

CHAPTER 17

WAVE SETUP ON BEACHES AND IN RIVER ENTRANCES

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Abstract

This paper investigates the phenomenon of wave setup both on beaches and within river entrances. Field measurements of the mean water surface through the Brunswick River Entrance on the North Coast of NSW, Australia and on the beach immediately south of the entrance are presented for a variety of incident wave conditions. These include wave heights up to 4m (Deepwater RMS). Data collected show very little setup in the river entrance even though wave breaking occurs across the entrance under relatively small wave conditions. At the same time significant wave setup was measured on the adjacent beach. This resulted in the super-elevation of the beach shoreline level above the mean water level of the adjacent river. This super-elevation has been observed to result in large scour holes as the water finds its way through the entrance training walls.

Introduction

The super-elevation or setup of river entrance water levels by wave breaking is a subject of great importance for the modelling of flood inundation levels in coastal rivers and for floodplain management in general. However, very little is known about wave setup within river entrances. Current practice in estimating river entrance setup has been to use either beach shoreline setup or to calculate the likely setup at the point of minimum depth using simple models like that of Bowen et al. (1968).

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Bowen's model gives the setup as a linear function of depth and is based on an assumption of constant wave height to water depth ratio and linear wave theory. Recent field studies have shown, however, that setup versus depth profiles tend to be upward concave steepening considerably near the shoreline (eg. Nielsen, 1988, 1990). This means that while the model of Bowen et al. (1968) tends to under-estimate the shoreline setup it over-estimates the setup across much of the surf zone. These results suggest that both of the above mentioned approaches to the estimation of river entrance setup are likely to be inappropriate. In any case, the application of 'beach results' to river entrances must be subject to considerable uncertainty because of the difference in breaking processes as a result of the current.

The aim of the present project is to investigate wave setup within a river entrance and to compare this with wave setup observed on beaches under similar conditions.

Concepts & Definitions

Beach and river entrance water levels fluctuate over various time scales. When the local water surface elevation $\eta(x, t)$ is averaged over a time span longer than the incident wave and surf beat periods but shorter than the tidal period, the result is the local, mean water level $\bar{\eta}(x)$ which traces the mean water surface (MWS).

Far offshore the mean water level (MWL) approximates the still water level (SWL) which is the level of the still water surface (ie, the sea surface in the hypothetical situation of no waves). The still water level for practical purposes is taken as the mean water level offshore from the surfzone.

The local setup $B(x)$ is the super-elevation of the mean water level above the still water level.

$$B(x) = \bar{\eta}(x) - SWL$$

Set-down corresponds to the situation where $B(x) < 0$.

Beach shoreline setup has in the past been used to approximate likely river entrance setup. The shoreline elevation and the shoreline setup B_s are defined by the intersection of the mean water surface and the beach sand surface.

Field Sites

Data for the present study have been obtained from several sites along the New South Wales coast. These include Brunswick Heads, Dee Why Beach, Palm Beach and Seven Mile Beach (figure 1).

The NSW coast is exposed to a moderate to high energy east coast swell environment. Dominant swell direction is from the south-east and deep water significant wave heights at Sydney exceed 1.5m at least 50% of the time and 4m, 1% of the time. The tidal regime is micro-tidal, diurnal with a semi diurnal inequality. Tidal range varies from about 2m at springs to less than 1m at neaps. The tidal regime is uniform along the whole NSW coast.

The main field site used in the present study was Brunswick Heads on the north coast of NSW (figure 2). This site was used to collect river entrance as well as beach setup data. The coastline at Brunswick Heads is oriented north-south and fully exposed to the regional wave climate. The Brunswick River enters the ocean at Brunswick Heads. This river entrance is regulated by rubble mound training walls. The channel width near the end of the training walls is approximately 40m and the mid tide depth is normally 4-5m but can be as shallow as 1-2m on the offshore bar which experiences wave breaking even under relatively small wave conditions (figure 3).

The tidal prism of the Brunswick River is approximately $4.8m \times 10^6 m^3$ corresponding to spring tidal peak velocities of about 1.8m/s at the entrance.

The setup monitoring installation at Brunswick Heads comprised two lines of manometer tubes, one through the river entrance extending from 300m upstream of the entrance to 150m offshore of the entrance; and the other spanning the surfzone on the beach 150m to the south. This line was 500m long and extends from the beachface to a depth of approximately 10m. The beachface here is relatively flat and the surfzone is characterised by a well developed bar/trough system. Mean swash zone grain size is 0.22mm.

