GUIDELINES FOR MONITORING AND EVALUATING BEACH EROSION AND SHORELINE DYNAMICS

REPORT OF A TRAINING WORKSHOP TARAWA, KIRIBATI, 14-16 MARCH 2000

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ABSTRACT

The following is a transcript and a report of lectures/training delivered in Tarawa, Kiribati on *Guidelines for Monitoring and Evaluating Beach Erosion and Shoreline Dynamics*. The training/lectures are part of in-country training and capacity building on Coastal Processes.

These lectures were delivered between 14-16 March 2000, at the Otintai Hotel, Tarawa, Kiribati.

The lecture discussed the need for understanding beaches, beach dynamics and neashore processes within the framework of coastal hazards and risks. Erosion and erosion processes were discussed, as wells as the hydrodynamics aspects of nearshore environments.

Engineering in the coastal zone was presented, within the framework of the coastal project cycle. Examples of coastal engineering projects were discussed, with reference to current port and harbour development in south Tarawa and the Nippon Causeway.

In addition, coastal protection structures were examined in the field and issues related to the appropriateness of these were highlighted. Construction material used along the shorefront were discussed, in particular concrete and its performance in coastal environments.

Issues related to optimum coastal management and engineering were also discussed. A full list of up-to-date and state-of-the-art references on the subject is also given and is included in this report.

The following text discusses erosion, coastal risks, engineering along shorefronts, sea-level rise and coastal adaptation technologies and data-collection programmes and includes two (2) multi-media copies of the lectures delivered.

ACKNOWLEDGEMENTS

The participation and delivery of this training was facilitated by the *Commonwealth Secretariat (COMSEC)* and *South Pacific Applied Geoscience Commission (SOPAC) Secretariat.*

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Ms. Naomi Atauea, of the Ministry of Natural Resources Development, Tarawa, Government of Kiribati coordinated the training/lectures. Her assistance is gratefully acknowledged.

1.0 INTRODUCTION

1.1 General Comments

The following is a transcript and a report of in-country lectures/training delivered in Tarawa, Kiribati. The training was on *Coastal Processes* and formed part of SOPAC Task 99.025 objectives to deliver simple technical training to community leaders and local Government personnel in Kiribati.

These lectures were delivered between 14-16 March 2000, at the Otintai Hotel, Tarawa, Kiribati.

The lecture discussed the need for understanding beaches, beach dynamics and nearshore processes within the framework of coastal hazards and risks. Erosion and erosion processes were discussed, as well as the hydrodynamics aspects of nearshore environments. Engineering in the coastal zone was presented, within the framework of the coastal project cycle.

Examples of a coastal engineering project was discussed, with reference to current port and harbour development in Betio, the Nippon Causeway and construction of seawalls and coastal structures in south Tarawa, Kiribati.

Issues related to optimum coastal management and engineering were also discussed. A full list of up-to-date and state-of-the-art references on the subject was also given and is included in this report.

There were eighteen (18) participants at this course. Their names are as follows:

1. Utimawa Tinimarewe
2. Moata Takirlia
3. Tanaki Ruaia
4. Tehoaniman Thmuera
5. Takuia Namarou
6. Taabua Teremia
7. Kautu Temakei
8. Daufung Binoka
9. Teekoiti Tebwerewa
10. Terabuntaake Tetaake
11. Manikaoti Timeon
12. Riaua Kaeka
13. Taarite Teiaa
14. Naomi Atauea
15. Taebo Aravea
16. Taebo Nakebae
17. Maroiofi
18. Naomi Atauea

1.2The Training Programme

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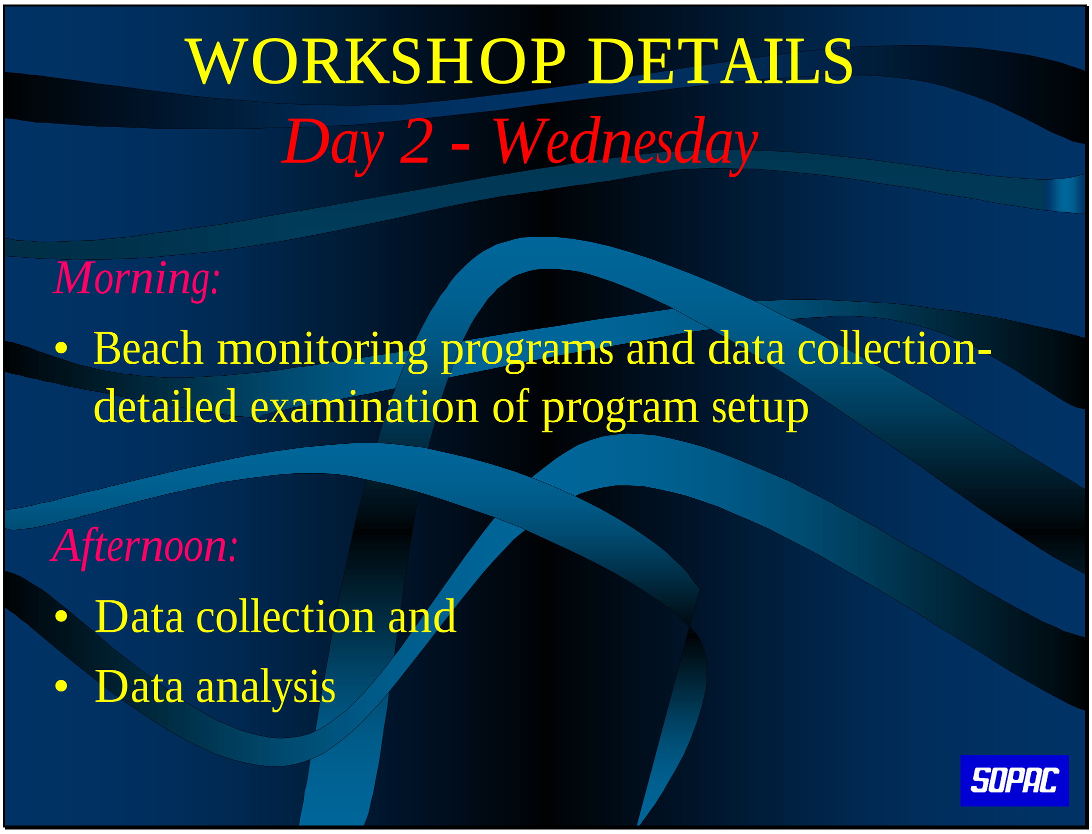

