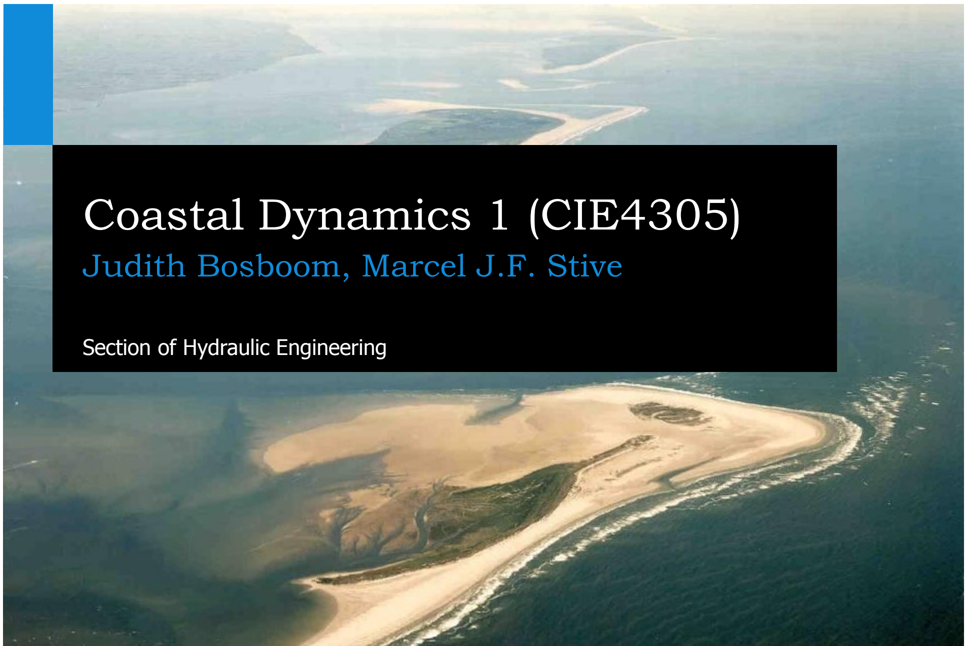


Coastal Dynamics 1 (CIE4305)

Judith Bosboom, Marcel J.F. Stive

Section of Hydraulic Engineering

TU Delft Delft University of Technology

Challenge the future

Coastal Dynamics 1

Maple-TA results Chapter 5-6

	Chapter 5 - Part II - Stage A	Chapter 5 - Part II - Stage B	Chapter 6 - Stage A	Chapter 6 - Stage B
#Attempts	188	186	183	180
Mean	91%	72%	91%	76%
Median	90%	77%	87%	83%
Total points	20.0	19.0	15.0	12.0

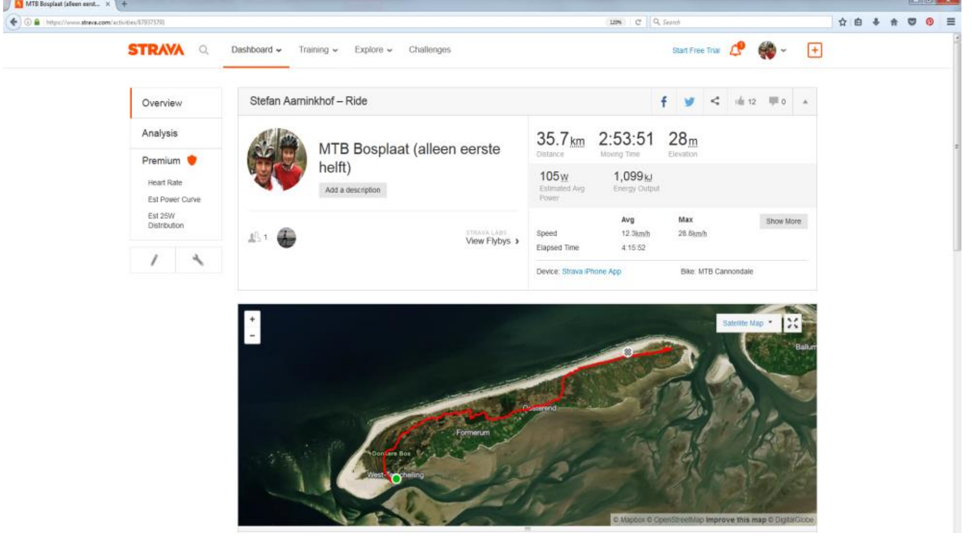
TU Delft Delft University of Technology

Challenge the future

7.

Cross-shore transport and profile development

Coastal Dynamics 1

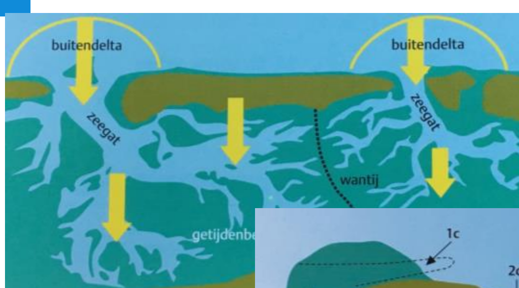


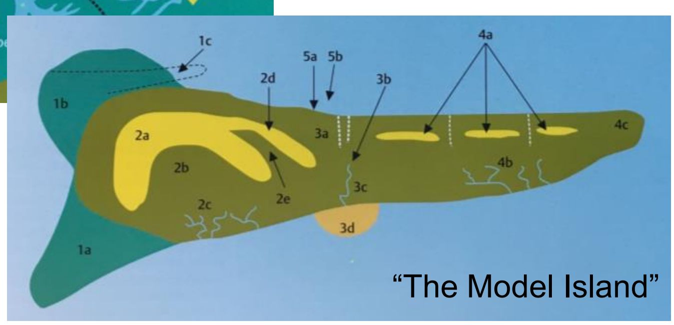
Coastal Dynamics 1

Terschelling – Boschplaat Tour

Coastal Dynamics 1

‘Eilanden Natuurlijk’ – Het tij geleerd





Coastal Dynamics 1

Terschelling – Washover complex

Coastal Dynamics 1

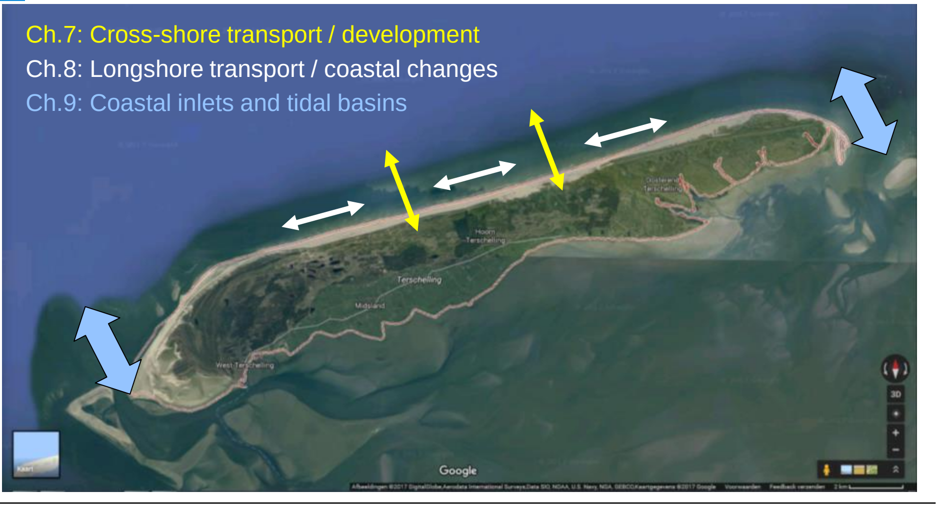
Terschelling – Beach erosion at tail

Coastal Dynamics 1

Terschelling – Salt marshes

Coastal Dynamics 1

Terschelling – Link to Contents CD-1



Coastal Dynamics 1

Contents

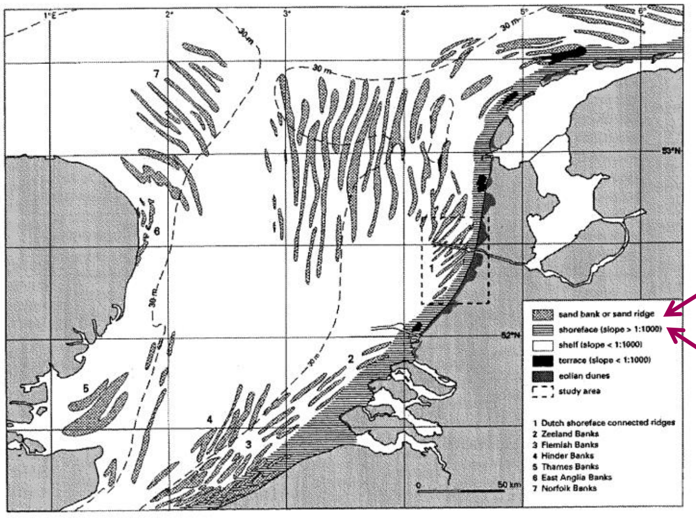
Cross-shore transport and profile development

Chapter 7 of lecture notes

A. **Equilibrium shoreface profile**
B. Beach states
C. Cyclic profile and bar behaviour
D. Episodic events: dune erosion
E. Cross-shore transport mechanisms

7-A Equilibrium shoreface profile

Shoreface and shelf of the North Sea

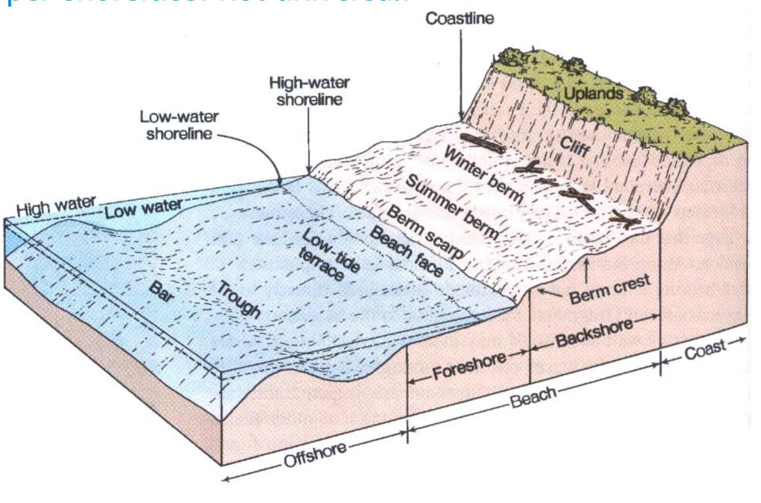


Tide induced:
ridges

Wave induced:
parallel depth-contours

7-A Equilibrium shoreface profile

Upper shoreface: not universal!



