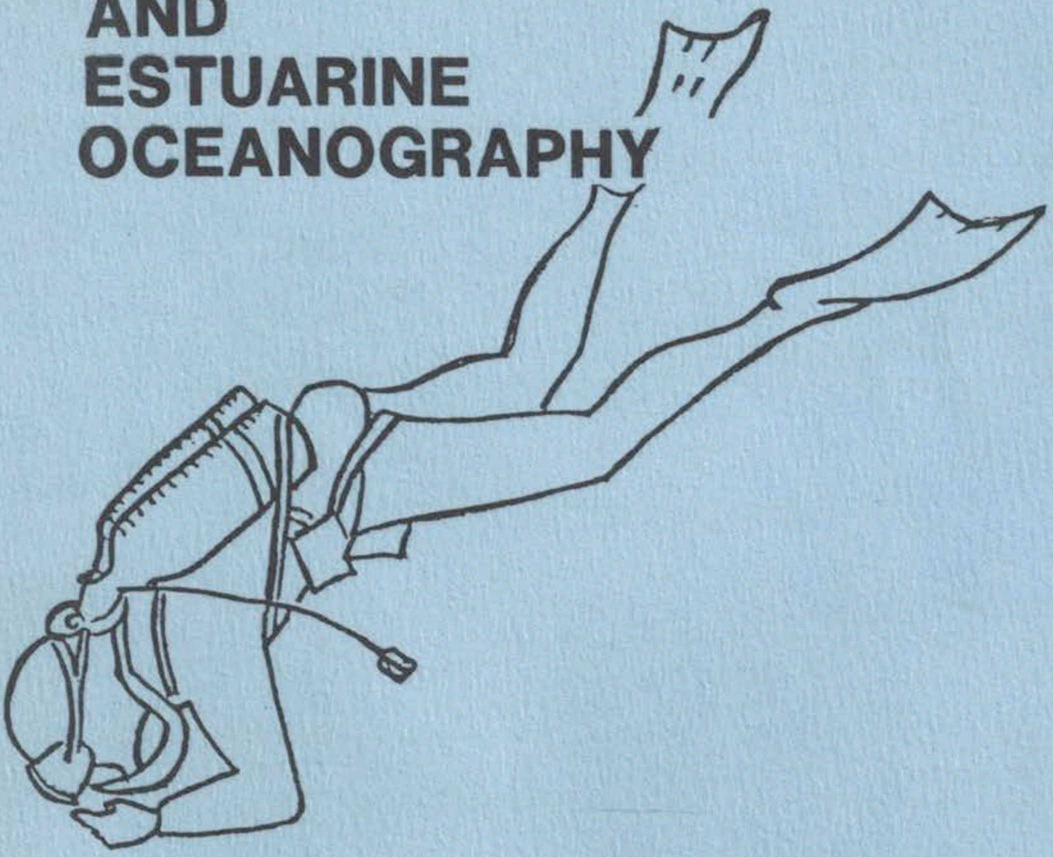
SCIENCE TEACHERS ASSOCIATION OF QUEENSLAND

COASTAL AND ESTUARINE OCEANOGRAPHY



UNIT II

COASTAL PHYSICS

written by

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TRIAL UNIT

"TO GREAT DAYS AT THE ALEX"

Australia's coastline forms a special place in our environment because over 90% of us live there. Due to different Ecological, Economic, Social and Recreational interests many conflicts arise over the use of our Estuaries, Beaches and Barrier Reefs. Sand Mining, High Rise development, Longline Fishing, Low water Land sales, Resort development and oil Pollution are but a few of the real issues that face us now. There is an urgent need for all Australians to develop an attitude towards sensible resolution of these conflicts. This set of notes is one in a series that hopefully will give students the skills necessary to become involved in these issues and make sensible contributions to coastal environmental decision making. In doing so I hope that the coastline may be managed in such a way that future Australians will derive as much pleasure out of it as I have.

My thanks must go to S.T.A.Q. for providing the financial backing and support for this project. Thanks also to my Mother and Father who deciphered and typed my bad writing; and to Len Zell of the Great Barrier Reef Marine Park Authority who read and critised the draft and for making many useful contributions. As this is a first draft any comments would be gratefully acknowledged.

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UNIT II

PHYSICAL COASTAL OCEANOGRAPHY

CHAPTER 3.

WAVES, CURRENTS AND BEACHES

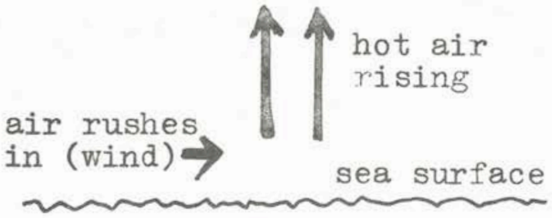
CHAPTER 4.

TIDES

CHAPTER 3.

WAVES, CURRENTS AND BEACHES

3.1 *Wave Formation*



As hot air rises over the sea it creates an area of low pressure below it.

Air from a higher pressure closer by moves into the low pressure area.

The moving air is called *WIND* and starts ripples on the sea surface. As the wind continues to blow, *WAVES* form and begin to move.

Fig 3-1: Wind Principle

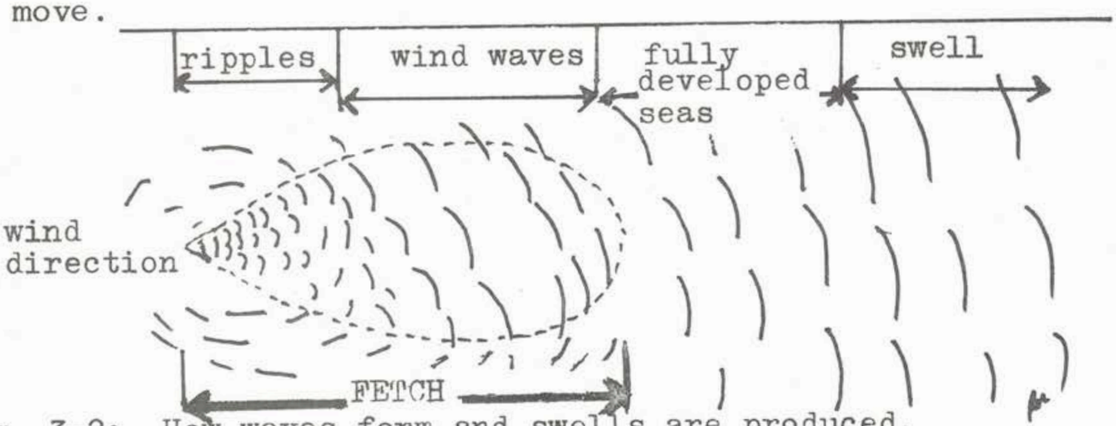


Fig. 3-2: How waves form and swells are produced.

The length of water over which the wind blows is called the *FETCH* and wave size increases proportionally with the length of the fetch, as well as with the strength of the wind. When waves leave the fetch zone they form a *SWELL*, and travel under their own *MOMENTUM*. Estuaries can be affected by wind, waves, or swells. As the waves move towards the estuary, the water depth decreases and the waves break.

3.2 *Breaking Waves*

The length of a wave is the distance between troughs. The height is the distance from the trough to the crest.

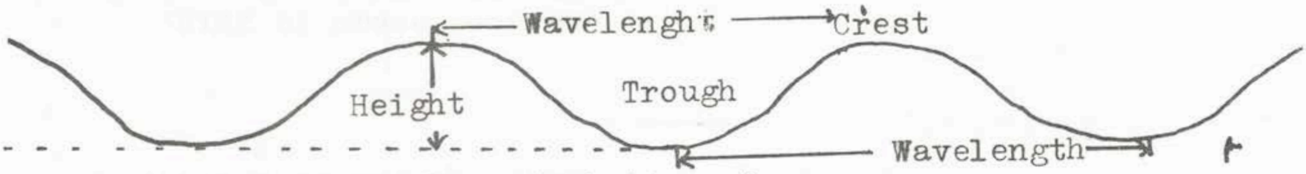


Fig. 3-3: Some characteristics of waves.

In the ocean, the maximum height a wave can attain is limited by the angle of steepness.

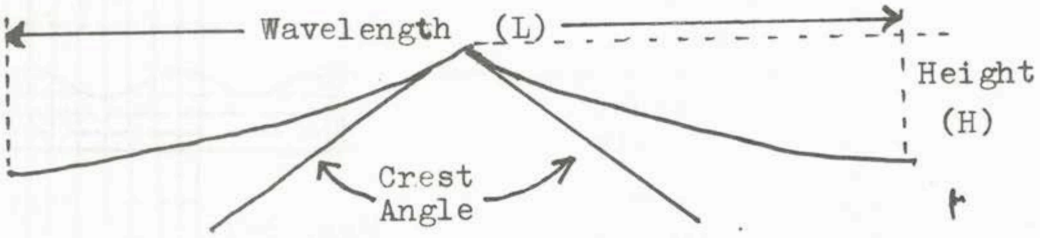


Fig. 3-4: Wave characteristics relevant to Breaking

Limiting Steepness $\frac{H}{L}$ = 0.142 or about 1/7th.

If the value of $\frac{H}{L}$ does not exceed 1/7th, then the wave will not break. If the value of $\frac{H}{L}$ is greater than 1/7th, then the wave will break.

Look at the two waves below. Measure their heights and lengths. *WAVE A* (1/7th) will not break, but *WAVE B* (2/7th) will.

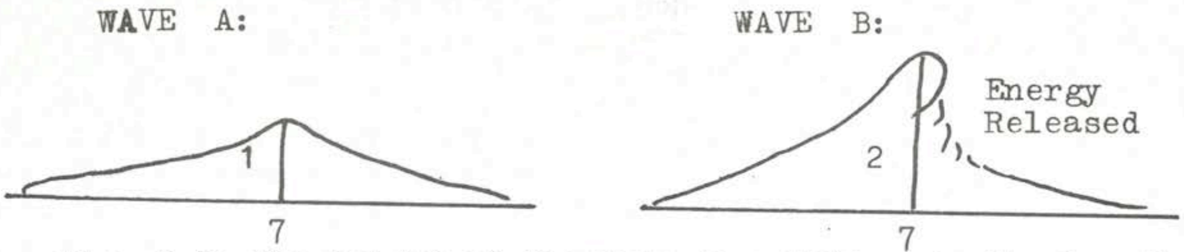


Fig. 3-5: The height of the wave in relation to its length.

As the wave breaks, its energy will commence to dissipate.

As the waves approach the shore, the limiting factor will be depth.

Three types of waves are seen in estuaries, each determined by the slope of the ocean floor.

Fig. 3-6 A: Spilling Waves

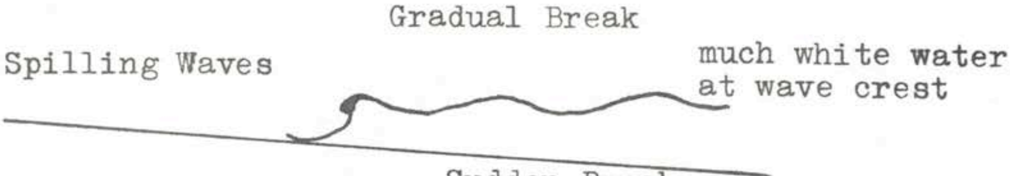


Fig. 3-6 B: Plunging Waves

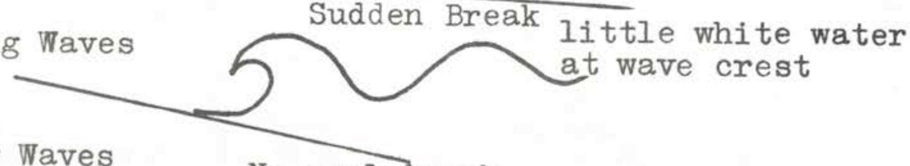


Fig. 3-6 C: Surging Waves

A. *Spilling Waves:* These are waves which break gradually and have much white water at the crest.

B. *Plunging Waves:* These waves curl over at the crest and this upper mass of water forms a pipe line break.

C. *Surging Waves:* These waves are seen at rocky outcrops or at breakwaters where the wave seems to surge from the base.

3.3 *Wave Refraction and Reflection*

Wave refraction is the bending effect on the wave crest as the wave tends to align itself with the shallowing sea bed.

Investigation 3-1: Waves and Reflection

You will need

* One ripple tank (complete with dampers)
* One overhead light
* One sheet of white paper
* A Wave generator (or piece of Dowel)
* Wax blocks or barriers
* Glass sheet

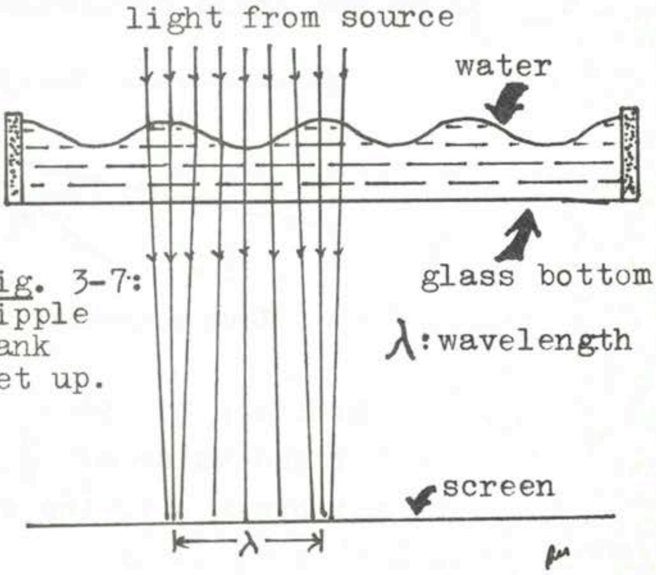


Fig. 3-7: Ripple tank set up.

