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TOPIC 3

TIDES AND CURRENTS

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Course Learning Outcomes

Upon completion of this course, students should be able to:

1. Evaluate the properties of offshore and near shore waves and establish design wave specification.
2. Assess currents and tidal processes.
3. Formulate sediment budget and perform shoreline evolution analysis.

Part 2: Nearshore Currents

LEARNING OUTCOMES

Upon completion of this topic, participants should be able:

- To identify the current type
- To estimate alongshore current velocity

STUDY OF NEARSHORE CURRENT

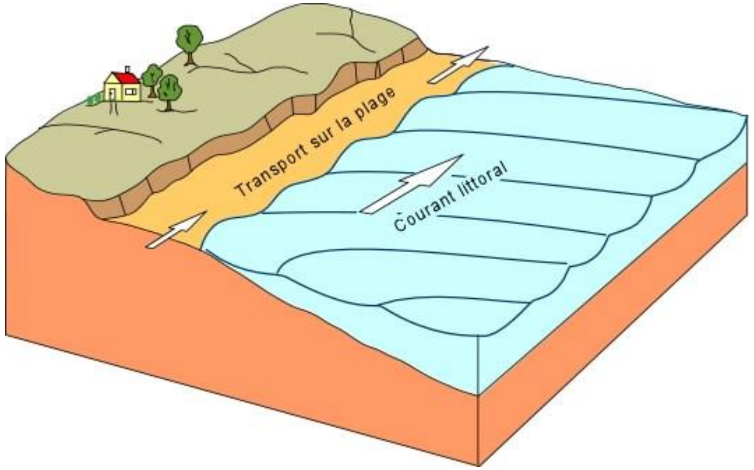
- Nearshore currents in the littoral zone are predominantly wind- and wave-induced motions.
- There is only slight exchange of fluid between the offshore and the surf zone.
- Significance:

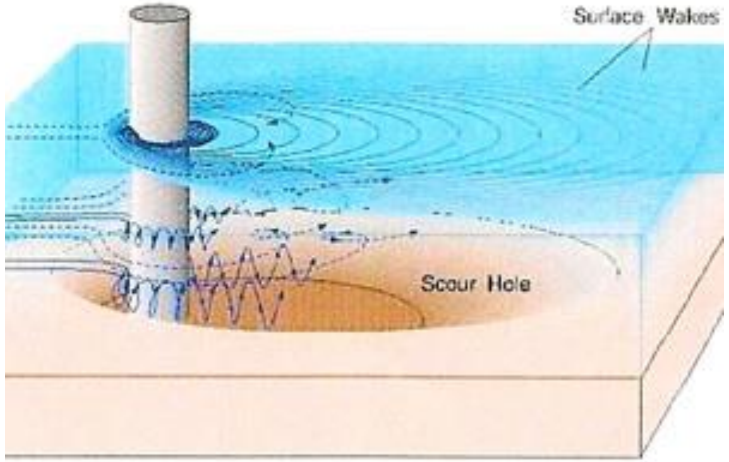
➢ Littoral transport

➢ Stability of structures

➢ Erosion of the seabed

➢ Speed of vessels

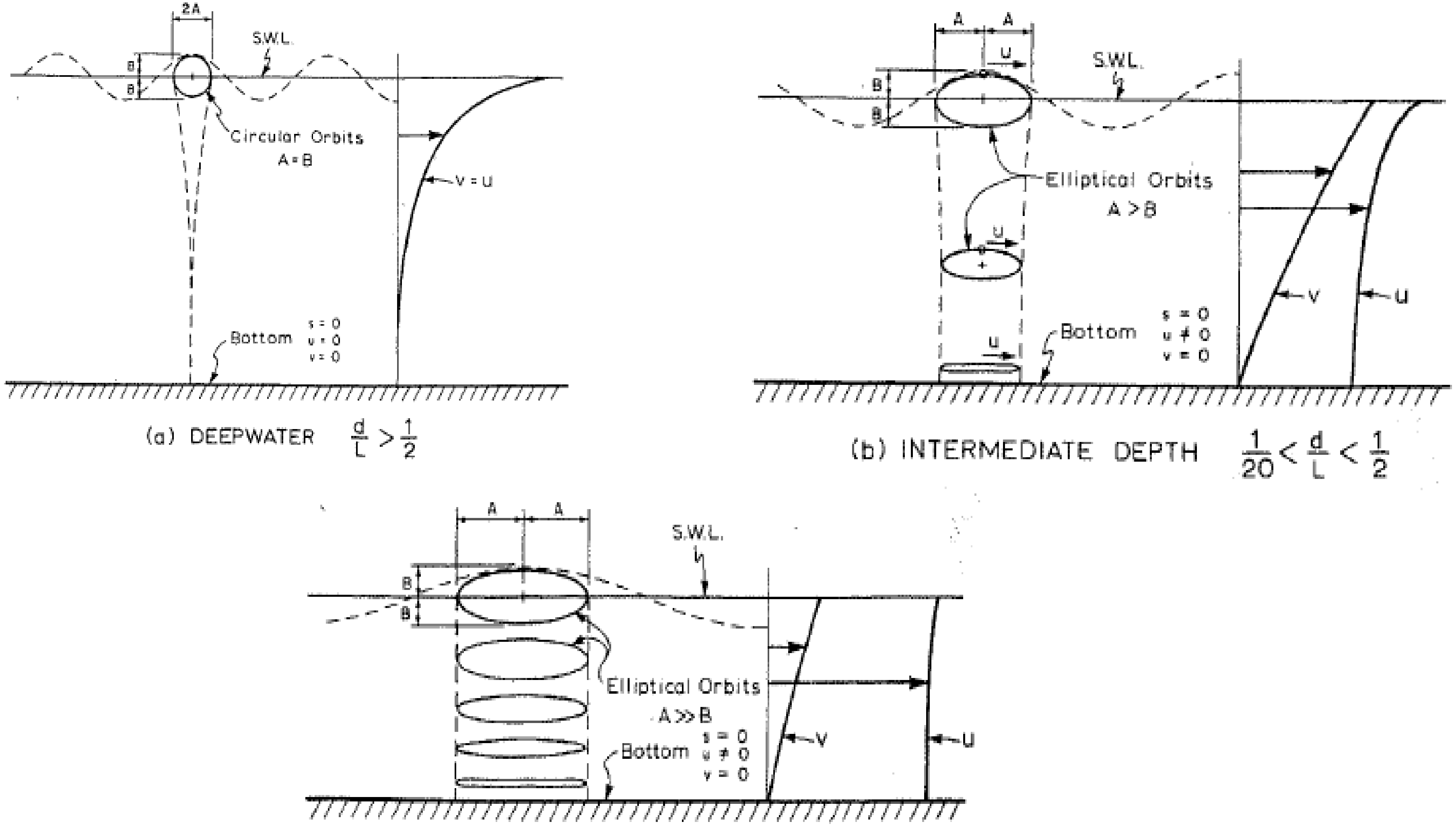




Types of Nearshore Currents

- Wave-induced water motion
- Fluid motion in breaking waves
- Tidal currents
- Wave-induced currents
- Undertow currents
- Rip currents