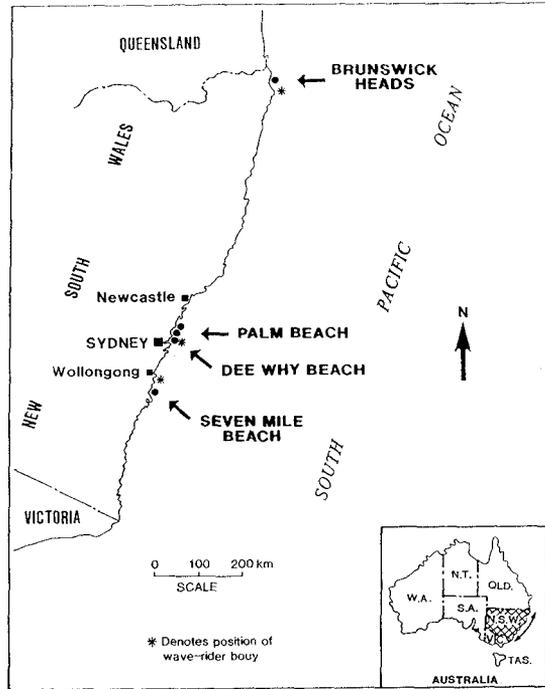


Figure 1: Location of field sites

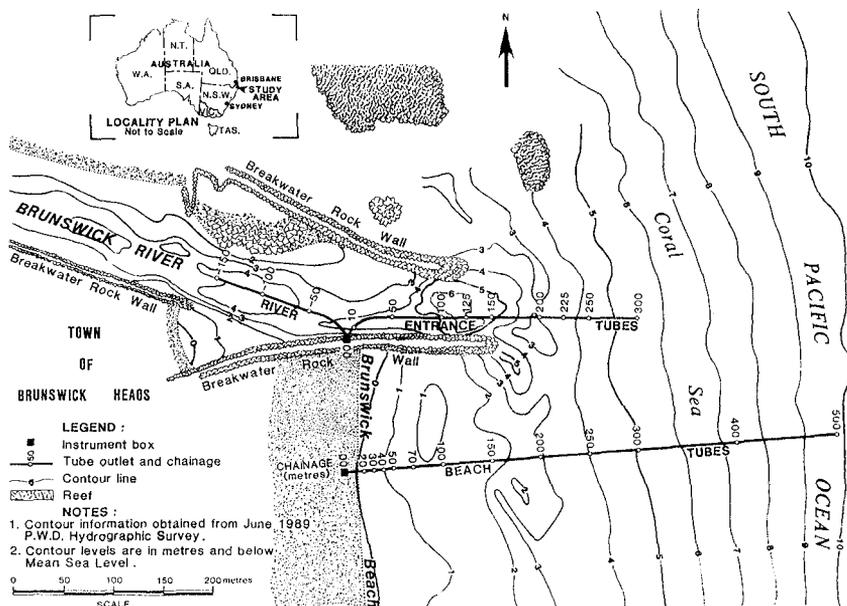


Figure 2: Setup monitoring installation at Brunswick Heads

Subsidiary field sites include Dee Why Beach, Palm Beach and Seven Mile Beach. These locations were used to obtain beach setup measurements from various beach types. Characteristics of these beaches are shown in table 1. A more detailed description of these sites is given in Nielsen & Hanslow (1991).

Equipment

The equipment and techniques used at the Brunswick Heads field site are in part similar to those described by Davis & Nielsen (1988) and Nielsen (1988).

TABLE 1.

Field Site	Beach Type During Experiments	Swash Zone Grain Size (MEAN)	Range of Beachface Slope During Experiments
Seven Mile Beach	Dissipative	0.18mm	$0.03 < \tan \beta_f < 0.05$
Dee Why Beach	Intermediate/ Reflective	0.5mm	$0.06 < \tan \beta_f < 0.16$
Palm Beach	Intermediate	0.4mm	$0.08 < \tan \beta_f < 0.12$
Brunswick Beach	Dissipative	0.22mm	$0.04 < \tan \beta_f < 0.08$



Figure 3: Wave breaking occurs at the Brunswick River entrance even during small to moderate wave conditions

Measurements of the mean water surface elevation were obtained at various points through the river entrance and on the adjacent beach via a system of manometer tubes which are permanently deployed. These tubes are made of hard but flexible nylon material and open to water pressure at their seaward ends. They are attached to a steel chain and became buried shortly after deployment.