PART A. Waves and Wave Length

Sometimes it is easier to fill the tank up and then siphon off to the required level. Note: Adding a drop of liquid detergent to the water breaks down the surface tension in the water, making the shadows more distinct.

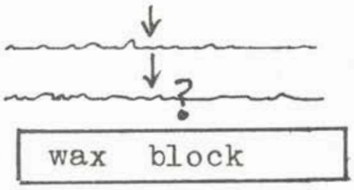
What to do If you have a strobe light you can stop the waves:

1. Generate some waves with the Dowel or Wave Generator.
2. Measure the wave length in cm. for various speeds of wave generation.

☐ Record in data table for *FAST*, *MEDIUM*, and *SLOW* wave generations.

PART B. Reflection

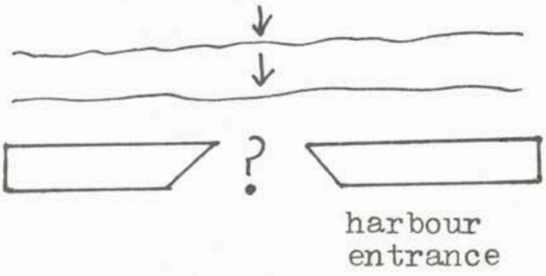
1. Use a wax block to study the effect of waves striking in at *straight* and at *angles*.



☐ Record the Angles of Reflection in each case.

PART C. Waves and Diffraction

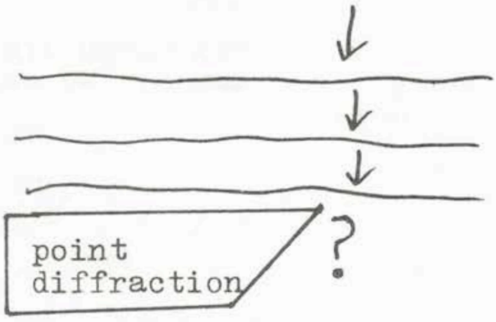
1. Use two sets of shaped paraffin blocks to model the harbour.
2. Generate short waves at the harbour entrance and observe what happens.



3. Slowly increase the speed of the waves.

☐ Record what happens.

4. Now use one of the shaped blocks and generate waves at the block.
5. Study the wave pattern around the sharp end of the block.



6. Now increase the speed of the waves and study the effect of shorter wave lengths.

☐ Record and draw what happens.

Questions:

PARTS A and B

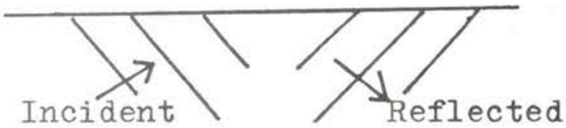
1. When a straight wave strikes a barrier so that its wave front is parallel to the barrier, in what direction is the wave reflected?
2. When a straight wave strikes a barrier at an angle, how do the angles of incidence compare with the angles of reflection?
3. How are straight waves affected by a parabolic reflector?
4. Make accurate drawings to illustrate your results.

PART C

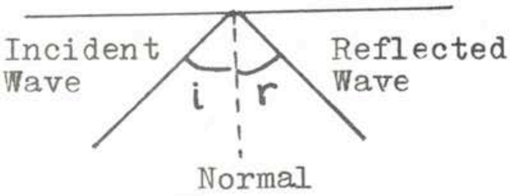
1. What kind of wave lengths are diffracted more? Long ones or short ones?
2. What is the relationship between the size of the opening and the amount of diffraction?
3. What happens around the ends of the shaped block?
4. Make accurate drawings of your results to illustrate your answers.

When waves strike a beach they are said to be reflected. Waves striking a beach straight on, are reflected straight back. The wave coming in is called the *incident* wave, and the wave going out to sea is called the *reflected* wave.

However, when waves strike a beach at an angle, the angle of strike becomes important.



If we draw a perpendicular to the beach (called the normal) there is a special relationship that exists between the angle the wave hits the beach and the angle reflected back.



THE ANGLE OF INCIDENCE = THE ANGLE OF REFLECTION

3.4 Beach Currents

Reflected waves are usually the start of rip currents along the beaches. We can make a generalized drawing of these currents.

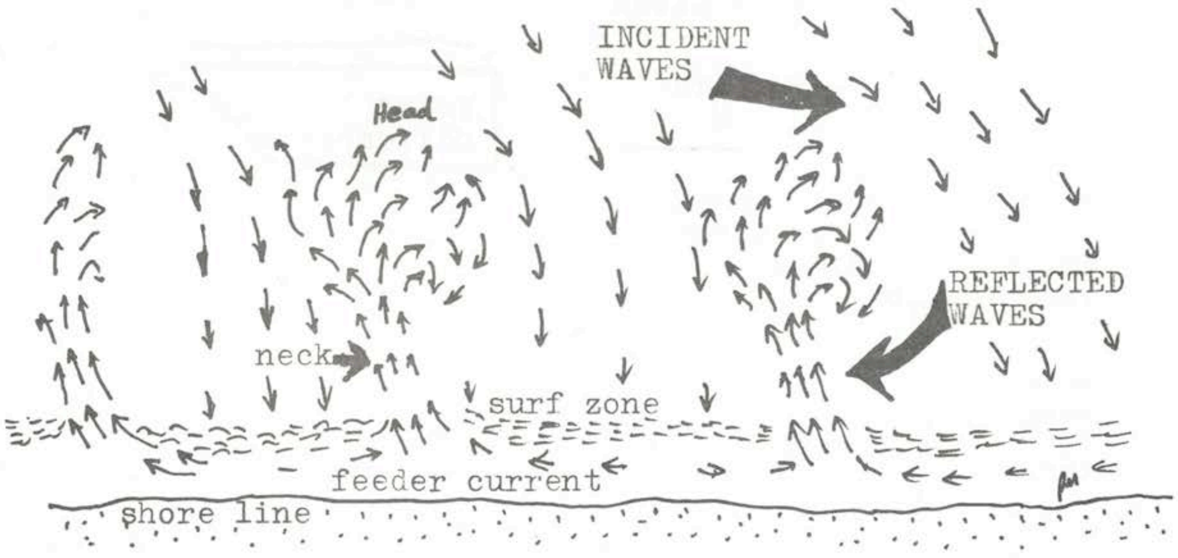
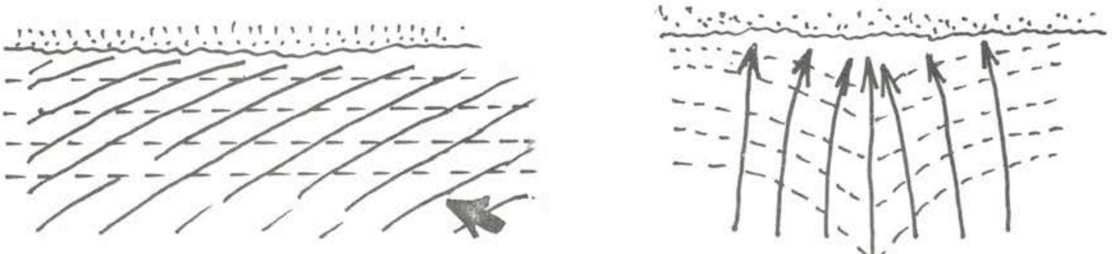


Fig. 3-8: Reflected waves off beaches cause rips.

A rip current could be described as a concentrated stream of water moving through the breaker zone. It represents the return movement of water piled up on the beach by incoming waves and wind. An idealised rip current has a feeder system made up of *REFLECTED* waves, a *NECK* (where the feeder current converges to flow through the breakers), and a *HEAD* (where the rip widens and disperses).

The number of, and speed of, rip currents, seems to be closely related to wave size and speed. Faster and bigger waves tend to generate bigger rips. However, much seems to depend on the bathymetry of the beach.

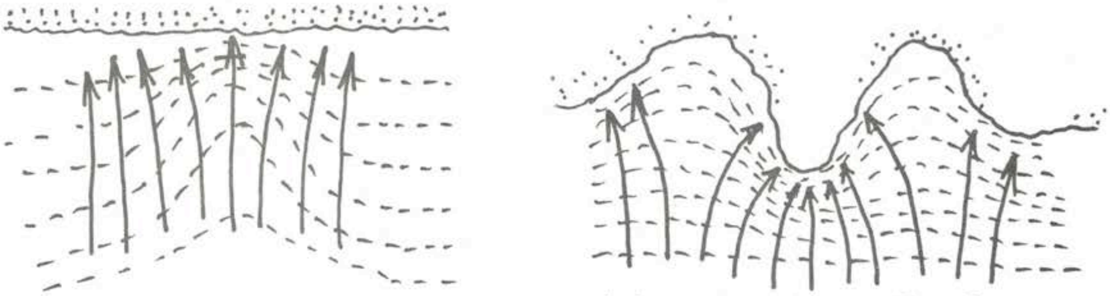
Consider a Bathymetric Survey



(a) Straight beach with parallel bottom contours

(b) Straight beach with ridges on bottom.

Fig. 3-9



(c) Straight beach with depressions on bottom.

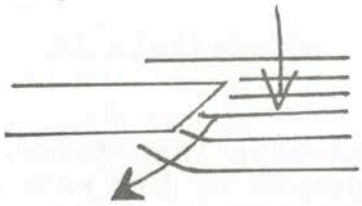
(d) Bay and Headland coastline.
(after B.P.A.)

So, to predict the direction and speed of rips is very difficult. On the Gold and Sunshine coasts of Queensland, life savers have the constant week-end problem of collapsing sandbanks and changing rips. However, surfers have a more enjoyable time at points because of wave *DIFFRACTION*.

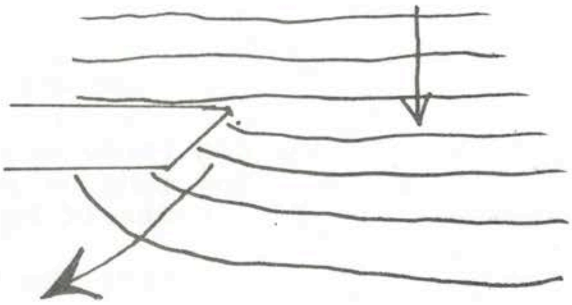
3.5 *Point Diffraction*

Consider Investigation 1, PART C

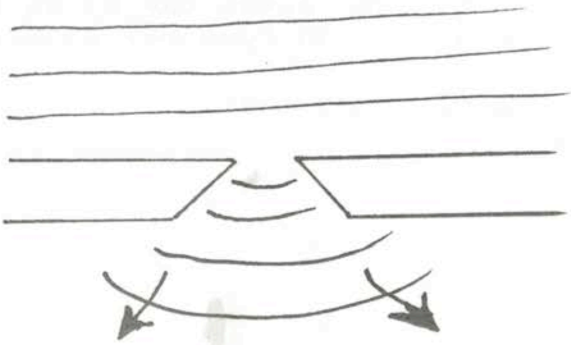
For *Short* Waves, diffraction was slight.



For *Long* Waves, the effect was more dramatic.



This can be seen to a larger extent when we consider two wax blocks together.



The Wave Set Up is the highest average water level achieved on the beach. There will, of course, be some run up, but this will be higher than the average since run up always runs back.

The Wave Set Down is the lowest average water level on the beach. This is usually at the break point.

Bigger waves will have a bigger set up and set down than the smaller waves. A measure of the force in waves is called *RADIATION* stress. This is the theoretical force that particles exert as they move around inside a wave.

Consider the diagram:

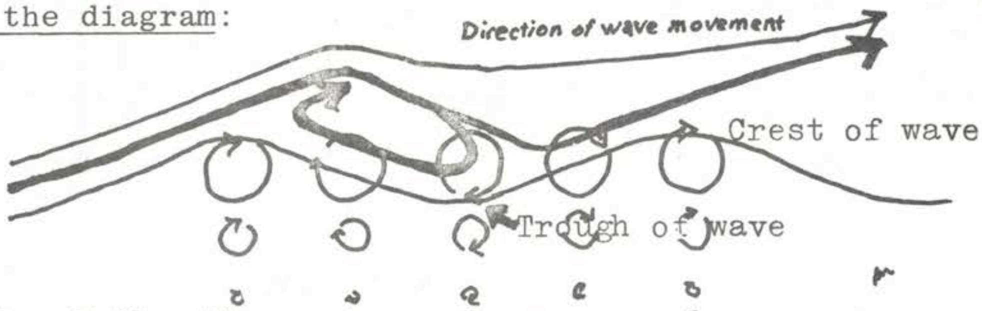


Fig. 3-13: The anatomy of a wave

A particle over the period of time would travel in a complete circle. As the wave breaks things become a little more complicated:

Fig. 3-14: Hypothetical movement of particle in breaking wave.

Particles are speeded up, change direction, and can exert forces in all different ways.

Fig. 3-15: Hypothetical movement of particle in broken wave.