Wave-induced water motion



(a) DEEPWATER $\frac{d}{L} > \frac{1}{2}$

(b) INTERMEDIATE DEPTH $\frac{1}{20} < \frac{d}{L} < \frac{1}{2}$

(c) SHALLOW WATER $\frac{d}{L} > \frac{1}{20}$

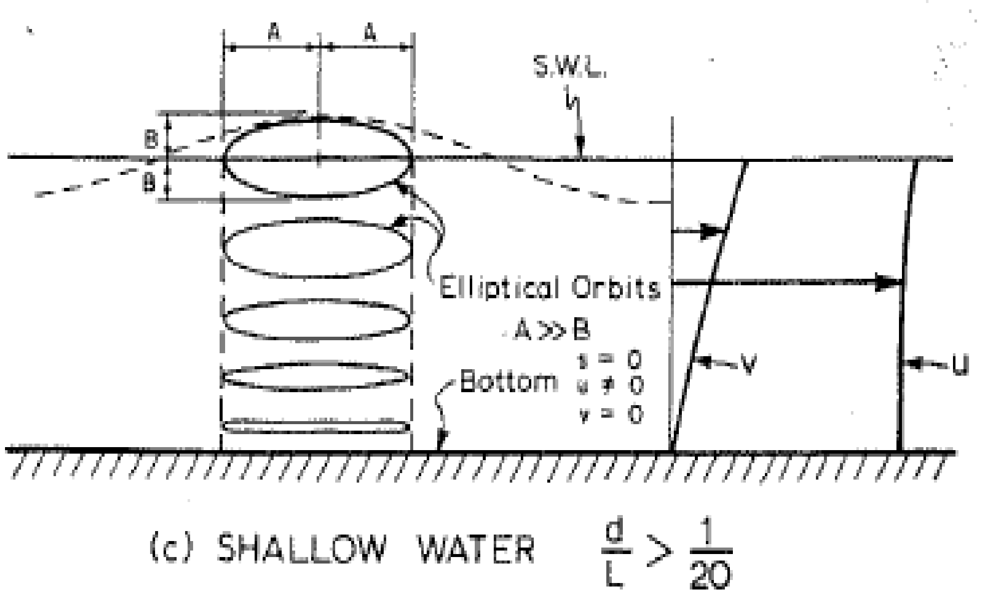
In shallow water, the horizontal water particle velocity is approximately horizontal and constant over the depth.

Making the small-amplitude assumption, the horizontal length 2A of the path moved by the water particle is

$$2A = \frac{HT\sqrt{gd}}{2\pi d}$$

The maximum horizontal water velocity is

$$u_{\max} = \frac{H\sqrt{gd}}{2d}$$



EXAMPLE

GIVEN: A wave 0.3 meters (1 foot) high with a period of 5 seconds is progressing shoreward in a depth of 0.6 meter (2 feet).

FIND:

(a) Calculate the maximum horizontal distance 2A the water particle moves during the passing of a wave.

(b) Determine the maximum horizontal velocity u_{max} of a water particle.

SOLUTION

(a) Using equation (4-16), the maximum horizontal distance is

$$2A = \frac{HT\sqrt{gd}}{2\pi d}$$

$$2A = \frac{0.3\ (5)\ \sqrt{9.8\ (0.6)}}{2\pi\ (0.6)} = 0.96 \text{ meter } (3.17 \text{ feet})$$

(b) Using equation (4-17) the maximum horizontal velocity is

$$u_{max} = \frac{HT\sqrt{gd}}{2d}$$

$$u_{max} = \frac{0.3\sqrt{9.8\ (0.6)}}{2\ (0.6)} = 0.61 \text{ meter per second } (2.0 \text{ feet})$$

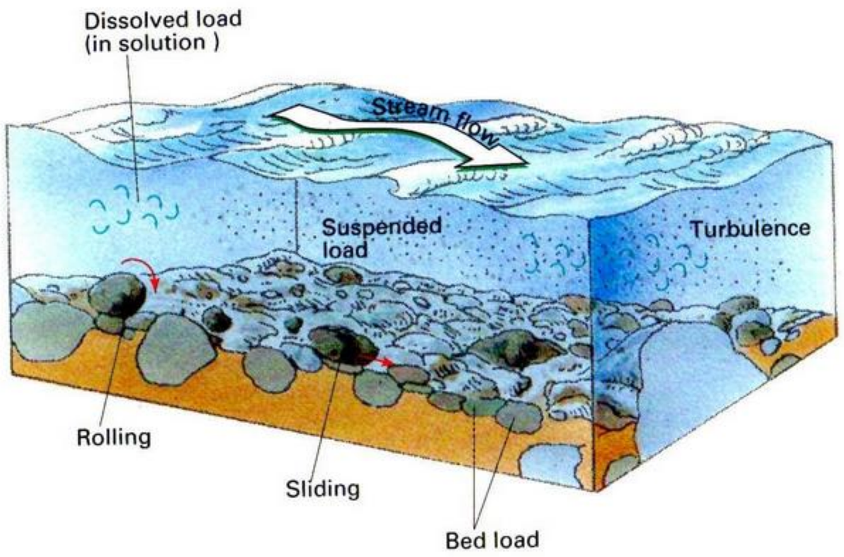
Fluid motion in breaking waves

- At breaker zone, there is significant vertical velocity as the water is drawn up into the crest of the breaker.

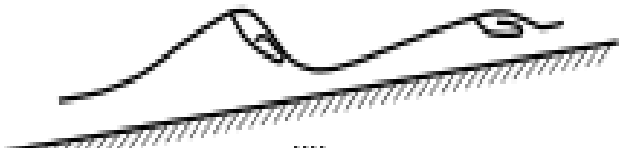
- The maximum water particle velocity under a breaking wave is approximately by solitary wave theory to be $u_{b,\max} = C = \sqrt{g(H+d)}$

  where $(H + d)$ is the distance measured from crest of the breaker to the bottom.

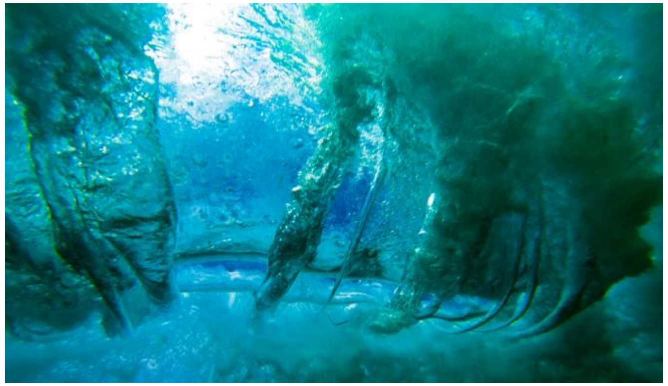
- Fluid motions at breaking cause most of the **sediment transport** in littoral zone because the bottom velocities and turbulence at breaking suspend more bottom sediment. These suspended sediment can then be transported by currents in the surf zone.



