

Waves, Lee Shores, and Breaking Waves

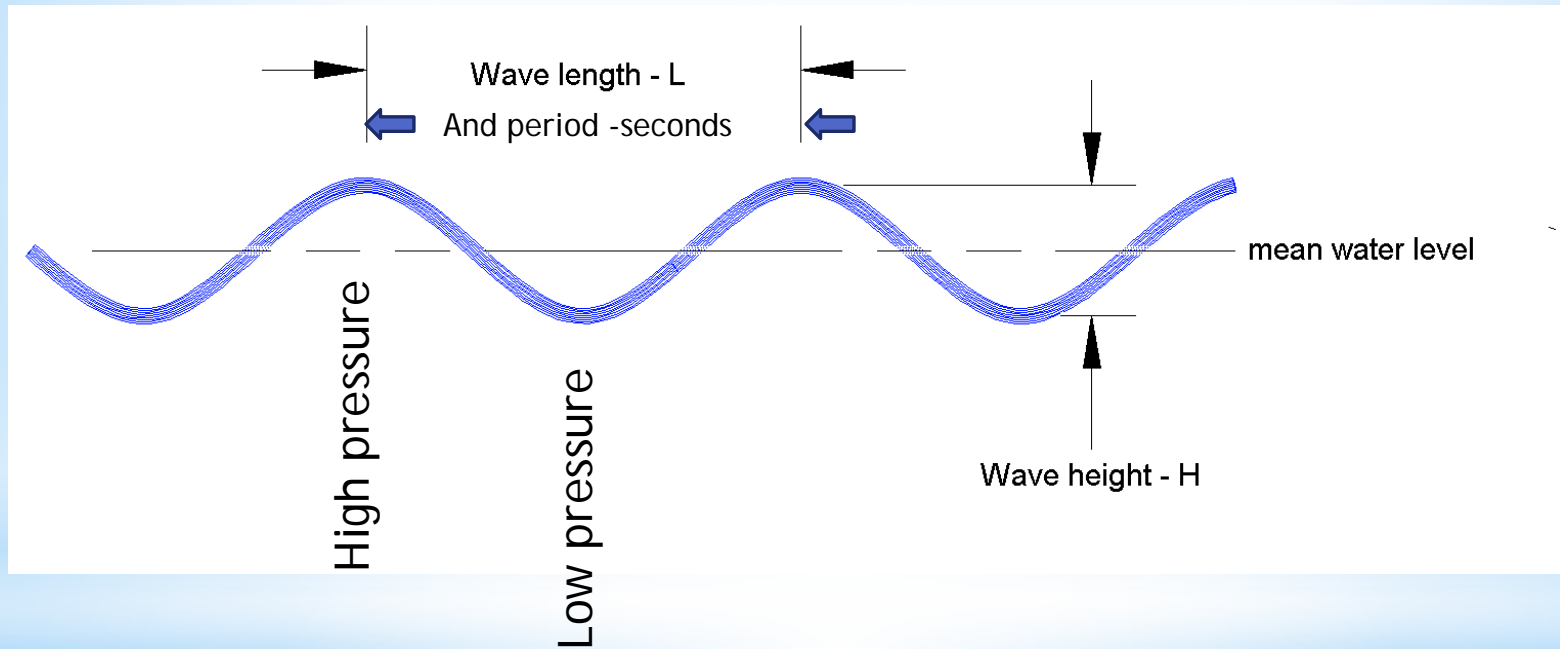
Safety at Sea Seminar

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An ocean wave is a moving pulse of PRESSURE,
NOT a movement of water across the sea



The wave energy is translated rather gently from one molecule to the next. Water particles barely move.

Watch the movement of things floating on the sea -
Think of a sound wave - no wind is created - the air is not moving.

A few formulae

Wave speed = $((L g) / (2 \pi))^{.5}$ ft/sec

g = gravity = 32.2 ft/sec²

π = 3.2808 etc

L = wave length in feet

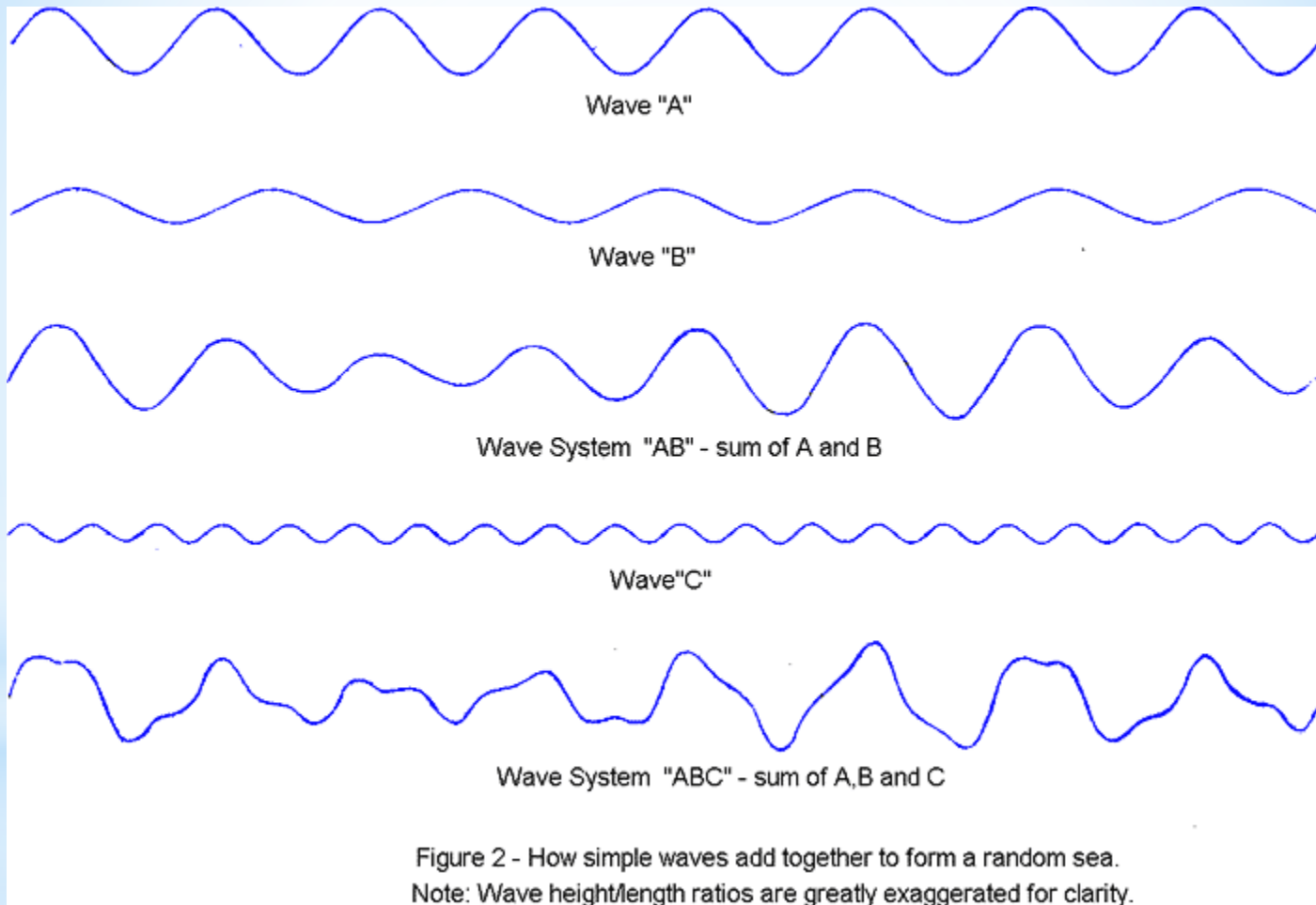
Divide by 1.689 to convert ft/sec to knots