As you see there are many different ways that forces could be exerted. How many of you have been dumped by big waves at the beach and felt yourself hurled in all directions. However, in general -

(i) the bigger the waves, the bigger and more complicated will be the movements of their water particles

(ii) the bigger the force.

The force exerted by some waves can be as much as 27,000 kilograms per square metre, or 30 tons per square metre.

No wonder our beaches wash away.

The effect can be seen around a headland when a swell coming in gets defracted as it passes the point.

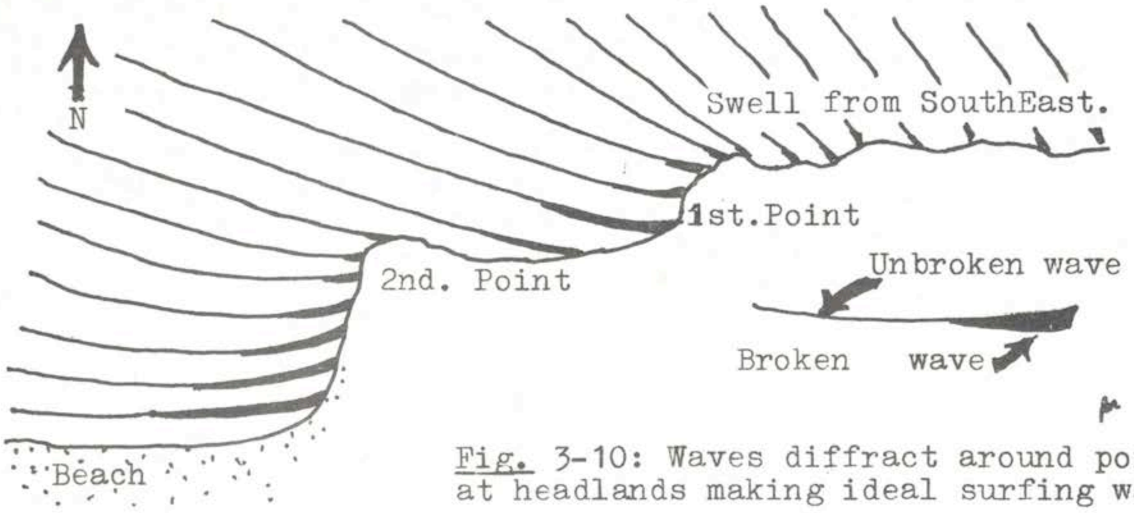


Fig. 3-10: Waves diffract around points at headlands making ideal surfing waves.

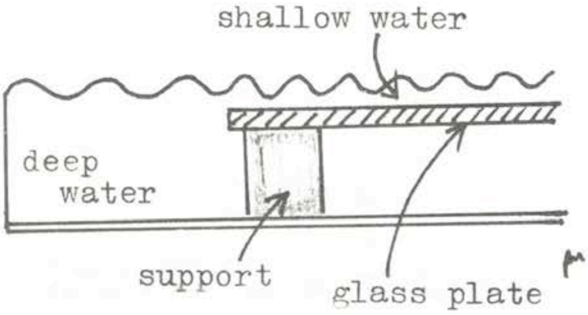
3.6 *Refraction*

Investigation 3-2: Refraction

You will need

- A ripple tank assembly
- Sheet of glass
- Block.

Set up your ripple tank as follows:



What to do

PART A

1. Support a glass plate on the spacers so that it is approximately 1.5 cm above the bottom of the tank, and about 15 cm from the wave generator. Its longest edge should be parallel to the generator.

   Note: Sometimes it is easier to fill the tank until the glass plate is covered and then siphon off the water until only a thin film (1mm) remains over the glass.

2. Put enough water in the tank to cover the glass plate to a depth of about 1mm. Adjust the height of the wave generator so that the bottom of the vibrator is just below the surface of the water.

3. Adjust the generator so that it produces waves with a long wavelength.

☐ As the waves pass from the deeper water to the shallow water, note what changes occur in their speed and their wavelength.

☐ Draw a diagram to show clearly what changes occur in their wavelength.

PART B

Now set the glass plate at an angle of approximately 45° to the incoming waves. Note any changes that occur in the direction of the motion of the waves.

☐ Draw clearly what you see.

Questions:

1. Does the wavelengths change from deep to shallow?
2. If so, by how much?
3. What changes in directions occurred when waves entered shallow water straight on or obliquely?

Investigation 2 showed that waves approaching an estuary or beach at an angle were bent. Such "bending" is called *REFRACTION*. We can summarize these ideas in the figure below:

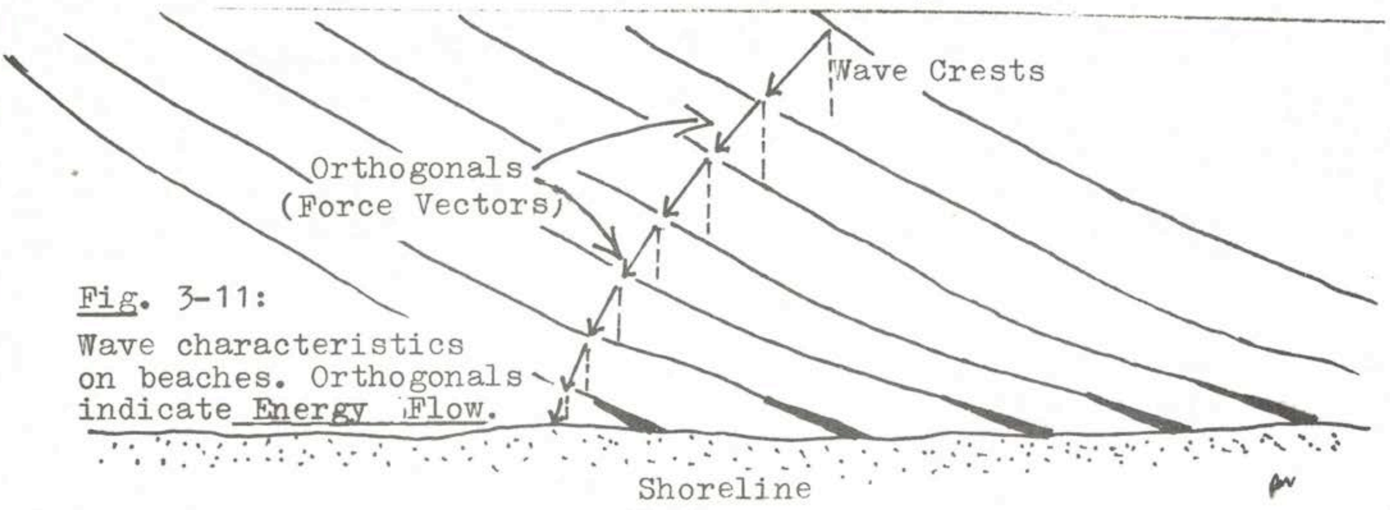


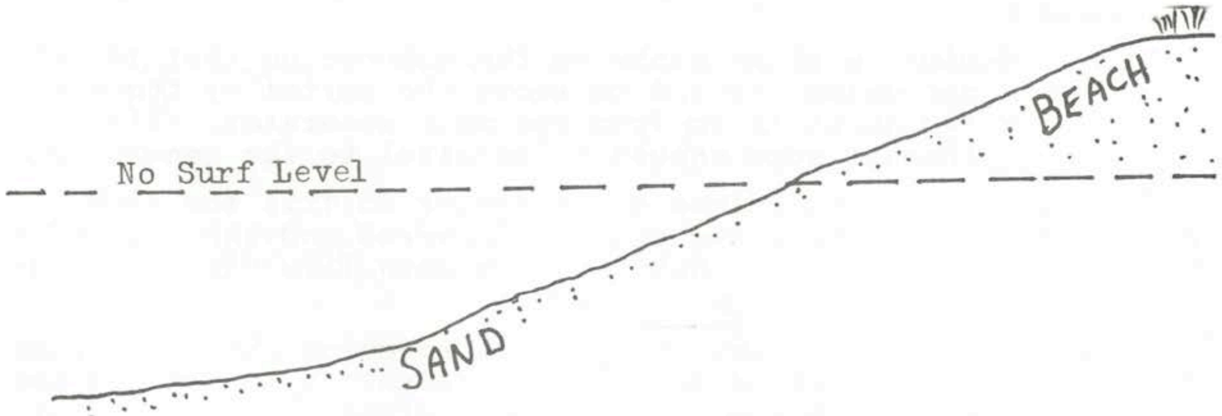
Fig. 3-11: Wave characteristics on beaches. Orthogonals indicate Energy Flow.

Lines drawn perpendicular to the wave crest are called *ORTHOGONALS* and can indicate how much refraction is taking place. Wavelength also decreases. Orthogonals represent the direction in which wave energy is transmitted.

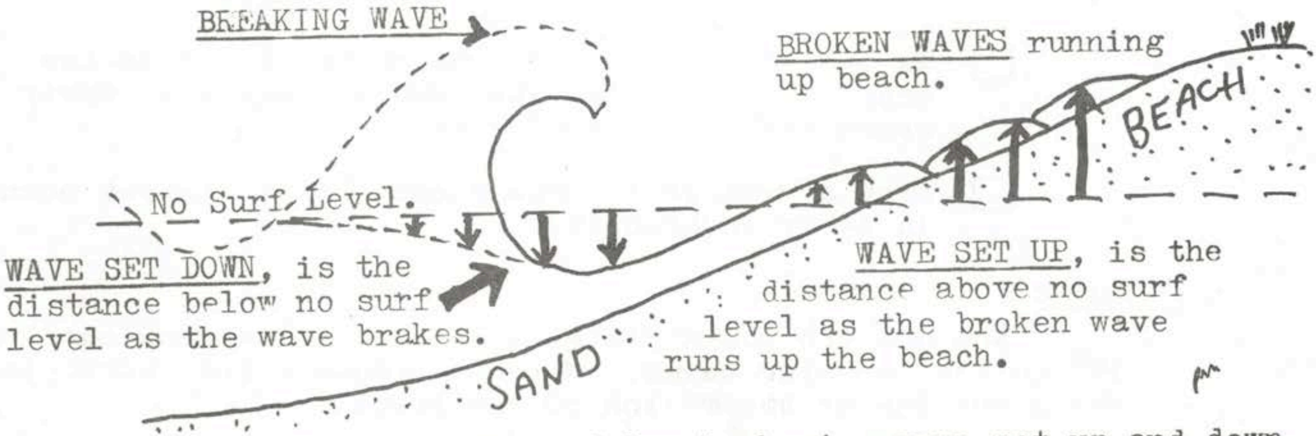
3.7 *Wave Set Up and Set Down*

Once the waves have been refracted, they break on the shoreline. This is known as *WAVE RUN UP*.

Consider a beach with no surf. We can represent this with a line which we call a still water level.



Now consider the same beach a few days later *WITH SURF*



WAVE SET DOWN, is the distance below no surf level as the wave brakes.

WAVE SET UP, is the distance above no surf level as the broken wave runs up the beach.

Fig. 3-12: Cross section of beach showing wave set up and down.

After the wave has broken, the height decreases rapidly and moves towards the shore. It may break again and run up the beach. The *maximum wave set up* is the average maximum level that water reaches on the beach.

3.8 *Longshore Currents*

Currents move along the shore from areas of large wave set up, to areas of small wave set up.