7-A Equilibrium shoreface profile

A beach scarp

Beach scarp Wenduine / Knokke-Heist, 04-01-2018
Source: VRT, 2018

MSc. Cas van Bemmelen (TUD, 2018)

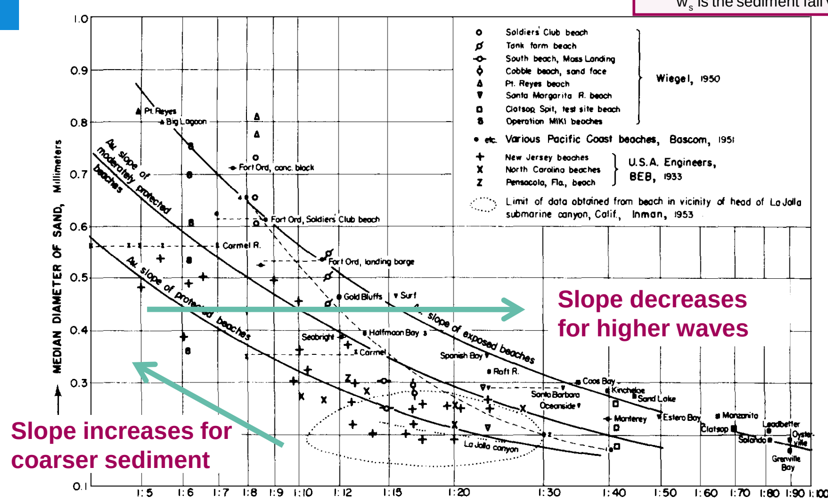
7-A Equilibrium shoreface profile

Beach slope versus grain-size

dimensionless fall velocity:

$$\Omega = \frac{H_b}{w_s T}$$

with: H_b is the wave height at breaking
w_s is the sediment fall velocity

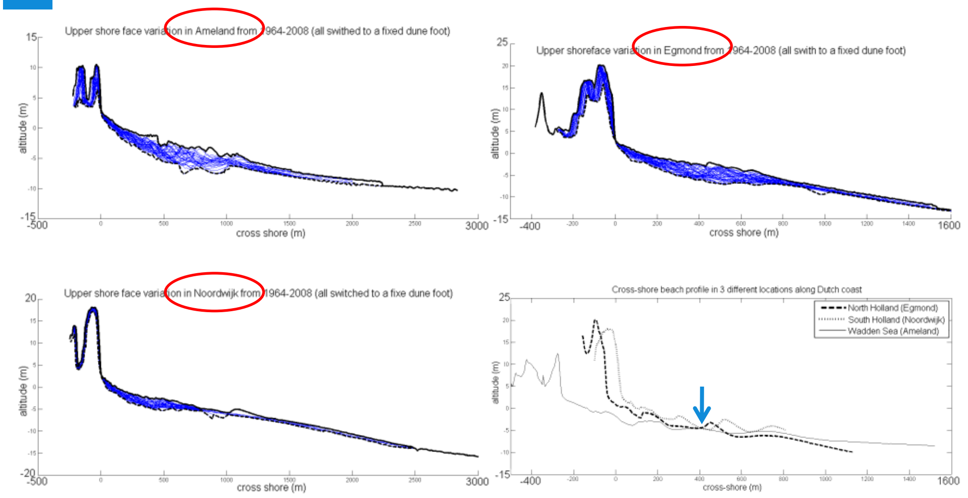


Ω low value (1) Ω high value (6)

after Wiegel (1964)

7-A Equilibrium shoreface profile

Upper shoreface profile variation



7-A Equilibrium shoreface profile

Semi-empirical derivations: Bruun (1954)

$$h = A(x')^m$$

the larger A the steeper the profile

x' => zero around the mean waterline and positive in offshore direction

m = $^2/_3$

A = dimensional shape factor (order 0.1 $m^{1/3}$)

7-A Equilibrium shoreface profile

Semi-empirical derivations: Dean (1977) =>

for a certain grain-size nature strives towards a uniform energy dissipation (loss in wave power) per unit volume of water across the surf zone

$$\frac{d\left(Ec_g\right)}{dx} = -D = -h\varepsilon\left(D_{50}\right)$$

$$\Downarrow$$

$$\frac{d}{dx}\left(\tfrac{1}{8}\rho g\gamma^2 h^2\sqrt{gh}\right) = -h\varepsilon\left(D_{50}\right) \Rightarrow$$

$$\varepsilon\left(D_{50}\right) = -\frac{1}{h}\frac{d}{dx}\left(\tfrac{1}{8}\rho g\gamma^2 h^{5/2}\sqrt{g}\right) =$$

$$= \frac{5}{16}\rho g^{3/2}\gamma^2\sqrt{h}\,\frac{dh}{dx'}$$

$$\Rightarrow \quad h = \overbrace{\left(\frac{24\varepsilon\left(D_{50}\right)}{5\rho g^{3/2}\gamma^2}\right)^{2/3}}^{A}\left(x'\right)^{2/3}$$

Empirically:

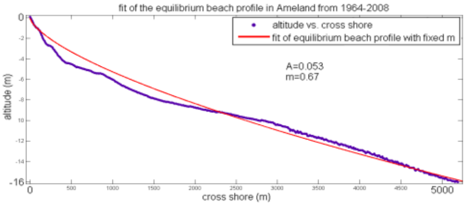
$$\boxed{A = 0.5 w_s^{0.44}}$$

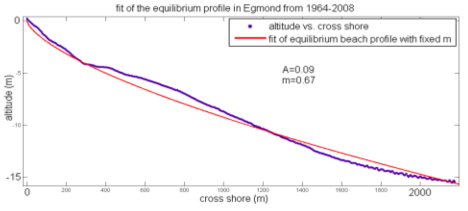
7-A Equilibrium shoreface profile

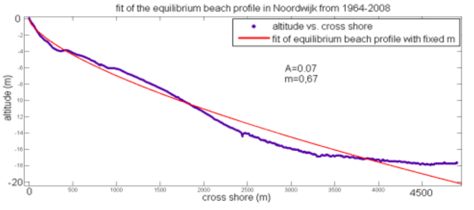
Fits to long-term averaged profiles

Values for A

$A = 0.5w_s^{0.44}$	Ameland	Egmond	Noordwijk
0.10	0.053	0.09	0.07



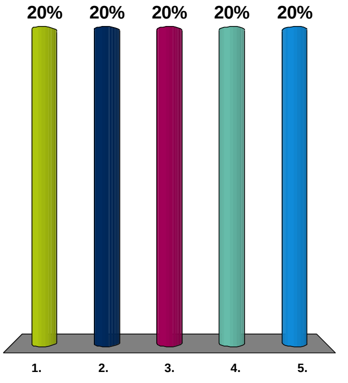




7-A Equilibrium shoreface profile

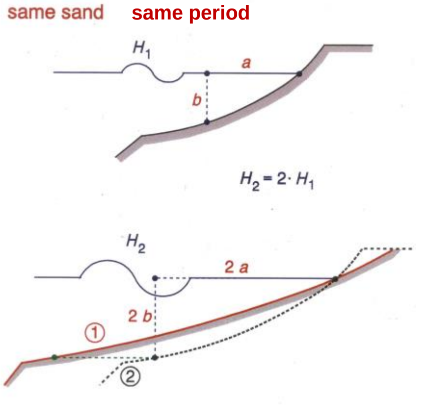
What is the most probable reason that **A** is different for the three regions?

1. The fall velocity of the sediment differs because of sea water temperature differences
2. ✓ The regions differ in wave exposure
3. The regions have different tidal ranges
4. A different reason
5. Abstain



7-A Equilibrium shoreface profile

Shape dependent on wave conditions and particle size



- Particle size:
  - Fine sand – gentle slope
  - Coarse sand – steep slope
- Wave height:
  - Larger wave height – gentler slope
  - Smaller wave height – steeper slope

dimensionless fall velocity:

$$\Omega = \frac{H_b}{w_s T}$$

with: H_b is the wave height at breaking

w_s is the sediment fall velocity

7-A Equilibrium shoreface profile

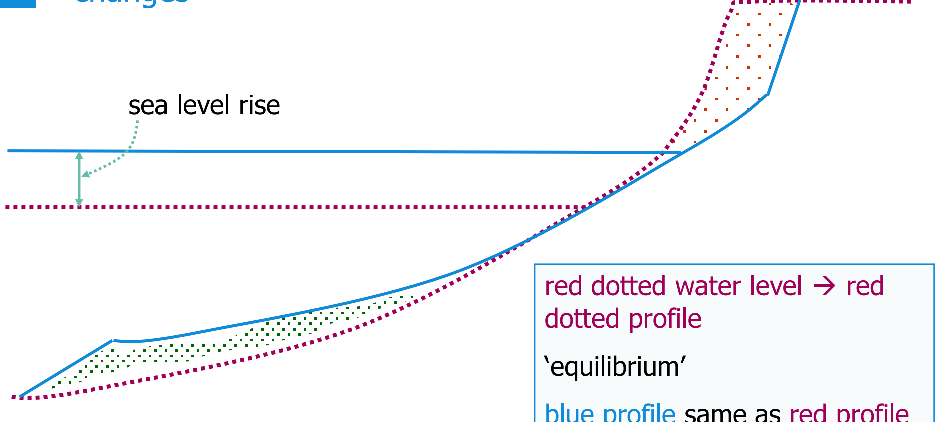
Practical value: what can an engineer do with this knowledge?

- Design a profile for a reclamation (see Chapter 10)
- Design nourishments with native and non-native nourishment material (see Chapter 10)
- Predict the impact of sea level rise
- Estimate dune erosion due to storm surge

However, try to calibrate and if possible validate **A**!

7-A Equilibrium shoreface profile

Bruun-rule: invariant profile shape in case of sea-level changes



red dotted water level → red dotted profile

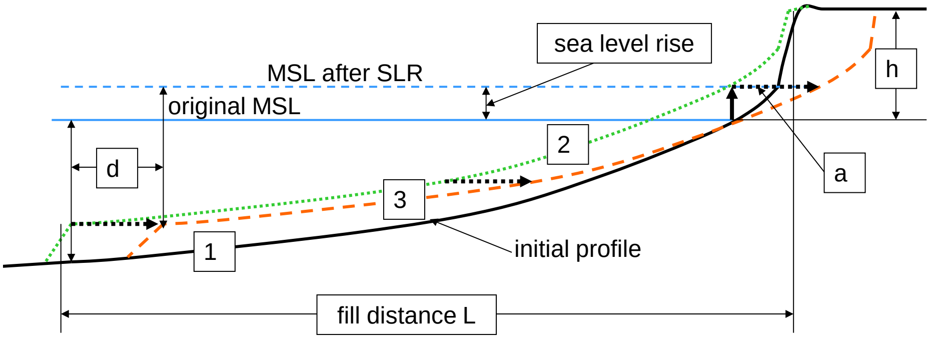
'equilibrium'

blue profile same as red profile

(w.r.t. water level)

Bruun-rule; how fast?