Thus a wave travels at $(1.34 L)^{.5}$

This is the same formula as hull speed

So a 25 ft boat has a hull speed of 6.7 knots

A 100 ft boat has a hull speed of 13.4 knots



WHY SEAS ALWAYS LOOK SO CONFUSED

Even in this crummy demo you can see the "beat"
and apparent irregularity

Let's not be confused about confused seas

Wind is always changing in strength and direction.

New waves are forming all the time, ripples, chop, bigger waves, swell.

They all pile on top of each other, usually coming from a variety of directions.

That's why there will be lulls and wave sets and "rogue waves" and "sneaker waves"

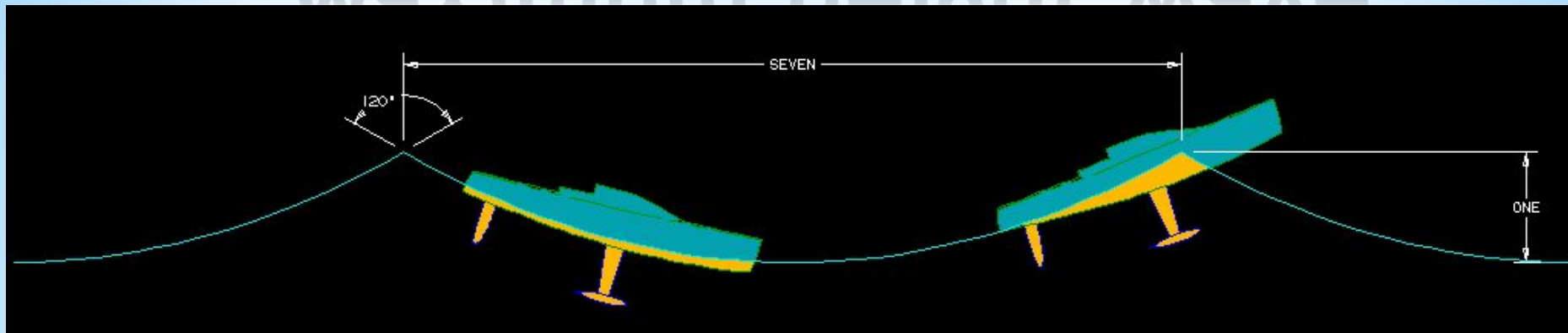
OCEANOGRAPHERS use STATISTICS and talk about **SIGNIFICANT WAVE HEIGHT**

SIGNIFICANT WAVE HEIGHT is average height of **TOP THIRD HIGHEST WAVES**

MAXIMUM WAVE HEIGHT is 2.2 TIMES SIGNIFICANT WAVE HEIGHT (EVERY 1000 WAVES OR SO)

FORECASTS GIVE RANGE OF HEIGHT FOR SWELL AND WAVES (SEPARATELY). TO BE CONSERVATIVE, ADD THE MAX HEIGHT OF WAVE AND SWELL TOGETHER.

Maximum height wave



Maximum height unbroken wave:

length to height ratio of 7:1

120 degree crest angle

If wave is slowed by *shallow water* or *adverse current*:

length compresses, height builds, wave breaks

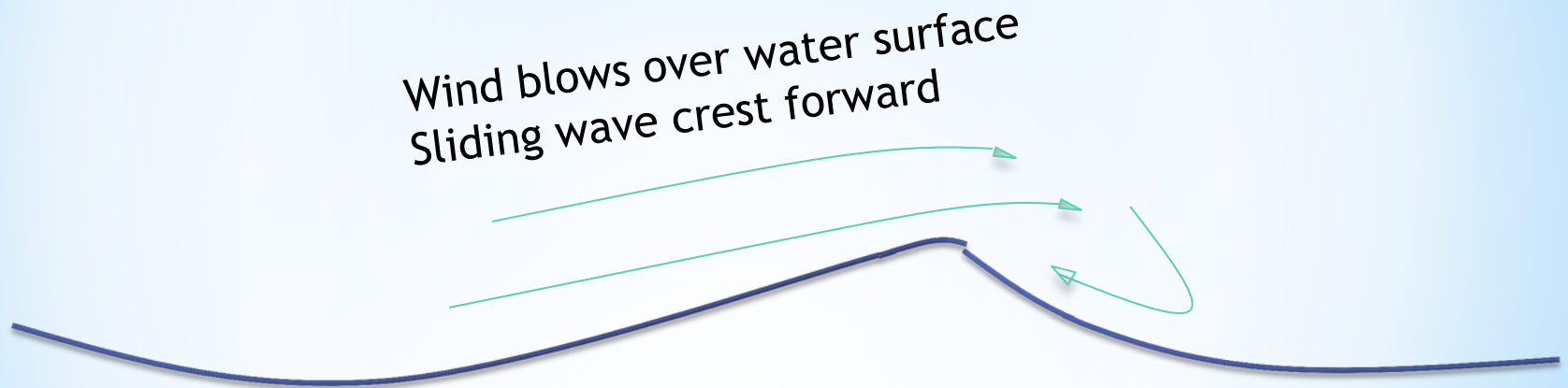
Breaking wave is dangerous because wave energy is now translated into water *sliding over the surface*.