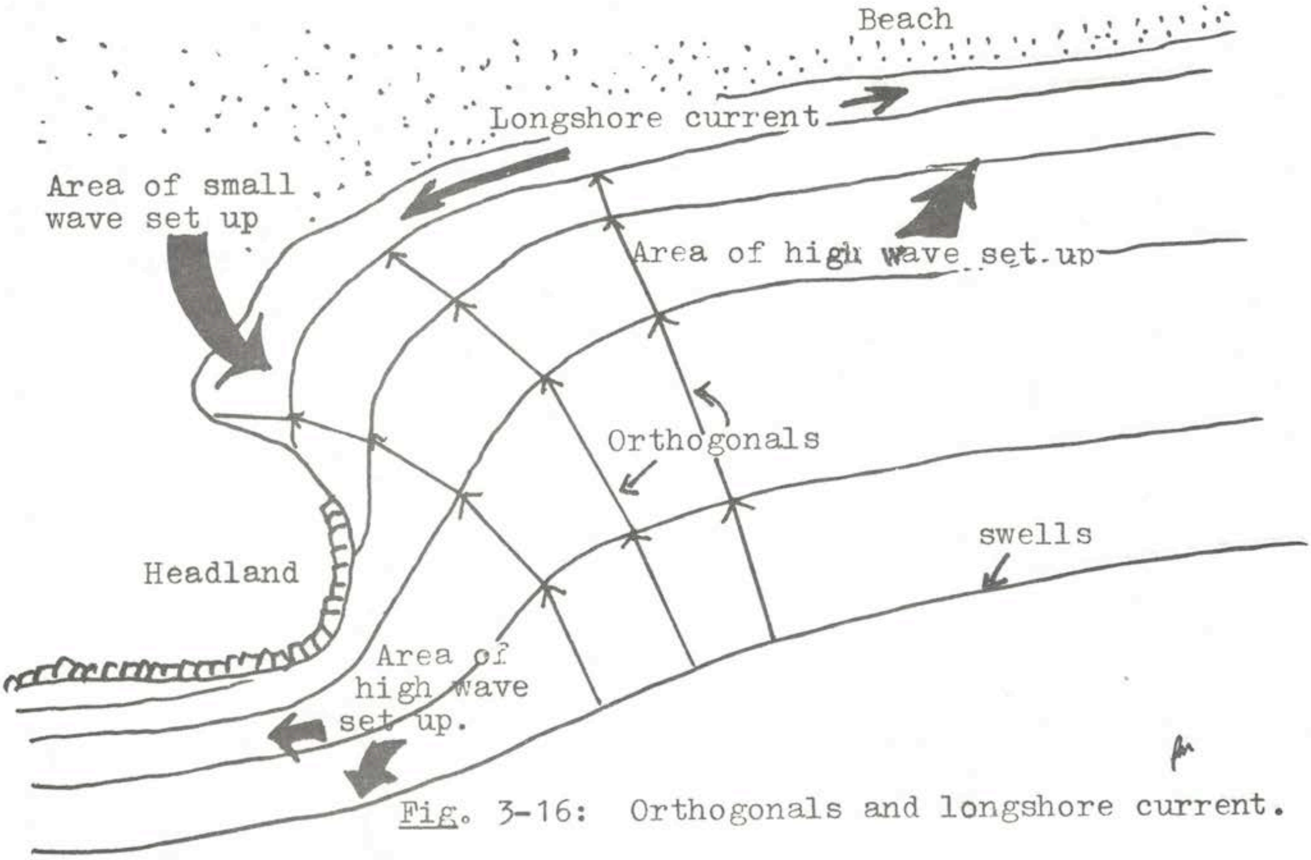


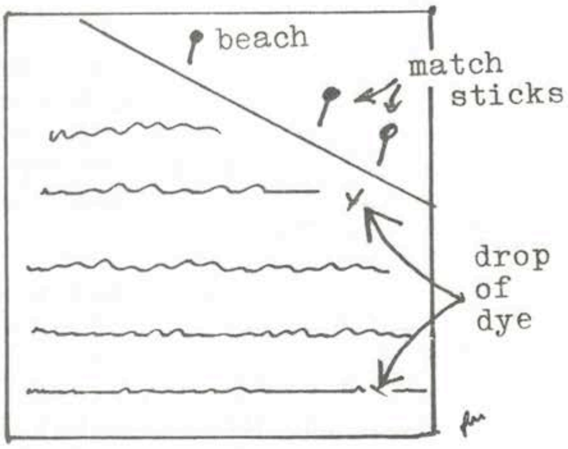
Fig. 3-16: Orthogonals and longshore current.

Investigation 3-3: Longshore Currents and Groynes

You will need

- A ripple tank or stream tray
- Some sand
- Wave generator
- Some Dye - Condys crystals
- 4 match sticks
- Some wood to make a Groyne

Longshore current ripple tank simulation set up.



What to do

PART A: Longshore Current:

1. Build a beach as shown in figure ➡ and insert four match sticks as shown.
2. Generate waves at the rate of about 100 per minute, as shown.
3. Drop a grain of Condys crystals at the point shown and study the movement of the Dye.

Questions:

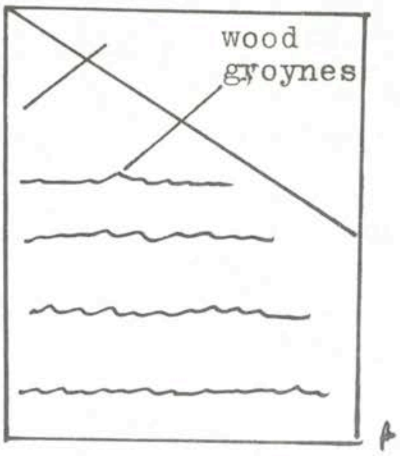
1. What was the effect of the waves on the simulated beach?
2. Where did the Dye go, and in which direction.
   Draw a diagram to illustrate your answer.

PART B: Groynes

1. Rebuild your beach as shown in Fig. and add 2 Groynes.
2. Generate the waves as before with the wave generator.
3. Drop in a drop of Dye and observe what happens.
4. Observe carefully what happens around the model groynes.

Questions:

1. Where did sand build up *MOST?*
   WASH AWAY MOST/
2. Where have groynes been built on Queensland beaches?



Groyne effects in simulated ripple tank

3.9 Depositional Landforms From Longshore Currents

A common depositional landform is a *SPIT*. A spit is usually composed of sand that runs along the beaches.

The Southport Spit is an excellent example of sand build up due to a longshore current that runs along the beaches at the Gold Coast in Queensland.

At other places along Queensland's Gold Coast sand movements also occur. So important are these sand movements to the tourist industry, that millions of dollars have been spent to keep the sand moving in the right directions.

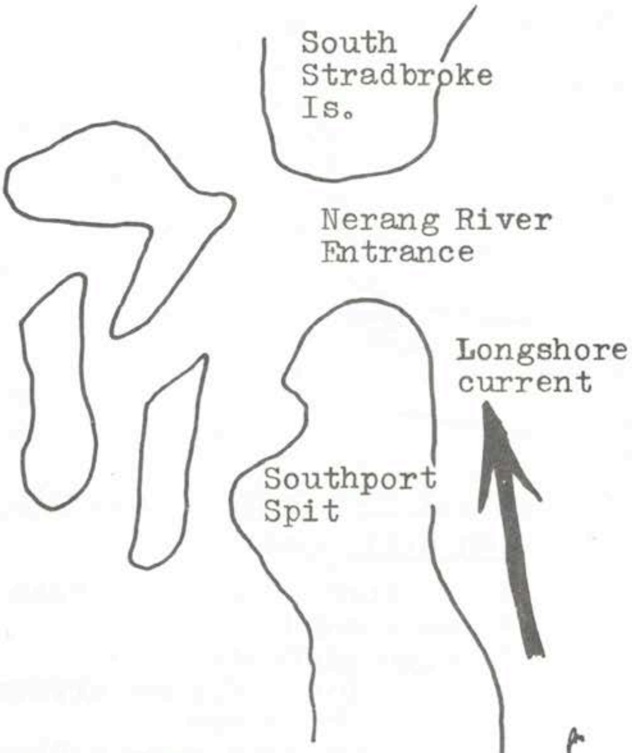


Fig. 3-17: Gold Coast: Longshore current direction.

On the Sunshine Coast at the mouth of the Maroochy River, a small island called Pincushion Island became joined to the mainland by a *SPIT* in 1962.

During a period of heavy weather, the longshore build up of sand closed off the old river mouth and caused the Maroochy River to make a new river mouth just to the *NORTH* of Pincushion Island.

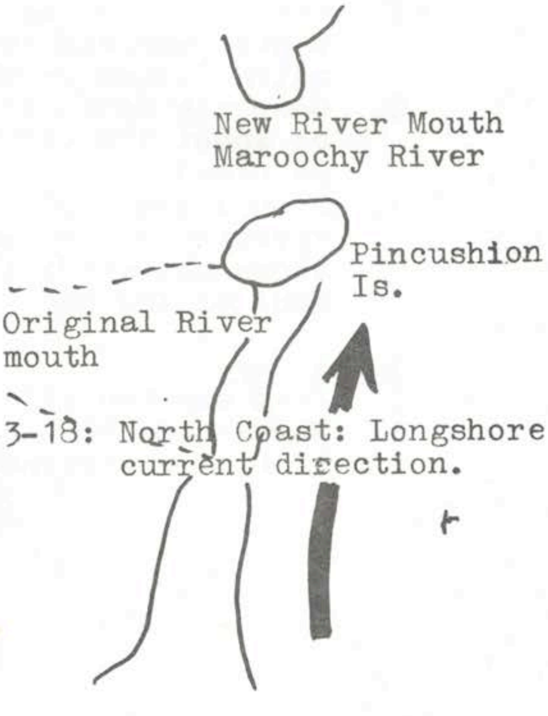


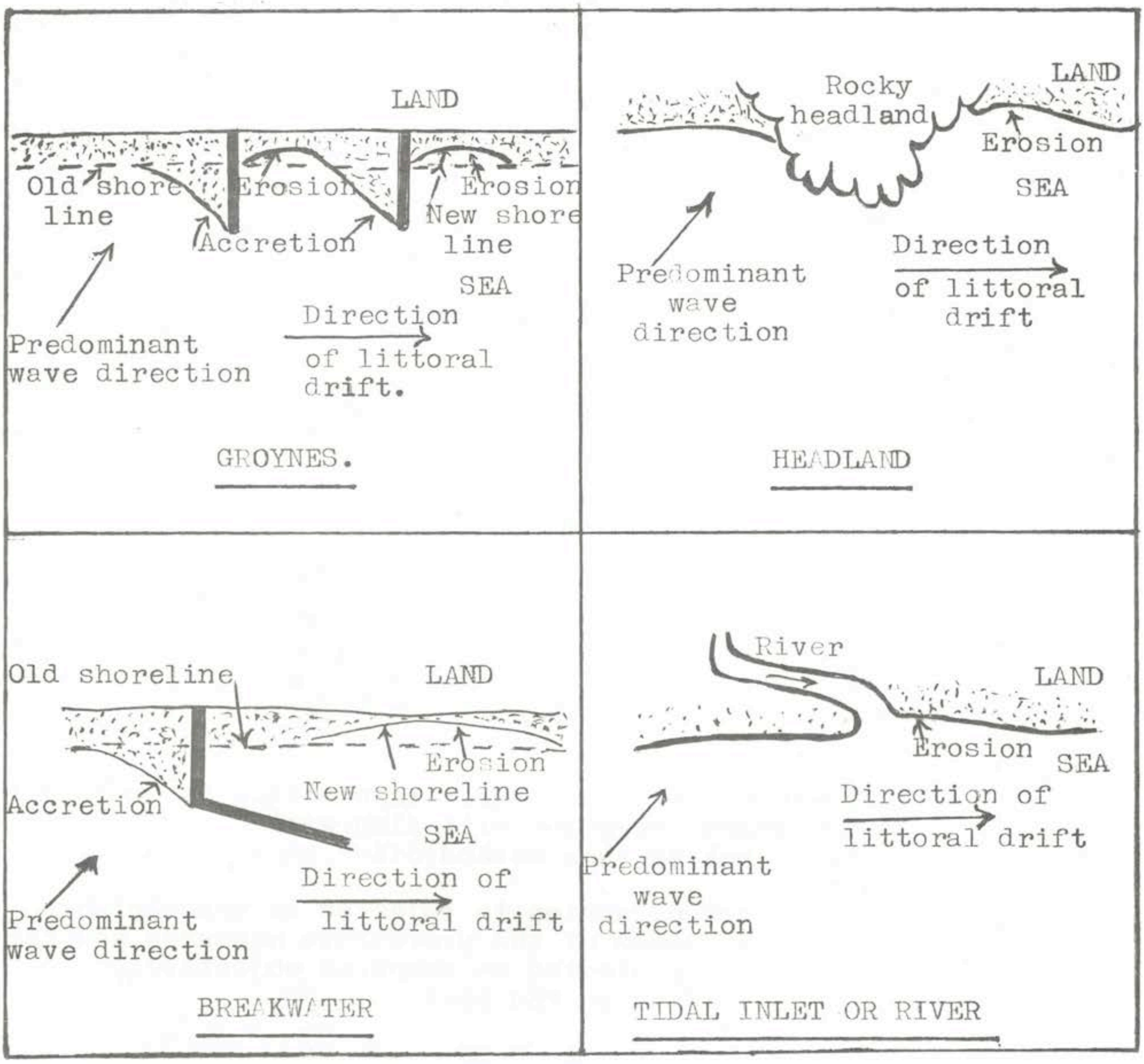
Fig. 3-18: North Coast: Longshore current direction.

3.10 *How Man Interferes With Longshore Currents*

You have seen how longshore currents can move sediment such as sand. These currents can cause the building up of deposits of sediment in some places and their removal from others.

Groynes and breakwaters are two examples of how man does this. In Investigation 3 we saw that when a groyne was built, the sediment built up (called *ACCRETION)* on one side, and eroded on the other.

Four effects are shown below:



(after Ford, 1980.)

3.11 *Beach Erosion*

The Problem. Beach erosion is a natural part of beach behaviour and becomes a problem only when it threatens property and improvements. The essence of the problem is not that beaches erode, but that development has occurred within the zone of these natural beach movements.

Combatting any particular beach erosion problem is usually a very expensive business which, in the case of future development, can be completely avoided simply by the provision of an adequate buffer zone between the development and the beach.

However, where existing development is experiencing erosion problems, remedial action can be taken by implementing one or more of the measures outlined below.

Alternative Erosion Control Measures

The selection of the most appropriate method of combatting an erosion problem is by no means simple and will be influenced by the type of beach, the erosion mechanisms at work and the availability of funds for the project.

There are 6 basic ways of dealing with beach erosion problems which can be implemented individually or in various combinations. These are:

1.	*No Action*	- allowing nature to take its course and accepting the resulting property losses
2.	*Relocate Development*	- removing the problem by relocating development outside the threatened zone.
3.	*Rock Revetment*	- providing a physical barrier to further erosion.
4.	*Groynes*	- to trap sand in the eroding areas.
5.	*Offshore Breakwaters*	- to reduce wave energy behind the breakwater and to trap sand in the eroding areas.
6.	*Beach Nourishment*	- rebuilding eroding beaches by direct placement of sand onto the beach.

