on the generation of currents by waves is therefore also negligible. The borrow pit does not influence the winds and only has a negligible impact on the tide. Tidal currents are insignificant in South African waters along the open coast. In addition, the Agulhas Current usually flows south-westwards along

Figure 2 Wave height difference map*



*Wave condition 5 – deep-sea significant wave height = 2,80 m; peak wave period = 9,6 s; direction = 204 degrees

Figure 3 Wave height along the 5 m contour for wave condition 5



the KwaZulu-Natal coast. The core of the Agulhas Current is, however, typically located just offshore of the continental shelf break. At Richards Bay the shelf break is approximately 15 km to 30 km from the shoreline. As such, the influence of the Agulhas Current on surf zone currents is only minor, if not negligible. In addition, the impact of the borrow pit on the Agulhas Current is minor.

It was thus concluded that the impact of the borrow pit on the waves and the currents in and near the surf zone would be negligible. Therefore, virtually no change resulting from the borrow pit is expected in the longshore transport rates along the northern beaches.

Cross-shore sand transport

The borrow pit is far enough offshore to prevent beach drawdown into the dredge hole from taking place (that is, the toe of the beach slope will not be dredged away causing slumping of the beach into the borrow pit).

Another consideration is that the dredging of the borrow pit may increase the wave height in certain areas along the shoreline whilst decreasing the wave height in other areas (wave focusing). These affected areas vary in location according to, for example, the wave direction. In terms of cross-shore transport, it means that in certain areas more erosion can be expected during storms, but less erosion in other areas. If the direction of the waves during a storm changes or the next storm approaches from a different direction, the zones where more and less erosion will occur shift. The effect is that the zone of less erosion of the second storm can counteract the zone of more erosion of the first storm, etc. This means that the impact of the borrow pit is reduced and spread over large areas.

The implication is thus that small or even moderate changes in the wave characteristics can result in small impacts. However, it was found in the wave refraction that only negligible changes can be expected in the wave characteristics along the shoreline (virtually no wave focusing). It can therefore be concluded that the impact of cross-shore transport resulting from the borrow pit will be negligible.

Aeolian sand transport

The dominant winds at Richards Bay generally blow alongshore (up and down the beach). Because the northern beaches are eroding, they are narrow, vegetation grows close to the water, and most of the time the beaches are wet. The result is that aeolian transport is low and as such, changes in beach width in the order of a few metres caused by changes in longshore and cross-shore transport will only have a small effect on the aeolian sand transport. However, both the expected impacts by longshore and cross-shore transport resulting from the borrow pit are negligible. It can therefore be concluded that the effect of aeolian sand transport resulting from the borrow pit is also negligible.

Sand transport at the borrow site

Two independent approaches were followed to estimate the rate at which sedimentation of the borrow pit will occur, namely (1) the migration rate of sand dunes on the seabed as determined from geophysical investigations; and (2) computing the infill rate by using the combined wave and current climate. It was found that the infill rate of the borrow pit will be between 50 m^3/m per year and 180 m^3/m per year. These rates compare well with the infill rates of harbour entrance channels found from around the world. The expected time that it will take to totally fill the borrow pit is estimated to range from 5 years to 16 years, with a best estimate of approximately 10 years.

SHORELINE CHANGES ALONG THE NORTHERN BEACHES

Usually shoreline erosion and accretion, especially over a time scale of months to a few years, are caused by:

- Gradients in longshore sediment transport along the shore
- Adding sand to the beach
- Extracting sand from the beach

The influence of the borrow pit on the longshore, cross-shore, and aeolian transport will be negligible. The borrow pit is located offshore of the littoral active zone (in about 32 m of water), which exceeds by far the limit of the littoral active zone at Richards Bay (approximately 9 m). (Note that limited sand transport does occur in deeper water.) The dredging of sand from the borrow pit will therefore take place outside of the littoral active zone and, as such, does not constitute sand mining in the littoral active zone along the shoreline. The borrow pit will therefore not change the gradients in the longshore transport in any significant way. Sand will also not be extracted from or added to the littoral active zone. It can therefore be concluded that the effect of the borrow pit on shoreline evolution will be negligible.

No mitigation measures are required as long as the sand is dredged over the whole borrow pit whilst limiting the depth of cut to 2 m vertically. A side slope of the dredge pit of approximately 1:10 is recommended.

Lukas de Waal, Transnet Capital Projects (lukasdw@npa.co.za)
Koos Schoonees and **Andre van Tonder**, WSP Coastal Africa (Pty) Ltd (koos.schoonees@wspgroup.co.za and andre.vantonder@wspgroup.co.za)
Quentin Hurt and **Mia Antoni**, Ecoserv (q@ecoserv.com and mia@ecoserv.com

Source:
http://www.saice.org.za/downloads/monthly_publications/2007/CivilEngMay2007/#/0