7-A Equilibrium shoreface profile
Bruun-rule: retreat distance

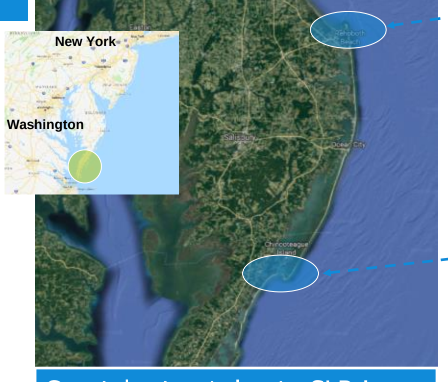


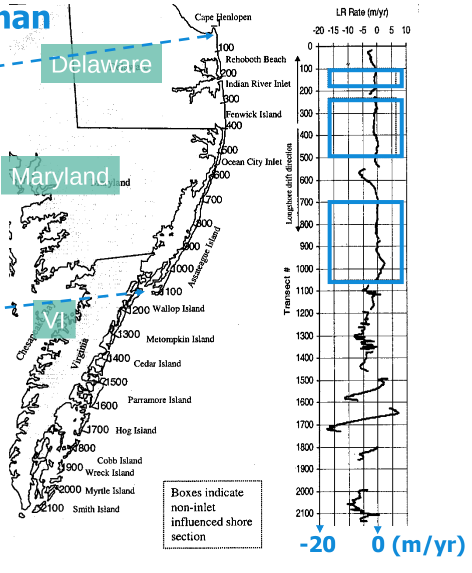
$$a = (L * SLR) / (h + d)$$

L: ± 1-2 km

h + d: ± 15-20 m

7-A Equilibrium shoreface profile
Data analysis of Leatherman

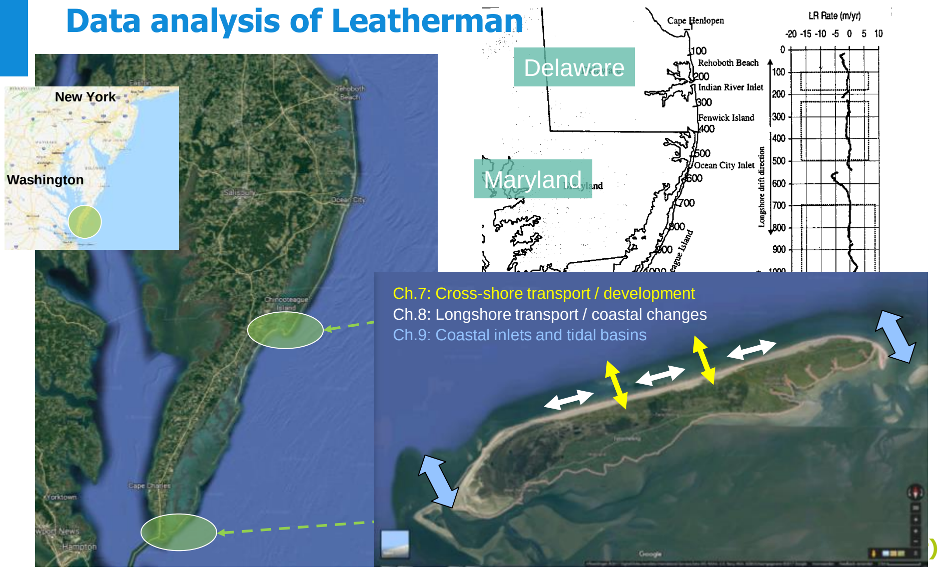




Coastal retreat due to SLR in non-inlet influenced sections:
- 50 to 120 times the SLR
- average = 78

7-A Equilibrium shoreface profile

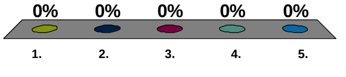
Data analysis of Leatherman



7-A Equilibrium shoreface profile

Why do we see much larger shoreline changes in sections influenced by tidal basins?

1. Tidal basins capture sediment, for instance under sea level rise ✓
2. Density currents are able to transport sediment into the basin
3. The coastal grain-size is coarser near inlets
4. The ebb-tidal delta is dynamic ✓
5. Abstain



7.

Cross-shore transport and profile development

7-A Equilibrium shoreface profile

Quick recap of yesterday

- Equilibrium profiles: Describe shoreface, long-term averaged profiles (decades and more)
- Theory (Bruun, Dean) relates profile shape to sediment characteristics only (w_s)
- BUT: Also affected by wave climate characteristics (H_b, T)
- Combined effect described by dimensionless fall velocity parameter Ω
- Useful concept for engineering applications (HPZ, MV2)

7-A Equilibrium shoreface profile (Bruun / Dean)

Fits to long-term averaged profiles

$$h = A(x')^m$$

Values for A

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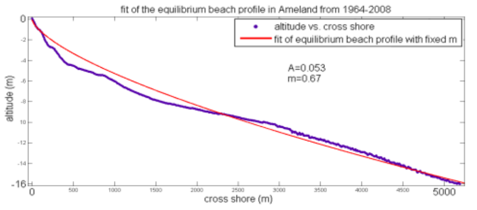
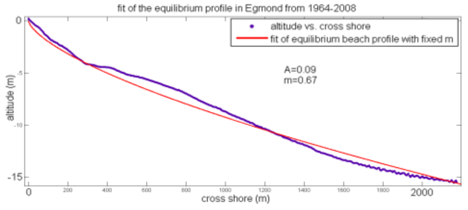
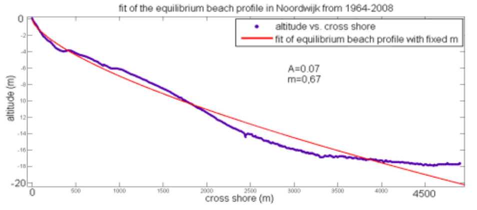
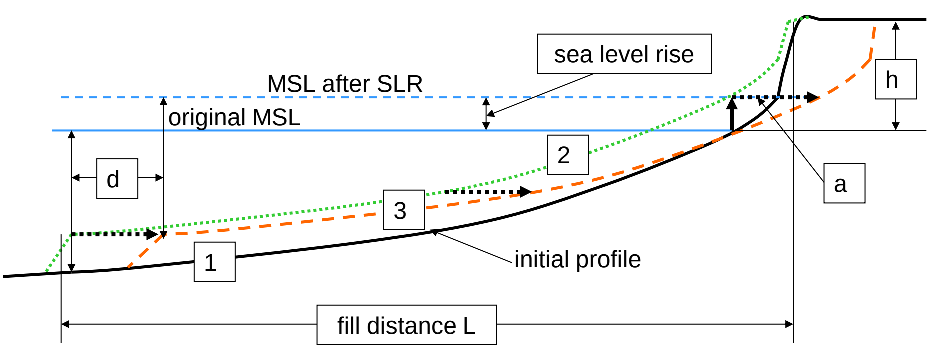






7-A Equilibrium shoreface profile

Bruun-rule: retreat distance



L: ± 1-2 km

a = (L * SLR) / (h + d)

h + d: ± 15-20 m

7-A Equilibrium shoreface profile

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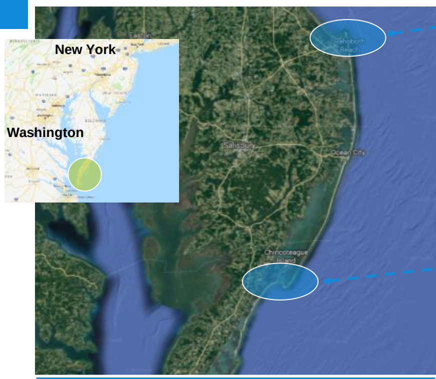

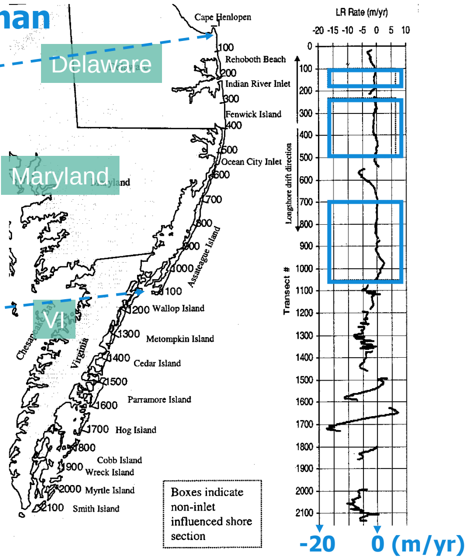

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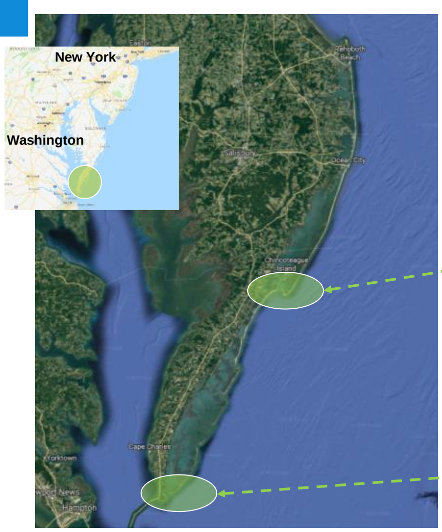

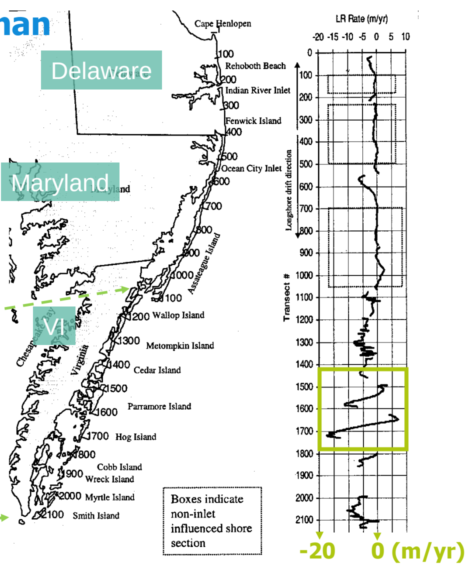

7-A Equilibrium shoreface profile

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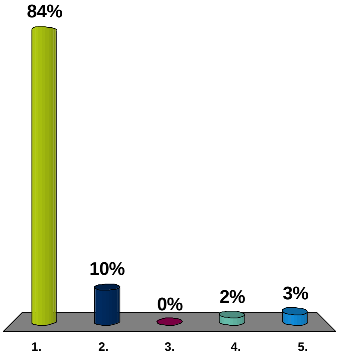
5. Abstain