1. NO ACTION (see Fig. 3-19)

A decision to take no action and allow erosion to continue is the best course of action when the threatened development has little value. Such a course of action requires no expenditure on protective measures and involves minimal interference with existing beach behaviour.

However, residents will naturally take action to protect their homes and Government agencies will also wish to protect their assets and amenities, making this method often impractical.

Before this course of action is rejected as unacceptable, it is desirable that the costs of the protective measures and the value of the assets to be protected be compared objectively. This has not always been done in the past.

2. RELOCATE DEVELOPMENT (see Fig. 3-20)

In cases where the development can be re-established elsewhere at reasonable cost, buffer zones can be provided where they previously did not exist. Such provision may necessitate moving amenities, roads and even domestic houses with payment of compensation to the people involved.

The financial and social costs involved in resumption and compensation payments are usually high especially in densely populated areas and public reaction against this general approach is understandably strong. In spite of its apparent drawbacks, in some areas relocation may well be cheaper in the long run than expensive protection works.

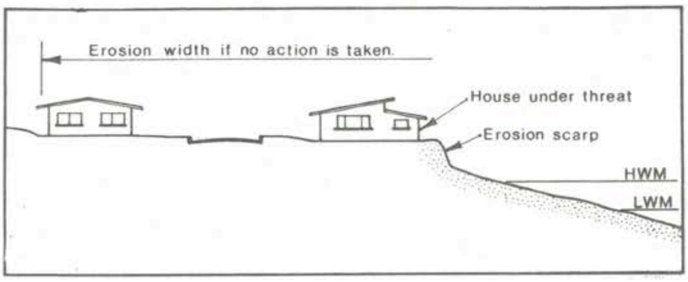


Fig. 3-19:
No Action.

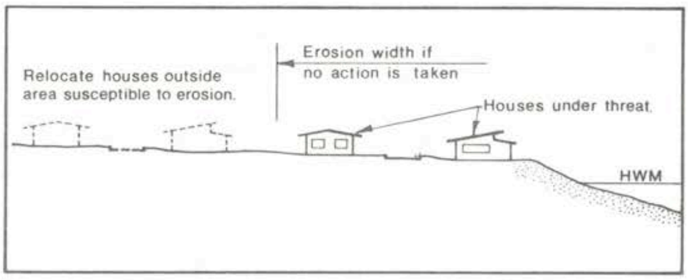


Fig. 3-20:
Relocate Development.

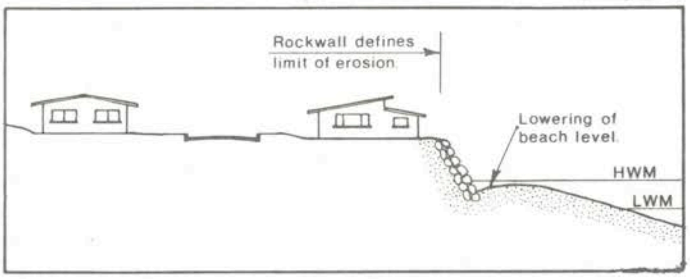


Fig. 3-21:
Rock Revetment

(diagrams courtesy beach protection authority)

3. *ROCK REVETMENT* (see Fig. 3-21)

Rock revetment is probably the most commonly adopted method of combatting erosion problems in Queensland. Rock walls are surprisingly expensive, but can be provided at short notice and, for this reason, are commonly used for erosion control during cyclones and severe storms. They also give property owners a feeling of security by their solid appearance but this will be an illusion unless the wall has been properly designed and constructed to resist severe wave attack.

Once provided, rock walls constitute a lasting artificial impediment to natural beach behaviour and generally result in an appreciable drop in the level of the beach. Erosion can still continue at each end of the rock wall and may even be accentuated at these locations.

Rock revetment offers protection against further erosion but only at the expense of the beach which may need beach nourishment to restore its value as a recreational asset.

4. *GROYNES* (see Fig. 3-22)

Groynes are a common but sometimes misunderstood method of combatting erosion. Groynes function by trapping sand moving along the coast on the updrift side of the groyne, but starve the beach of sand supply on the downdrift side.

The main problem with groynes is they do not solve an erosion problem but merely transfer it along the beach. Often this leads to the construction of a series of groynes (a groyne field) with the result that the erosion problem becomes concentrated on the downdrift side of the last groyne.

During severe wave attack, groynes do not prevent erosion because they have no effect in reducing the movement of sand in the offshore direction (i.e. at right angles to the beach). However, by trapping sand on the updrift side they do help to provide a wider beach to accommodate erosion. At the same time, the depleted beach on the downdrift side of the groyne will be more susceptible to erosion than before.

The erosion problems associated with groynes can be compensated for to a large extent by beach nourishment. As a general rule a combined approach is preferable to using groyne construction by itself unless the concentration of erosion on the downdrift side is acceptable.

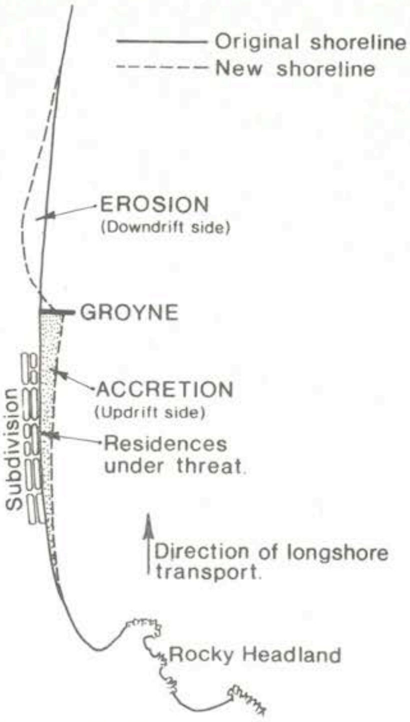


Fig. 3-22: Groynes

(after Ford, 1980)

5. *OFFSHORE BREAKWATERS* (see Fig. 3-23)

Offshore breakwaters constructed parallel to the beach alter the height and direction of waves reaching the beach. They create a sheltered zone behind them into which sand may be moved by longshore transport processes but out of which longshore transport will be greatly reduced because of the altered wave climate. In addition, short term storm erosion will be reduced as much smaller waves will reach the beach.

6. *BEACH NOURISHMENT* (see Fig. 3-24)

Beach nourishment refers to the deposition of sand onto beaches by pumping or other means with a view to restoring an adequate buffer zone in front of the threatened property.

Beach nourishment has been carried out successfully in Queensland on the Gold Coast and the approach is undoubtedly suitable for many of the erosion problems throughout the State.

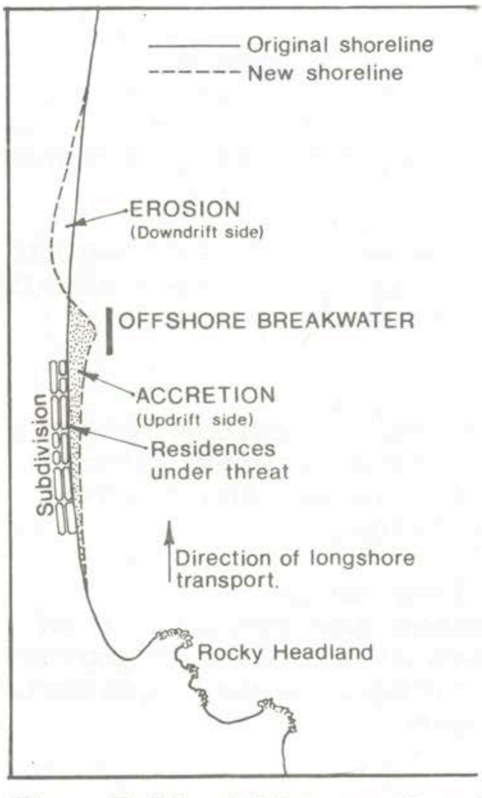


Fig. 3-23: Offshore Breakwater

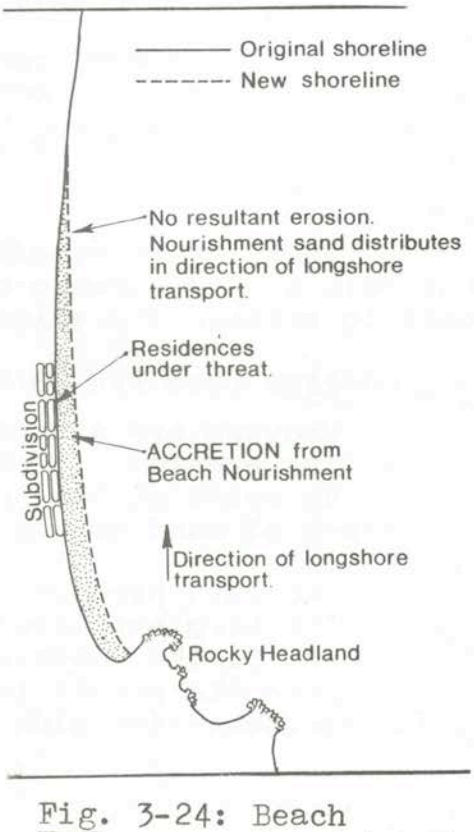


Fig. 3-24: Beach Nourishment

(diagrams courtesy Beach Protection Authority)

MAIN IDEAS

1. Nearly *all waves are formed* by wind in an area called a fetch. Wave height is proportional to fetch length.

2. *Waves break* when their height exceeds their length by one-seventh.

3. Three types of breaking wave are spilling, plunging and surging.

4. Wave motion can be simulated in a ripple tank.

5. Beach currents transport sand along the shoreline.

6. Longshore currents can be affected by beach housing development and groynes.

7. The Beach Protection Authority has been established to conserve and research our beaches.

REVIEW QUESTIONS

1. Draw a fully labelled diagram of a *WAVE*.

2. What is a *FETCH?* How is it important in establishing a swell?

3. Diagram the apparatus used in a Ripple Tank.

4. Distinguish between *INCIDENT*, *REFLECTED*, *REFRACTED* and *DEFFRACTED WAVES*.

5. How does the Ocean Bathymetry affect wave set up?

6. How does a Groyne affect the Longshore Current?

7. List any 5 steps used to conserve our beaches.

8. What is *ACCRETION?*

STUDY ASSIGNMENTS

1. Write to the Gold Coast Waterways Authority and ask them for their proposal to redevelop the Southport Spit. Summarise their proposals in 500 words and debate the value of this project.

2. Design a Wave Tank or try to build one to show wave notions.

3. Build a Beach and Headland Model and outline what beach protection measures you would take.

4. Compare and contrast the Surfers Paradise Beach Highrise with Sunshine Coast Frontal Dune Systems.

CHAPTER 4.

TIDES

4.1 The Importance of Tides

An understanding of tides and tidal currents is important to all who live near an estuary. For the fisherman, they provide the times to fish - most fish, they say, are caught at the top or bottom of the tide when the water currents are low, which allows the fish to feed; therefore a baited hook is more likely to be taken then.

Also, Department of Harbours and Marine engineers need to know how far water levels will fall in order to construct jetties; ships' masters need to know how much water is in a shipping channel before attempting to navigate through that channel; even social clubs have planned afternoon get-togethers on the foreshore around the tides, so that mud banks are covered and the area is therefore aesthetically pleasing. Over history, tides have played an extremely important part in naval battles (some say the battle of Alexandria was lost due to an unfavourable tide). So what are the causes of tides?

4.2 The Sun, Earth, Moon Systems

A knowledge of the Sun, Moon and Earth's Orbital Systems is essential, because both the sun and the moon exert tide producing forces on the earth's waters. However, it is the moon that controls the timing of the tidal rise and fall of the ocean head.

Investigation 4-1: Plotting the Tide

You will need

- 2 sheets of Graph paper
- Tide book (or tidal predictions for Brisbane and Mackay)
- A "Phases of the Moon" chart (see desk diary for this or tide book).

What to do

PART A: The Tide over 24 hours

1. Select a day which has *four* tides in it.
2. Plot the tide height versus time for that day at the Mackay and Brisbane Bars.

PART B: The Tide over a month

1. Select any month of the year and plot the tide heights for that month versus days in the month for Brisbane and Mackay (on the same graph, but using different colours).
2. Mark on your graph the phases of the moon with the symbols:

New


First Quarter


Last Quarter


Full


Analysing the Results

In PART A:
1. What are their heights for high and low tides?
2. Are the high tides the same height?
3. Are the low tides the same height?
4. Why is there a difference in heights?

In PART B:
1. Are there any differences in tidal height over the month?
2. Is there any correlation between the moon phases and this?

To understand fully Investigation 1: we need to look at the moon's orbit.

4.3 *The Moon's Orbit*

The moon, a satellite of the earth, is about 3,500 km in diameter, and has a mass of about 1/81th of the earth. The moon revolves in a elliptical orbit in which the mean distance between the earth and the moon is about 386,400 km. The direction of revolution is similar to the earth's direction of revolution about the sun. If we imagine ourselves to be looking *down* on the earth, moon and sun so that the earth's north pole is between us, the moon's motion is clockwise.