Wave in this diagram is quite short. If boat is 40feet, this is a 104 foot wave, just under 15 feet tall, traveling at 13.7 knots with a 4.5 second period.

* Kinda looks like this



HOW WAVES ARE FORMED, AND WHY THEY DON'T LOOK LIKE THE THEORY



Water is 836 times more dense than air.

Imagine trying to build a hill of water,
doesn't have to get very big before it falls over

Waves grow with *duration* and *fetch*, building more quickly at first,
more slowly as wave speed approaches wind speed.

When wave speed exceeds wind speed, now it is swell and the shape
looks rounded like sine wave theory.

This is SWELL!

Waves build with duration and fetch, waves lengthen and wave speed increases, eventually wave speed approaches wind speed.

When wave speed exceeds wind speed, now it is swell and the wave shape looks rounded like sine wave theory.

Unless it gets even windier!

Swell typically have a period of 6-16 seconds, which is a speed of 18 to 49 knots. **Wave period times 3 = wave speed in knots.** (very close)

Longest swell ever reported had a period of 22.5 seconds, which would be a speed of 68 knots.

Because swell is big and moving fast, it has much more energy than "wind waves". Hence big waves in shallow water are primarily the formerly docile swell.

Beaufort Number*	Wind Speed (knots)	Seaman's Term	Sea Condition	Typical*** Condition Attainment Time	Wave height range Probable	Maximum	Period of wave matching wind speed (sec)
					(feet)	(feet)	(sec)
0	0-1	Calm	Glassy-smooth, mirror-like	--			0
1	2-3	Light air	Scale-like ripples	1-10 min	0.3	0.3	1
2	4-6	Light breeze	Small, short wavelets with glassy crests	5-15 min	0.6	1.0	2
3	7-10	Gentle breeze	Large wavelets, crests begin to break, occasional form	5-20 min	2	3	3
4	11-16	Moderate breeze	Small waves, some whitecaps, more frequent form	15-60 min	3	5	5
5	17-21	Fresh breeze	Moderate longer waves, better formed, many whitecaps, much foam, some spray	15-60 min	6	8	7
6	22-27	Strong breeze	Large waves form, many whitecaps, foam everywhere, more spray	1/4-2 hr.	10	13	8
7	28-33	Moderate gale	Sea heaps up, streaks of foam spindrift begins	1/2-3 hr.	13	18	10
8	34-40	Fresh gale	Moderately-high long waves, crests into spindrift, well-marked streaks of foam	1/2-3 hr.	18	25	13
9	41-47	Strong gale	High waves, sea rolls, dense streaks of foam. Crests begin to topple, tumble and roll over. Spray affects visibility	1/2-4 hr.	23	33	15
10	48-55	Whole gale	Very high waves with long overhanging crests. The resulting foam in great patches is blown in dense white streaks in the direction of the wind. On the whole the surface takes on a		29	41	18
11	56-63	Storm	Exceptionally high waves. Small and medium sized ships are lost to view for long periods		38	52	20
12	64+	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.		45+		23

TYPICAL SWELL 6-16 SEC



Force 0: Wind Speed less than 1 knot
Sea: Sea like a mirror



Force 1: Wind Speed 1-3 knots
Sea: Wave height .1m (.25ft); Ripples with appearance of scales, no foam crests



Force 2: Wind Speed 4-6 knots
Sea: Wave height .2-.3m (.5-1 ft); Small wavelets, crests of glassy appearance, not breaking



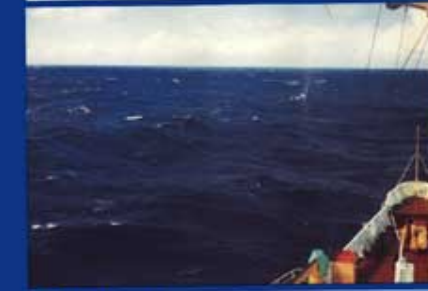
Force 3: Wind Speed 7-10 knots
Sea: Wave height .6-1m (2-3 ft); Large-wavelets, crests begin to break, scattered whitecaps



Force 4: Wind Speed 11-16 knots
Sea: Wave height 1-1.5m (3.5-5 ft); Small waves becoming longer, numerous whitecaps



Force 5: Wind Speed 17-21 knots
Sea: Wave height 2-2.5m (6-8 ft); Moderate waves, taking longer form, many whitecaps, some spray



Force 6: Wind Speed 22-27 knots
Sea: Wave height 3-4m (9.5-13 ft); Larger waves forming, whitecaps everywhere, more spray



Force 7: Wind Speed 28-33 knots
Sea: Wave height 4-5.5m (13.5-19 ft); Sea heaps up, white foam from breaking waves begins to be blown in streaks along direction of wind



Force 8: Wind Speed 34-40 knots
Sea: Wave height 5.5-7.5m (18-25 ft); Moderately high waves of greater length, edges of crests begin to break into spindrift, foam is blown in well marked streaks



Force 9: Wind Speed 41-47 knots
Sea: Wave height 7-10m (23-32 ft); High waves, sea begins to roll, dense streaks of foam along wind direction, spray may reduce visibility



Force 10: Wind Speed 48-55 knots (storm)
Sea: Wave height 9-12.5m (29-41 ft); Very high waves with overhanging crests, sea takes white appearance as foam is blown in very dense streaks, rolling is heavy and shocklike, visibility is reduced.