Cross-shore transport and profile development

Chapter 7 of lecture notes

A. Equilibrium shoreface profile
B. Beach states
C. Cyclic profile and bar behaviour
D. Episodic events: dune erosion
E. Cross-shore transport mechanisms

7-B Beach states

Storm wave climate: high and short waves and highly variable (Ω large)

dimensionless fall velocity:

$$\Omega = \frac{H_b}{w_s T}$$

with: H_b is the wave height at breaking
w_s is the sediment fall velocity

- Higher and shorter waves give **wide and flat** sandy coastal zone with **multiple bars**, dunes and a wide beach:
  - High waves break far offshore
  - High waves tend to move sediment offshore
  - "Spilling" breakers
- Variability in wave heights results in:
  - **highly dynamic** coastal profile

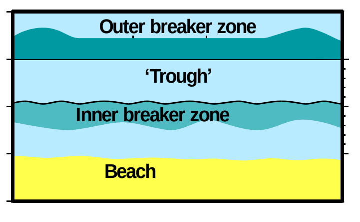
See Chapter 4

7-B Beach states

At end of spectrum: Dissipative beach (Ω>6)

See Chapter 4

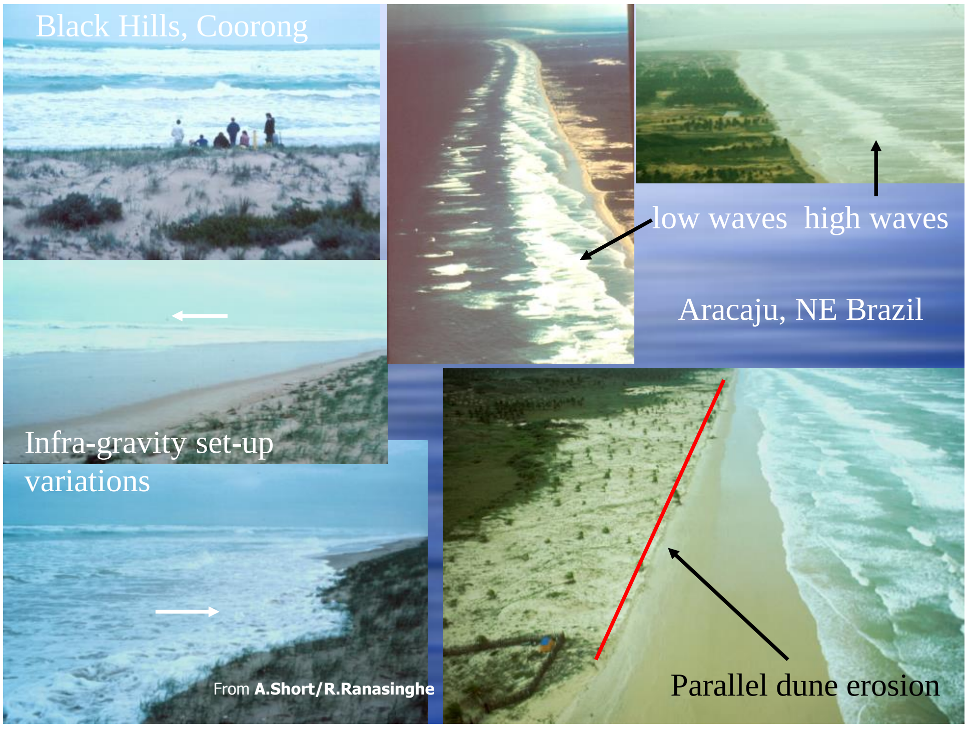
DISSIPATIVE



Muriwai, NZ

Aracaju, NE Brazil

From A.Short/R.Ranasinghe



7-B Beach states

See Chapter 4

Swell (and monsoon) wave climate: low, long waves (relatively constant in time): Ω small

- Low and long waves break close to the shore and tend to move sediment onshore
  - Narrow sandy profile
  - Steep
  - Berms
- Less dynamic

Jibbon (Sydney)

At end of spectrum: reflective beach Ω<1

Photo A.Short/R.Ranasinghe


BANEN
DIGITALE KRANT SERVICE WINKEL INCLUSIEF
ABONNEER
Nieuws
Cultuur & Leven
deVolkskrant
ZOEKEN
INLOGGEN
Binnenland

Toch pogingen om te zwemmen bij Hoek van Holland

14 juli 2007, 20:38

HOEK VAN HOLLAND (ANP) - De strandwacht van Hoek van Holland heeft zaterdag tientallen mensen tegengehouden die een duik in de Noordzee wilden nemen. Dat meldde een woordvoerder van de strandwacht.Voor de zee bij Hoek van Holland geldt een zwemverbod. Door zandsuppletie is namelijk vlak voor de kust een gevaarlijke geul met los zand ontstaan. Op het strand is de situatie onveilig vanwege extra golfslag en risico op uitglijden in het water.De provincie Zuid-Holland besloot vrijdag om een zwemverbod af te kondigen voor een stuk strand van drie kilometer vanaf de pier naar het noorden. Volgens de strandwacht gaat het echter slechts om een stuk van anderhalve kilometer. Dit gedeelte is gemarkeerd met een rood lint. De reddingsbrigade heeft de rode vlag uithangen.**Matig strandweer**,,Sommige mensen dachten ondanks de vele waarschuwingen toch een duik te kunnen nemen. We hebben ongeveer 75 mensen teruggewezen", aldus de woordvoerder. Langs de toegangsweg naar Hoek van Holland staat een bord, waarop mensen worden gewaarschuwd niet het water in te gaan. Wie wel in de zee duikt, riskeert een boete van 150 euro.Door het matige strandweer viel het met de toeloop naar het strand wel mee volgens de zegsman. ,,Het was bewolkt en winderig, dus niet lekker om even lekker naar het strand te gaan. Zondag wordt het waarschijnlijk warmer, dan krijgen wij het drukker. Er zullen verschillende strandwachters langs de kust lopen om de

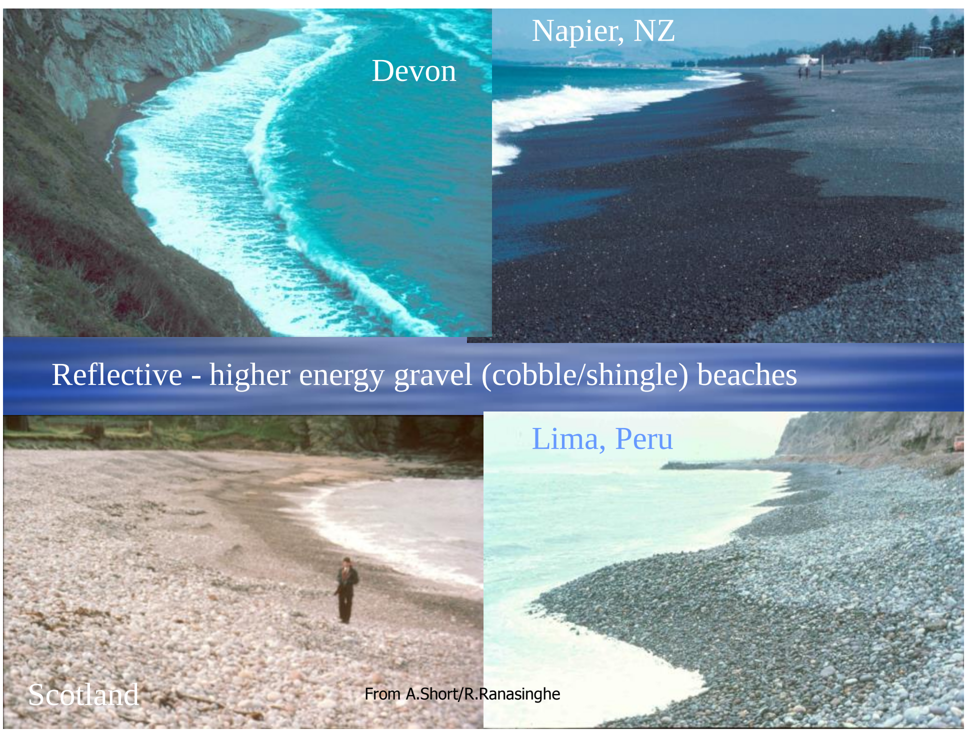
AANBEVOLEN ARTIKELEN

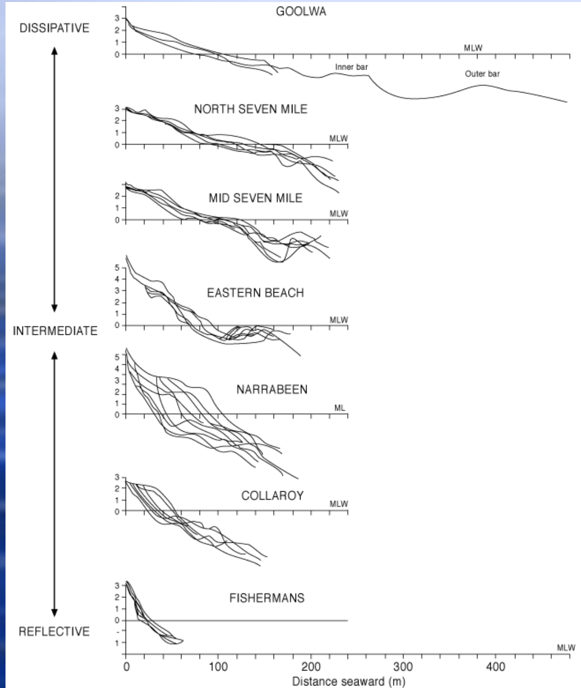
Amerikanen boos om 'racistische' Wilders-tweet van politicus
13 maart 2017

Clingendael-expert: 'Politieke schade van rel ligt vooral bij Nederland'
11 maart 2017

Huishoudchemicaliën veroorzaken mogelijk hersenstoornissen
8 maart 2017

MEEST GELEZEN BINNENLAND

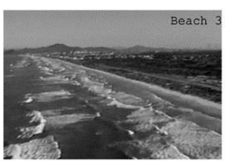


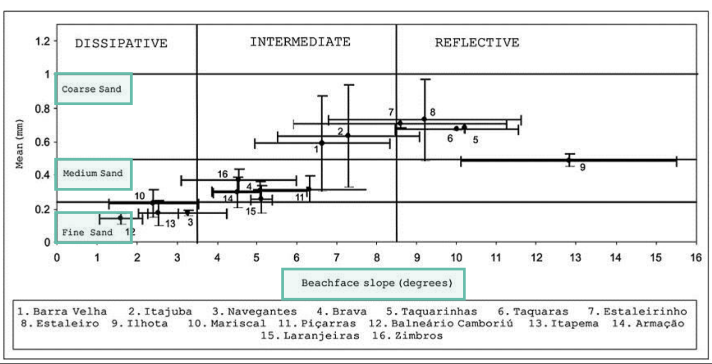


From A.Short/R.Ranasinghe

7-B Beach states

Beach slope and material versus beach state (Klein et al)



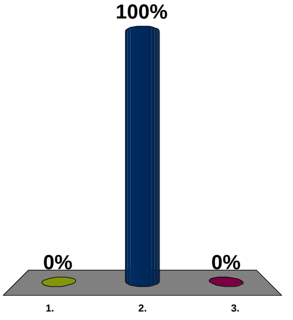


7-B Beach states

Dean’s derivation - based on uniform energy dissipation per unit volume - leads to an equilibrium profile that to first order is a function of D_{50} only. The data of Klein et al seems to support this.