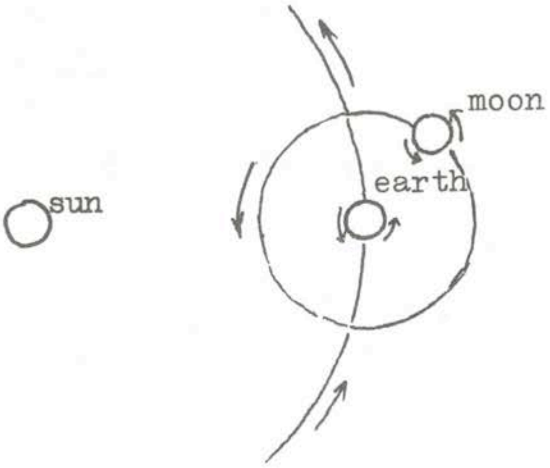


Fig. 4-1:

Moon and Earth revolve and rotate in the same direction.

The Moon Orbit is an ellipse, considerably more flattened than the ellipse of the earth's *ORBIT* with the earth located at one *FOCUS*.

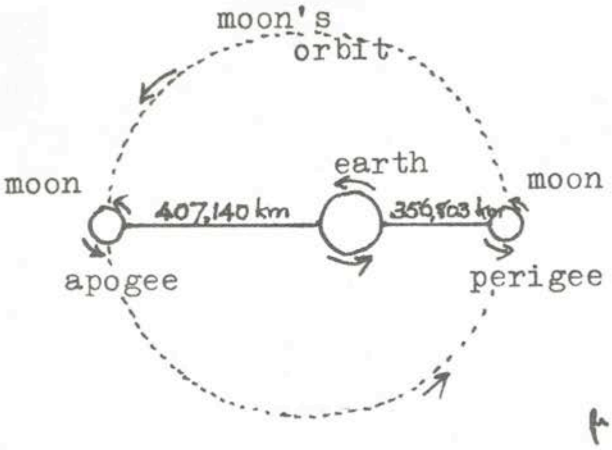


Fig. 4-2: Apogee and Perigee

When the moon is at its nearest point, the moon is said to be at *PERIGEE*, and when farthest, in *APOGEE*. Distances are 407,104 km. *APOGEE*, and 356,803 in *PERIGEE*.

4.4 *Period of Moon's Revolution*

If we observe the position of the moon in the sky, we notice that it changes every 24 hours. In fact, each night it is about 13° eastwood. It takes about 29½ days for the moon to make one complete revolution of the earth. This time is called a *SYNODIC MONTH*.

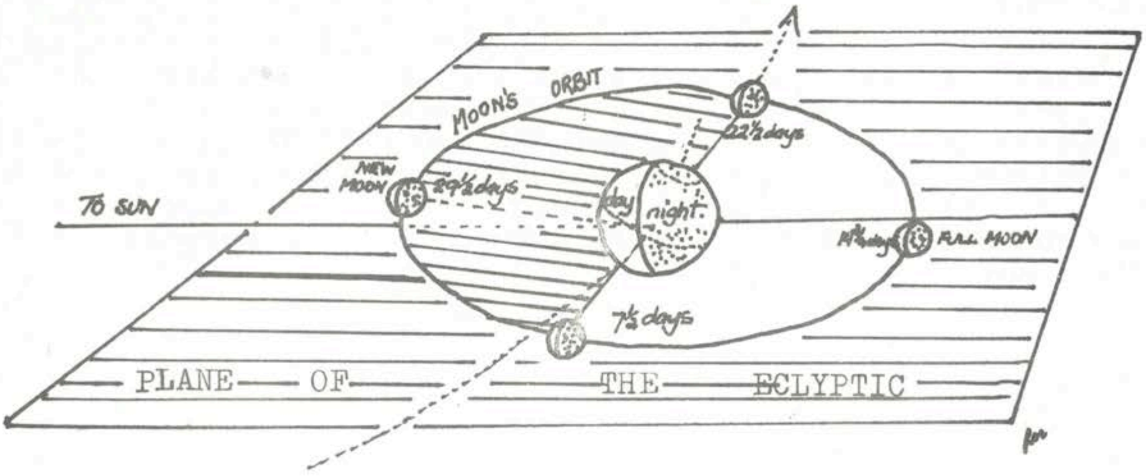


Fig. 4-3: The eclyptic of the Moon's Orbit

4.5 *Phases of the Moon*

As seen in your last Investigation, the moon is said to have various phases. The *SYNODIC* month begins with a new moon (see Fig. 4-1). Because the illuminated half of the moon faces entirely away from the earth, the moon would appear entirely dark to the observer on the earth except for a faint glow of light reflected to it by the earth. A new moon is seen about 3-3/4 days of the *SYNODIC* month because the sun's rays can then reflect off the moon's surface.

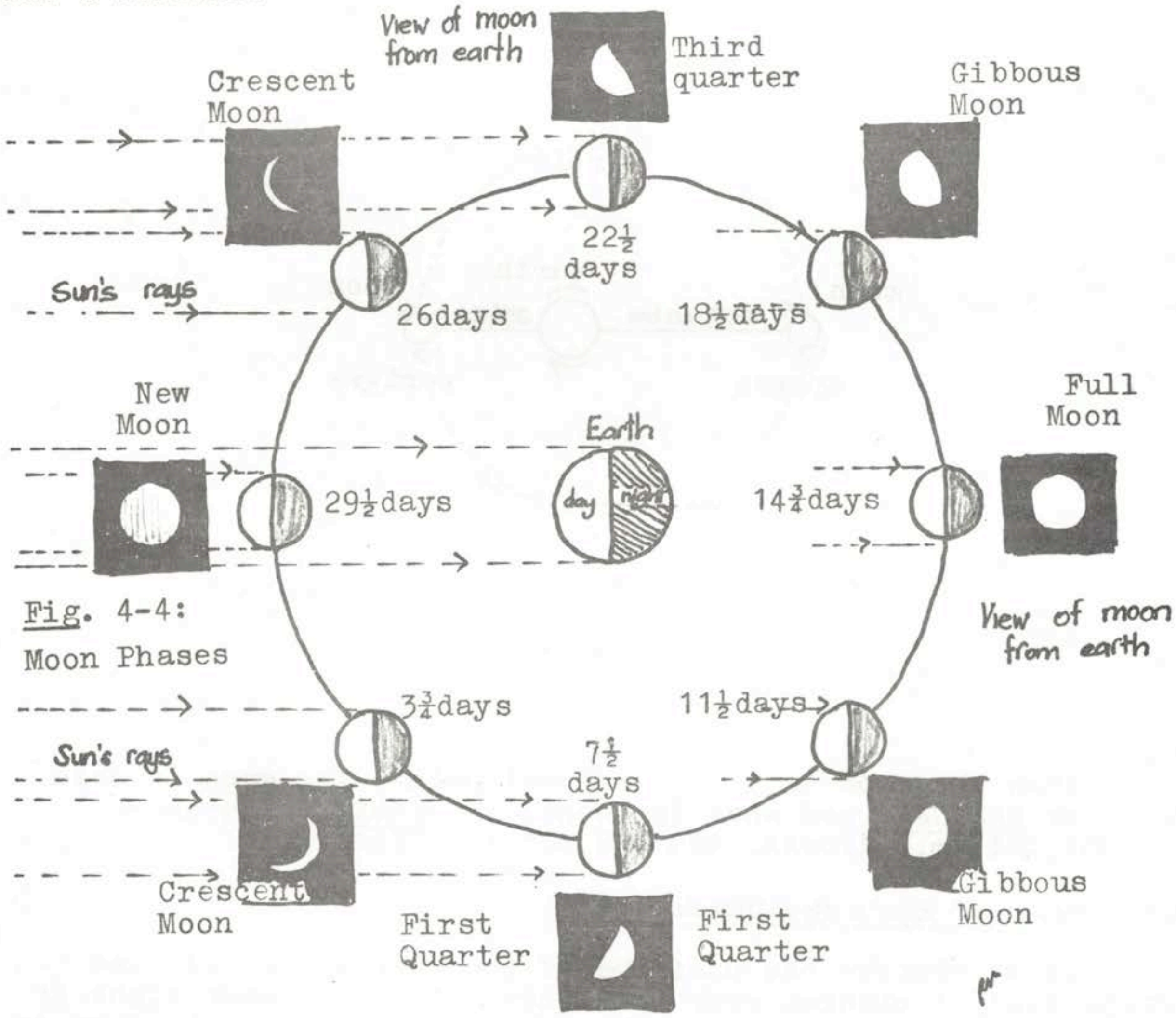


Fig. 4-4: Moon Phases

This is called a CRESCENT new moon. During the preceding 3 3/4 days the moon has dropped behind the sun in the sky about 45°, hence the crescent new moon rises in the eastern horizon when the sun has already reached a point in the sky about midway between the horizon and its new position.

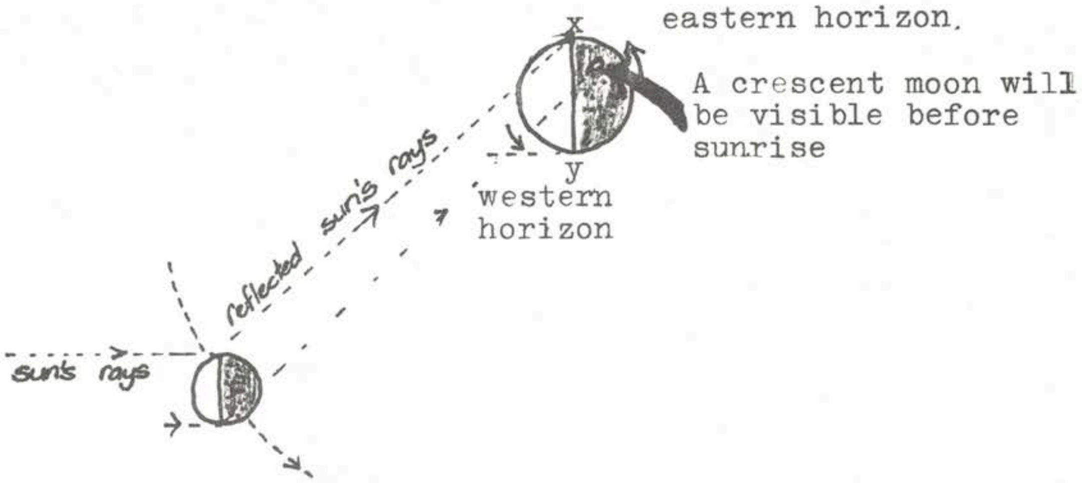


Fig. 4-5 The Earth-Sun-Moon System as seen from the North Pole. Sunrise is at (x) and Sunset is at (y)

The crescent moon follows the same general path as the sun, but is still shining low in the Western sky long after the sun has set.

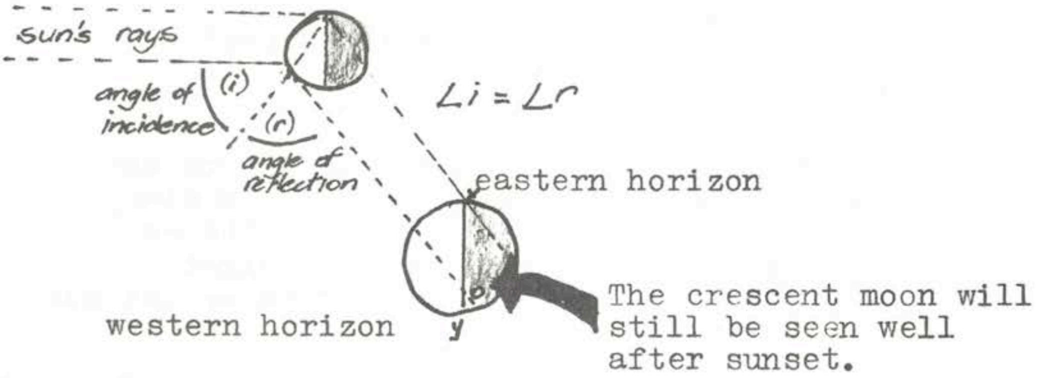


Fig. 4-6: After $7\frac{1}{2}$days have elapsed, Quadrature is reached.

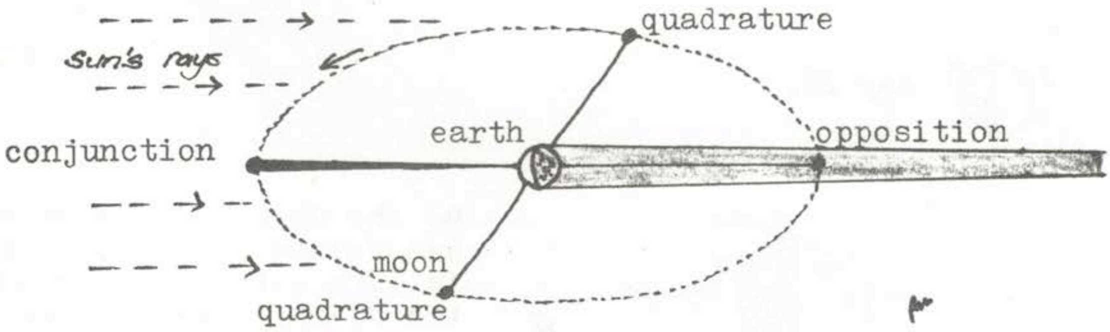
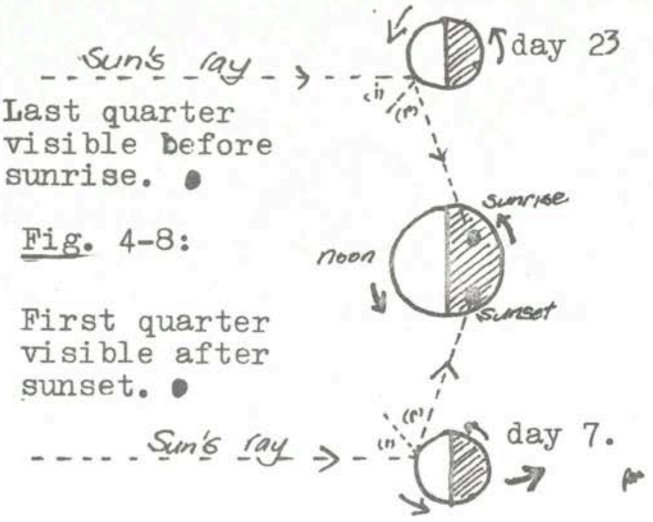


Fig. 4-7: These relationships among the Sun-Moon-Earth influence the height of the tide.