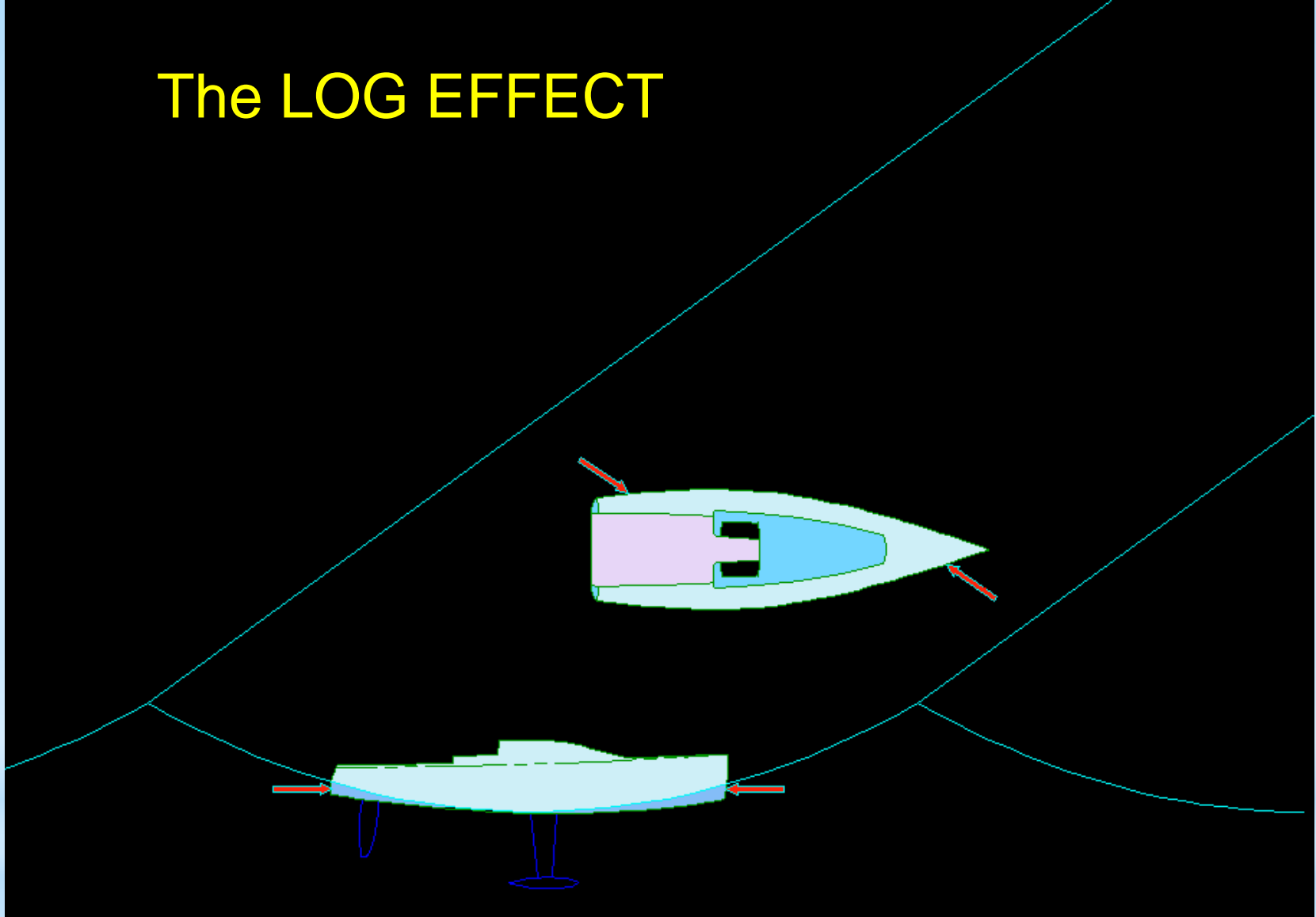


Force 11: Wind Speed 56-63 knots
Sea: Wave height 11.5-16m (37-52 ft); Exceptionally high waves, sea covered with white foam patches, visibility still more reduced

Have you ever noticed that a log always comes into the beach sideways?



The LOG EFFECT

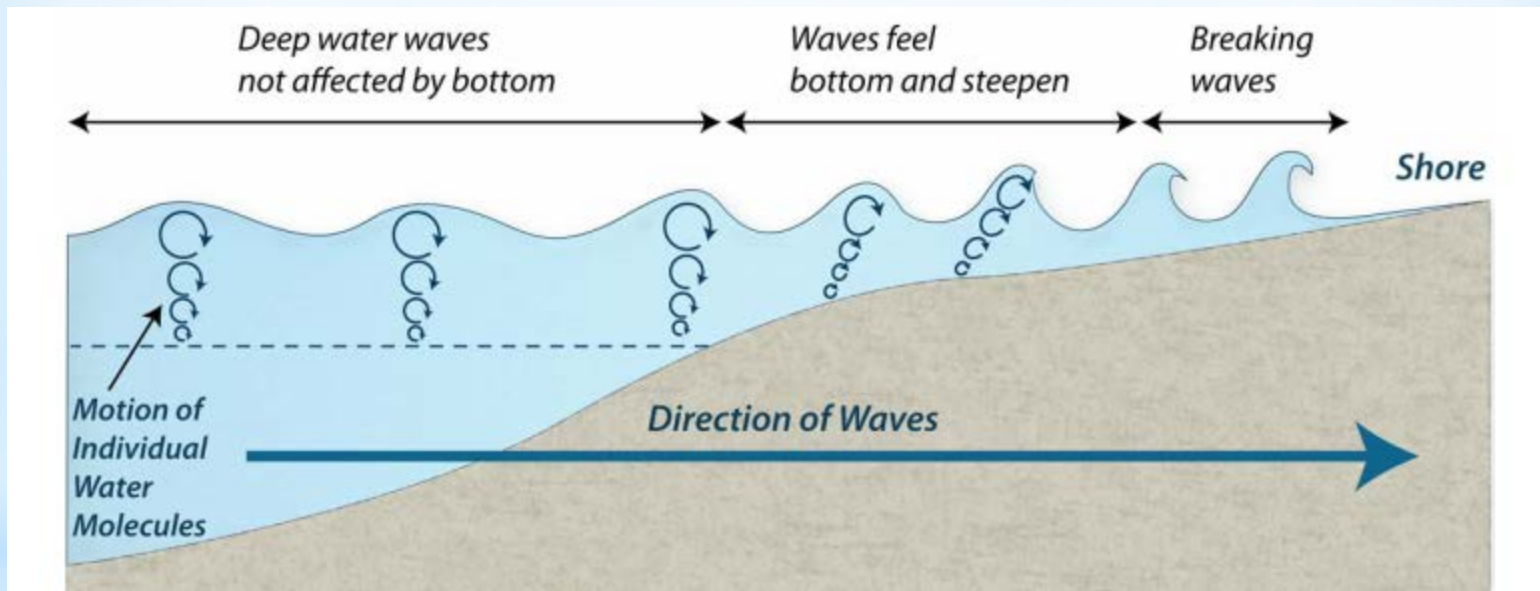


Buoyancy of bow & stern in wave turns boat parallel to wave front
If the boat is stopped, it will turn broadside to the seas!
You need speed to steer.