Can we now draw the conclusion that the wave conditions do not play a role?

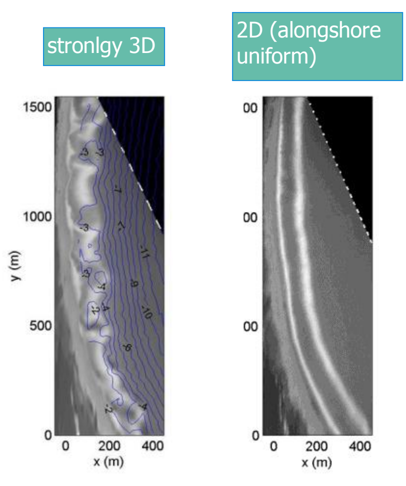
1. Yes
2. No ✓
3. Abstain



7-B Beach states

The beach state is not invariable and depends on amongst others the energy level and (a 2nd order effect) on the water level (tide)

- Beaches can move through a series of beach states
- **Reset event**: 2D alongshore uniform morphology is restored
- Sequence of 6-8 beach states from dissipative to reflective
  - down-state: from reset under high energy to gradually less energy

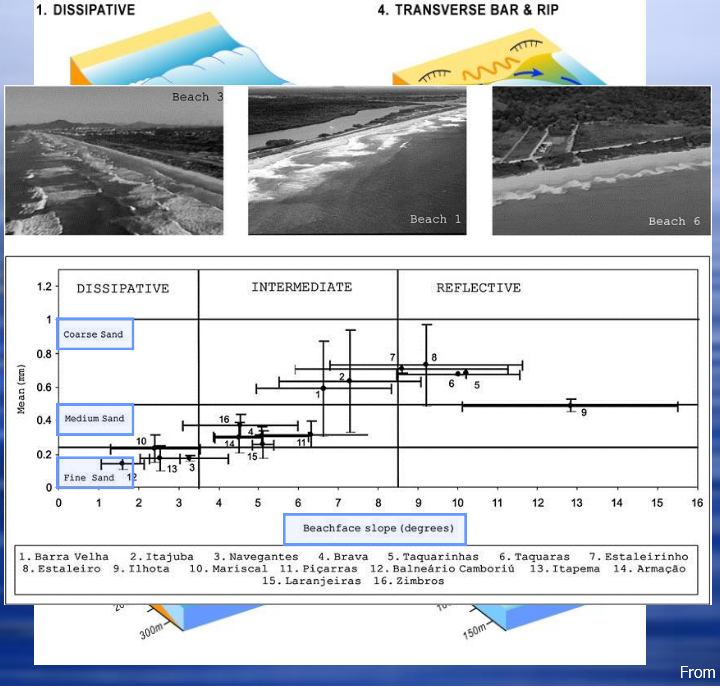


Images from Graham Symonds

OBJECTIVE CLASSIFICATION

Predictive		Descriptive	
Dimensionless fall velocity: $\Omega = \dfrac{H_b}{w_s T}$		**Iribarren number:** $\xi = \dfrac{\tan\alpha}{\sqrt{H_0 / L_0}}$	bottom slope; wave steepness
Dissipative	$\Omega > 6$	$\xi = 0.2 - 0.3$	Flat slopes, short & high waves
Intermediate	$1 < \Omega < 6$	$\xi = 0.3 - 2.0$	
Reflective	$\Omega < 1$	$\xi > 2$	Steep slopes, long & low waves

From A.Short/R.Ranasinghe



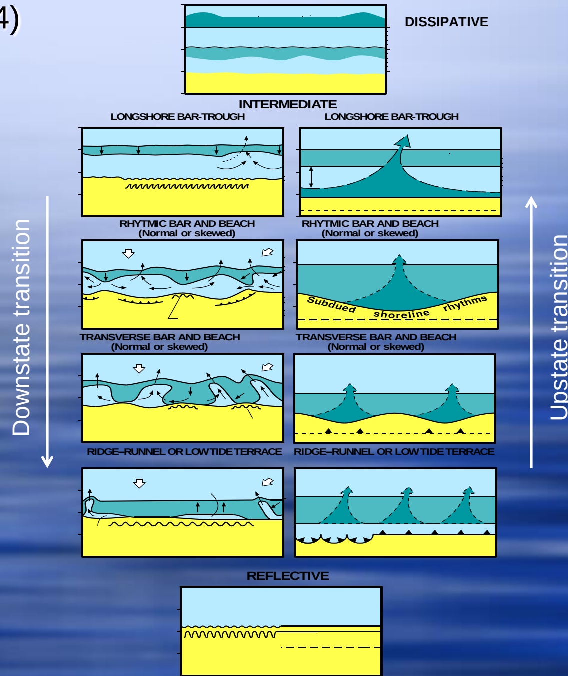
From A.Short/R.Ranasinghe

Wright and Short (1984)

dissipative

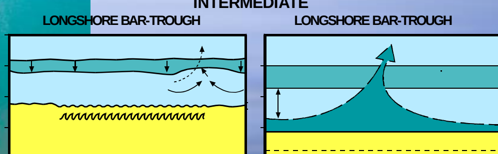
intermediate

reflective



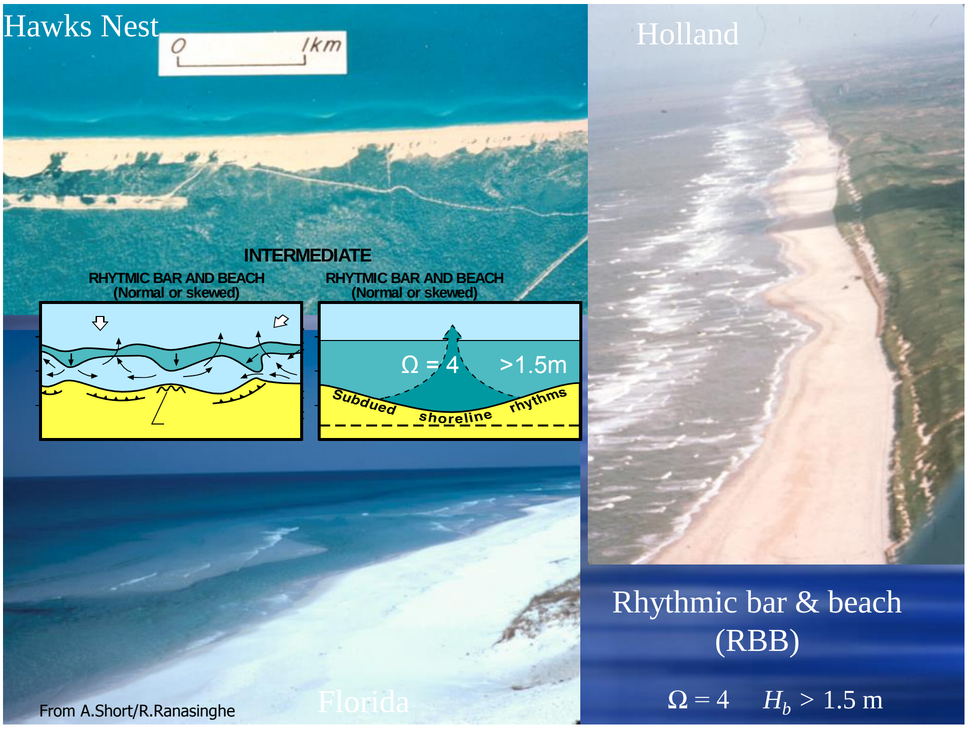
Based on 2 years of daily visual observations at Narrabeen Beach, Sydney

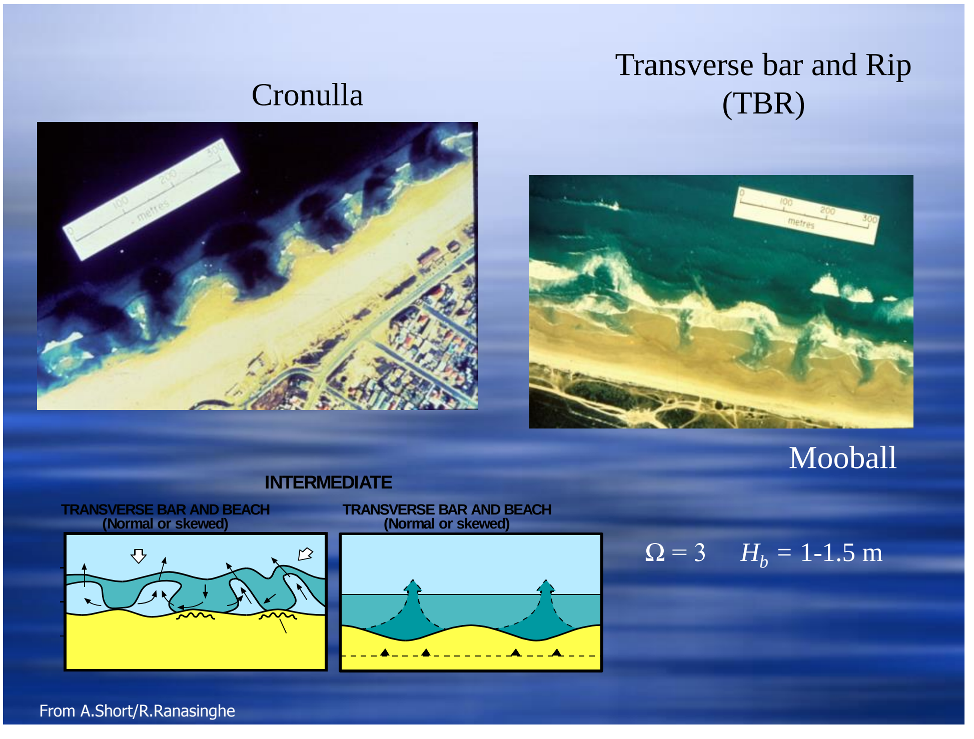
Longshore bar & trough (LBT)