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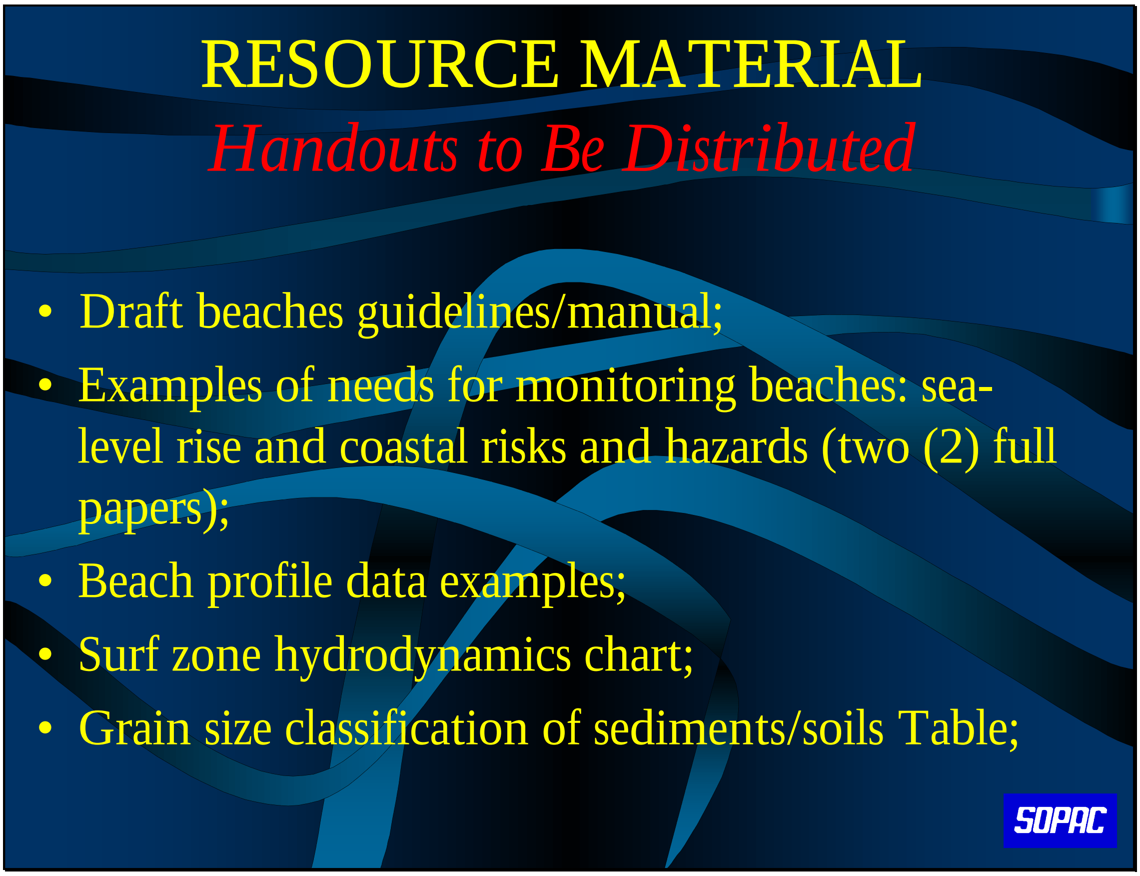