QUADRATURE means that the sun and the moon are so situated that there is an angle of 90° between the sun and the moon, ie. when the moon is at its first and last quarters.



Last quarter visible before sunrise. ●

Fig. 4-8:

First quarter visible after sunset. ●

Roughly speaking, the moon in this phase rises about the time the sun is in the noon position, and reaches its highest point in the sky when the sun is setting.

We assume that the sun rises at 6 am and sets at 6 pm as it would at the equinoxes, or at the Equator.

By the time the moon has travelled 3/8 of its orbit and after about 11¼ days, the moon is 3/4 illuminated. It is called a *GIBBOUS* moon.

When the moon is 14-3/4 days old in the *SYNODIC* north, it is on the opposition position (see Fig. 6-2), and is in full moon phase.

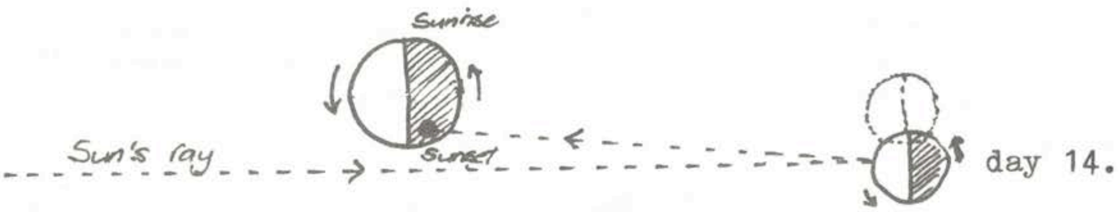
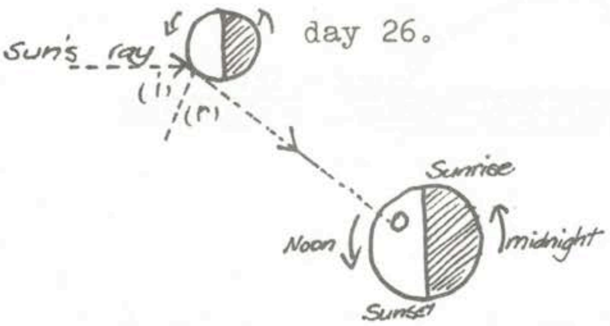


Fig. 4-9: Full Moon visible after Sunset. ●

The moon appears red at moon-rise due to the fact that the sun's rays are reflected through the earth's atmosphere. Because the moon and sun are on opposite sides of the earth, the full moon will be highest in the sky about midnight. If day and night are about equal length, the moon will rise as the sun sets, and will set when the sun rises.

The remaining phases of the moon are similar to those already described, except that they occur in the reverse order. One important difference is that the moon appears as if it were a mirror image of its corresponding phases of the first half of the *SYNODIC* month. By the time the phase of the old crescent moon is reached, 26 days have elapsed in the *SYNODIC* month and the moon will have lagged so far behind the sun in the sky that it seems, instead, to be travelling about 45° ahead of the sun.



By the 29th day the moon has fallen back to a place in line with the sun and the *SYNODIC* month draws to a close.

Fig. 4-10: Crescent Moon visible during the day. ○

4.6 *Rotation of the Moon*

If we photographed the moon continually over a year and compared the photographs, we would find that only 59% of the moon's surface is seen. This means that the moon rotates on its axis exactly once each *SIDEREAL* month of 27-1/3 days.

4.7 *Gravitation and Tides*

In 1686 a famous scientist, Sir Isaac Newton, published the Law of Universal Gravitation. Newton decided that every apple, every rock, every planet, every particle in the Universe, attracts and is attracted to every other particle in the Universe. The strength of the attraction depends on the masses of the objects and on the distance between them. The equation Newton gave for this force is:

$$F = G\frac{m_1 \ m_2}{d_2}$$

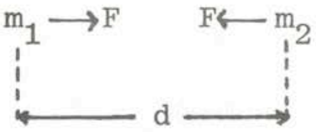
when F is the force of attraction between the objects

m_1 is the mass of one object

m_2 is the mass of the other

d is the distance between them

and G is a Constant = $6.67 \times 10^{-11} N.m^2/Kg^2$



Now, water being made of particles, will be attracted to the moon.

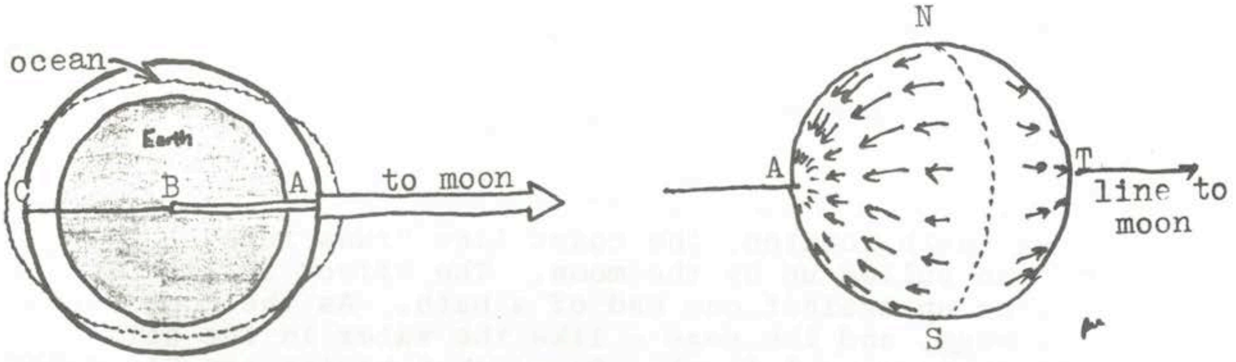


Fig. 4-11: Gravation and the Moon.

4.8 *Daily Tides*

Consider Fig. 8-1 and let us make the assumption that the ocean has uniform depth. On side A. the moon attracts the water toward it. As the earth spins, water on the other side is spun out by *centrifugal force* (much the same way as the clothes are spun out in a clothes dryer).

Let us go back to Investigation 4-1. Suppose that your graph looked like this. Sunrise was at 6 am and sunset at 6pm and that the moon did not move around the earth.

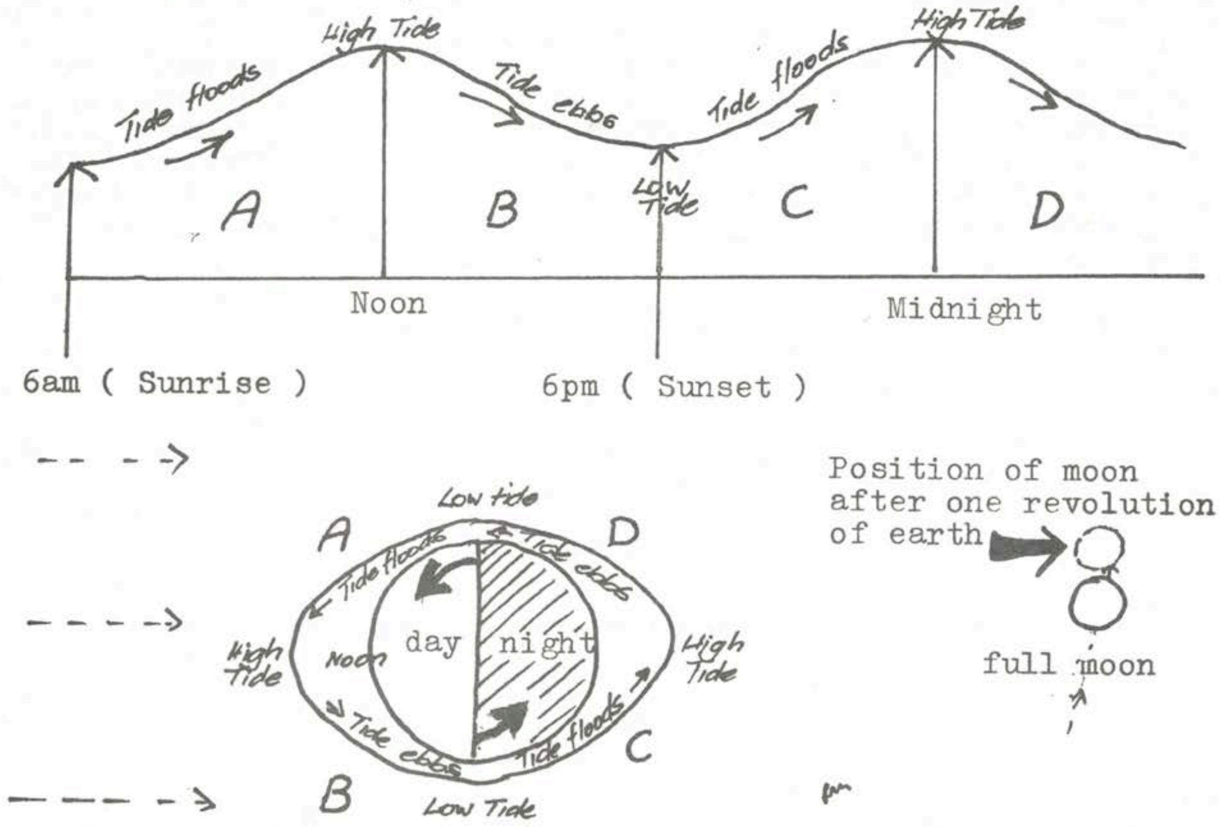


Fig. 4-12: Explanation of high and low tides.

As the earth rotates, the coast line "runs into" the humps of ocean pulled up by the moon. The effect is like that of water slashing up against one end of a bath. As the moon "sets" its pull lessens, and the seas - like the water in the bath - run back to their normal level. Some ocean basins are "in tune" with the moon, and so experience large tidal ranges (the difference between high and low tide), whereas others are completely out of tune, such as the Mediterranean Sea, which has a range of 24".

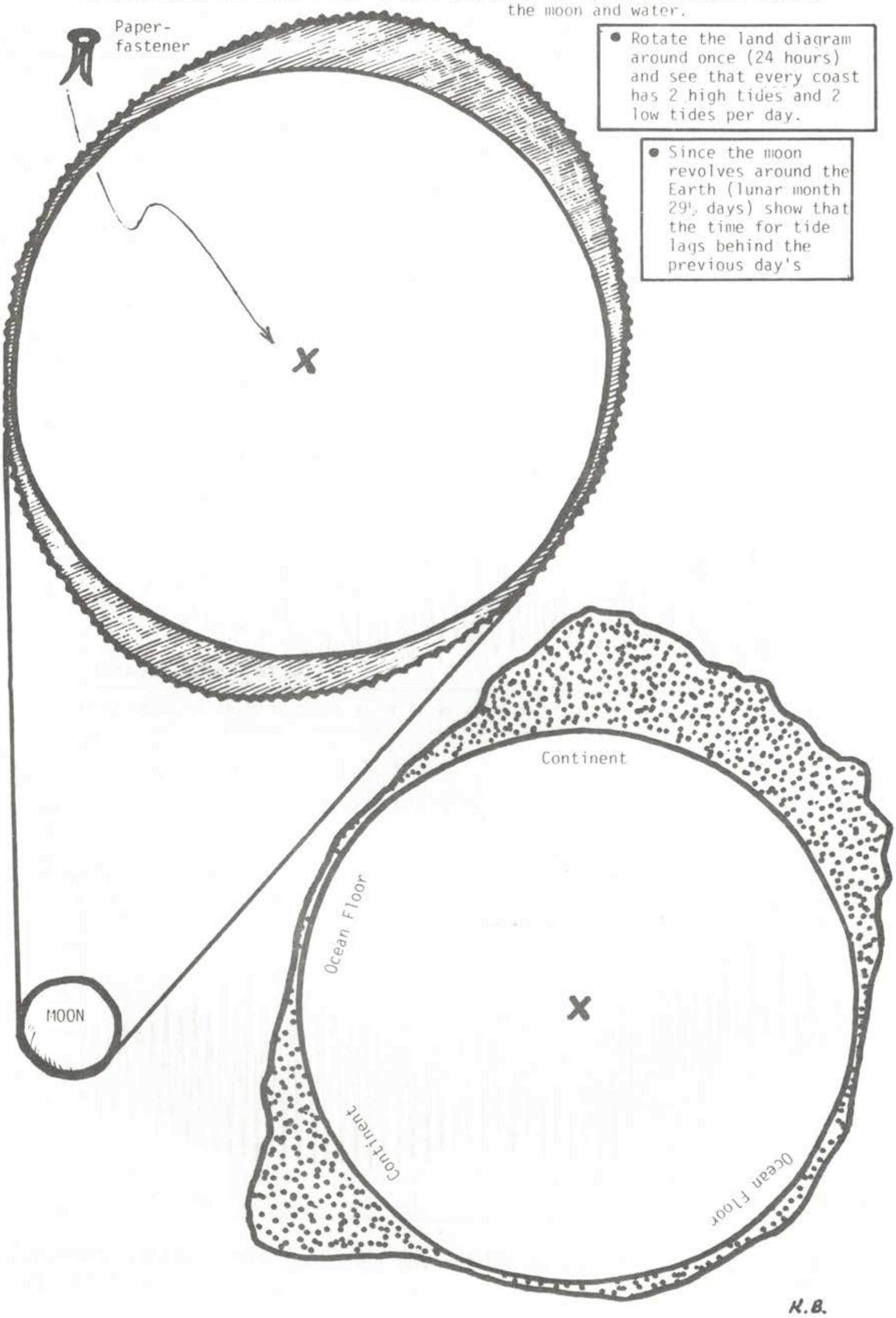
Investigation 4-2: Tide Models

THE TIDES

PASTE whole sheet on to stiff cardboard.
CUT out both shapes below around the outside heavy line. PUNCH a hole in the centre of each diagram, and JOIN with a paper fastener, so that the diagram showing the continents and ocean floor is free to rotate on top of the diagram showing the moon and water.