FLUID MOTION IN BREAKING WAVES



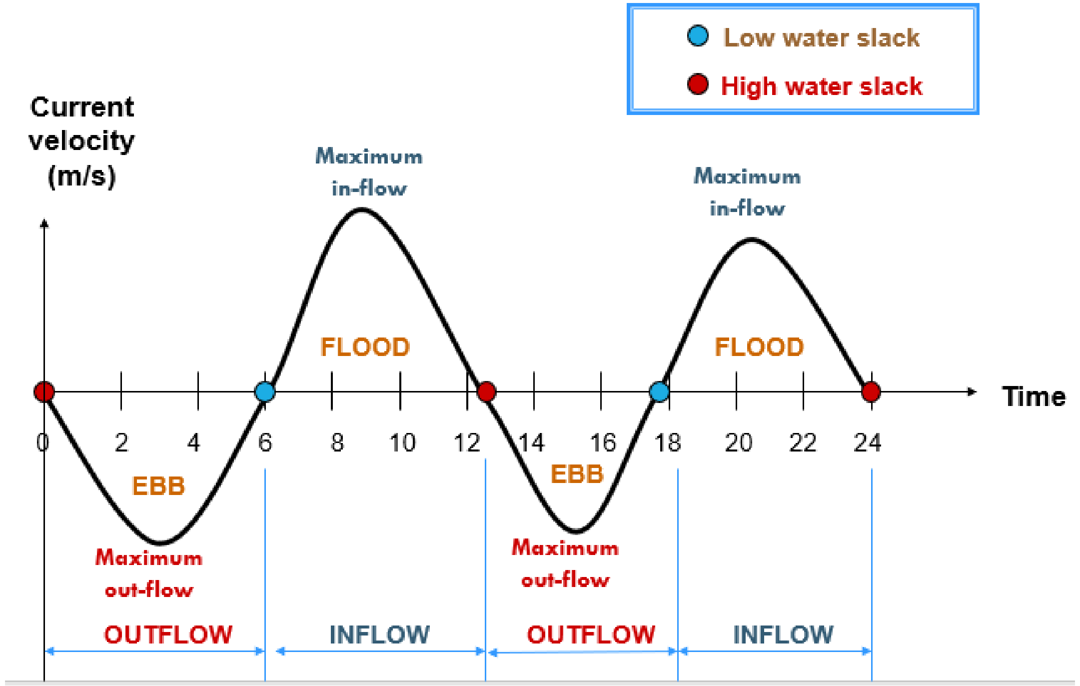
- Spilling breakers generate less bottom turbulence and thus tend to be less effective in transporting sediment than plunging or collapsing breakers.
- The most intense local fluid motions are produced by plunging breakers. The crest of the wave acts as a free-falling jet that scours into the bottom.



https://www.theinertia.com/surf/spilling-surging-plunging-the-science-of-breaking-waves/

TIDAL CURRENTS

- The alternating horizontal movement of water associated with the rise and fall of the tide caused by astronomical tide-producing forces.
- Tidal current speed ∝ Tidal range
- Strong tidal currents found at river mouths, tidal inlets and harbors.
- Slack tide period – a pulse of about ½ - 1 hr in the current at the turning of each tide; weakest tidal current between flood and ebb



WAVE-INDUCED CURRENTS

- Waves induce an orbital motion in the water. These orbits experience a slight drift forward due to wind/surface effects.
- The forward motion causes the transport of mass which can be important in carrying sediment onshore or offshore, particularly in the breaker zone.
- As waves cross the surf zone after breaking, usually at a slight angle to the shoreline, there is usually a longshore component of momentum which is the cause of longshore currents.