At the landward end of each line, each tube is connected to a glass riser tube. The glass riser tubes are closed to the atmosphere but interconnected, so that the air pressures inside are at all times identical. Partial evacuation of the system enables relative water levels at the tube outlets to be monitored. Absolute levels can be obtained by connecting one of the riser tubes to a known (surveyed) water level.

The system facilitated measurements of the mean water surface at fixed locations through the river entrance and across the surfzone on the adjacent beach. Measurements of the mean water surface closer to the beachface at Brunswick Heads as well as the other field sites were obtained using an array of stilling wells. During individual experiments, wells were placed with 2-5m spacing along shore normal transects. The wells were made of clear polycarbonate tubing of 25-35mm internal diameter. The bottom end of each well was covered with geotextile filter cloth to prevent the entry of sand, and were damped with foam to eliminate fluctuation by individual waves and infragravity oscillations. The wells were sunk to at least 20-30cm below the lowest level of the local watertable.

Well top levels were surveyed and measurements taken from the well top to the water surface and to the beach sand surface. This enabled fairly accurate definition of the intersection point between the mean water surface and the beachface otherwise known as the shoreline.

Wave Setup on Beaches

Data collected for the present study confirmed earlier results by Nielsen (1988), (1990) regarding the nature of the mean water surface on natural beaches. That is, as seen in Figure 4, the mean water surface displays an upward concave profile, steepening considerably near the shoreline. Here relative setup is plotted versus still water depth for several data collection exercises at Brunswick Heads. Nielsen's data suggest that Bowen's model

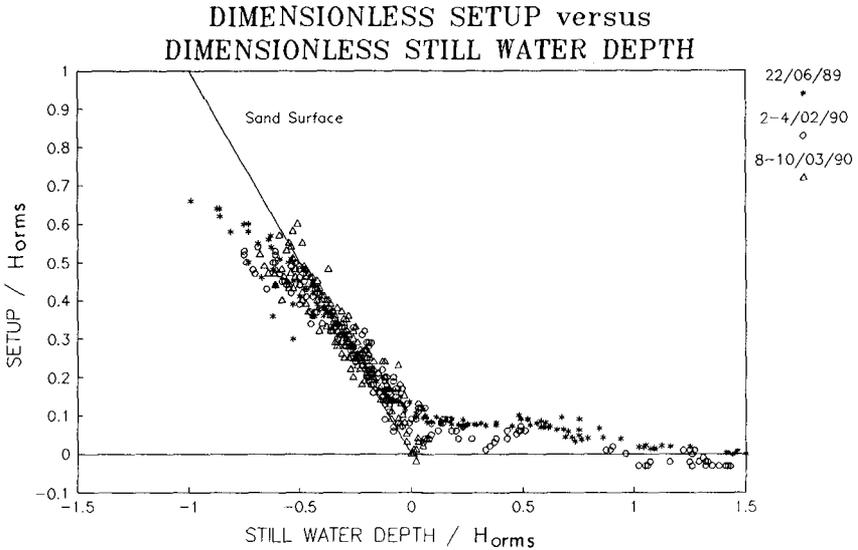


Figure 4: Relative setup plotted versus still water depth for 3 different experiments at Brunswick Heads

may over-estimate setup across much of the surfzone while under-estimating setup at the shoreline.

The elevation of the shoreline above the still water line is plotted as a function of wave height in Figure 5. As seen in this plot a relationship of the form

$$B_s \approx 0.38 H_{orms}$$

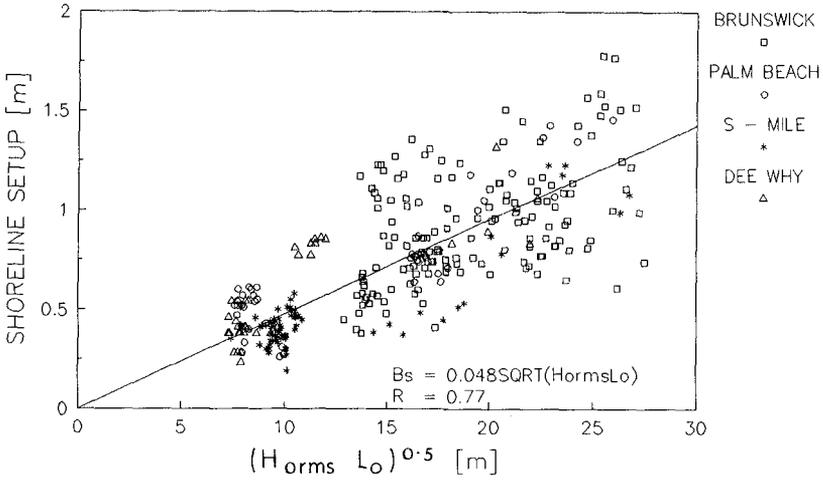


Figure 5: Shoreline setup plotted as a function of wave height (H_{orms}) for all data