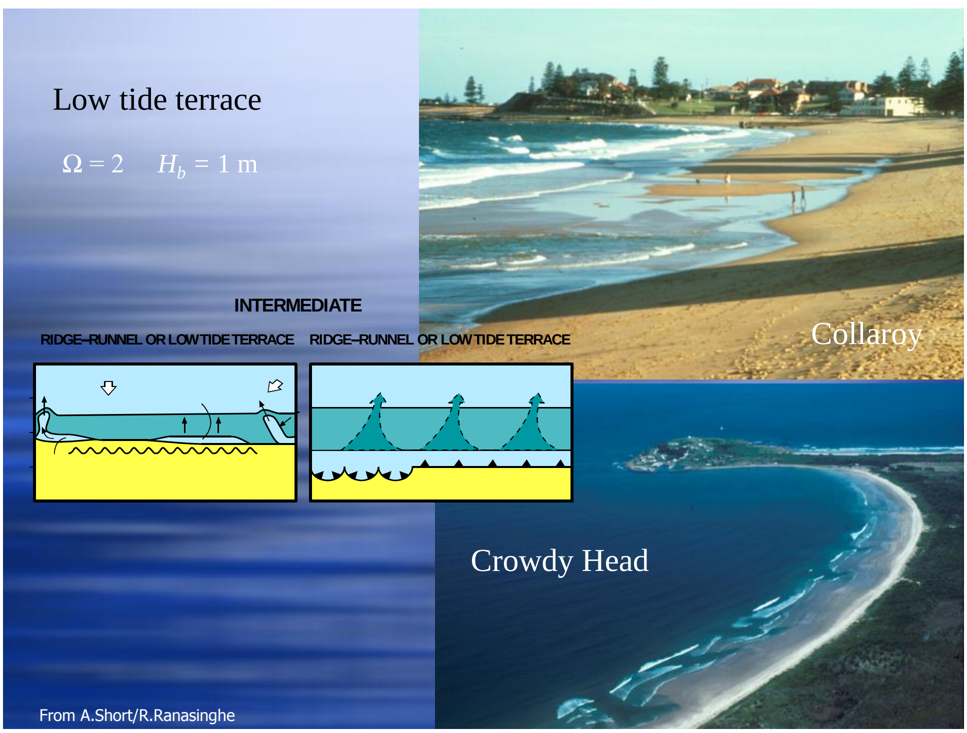
$\Omega = 5 \quad H_b = 2$ m

From A.Short/R.Ranasinghe


Hawks Nest
0
1km
Holland
INTERMEDIATE
RHYTMIC BAR AND BEACH
(Normal or skewed)
RHYTMIC BAR AND BEACH
(Normal or skewed)
Ω = 4
>1.5m
Subdued
shoreline
rhythms
Rhythmic bar & beach
(RBB)
Ω = 4 H_b > 1.5 m
From A.Short/R.Ranasinghe
Florida


Cronulla
Transverse bar and Rip
(TBR)
Mooball
INTERMEDIATE
TRANSVERSE BAR AND BEACH
(Normal or skewed)
TRANSVERSE BAR AND BEACH
(Normal or skewed)
Ω = 3 H_b = 1-1.5 m
From A.Short/R.Ranasinghe


scarp
rip embayment erosion
and discrete dune scarping
From A.Short/R.Ranasinghe


Low tide terrace
$\Omega = 2$ $H_b = 1$ m
INTERMEDIATE
RIDGE–RUNNEL OR LOW TIDE TERRACE
RIDGE–RUNNEL OR LOW TIDE TERRACE
Collaroy
Crowdy Head
From A.Short/R.Ranasinghe

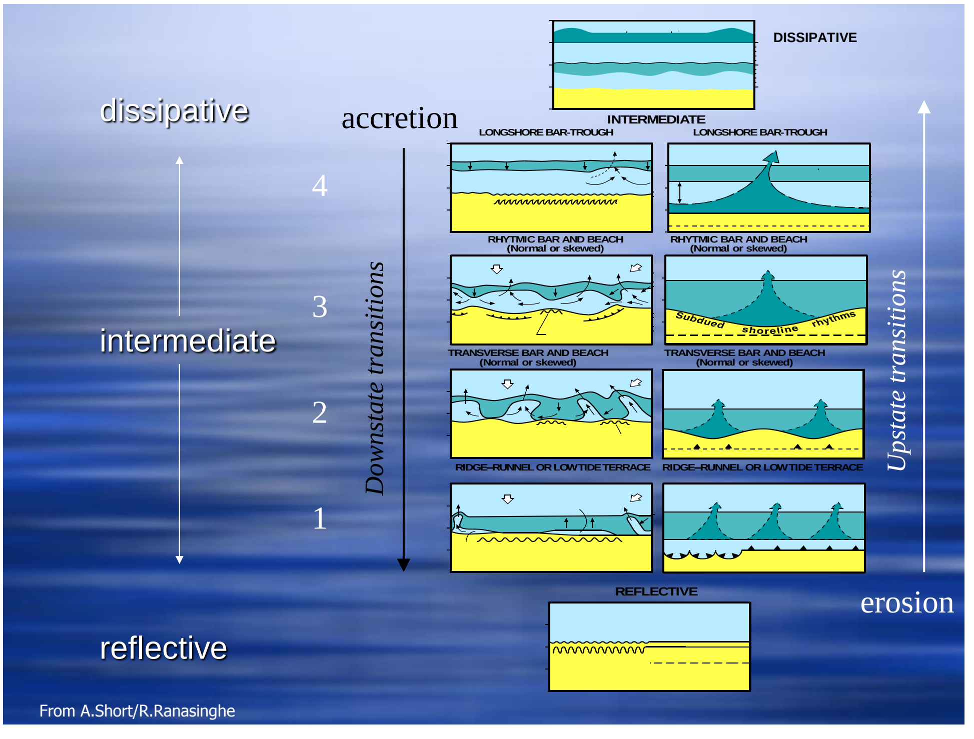
Spatial scales governed by external forcing or internal dynamics (self-organization)?

Rip current types

Rip current spacing, type and velocities

- spacing approximately = surf zone width x 4
- on open swell coast rip spacing from 100 to 500 m, commonly 150 to 250 m apart
- on multi-bar beaches, spacing increases seaward.
- spacing is also a function of beach slope, the lower the slope (hence wider the surf zone) the wider the rip spacing.

From A.Short/R.Ranasinghe



Cross-shore transport and profile development

Chapter 7 of lecture notes

A. Equilibrium shoreface profile
B. Beach states
C. Cyclic profile and bar behaviour
D. Episodic events: dune erosion
E. Cross-shore transport mechanisms

7-C Cyclic profile and bar behaviour

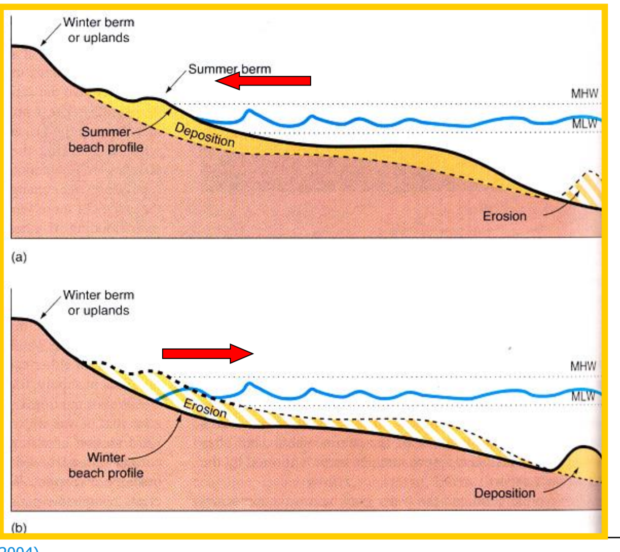
Storm and seasonal changes

Summer: beach rich in sediment

(resembling reflective beach)

Winter and/or after storm: beach poor in sediment

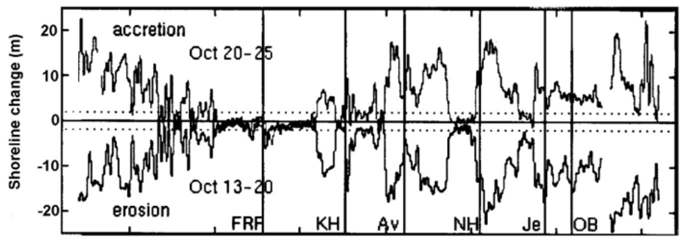
(resembling dissipative beach)

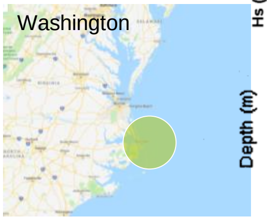


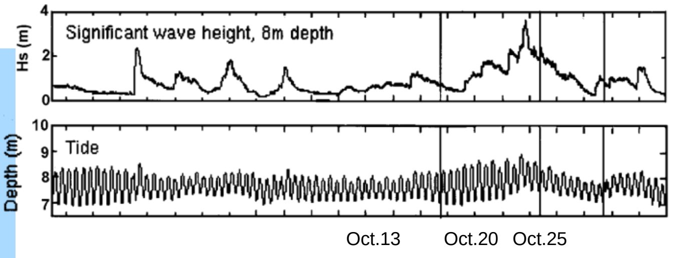
From Sverdrup et al. (2004). The world's oceans.