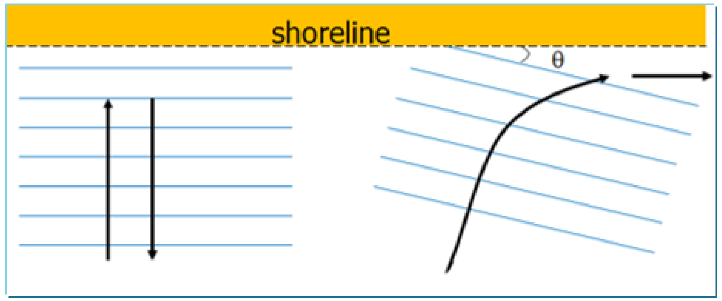
WAVE-INDUCED CURRENTS

Onshore/Offshore currents

Generated by waves breaking **parallel** to the shoreline

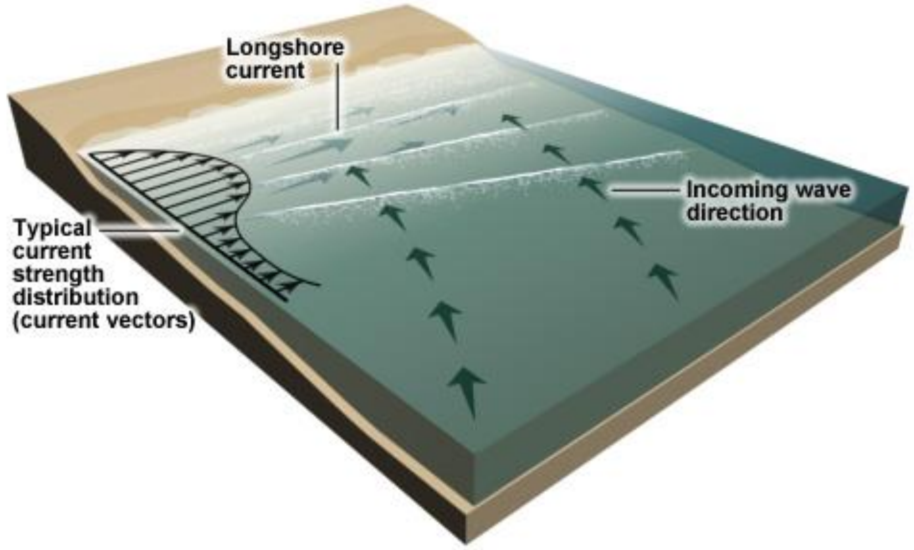
Alongshore currents

Generated by waves breaking **oblique** to the shoreline



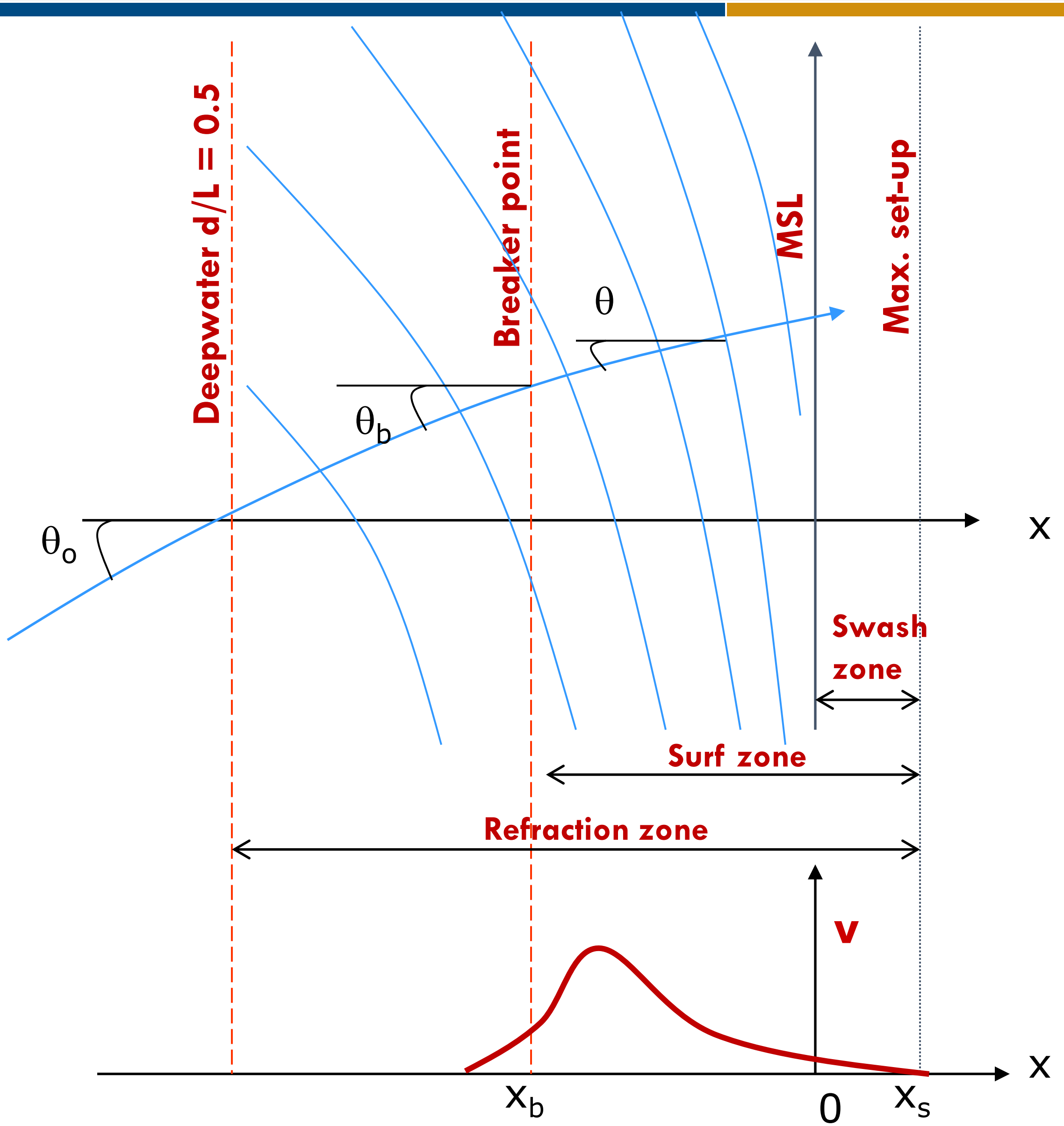
Alongshore Currents

- Generated by the longshore component of motion in waves that obliquely approach the shoreline.
- Longshore currents may flow in one direction along the shore between the breakers and the shore (mainly within the surf zone).
- Typically have mean values of 0.3 m/s or less. The observed alongshore currents are rarely more than 1 m/s unless it is wind-aided.
- Although alongshore currents generally have low speeds, they are important in littoral processes because they flow along the shore for extended periods of time, transporting sediment set in motion by the breaking waves.



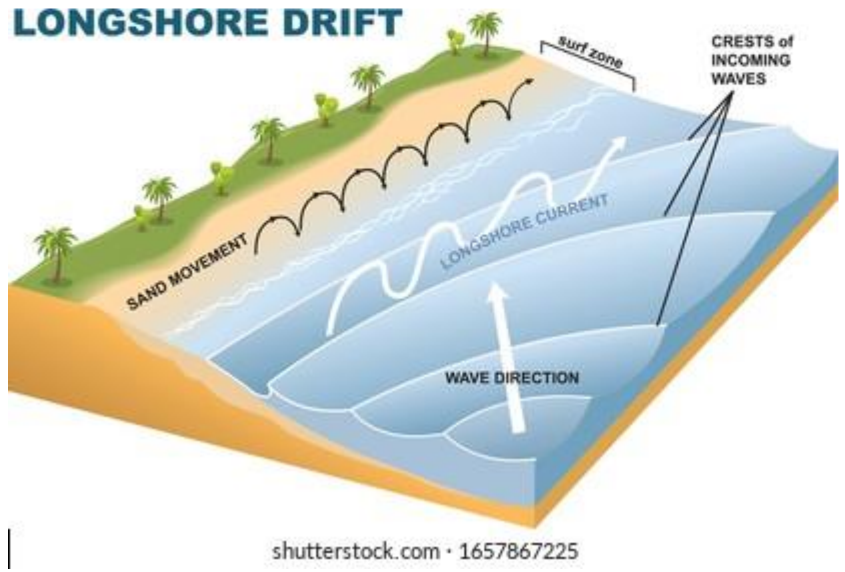
Generally, longshore currents increase with
- increasing breaker height
- increasing breaker-crest speed
- increasing angle between breaker crests and bottom contours
- increasing beach gradient

The highest velocities in a longshore current are typically near the water surface and nearer the breakers than the shore.



How to spot wave-induced currents?

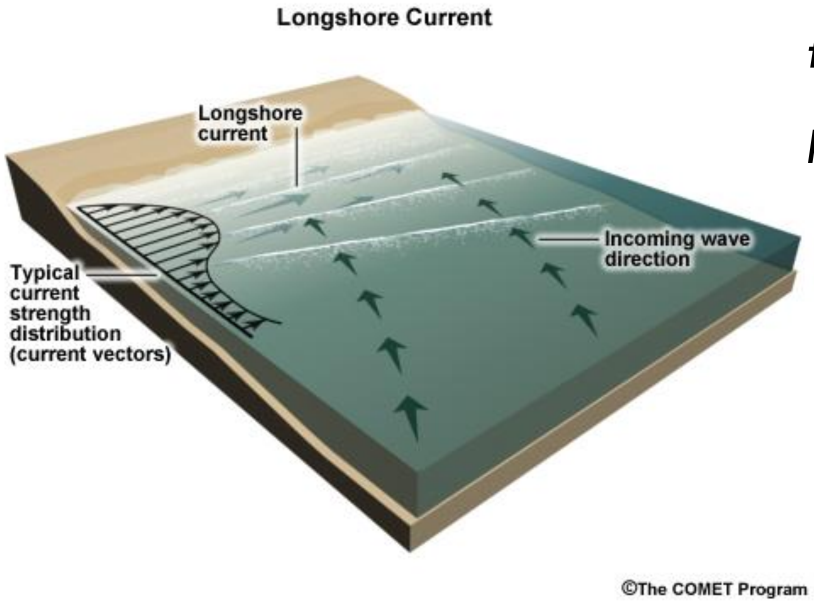
- Floating debris, foam patches or foam lines are helpful indicators of currents.
- If they are drifting parallel to shore, it is a longshore current.
- If the debris or foam are drifting offshore, there is probably an offshore or rip current present.
- If you are standing on the beach facing the water, and the waves are approaching at an angle to the shore from the right, the longshore current is probably moving in one direction towards your left.
- Longshore currents can be escaped by swimming towards the shore.



https://www.shutterstock.com/search/longshore+drift

Uniform Alongshore Current Velocity

$$v = K_\theta \frac{\tan\alpha}{f_{wc}} \sqrt{gH_b}\,.\sin 2\theta_b$$



$\tan\alpha$ = beach slope

f_{wc} = friction factor for the current in the presence of waves ($f_{wc} \approx 0.02$)

K_θ = constant depending on the type of velocity

when $v = v_b$; $K_\theta = 0.247$

when $v = v_{mean}$; $K_\theta = 0.276$

when $v = v_{max}$; $K_\theta = 0.375$

Uniform Alongshore Current Velocity in Mid Surf Zone

$$v = K_\theta \frac{\tan\alpha}{f_{wc}} \sqrt{gH_b}\,.\sin 2\theta_b$$

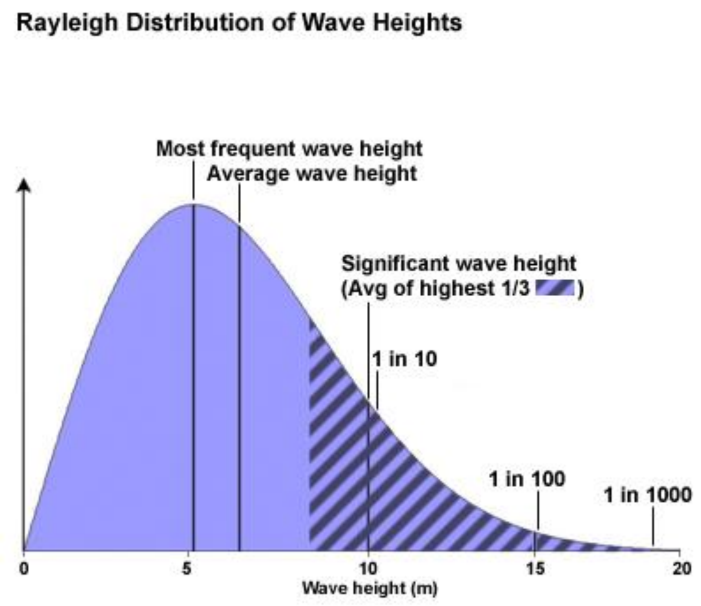
- $\tan \alpha / f_{wc}$ is a constant for natural beaches.
- Velocity in **mid surf zone** is given by (Komar, 1975):