In shallow water, wave may become so tall and steep that you don't have sufficient speed and momentum to summit the wave.

LEE SHORES, WAVES IN SHALLOW WATER

When the water depth is about $\frac{1}{2}$ the wave length
It starts to "feel the bottom and slow down.

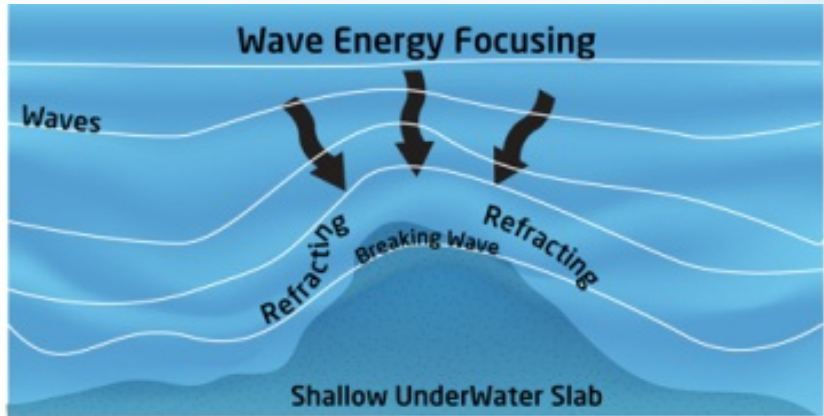
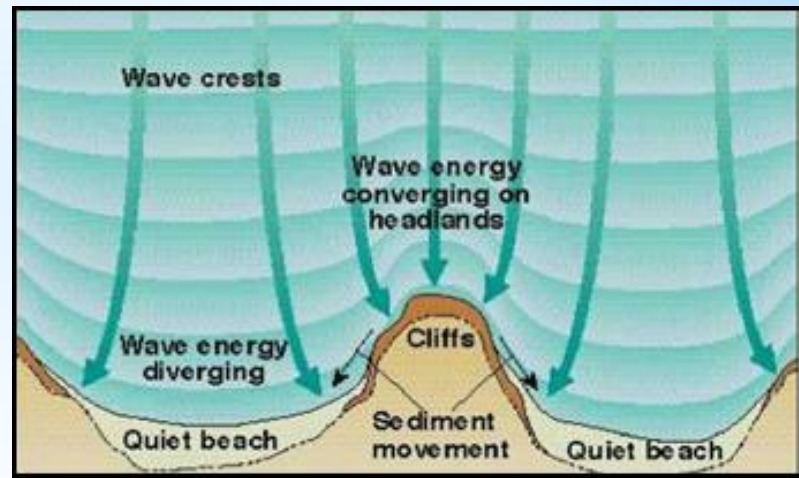
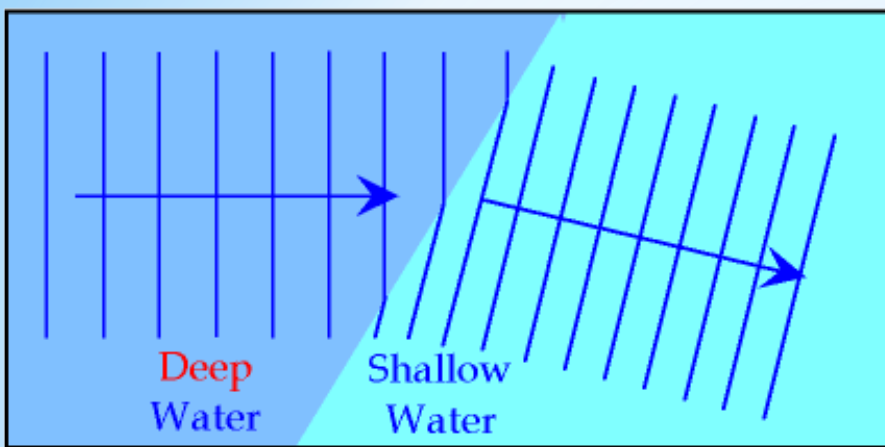


	DEEP WATER		10 FT DEPTH	
Period	Wave length	Wave speed	Wave length	Wave speed
seconds	feet	knots	feet	knots
6	184.5	18.2	110.4	10.8
9	415	27.3	171.2	11.3
12	737	36.4	237.7	11.4
15	1152	45.5	317.2	11.5

WAVES SLOWED AND SHORTENED BY SHALLOW WATER

(notice that wave speed in deep water is about 3 x period)

wave speeds converge in shallow water,
so on a gently sloping beach or mud flat
waves combine & appear more orderly



Shallow water slows the wave,
causes it to refract (bend)

***THIS IS EXACTLY WHAT HAPPENS
AT THE DANGEROUS CORNER OF
THE FARALLON ISLANDS !!***

Shape of Lee Shore is significant

Let's take a trip to the seashore



Where did this come from?



the "Potato Patch"
(Four Fathom Bank)

BROKEN WAVE IS A MASS OF WATER MOVING OVER THE SURFACE!



When you walk into the surf at the beach, you are pulled toward the crest of an unbroken wave;
but when hit by a broken wave the water knocks you backward.



WHEN A WAVE *BREAKS* -
NOW THE WATER IS MOVING AND THE POWER IS IMMENSE



Hurricane Iniki

Lahaina, Maui



BOLD ADVENTURERS!

Risking life and limb just for your benefit



SHALLOW WATER (MUD FLAT) WAVES

Note separation between peaks (trough is spread)

More orderly than ocean waves

Let's go to sea!



After all, the real point is to *have fun!*

SOME WAVE HEIGHT SOURCES

BEFORE leaving the dock, refer to buoy reports:

Forecast:

<http://www.ndbc.noaa.gov/data/Forecasts/FZUS56.KMTR.html>

Dial a buoy:

<https://www.ndbc.noaa.gov/dial.shtml>

WVHT on these pages is "significant wave height" or H

http://www.ndbc.noaa.gov/station_page.php?station=46214

(West of Pt. Reyes)

http://www.ndbc.noaa.gov/station_page.php?station=46026

(Half way to Farallons)

Here is real time data & explanation of various data:

http://www.ndbc.noaa.gov/station_realtime.php?station=46214

PZZ570-120430- POINT ARENA TO PIGEON POINT 10 TO 60 NM OFFSHORE- 219 PM PDT
THU APR 11 2013

GALE WARNING IN EFFECT THROUGH FRIDAY MORNING TONIGHT

NW WINDS 20 TO 30 KT...GUSTING TO 35 KT. WIND WAVES 5 TO 8 FT. NW SWELL 9 TO 12 FT AT 11 SECONDS.