7-C Cyclic bar and profile behaviour

Shoreline changes



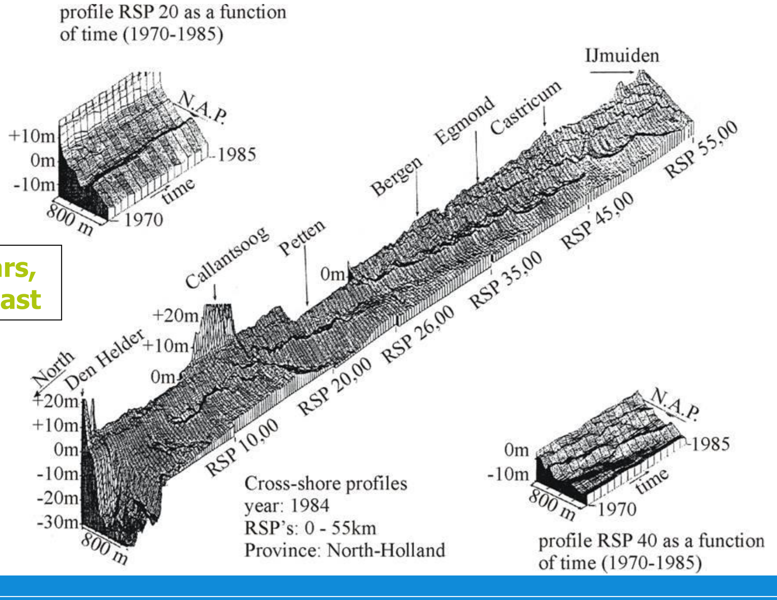




7-C Cyclic bar and profile behaviour

Bar cycles over years

breaker bars, Holland coast

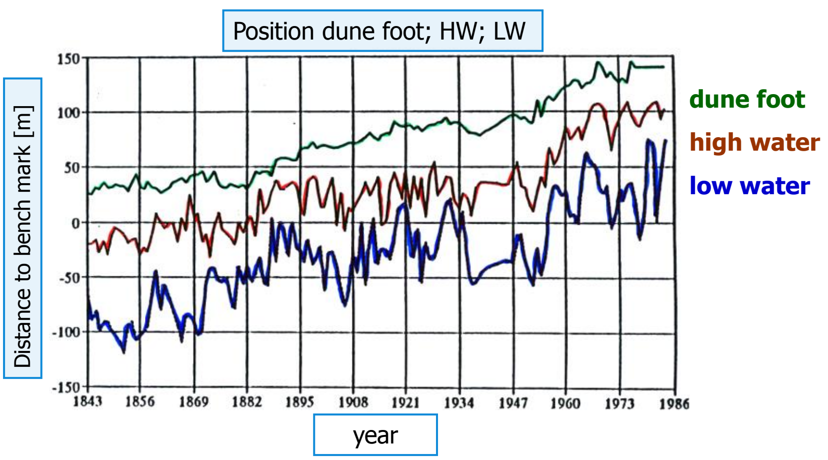


TUDelft: jet-ski as measuring tool

- GPS
- echo sounder

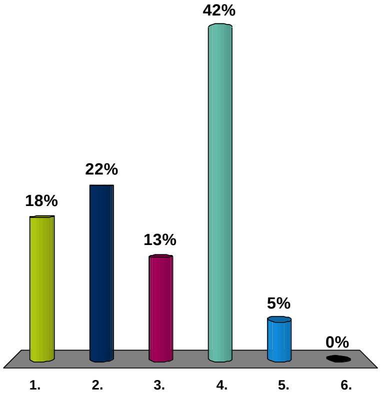
7-C Cyclic bar and profile behaviour

Seasonal behaviour versus long term trend



The yearly variability of the LW position along the Dutch coast is larger than of the dunefoot position due to:

1. Wind-induced transport
2. Human interference such as vegetation maintenance
3. Rip-currents are more normal under intermediate energy situations
4. ✓ Stormy years impact the lower parts of the profile more
5. None of the above
6. Abstain



7.

Cross-shore transport and profile development

Cross-shore transport and profile development

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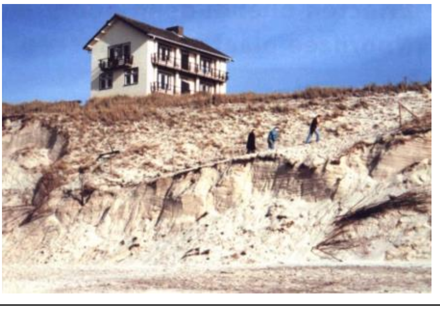
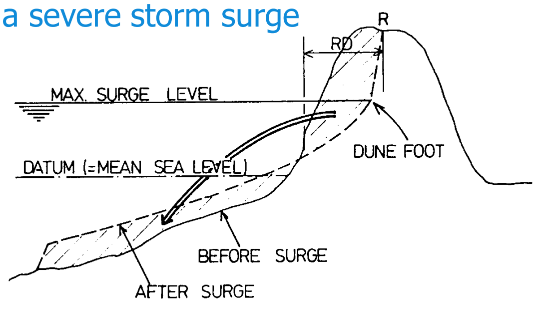
7-D Episodic events: dune erosion

Damage (1)



7-D Episodic events: dune erosion
Damage (2)

7-D Episodic events: dune erosion
Dune erosion during a severe storm surge



- redistribution over cross-shore profile
- no loss out of control volume
- sooner or later return of sediments (in a stable case)

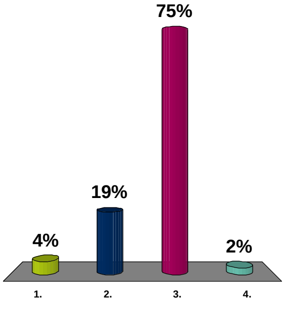
7-D Episodic events: dune erosion

Which of the below statements is true?

Nr 1. Dune erosion due to a storm surge creates an equilibrium profile relative to the storm surge level

Nr 2. We can estimate the retreat due to dune erosion from a Bruun type rule

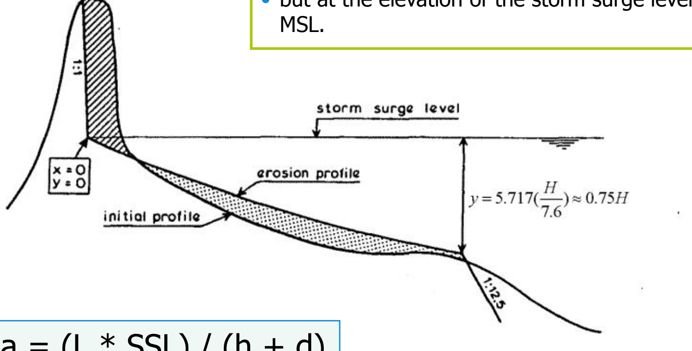
1. Nr 1 only
2. Nr 2 only
3. ✓ Both
4. Abstain



7-D Episodic events: dune erosion

Extent of the sedimentation zone (Vellinga)

first-order magnitude estimate of dune retreat:
- using Bruun's rule;
- assume erosion profile is same as the pre-storm equilibrium profile;
- but at the elevation of the storm surge level instead of the MSL.



a = (L * SSL) / (h + d)

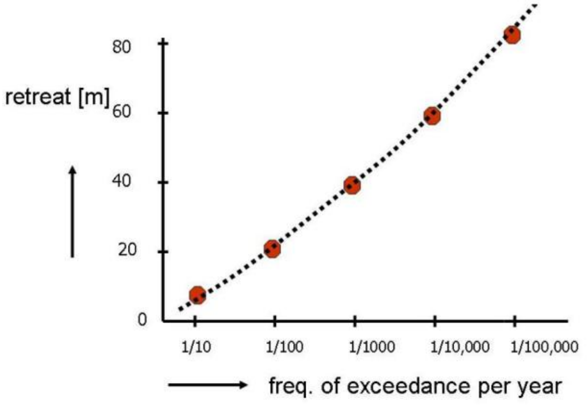
7-D Episodic events: dune erosion
First order estimate of dune erosion

- Design storm conditions:
  - offshore water levels approximately 5 - 6 m above MSL
  - severe wave conditions $H_s \approx$ 7 - 9 m and $T_p \approx$ 12 - 18 s
  - $h+d$ = 10 m (dune height above MSL)
  - L= 200 m (beach width between top of duneface to MSL)

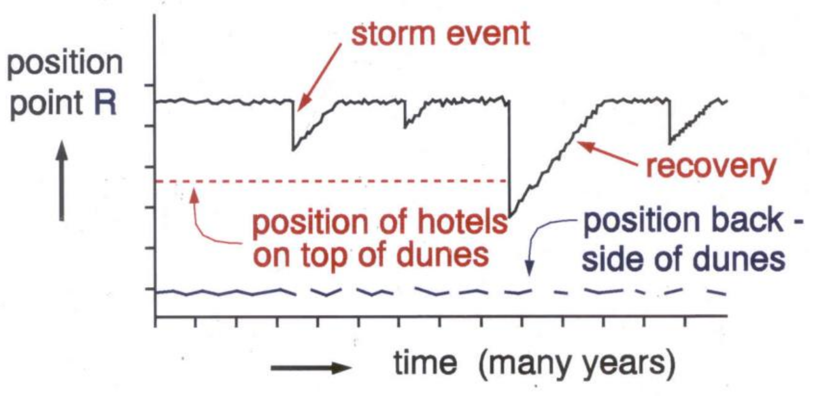
⇒ Dune retreat ~ 100 - 120 m (cf. design rule outcome of 80 to 100 m)

retreat = (L * SSL) / (h + d)

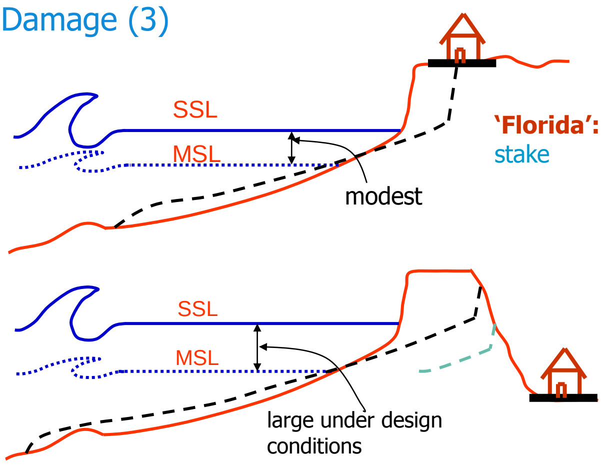
7-D Episodic events: dune erosion



7-D Episodic events: dune erosion
Set-back lines



7-D Episodic events: dune erosion
Damage (3)



'Florida': single houses at stake

'Holland': *Break through:* part of population at stake

Cross-shore transport and profile development

Chapter 7 of lecture notes

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7-E Cross-shore transport mechanisms

Order of magnitude of cross-shore transport

Typical cross-shore sediment transport into the surfzone Holland and Wadden coast	
Integral gross	$O(10^2)$ $m^3/m/year$ or per extreme event
Integrated net	$O(10^1)$ $m^3/m/year$
Effective profile height	10 m
Net natural shoreline changes	O(1) m/year
Net gross shoreline changes	O(10) m/year or per extreme event

7-E Energetics approach

Decomposition of the transport rate

$$\langle S_b \rangle \propto \langle u|u|^2 \rangle$$

Assuming that $\bar{u} \ll u_{lo} \ll u_{hi}$

$$u = \underbrace{\bar{u}}_{\substack{\text{time-mean component} \\ \text{(streaming outside surf zone,} \\ \text{undertow in surf zone)}}} + \underbrace{u_{lo}}_{\substack{\text{low-frequency motion} \\ \text{at wave-group scale}}} + \underbrace{u_{hi}}_{\substack{\text{osillatory motion at} \\ \text{short wave scale}}}$$

$$\langle u|u|^2 \rangle = \underbrace{3\langle \bar{u}|u_{hi}|^2 \rangle}_{1} + \underbrace{\langle u_{hi}|u_{hi}|^2 \rangle}_{2} + \underbrace{3\langle u_{lo}|u_{hi}|^2 \rangle}_{3} + \ldots$$