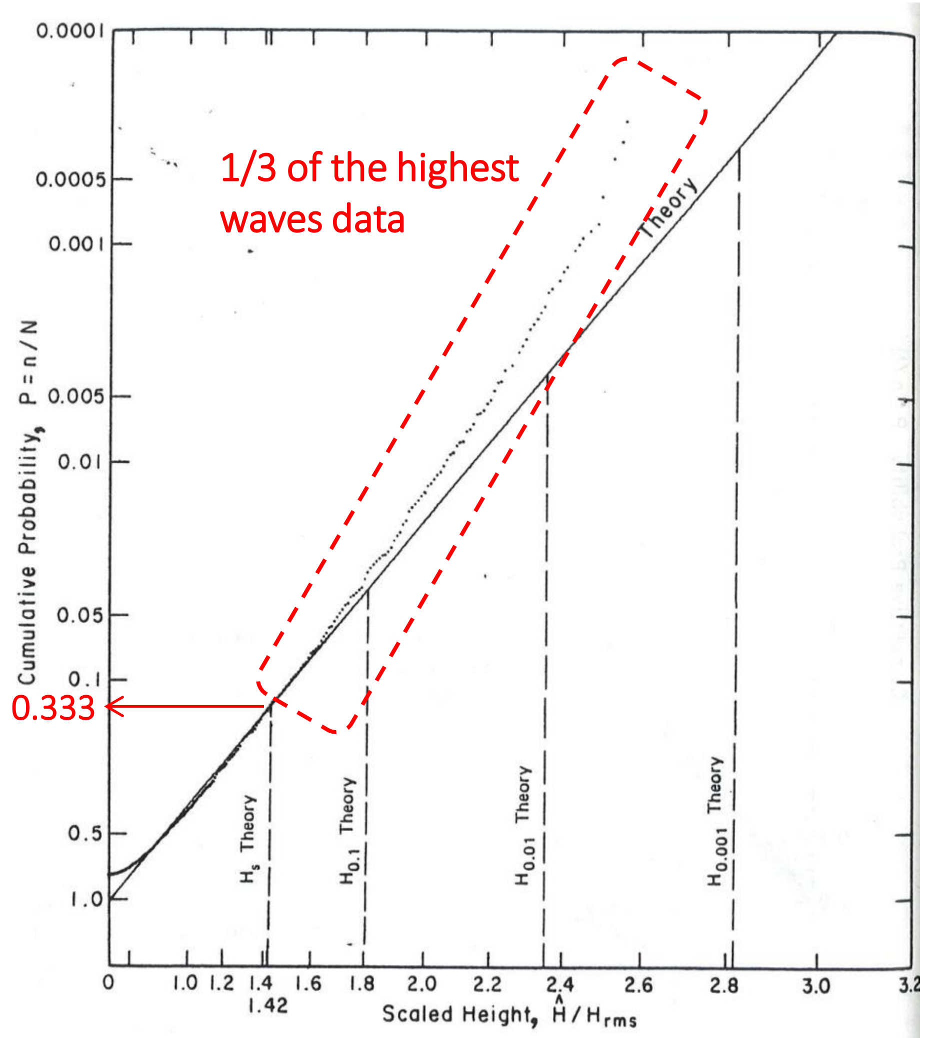
$$v = 0.60\sqrt{gH_{b,rms}}\,.\sin 2\theta_b$$

$$v = 0.50\sqrt{gH_{b,s}}\,.\sin 2\theta_b$$

$$H_{rms} = \sqrt{\frac{1}{N}\sum_{j=1}^{N} H_j^{\,2}}$$

Significant Wave Height





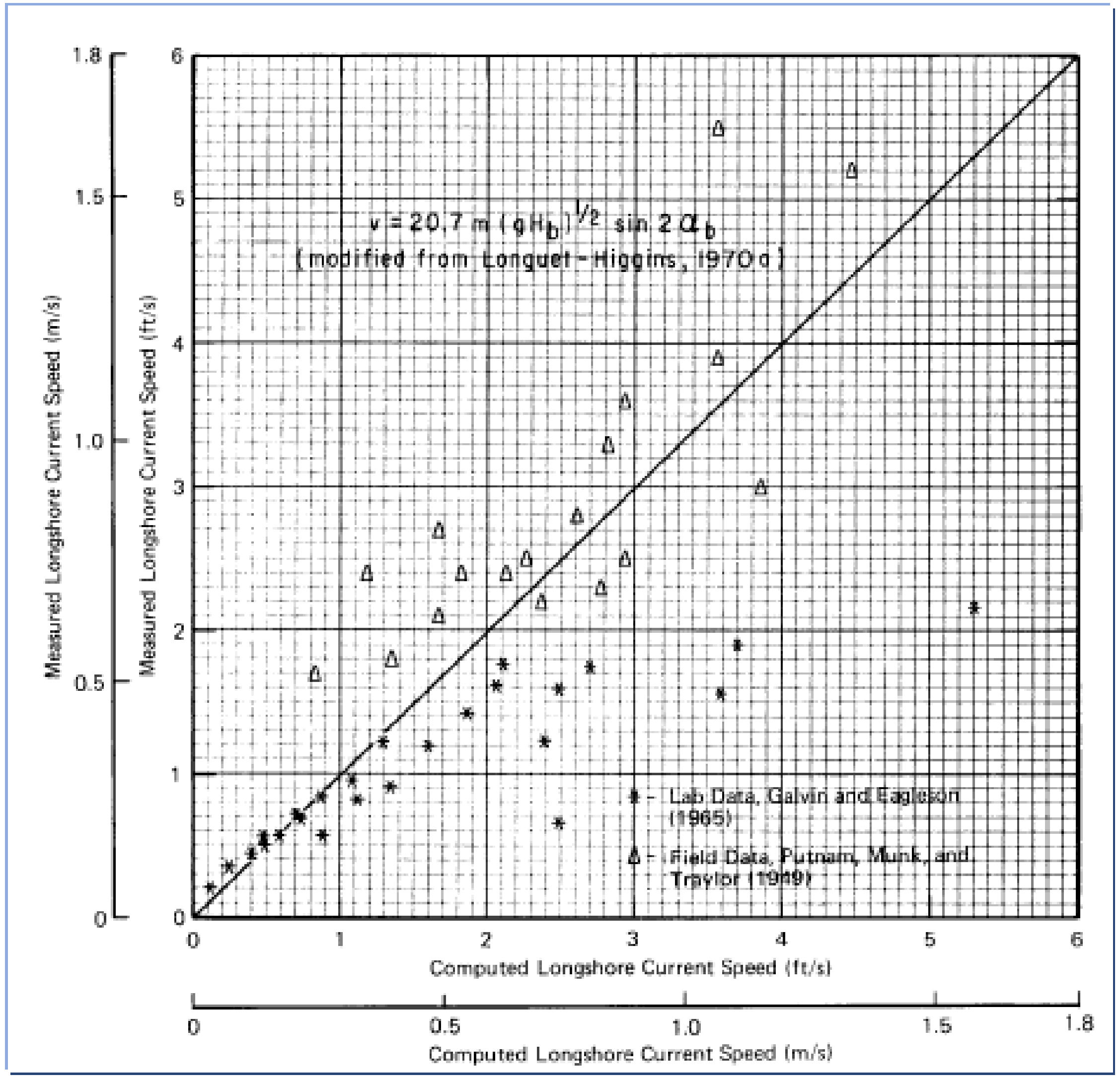
Significant wave height (H_s or $H_{1/3}$)

The average height of the one-third highest waves from measurements/the data set.