FRI

NW WINDS 20 TO 30 KT. WIND WAVES 4 TO 7 FT. NW SWELL 9 TO 12 FT AT 10 SECONDS.

FRI NIGHT

NW WINDS 20 TO 30 KT. WIND WAVES 4 TO 7 FT. NW SWELL 8 TO 10 FT AT 10 SECONDS.

SAT

NW WINDS 20 TO 30 KT. WIND WAVES 4 TO 7 FT. NW SWELL 8 TO 10 FT AT 10 SECONDS.

SAT NIGHT

NW WINDS 20 TO 30 KT. WIND WAVES 7 TO 10 FT. NW SWELL 10 TO 13 FT AT 10 SECONDS.

SUN

NW WINDS 20 TO 30 KT. WIND WAVES 6 TO 9 FT. NW SWELL 8 TO 10 FT. SLIGHT CHANCE OF SHOWERS.

From Forecast site

DO YOUR HOMEWORK *BEFORE* YOU LEAVE!

CHECK OUT THE WEATHER FORECAST AND WAVE HEIGHT PREDICTION.

DECIDE ON SAFE DEPTH.

PLOT SAFE WAYPOINTS, INFORM CREW OF DANGER LIMITS & MINIMUM DEPTH

RULES OF THUMB:

SUM OF MAX SWELL + WAVE x 2.5

EVEN SIMPLER: 6 FATHOMS at FARALLONS

BEWARE OF 4-6 FATHOM BARS ON ROUGH or WINDY DAYS

DON'T FORGET:

RARE WAVE CAN BE TWICE TYPICAL WAVE HEIGHT

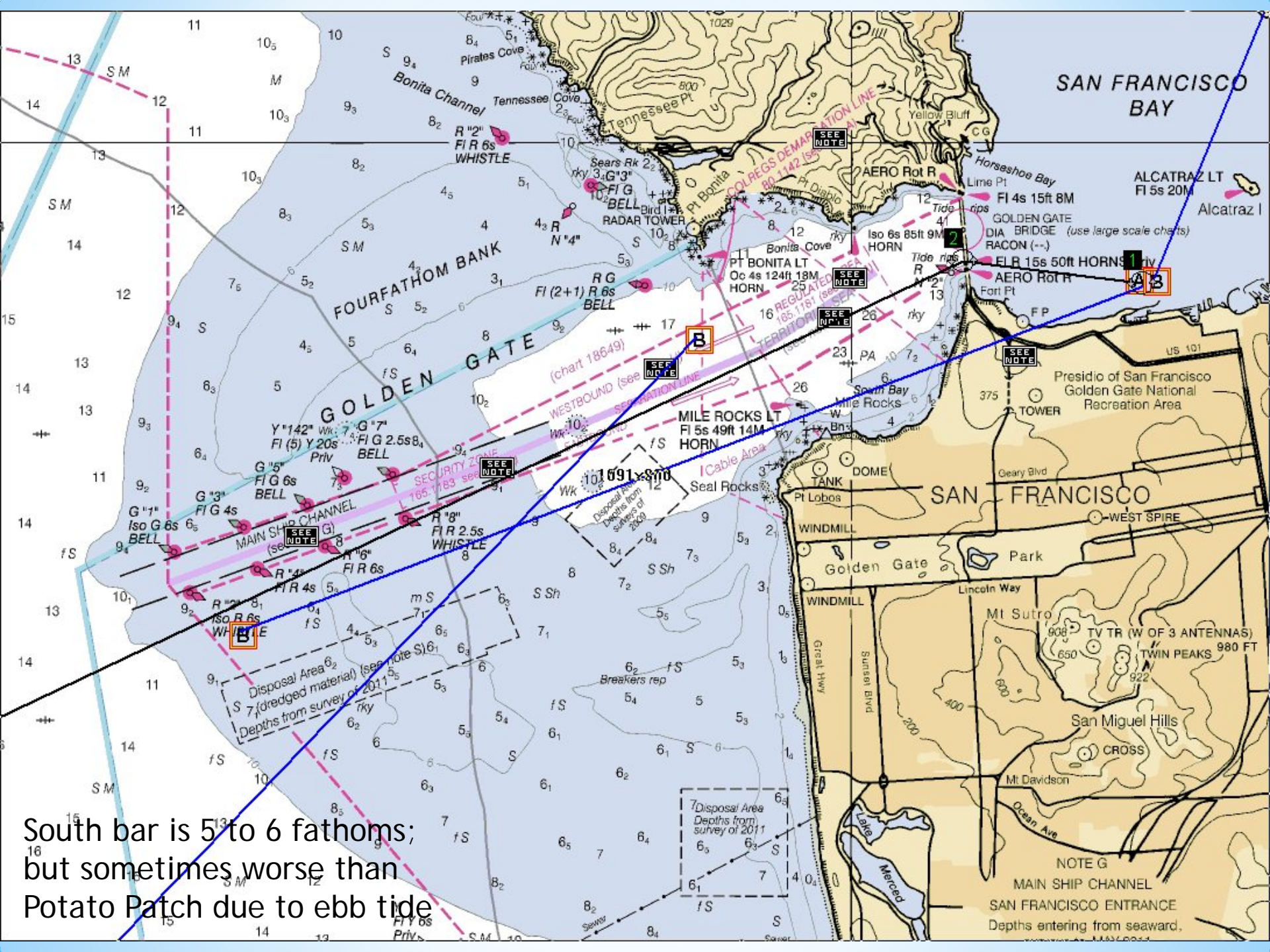
ADD HALF OF WAVE HEIGHT TO BOAT'S DRAFT

JUST TO AVOID HITTING BOTTOM

MOST IMPORTANT -

WHEN YOU ARE AT SEA, FORGET THE MATH. OBSERVE.

WATCH THE SEA, NOT THE CHART TABLE!



South bar is 5 to 6 fathoms;
 but sometimes worse than
 Potato Patch due to ebb tide

NOTE G
 MAIN SHIP CHANNEL
 SAN FRANCISCO ENTRANCE
 Depths entering from seaward,
 ...