fits the data fairly well with scatter between $0.2 H_{orms}$ and $0.65 H_{orms}$.

A slightly better relationship is obtained by including wave length as seen in Figure 6. Here the line of best fit is given by

$$B_s = 0.048 (H_{orms} L_0)^{0.5}$$

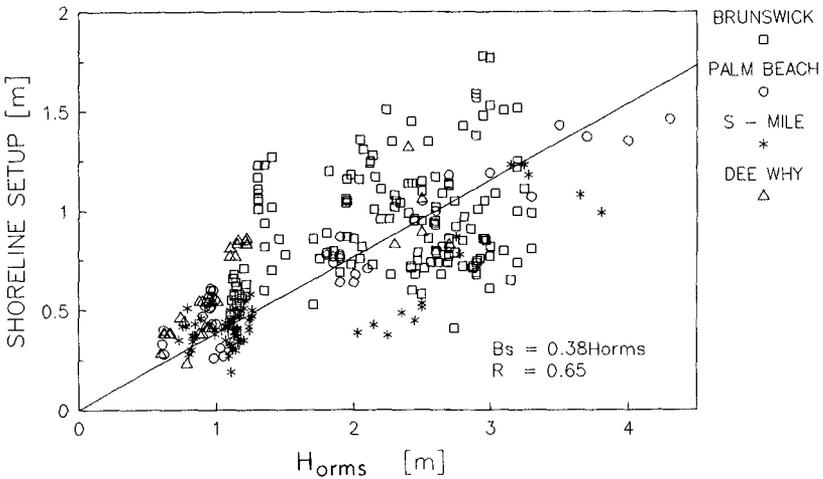


Figure 6: Shoreline setup plotted as a function of $(H_{orms} L_0)^{0.5}$ for all data

River Entrance Setup

Mean water surface data collected during the present investigation were obtained under widely varying conditions. These included wave heights up to 4m (deepwater RMS), all stages of the tide and two minor flood events.

An example of the mean water surface data collected is given in Figure 7. Here mean water surface profiles through the Brunswick River entrance during an ebbing tide on 17 March, 1992 are presented. The river flow during these observations was assisted by considerable fresh water input. Drogue velocities in the entrance recorded at 11.30 were between 2.0 and 2.5ms⁻¹ offshore RMS wave height varied between 2.0 and 2.4m while wave period was approximately 8 seconds. Most wave breaking occurred 50–100m seawards of the end of the breakwaters, a distance of 200–250m from the instrument box. The furthest offshore data point in this graph (chainage 500) is the ocean tide level calculated by averaging the recorded tide levels at Coffs Harbour and Sydney Harbour, both corrected for barometric effects. These tide gauges are well removed from the study site but have been included as a check on the level of the offshore manometer tube.