Alongshore current speed at the **breaker line**:

$$V_b = M_1 m \sqrt{gH_b} \sin 2\alpha_b$$

m = beach slope
H_b = breaking wave height
α_b = angle between breaker crest and shoreline
g = acceleration due to gravity
M_1 = 9.0



MODIFIED LONGUET-HINGGINS EQUATION

Observation: The measured velocities at the shoreward of the breaker line is always higher than the computed velocities at the breaker line.

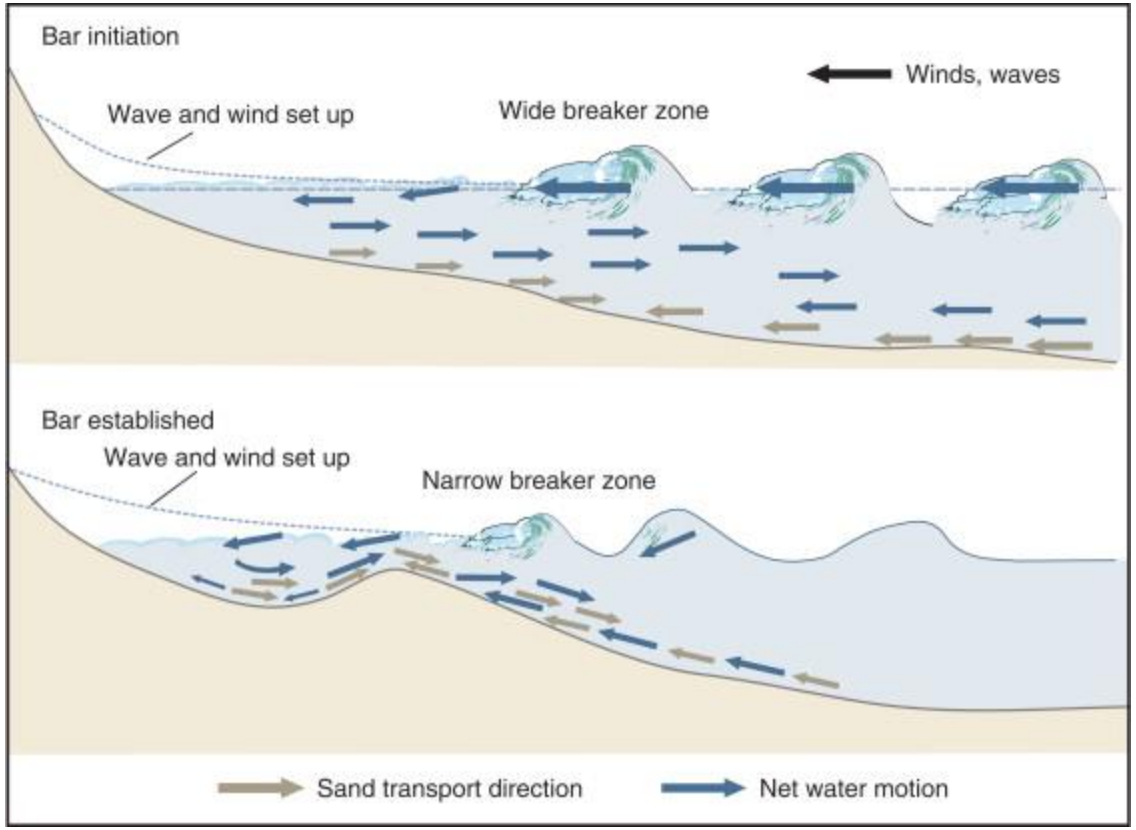
Mean longshore current velocity of fully developed flow:

$$V = 20.7m\sqrt{gH_b}\sin 2\alpha_b$$

where, m = beach slope
H_b = breaking wave height
α_b = angle between breaker crest and shoreline
g = acceleration due to gravity

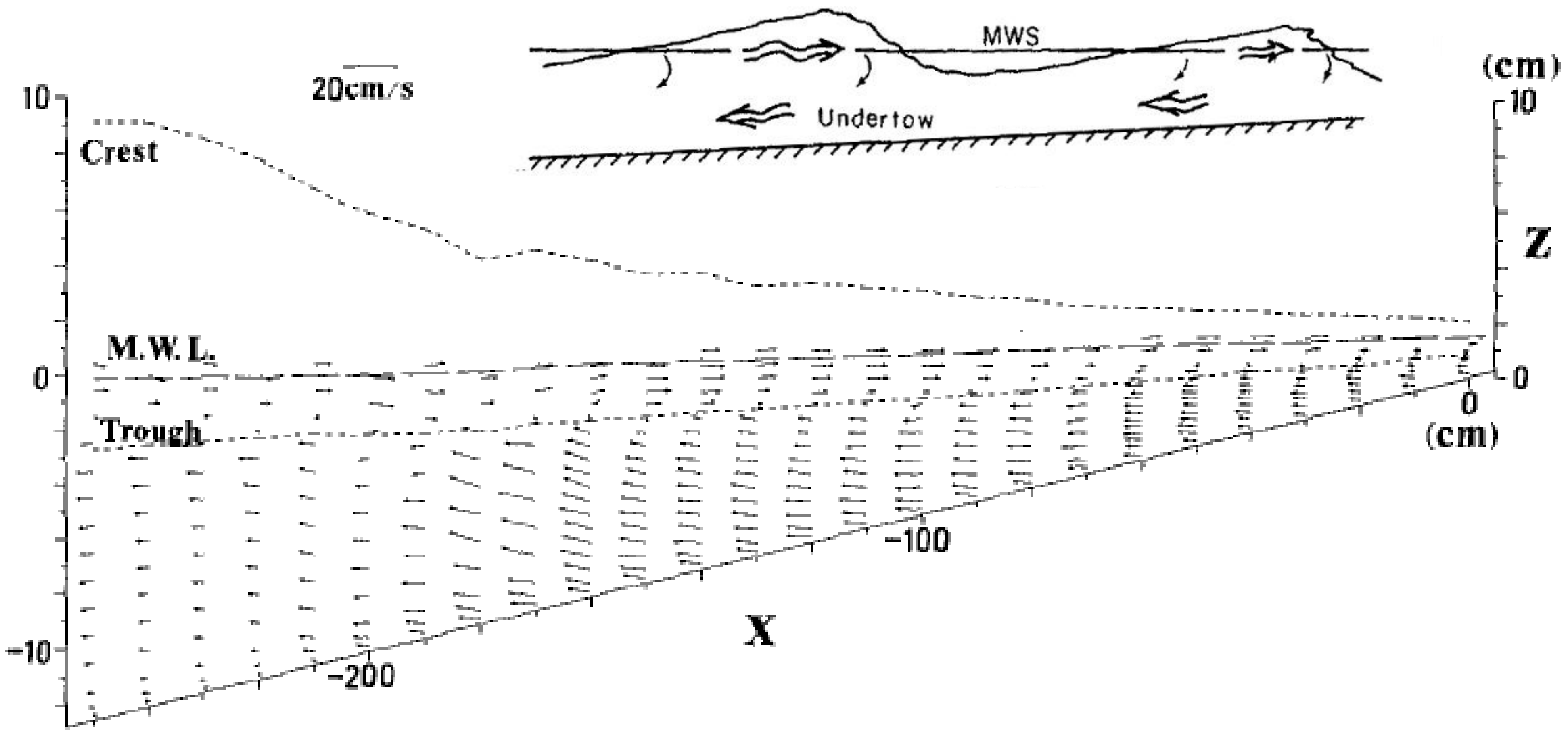
NOTE: Although the equation is generally considered to be the best available for longshore current velocity prediction, the difference between predicted and observed velocities can exceed 50%.