01'

50'

40'

30'

20'

10'

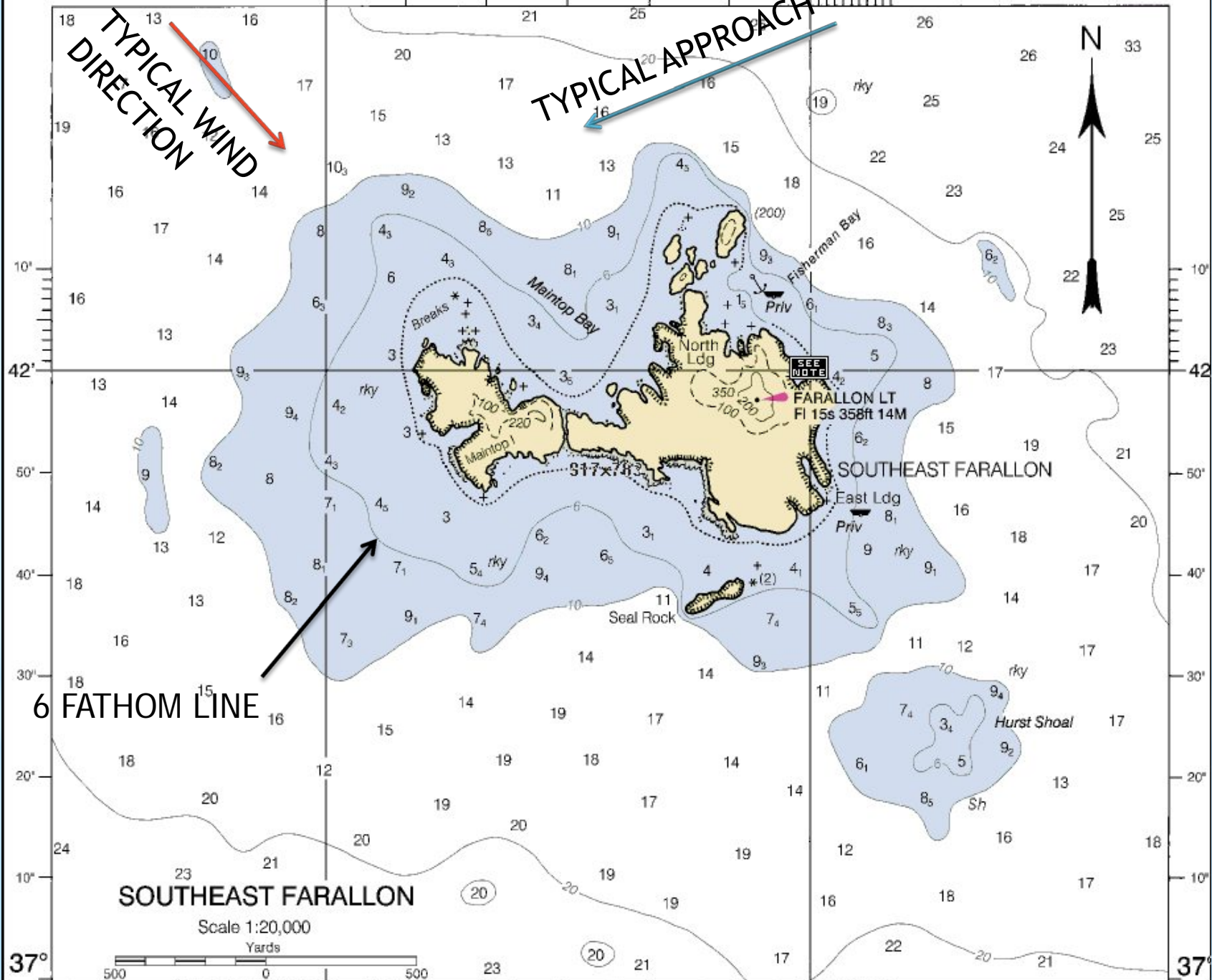
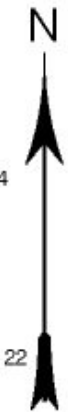
123°

50'