1: mean flow as transporting velocity

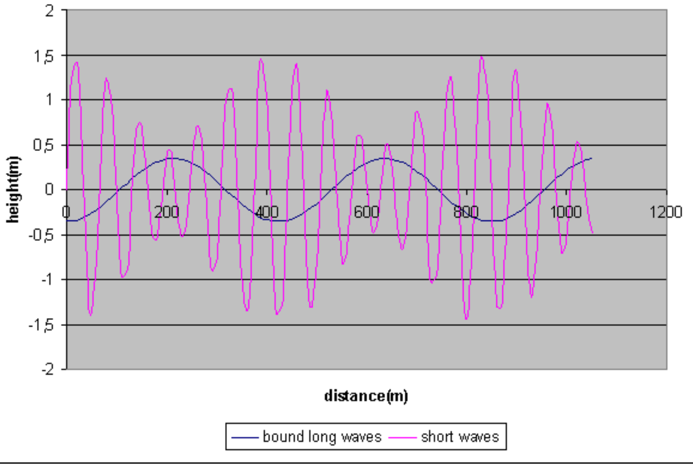
2: short wave skewness

3: correlation bound long waves and short wave envelope

7-E Cross-shore transport mechanisms

Intermezzo: bound long waves due to set-down variations on the wave group scale

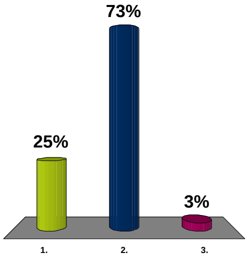
See Chapter 5

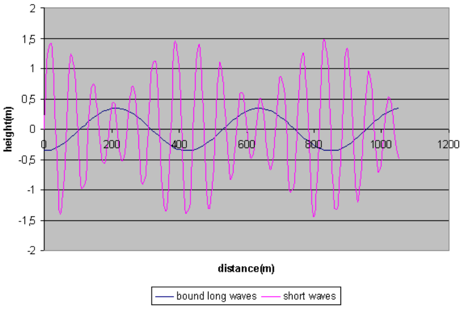


7-E Energetics approach

The correlation between high short waves and the bound long wave in the offshore results in a net onshore transport

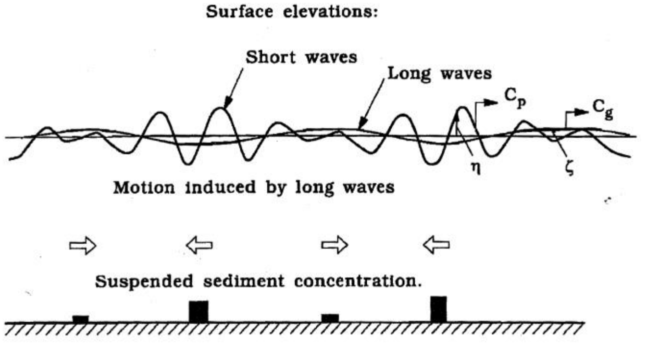
1. True
2. ✓ False
3. Abstain





7-E Energetics approach

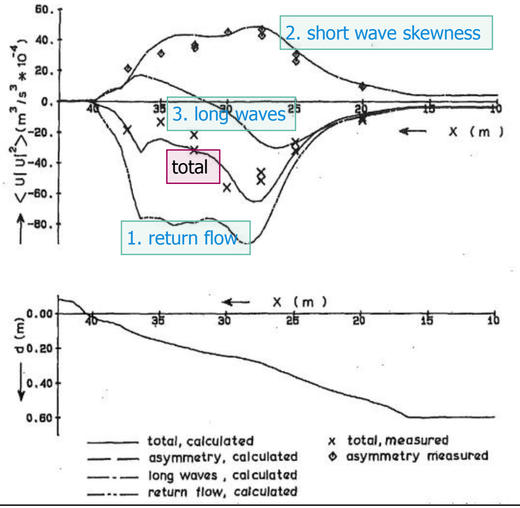
Offshore (suspended) sediment transport under bound long wave



7-E Energetics approach

Measurements and model predictions

$$\langle u|u|^2\rangle \approx \underbrace{3\langle \bar{u}|u_{hi}|^2\rangle}_{1} + \underbrace{\langle u_{hi}|u_{hi}|^2\rangle}_{2} + \underbrace{3\langle u_{lo}|u_{hi}|^2\rangle}_{3}$$



7-E Cross-shore transport mechanisms

On- and offshore transport mechanisms

- **Onshore directed**
  - LH streaming (outside surf zone)
  - Wave asymmetry
  - Free long waves (in surf zone)
- **Offshore directed**
  - Undertow (in surf zone)
  - (Bound) long waves (outside surf zone)
- **Down-hill (on average offshore)**
  - Gravity

7-E Cross-shore transport mechanisms
Analytical solutions for the lower and middle shoreface

See Bowen (1980)!

Basic idea

An equilibrium profile (purely in suspended load) exists if:

$$\langle I_s \rangle = 0$$

Bagnold's transport description adapted for non-linear oscillatory motion:

$$I_s = \frac{\varepsilon_s c_f \rho}{w_s} \frac{u^3 |u|}{(1-\gamma u)} \text{ with } \gamma = \frac{\tan \alpha}{w_s}$$

Eqs. 6.49 / 7.17

7-E Cross-shore transport mechanisms
Velocity consist of symmetrical orbital velocity plus a perturbation

$$u = U_0 + U_1 = u_0 \cos(\omega t) + U_1, \text{ with generally } U_0 \gg U_1$$

Considered perturbations:

1. Mean flow (e.g. outside surf zone Longuet-Higgins streaming)

$$U_1 = u_1$$

2. Second harmonic of the primary wave:

$$U_1 = u_2 \cos(2\omega t)$$

7-E Cross-shore transport mechanisms

Taylor expansion to first order:

$$\boxed{\langle I_s\rangle = \frac{\varepsilon_s c_f \rho}{w_s}\left[\overline{4U_1U_0^2|U_0|} + \gamma\overline{U_0^4|U_0|} + \ldots\right]}$$

With perturbation is the LH streaming:

$$\boxed{\langle I_s\rangle = \frac{\varepsilon_s c_f \rho}{w_s}\left[\frac{16}{3\pi}u_1u_0^3 + \frac{16}{15\pi}\gamma u_0^5\right]}$$

$$\boxed{\langle I_s\rangle = 0}$$

$$\boxed{U_1 = -u_0^2/c}$$ **See Eq. 5.29**

$$\boxed{\gamma = \frac{\tan\alpha}{w_s} = -\frac{5u_1}{u_0^2}}$$

$$\boxed{\tan\alpha \simeq \frac{5w_s}{c} = \frac{5w_s\omega}{g\tanh kh}}$$

7-E Cross-shore transport mechanisms

Equilibrium profile implies that gravitational effects balance influence of streaming everywhere

$$\tan\alpha \simeq \frac{5w_s}{c} = \frac{5w_s\omega}{g\tanh kh}$$

$$\tan\alpha = \frac{dh}{dx} \simeq 5w_s/\sqrt{gh} \Rightarrow h^3 \simeq (7.5w_s x)^2/g$$

$$\boxed{h \simeq \underbrace{(7.5w_s)^{2/3}/g^{1/3}}_{A}\, x^{2/3}}$$

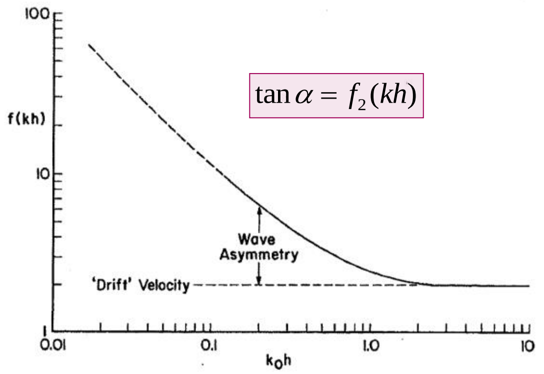
(Compare Bruun/Dean profile Eq. 7.1)

$$\boxed{\text{for } w_s = 0.0256 \text{ m/s} \;\; => \;\; A = (7.5w_s)^{2/3}/g^{1/3} = 0.16}$$

7-E Cross-shore transport mechanisms

Inclusion of effect higher harmonic $u_2 \cos(2\omega t)$

$$\langle I_s \rangle = \frac{\varepsilon_s c_f \rho}{w_s} \frac{16}{15\pi} u_0^3 \left[5u_1 - 3u_2 + \gamma u_0^2 \right] = 0 \;\Rightarrow\; \gamma = \frac{\tan\alpha}{w_s} = -\frac{5u_1}{u_0^2} + \frac{3u_2}{u_0^2}$$



Exam question april 2010

14(90)

2. Transport mechanisms [14]

Consider normally incident waves at the shoreface (including the surf zone). The horizontal velocity $u(t)$ at a certain distance from the bed consists of a time-averaged component $\overline{u}$ and a short-wave oscillatory component $u_{hi}(t)$. Oscillations on the wave-group scale are neglected, hence $u(t) = \overline{u} + u_{hi}$. The onshore direction is taken as positive.

It is often assumed that the sediment transport responds instantaneously to the shear stress or velocity to a certain power, e.g. $S(t) \propto u(t)^3$. For $|\overline{u}| \ll |u_{hi}|$ this gives for the time-averaged transport (time-averaging now indicated by brackets):

$$\langle S \rangle \propto 3\underbrace{\langle \overline{u} |u_{hi}|^2 \rangle}_{1} + \underbrace{\langle u_{hi} |u_{hi}|^2 \rangle}_{2} + \ldots$$

a. [3] Interpret the term $|u_{hi}|^2$ in terms of sediment transport processes. (70 words).

b. [3] Give a physical interpretation of the first term (indicated by 1) and explain the sign of this term at the upper shoreface (say surf zone) and lower shoreface. (70 words).

c. [3] Give the simplest expression for u_{hi} for which the second term (indicated by 2) is non-zero and onshore directed and make a sketch of the signal. Do not forget an explanation. (60 words).

d. [5] For a real-world situation, describe and sketch the distribution of the second term over the shoreface from deep water to the water line. Indicate the approximate extent of the surf zone in your sketch. (130 words).

Exam topic june 2011

Dynamic equilibrium profile:

- Definition dynamic versus stable equilibrium profile
- Dependency equilibrium profile on fall velocity
- Reasoning behind Bruun rule for sea-level rise
- Overview cross-shore transport mechanisms
  - Mechanism for onshore transport
  - Mechanism for offshore transport