Undertow



https://www.sciencedirect.com/topics/earth-and-planetary-sciences/wave-setup

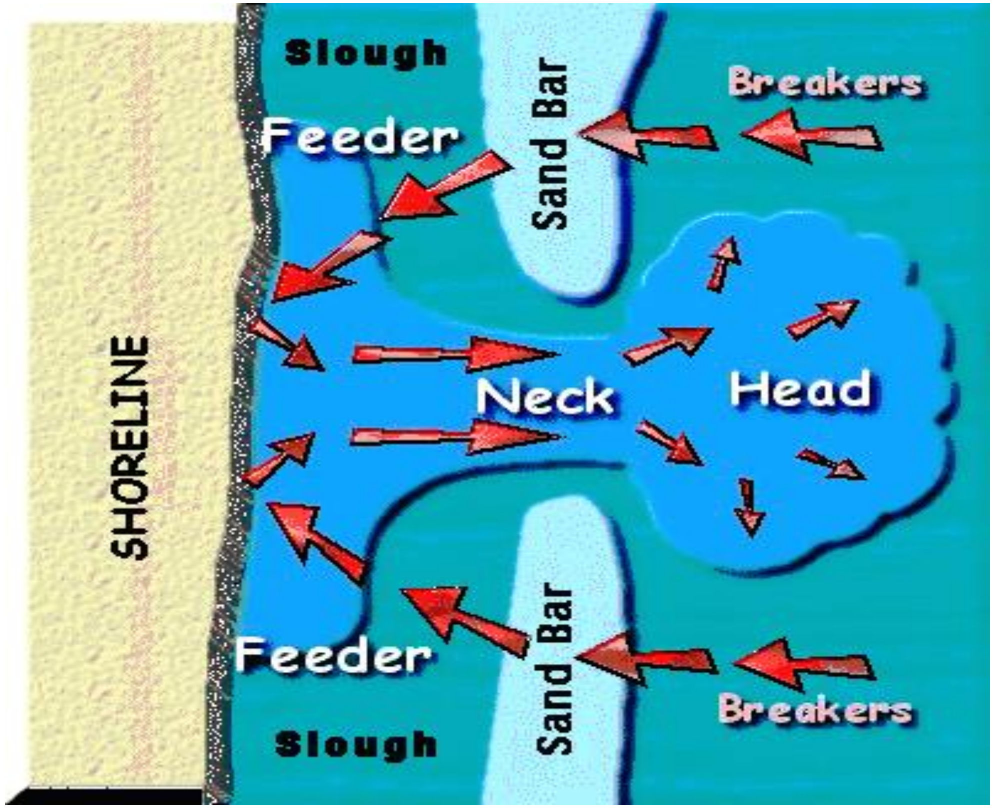
- Undertow is dispersed along the shore and moves seaward in the lower water column beneath the waves with the highest velocities close to the bed between the breakers and shore.
- Under mild conditions with small to moderate waves (less than 1 m high), this return flow is not usually a problem for agile swimmers and waders, except sometimes for small children.
- The undertow is strongest when the waves are high and approaching nearly perpendicular to shore.
- Undertow can't be spotted but can only be felt.


MWS
Undertow
20cm/s
10
Crest
M.W.L.
0
Trough
-10
-200
-100
X
(cm)
10
Z
0
0
(cm)

https:

A Swimmer is Caught in the Undertow

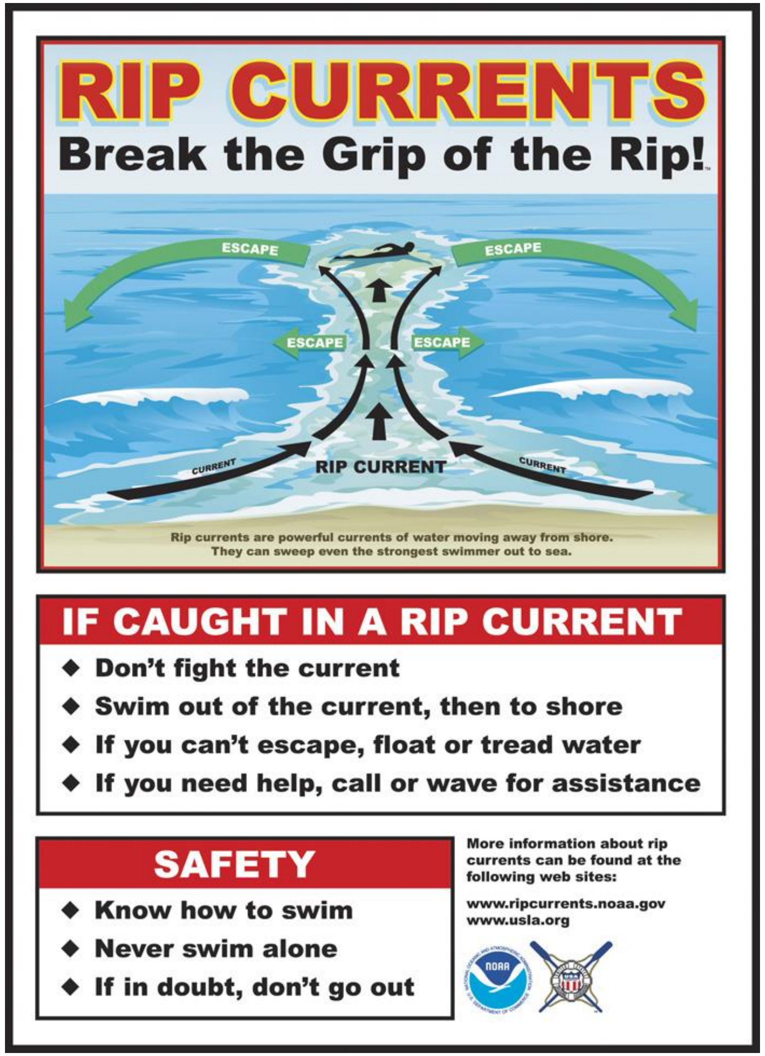
Rip Current



- Rip currents develop in shallow, nearshore areas as the result of water pilling up (wave set-up) landward of sandbars, then returning seaward through low spots/breaks in the bars until the set-up is relieved.
- They increase in speed from the shoreline and reach a maximum in the middle of the rip neck.
- Under normal wave condition, the narrow rip current rushing through ridge in a sandbar may reach a velocity of up to 1 m/s and extend offshore as much as 600 m.
- Flash rip currents and mega-rips can flow up to 3 m/s.