TYPICAL WIND DIRECTION



TYPICAL APPROACH

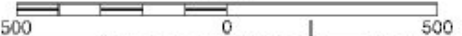


6 FATHOM LINE

SOUTHEAST FARALLON

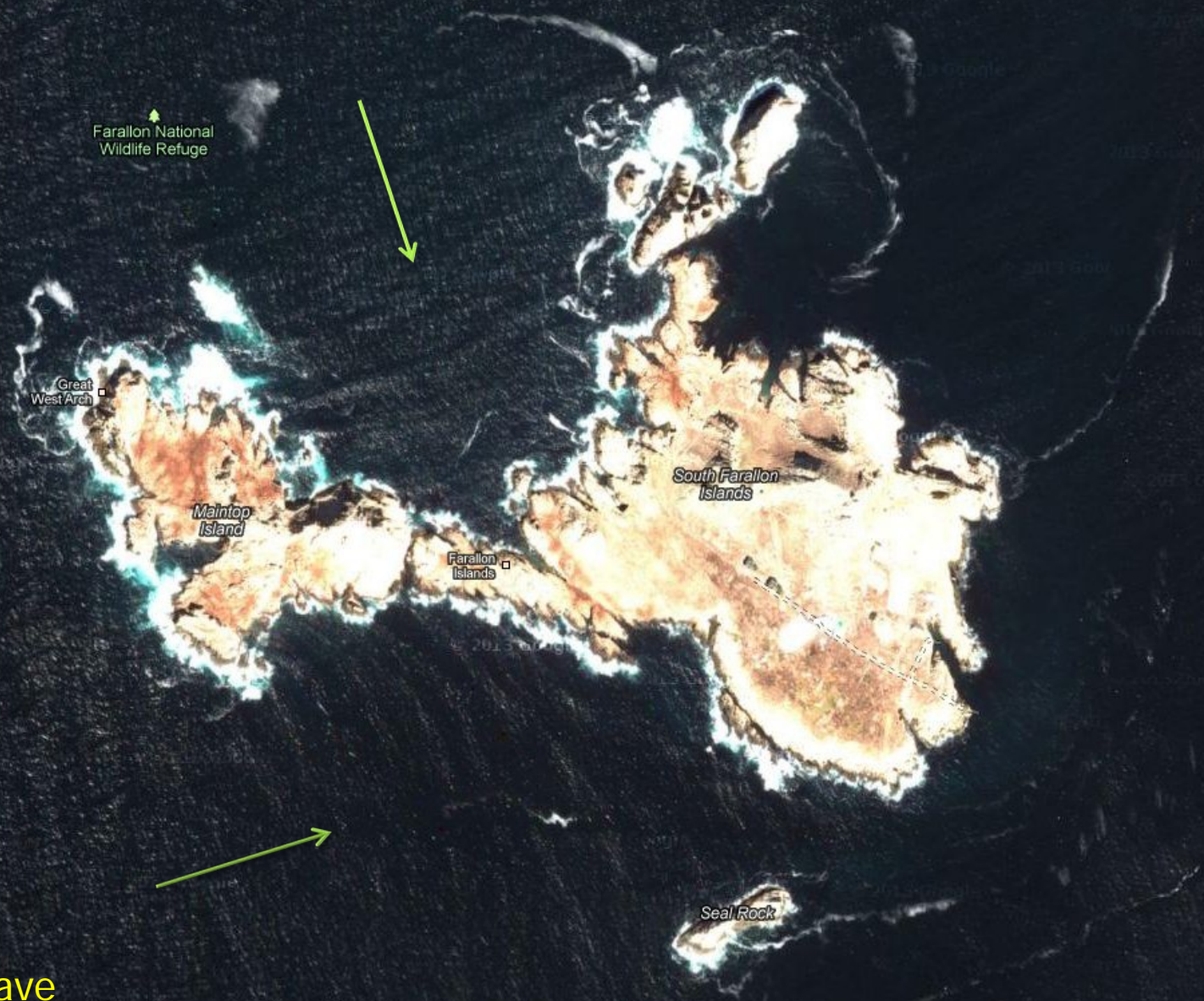
Scale 1:20,000

Yards



37°

37°



Note Wave Refraction



FOAM LINE DENOTES
DANGEROUS SPOT

BIG SURF-
GAME OVER

Intermittent
breaking
wave →



Roils, aeration:
Signs of danger! →

DANGERS OF LEE SHORES

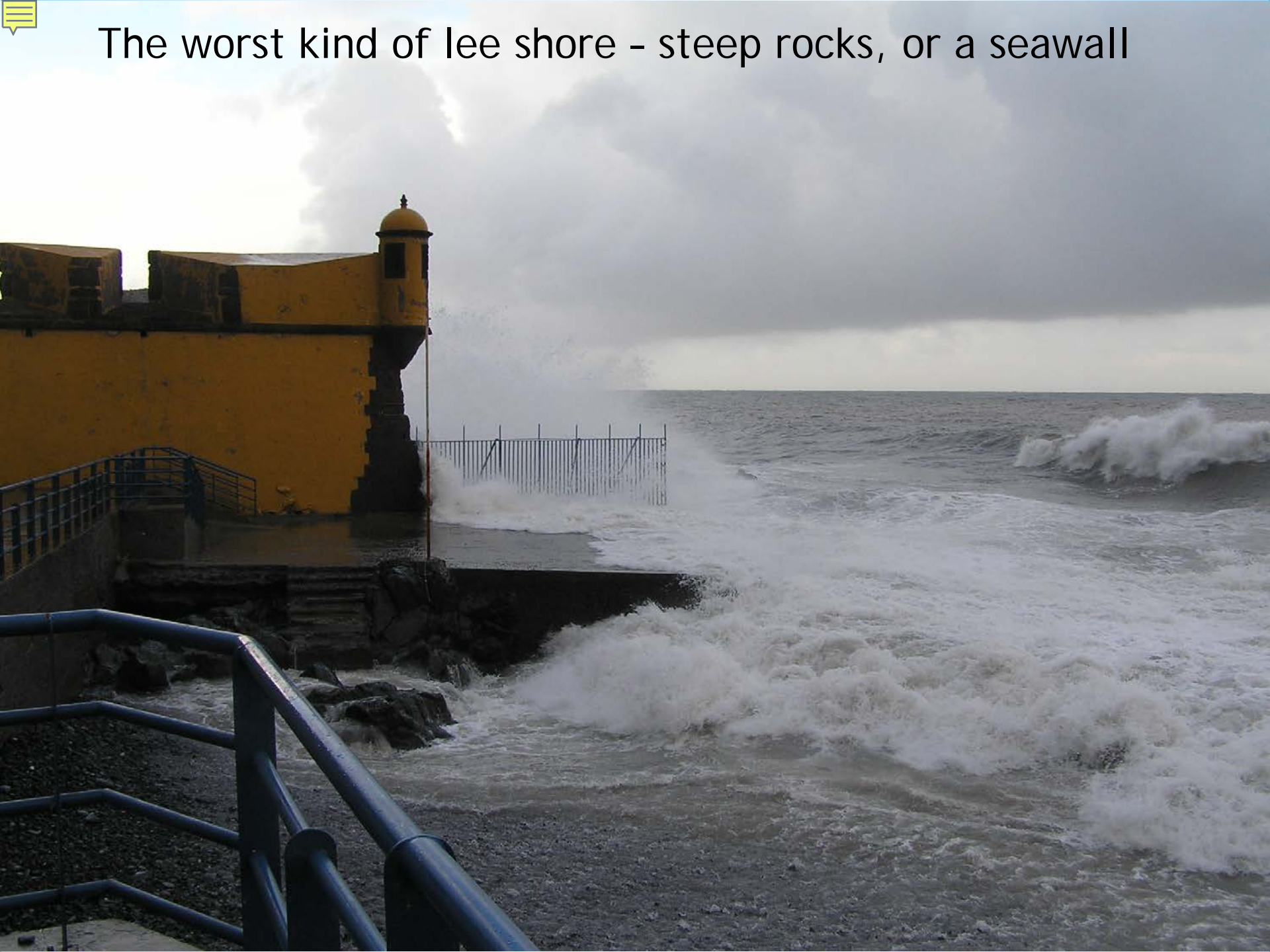
WAVE MAY BECOME SO HIGH YOU DON'T HAVE THE SPEED OR MOMENTUM TO SURMOUNT IT

WITH LOSS OF SPEED OR CONTROL *FOR ANY REASON* BOAT TURNS BROADSIDE TO THE SEA - DANGEROUS IN ITSELF

NEXT STEP - BREAKING WAVE SLAMS THE BOAT AND USUALLY ROLLS IT OVER



The worst kind of lee shore - steep rocks, or a seawall





HAVE FUN AND COME HOME SAFE!



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