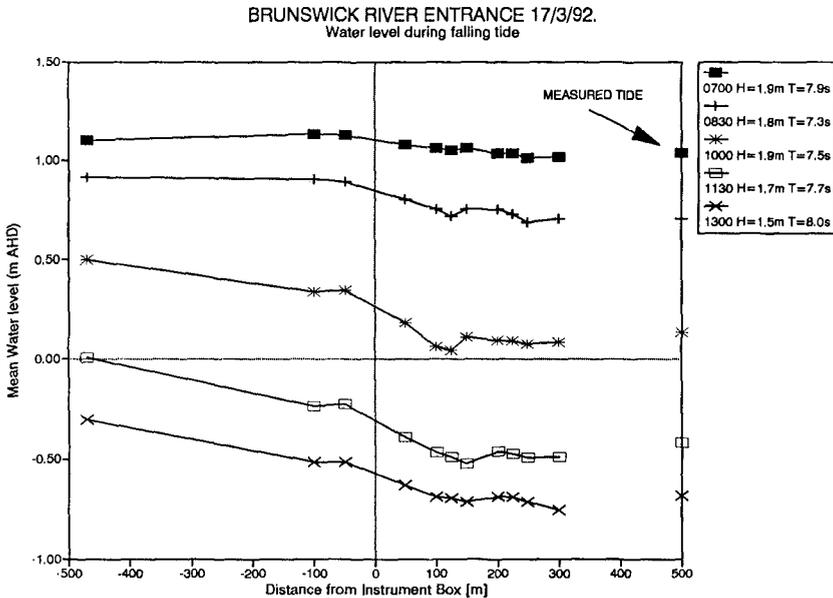


Figure 7: Mean water surface profiles through the Brunswick River entrance during an ebbing tide on 17-3-92

The elevation of the mean water surface increases by an average of 0.05m from the breakpoint (250m) to the 150m or 200m point. There is a small decrease in the mean water surface elevation at (150m) or just landwards of (125m) the end of the breakwaters. Landwards of this region the mean water surface slopes upstream with a maximum gradient of 0.0024.

This data suggests there is very little setup occurring (less than $0.03 H_{\text{orms}}$) in the river entrance.

All measurements of the river entrance setup obtained at Brunswick Heads are presented in Figure 8. Here super-elevation of the mean water surface at the river entrance ($\bar{\eta}_{150m \text{ tube}} - \bar{\eta}_{300m \text{ tube}}$) is plotted as a function of wave height.

The data presented in this figure show very little wave setup in the Brunswick River entrance under any conditions.

All Data

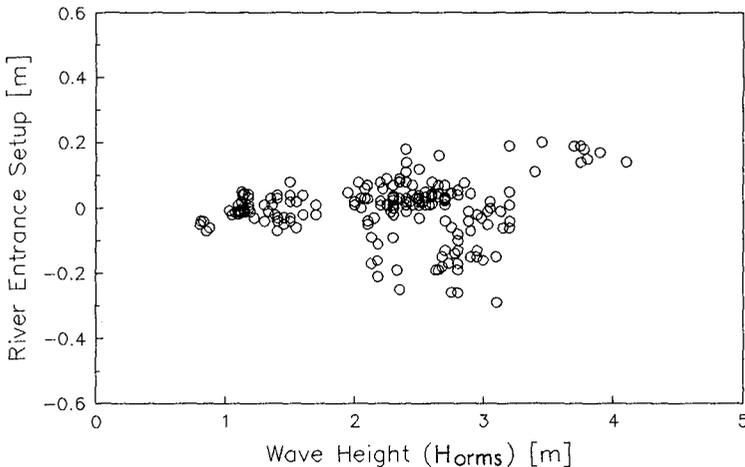


Figure 8: River entrance setup versus wave height for all data

Combined Data

The collection of simultaneous river entrance and beach water level data was made difficult during severe weather conditions, thus measurements of this type were limited. However, one data set was collected on 22 June, 1989. Figure 9 presents a mean water surface profile and bed profile through the river entrance and across the surfzone on the adjacent beach, both taken at 1600 hrs on this day. Offshore RMS wave height at this time

was around 2.4m with a period of 11.1/s. This figure illustrates the absence of setup in the river entrance during conditions which produce significant setup on the adjacent beach.

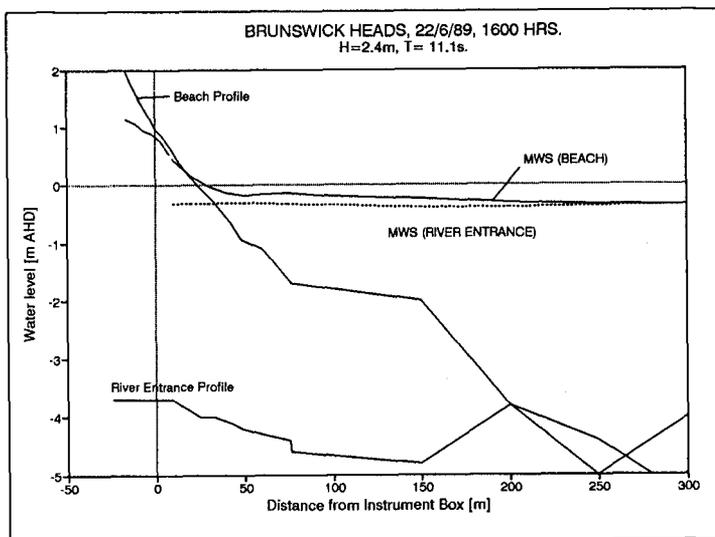


Figure 9: Mean water surface through the Brunswick River entrance and across the adjacent beach at 1600hrs on 22-6-89

Comparison between the beach shoreline setup and the water level in the river entrance on 22 June, 1989 is presented in figure 10. On this occasion the offshore RMS wave height increased from 2m at 1500hrs to 3.2m at 2400hrs, while the period averaged 12 seconds. Elevation of the mean water surface at the 10m and 300m stations in the river entrance are plotted together with the shoreline elevation on the adjacent beach over part of a tidal cycle.