Would you know how to spot a rip?
Rip Current Awareness Day
Saturday 26 November

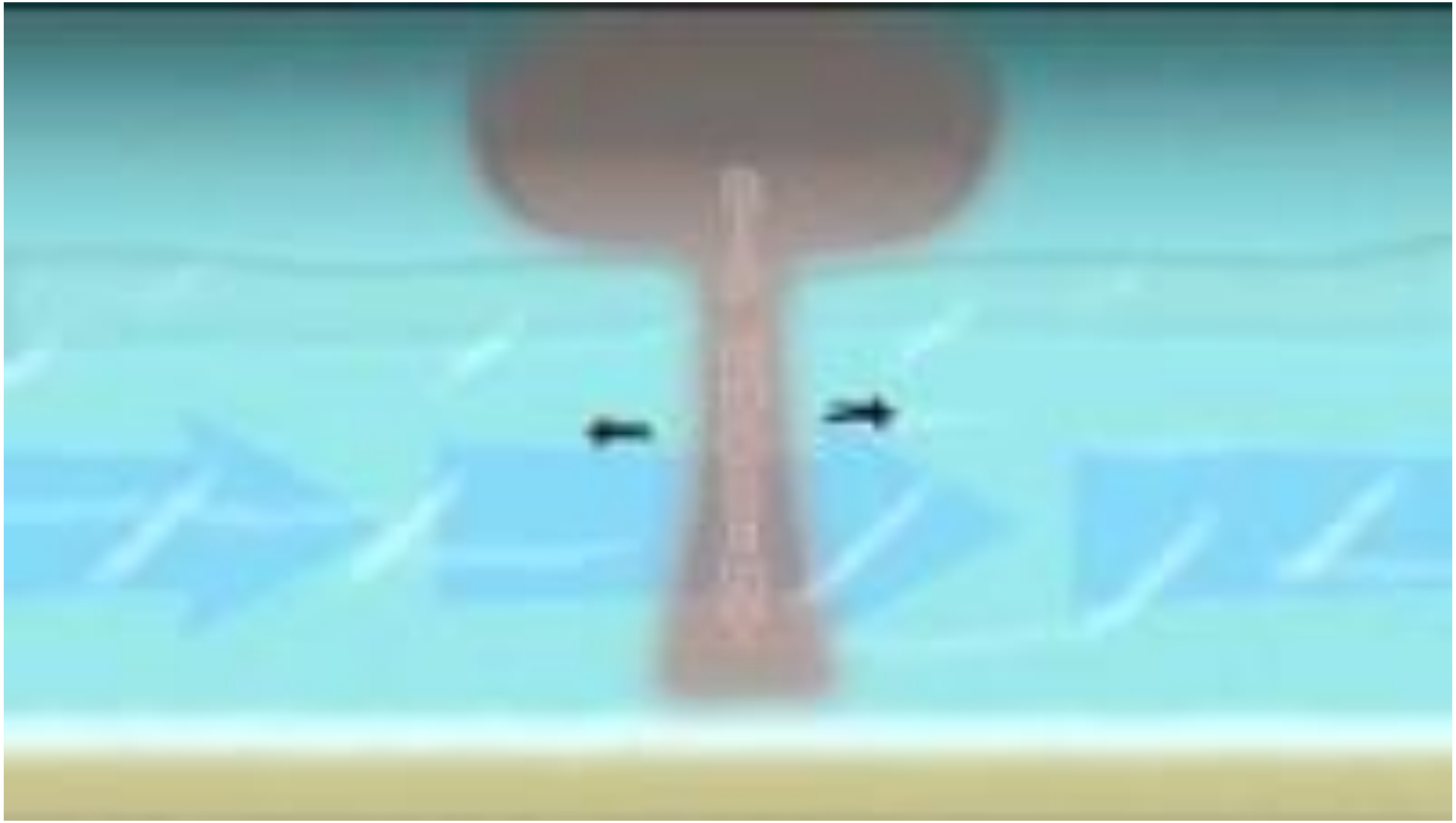
How to Escape From Rip Currents?



If you get caught in a rip current, you need to know your options:

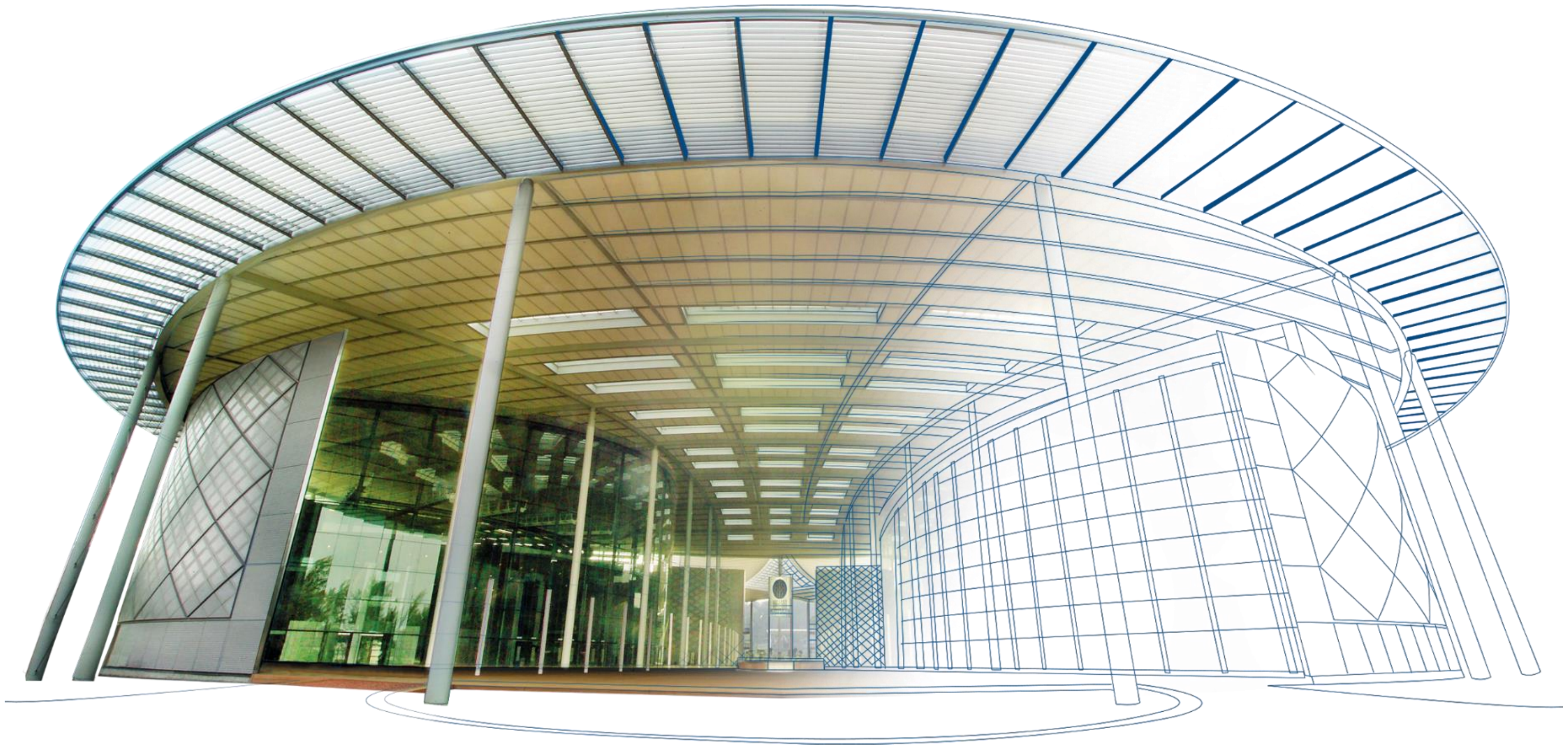
- For assistance, stay calm, float and raise an arm to attract attention.
- While floating, rip currents may flow in a circular pattern and return you to an adjacent sandbar.
- You may escape the rip current by swimming parallel to the beach, towards the breaking waves.
- You should regularly assess your situation. If your response is ineffective, you may need to adopt an alternative such as staying calm, floating and raising an arm to attract attention.

Rip Current



RIP CURRENT


SUMMER SAFETY
SURVIVING A RIP CURRENT
GINGER TAKES ON DEADLY FORCE



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