- Rotate the land diagram around once (24 hours) and see that every coast has 2 high tides and 2 low tides per day.

- Since the moon revolves around the Earth (lunar month 29½ days) show that the time for tide lags behind the previous day's



From, " Oceanography ", by R. Jenkin,
F.U.S.E. Australia, Comm. Gov.

In the last Investigation we saw that the land really moves into a body of water that is called the tide. Because the moon moves around the earth by the time the earth has made one revolution, the moon is now a little bit further around. (see Fig. 9-1). This accounts for the fact that the tides occur about every 6¼ hrs, *OR* there would be about 12-1/8 hrs. between two high tides.

But, why are the two high tides of different heights? (eg. look at the tide book for the year). You may notice that in Summer the highest high tide is during the day, whereas in Winter, the highest high tide is during the night.

Fig. 4-12: Summer and Winter Tides.

This raises the question of the effect of the Sun.

4.9 *Spring and Neep Tides*

In Investigation you discivered that the tide heights changed over the month. A typical Group would look like this:

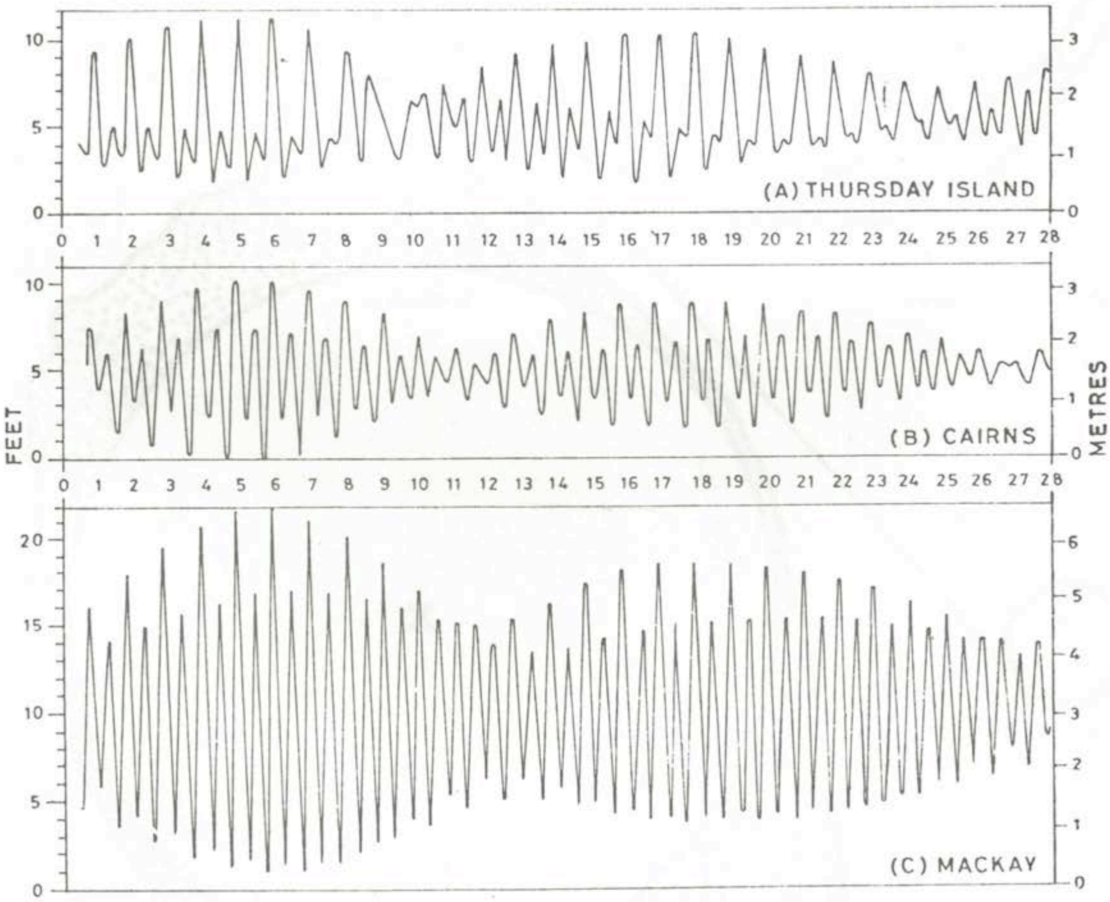


Fig. 4-13: Typical Tide variations over Qld. Coast. (after Maxwell)

What positions would the sun, earth, and moon have to be for the highest tide of the year? Check your tide book.

We can explain the difference in tide height by the diagram below:

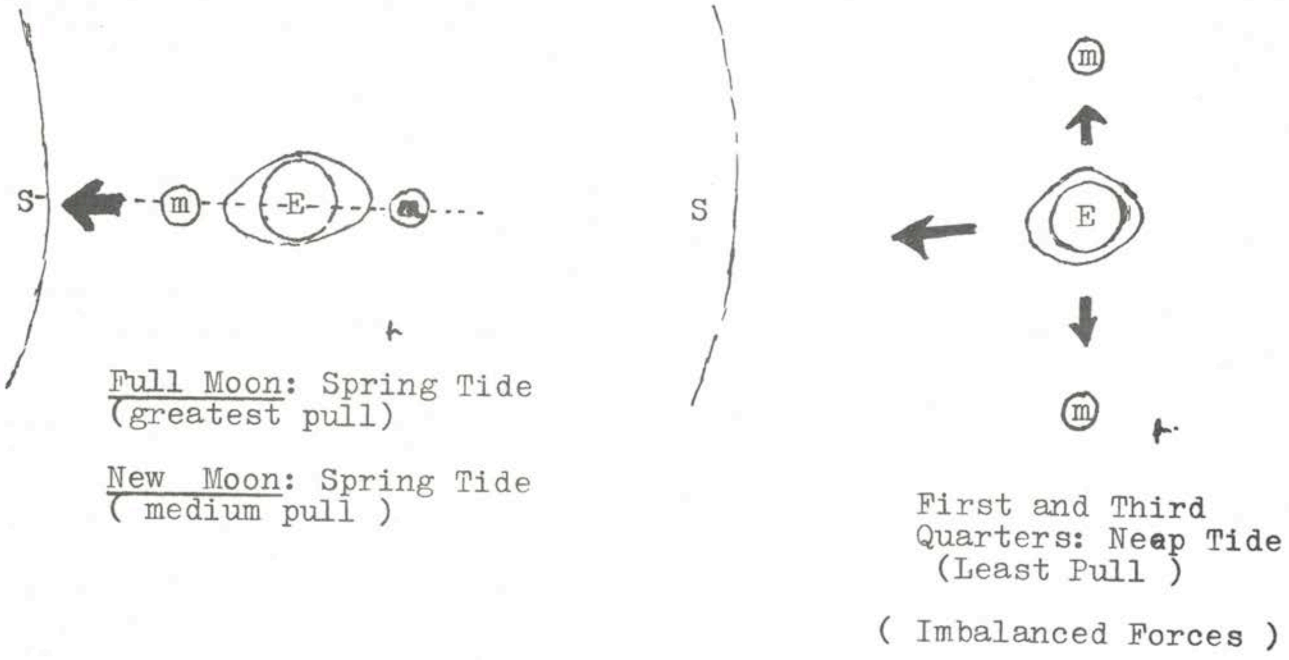


Fig. 4-15: Spring and Neap tides.

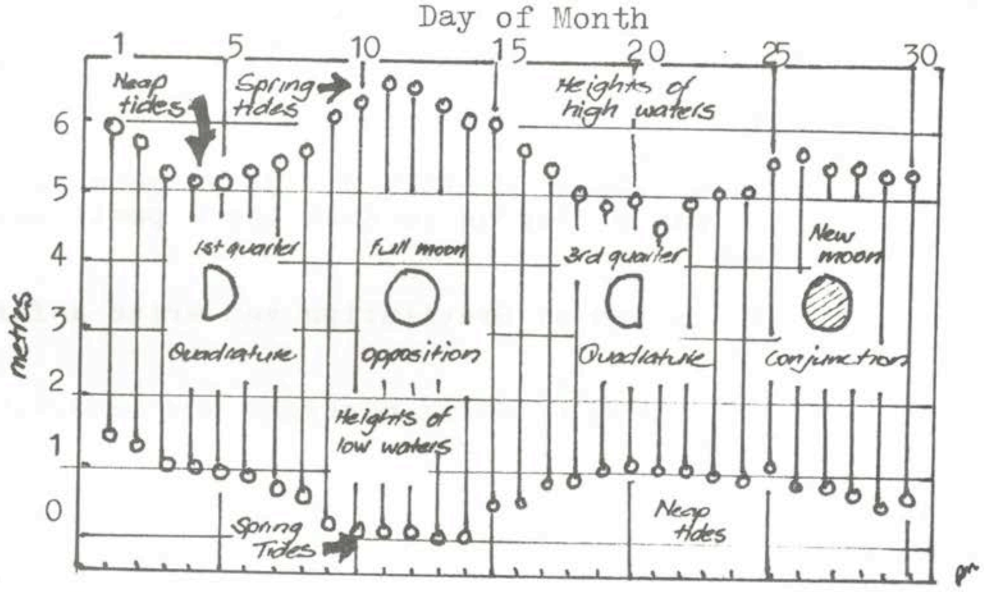


Fig. 4-16: Spring and Neep Tides over one month.

4.10 *River Tides*

Many rivers experience tides in their lower parts. This condition often results when the coast has subsided, or the ocean level risen. As the tide rises (or more correctly we move into the tidal bulge), a wave is generated which runs into the inner end. Rate of travel of this tidal wave depends upon the depth of water. It is expressed mathematically by the formula

$$v = 3.6 \sqrt{d}$$

When v = speed of the wave in knots, and d = depth in metres. River tides can sometimes be faster, so much so that in some parts of the world a wave can be seen. This is called a Tidal Bore. Some surfers can surf a Tidal Bore.

These tides are used in France to run Tidal Power Stations. The electricity generated is from a renewable source and could prove useful to solving some energy crisis problems. Find out more about this.

MAIN IDEAS

1. *TIDES* are the periodic up and down movement of the sea.

2. *TIDES* are caused by the dynamic interaction of sun, moon and earth.

3. *THESE FORCES* pull the water outwards in certain places and the earth spins into this water causeing a *"TIDE"*.

4. There are four tides each day. Each tide has a different height caused by different positions of earth and moon.

5. There are four tides over a month. These are *MEAN HIGH WATER SPRING (M.H.W.S.); M.H.W.N. (MEAN HIGH WATCH NEEP); M.L.W.N; M.L.W.S.*

6. *SPRING TIDES* are caused by the sun, moon and earth in line.

7. *NEEP TIDES* are caused by the sun and moon at right angles.

8. The tides vary over the year due to the changing positions of the earth around the sun.

REVIEW QUESTIONS

1. Draw diagrams which show - *THE MOON'S ORBIT AROUND THE EARTH, THE EARTH'S ORBIT AROUND THE SUN.*

2. Where is the moon at *APOGEE, PERIGEE?*

3. How long is a *SYNODIC* month? A *GIBBOUS* moon is how many days old? Draw a diagram to show the 2 positions of a *GIBBOUS* moon.

4. State Newton's Law of Gravitation and write a formula for it.

5. Why would the high tides at midnight and midday be different heights?

6. Why does Mackay have 6 metre tides whereas Brisbane only 2 metre?

7. What are *RIVER TIDES?* What is the speed of a wave in a 9m river?

STUDY ASSIGNMENTS

1. Obtain a Tide Book and find out how to calculate the tide height and time for in between predicted times.

2. What is the uniform System of Bouyage? In 1000 words explain why it is useful to mariners.

3. Make a poster on the International Code Signals

4. What is the Beaufort Winds Scale.

5. Why does the Mediterranean Sea have no tide?

6. Find out about *TIDAL POWER*. How is the energy converted to electricity? Where does the energy come from originally? Is it a non renewable source of energy?

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