The 10m and 300m tubes in the entrance are on opposite sides of the breaker zone in (and offshore from) the entrance. The difference in elevation between the 10m tube and 300m tube suggest there is very little wave setup through the river entrance, in fact their relative elevation changes with the tide suggesting tidal gradients may be more important than any wave induced slopes. At the same time the shoreline on the adjacent beach was consistently about 1m above the offshore water levels.

The setup of the shoreline on the beach above the levels in the river, has been observed to result in large scour holes where water from the beach found its way through the entrance training walls (fig. 11).

BRUNSWICK HEADS 22·6·1989

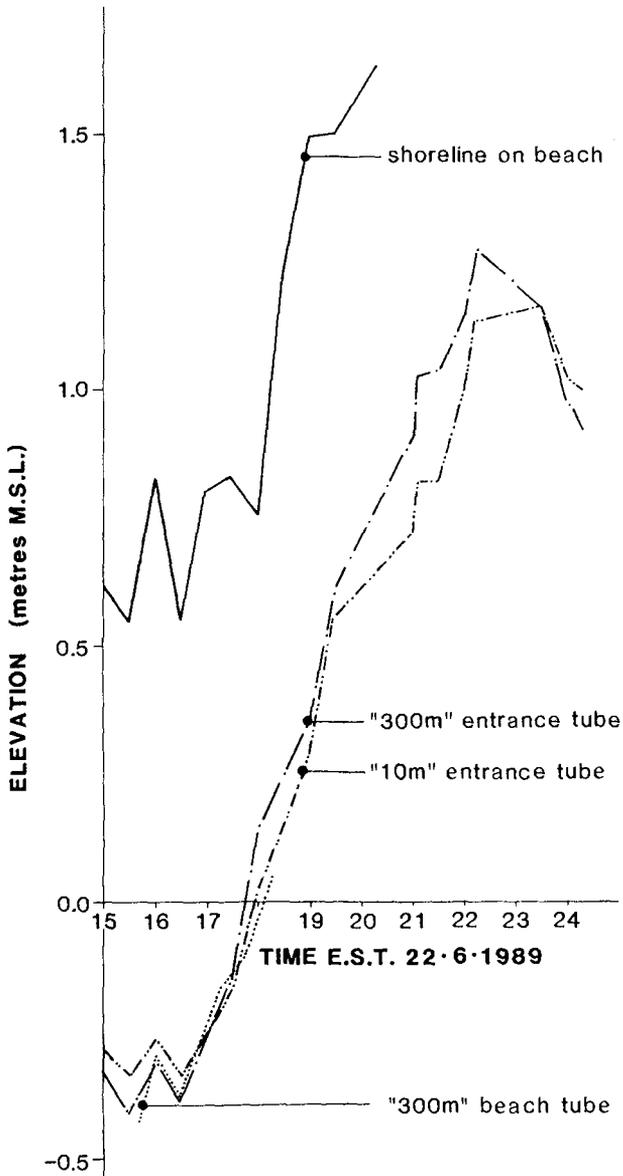


Figure 10: Time series of water levels in the Brunswick River Entrance (22-6-89) (10m tube and 300m tube) and on the southern beach (shoreline). Offshore RMS wave height increased from 2.4m at 1500hrs to 3.2m at 2400hrs, while wave period averaged 12 seconds.

Conclusions

Measurements of the mean water surface through the Brunswick River entrance show very little wave setup. This is in spite of the fact that wave breaking occurs across the entrance even under relatively small wave conditions. At the same time measurements of the mean water surface on the adjacent beach show significant setup. This setup occurs mostly close to the beach, and results in the super-elevation of the shoreline above the level of the river. This super-elevation has been observed to result in large scour holes as the water finds its way through the entrance training walls.



Figure 11: Scour hole formed on the beach next to the southern breakwater on 22-6-89

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