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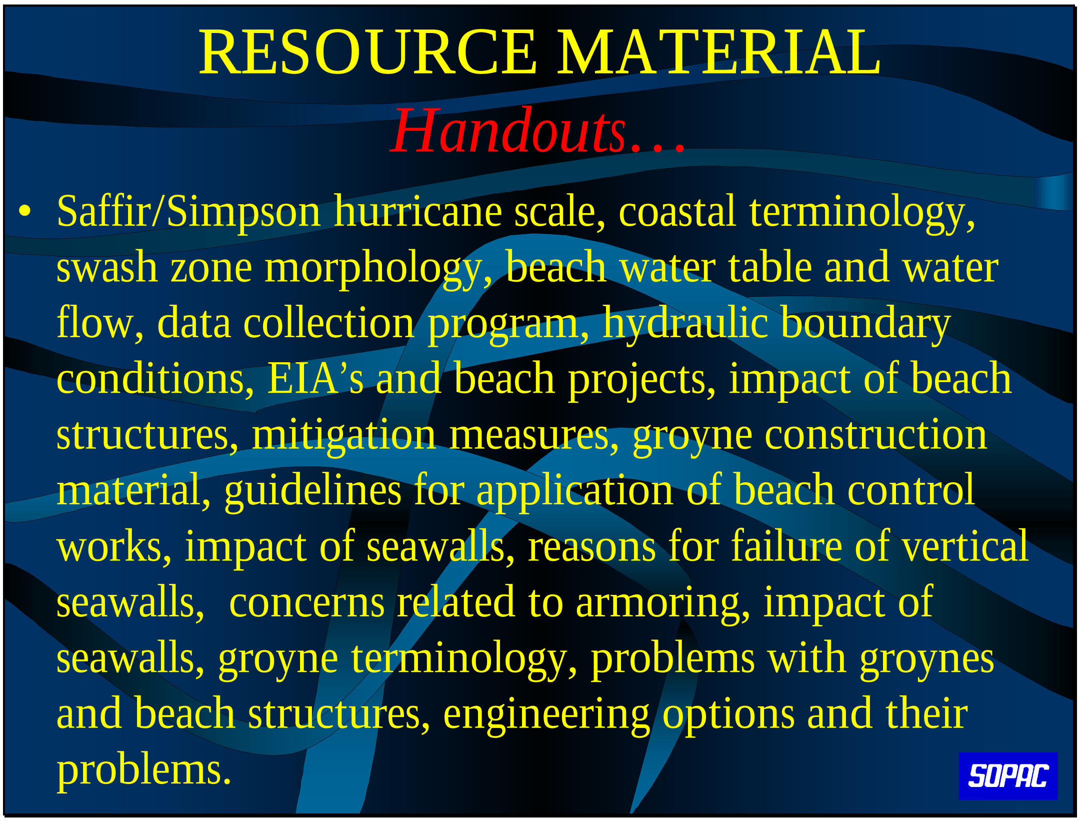

The following text discusses erosion, coastal risks, engineering along shorefronts, sea-level rise and coastal adaptation technologies and data collection programmes and includes two (2) multi-media copies of the lectures delivered.

2.0 BACKGROUND

The Pacific Ocean is dotted with thousands of coral atoll islands, many of which are inhabited along coastal strips and foreshore areas and used for various socio-economic activities, ranging from nearshore fishing to aggregate extraction.

In the region which is serviced by the South Pacific Applied Geoscience Commission (SOPAC), there are some sixteen (16) small island developing states (SIDS), occupying a total land area of about 560,000 km^2, in an ocean space of about 26 Million km^2. These countries are the Cook Islands, the Federated States of Micronesia, Republic of the Fiji Islands, French Polynesia, Guam, Kiribati, Republic of the Marshall Islands, Nauru, New Caledonia, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

Many of these SIDS consist of coral atoll islands and are geologically young, have low elevations above mean sea level and are generally flat. Elevation ranges from 1-5 metres above mean water level and it is possible to see from one side of the island to the other. This makes these islands entirely coastal, in terms of their influence by the sea, their geographical disposition and their relative relief.

As a result of their small land area, which can be between 0.0028 to 14.81% of their surrounding maritime area, many Pacific SIDS are exposed to large-scale regional oceanographic and weather phenomena. Frequent and annual events include cyclones and storms. These wreck havoc along the coastal and inland areas of many of these coral atoll islands, usually resulting in damage and destruction of coastal property, agricultural land and coastal engineering facilities. These also cause coastal flooding, coastal erosion/land loss and in some cases, loss of life. For many SIDS, the loss of lives can erode the skills base of the country and can prove to be a hindrance to economic development, causing persistent and undue poverty.

The scale of many natural hazards in PICs, are in many cases, several orders of magnitude larger than the size of individual islands and consequently, are capable of engulfing entire island states. A typical example was cyclone Cora, which caused considerable damage to infrastructure and property on Tonga in December 1998.

On account of their small size and geographic location within a large ocean space, Pacific SIDS are continually affected by large ocean waves. These cause continuous erosion of coastlines, even under normal wave climate. In addition, the frequency of oceanographic hazards, modification of coastlines for human habitation and the mining of aggregate along the shore make many of these islands and communities vulnerable to coastal erosion.

Oceanographic hazards and the possible threat of global warming and associated sea-level rise, in these low, small island countries, can also exacerbate the erosion hazard. Consequently, population and communities along the coastal fringes of these island states are vulnerable and face a possible threat to their very existence. These natural events and human occupation of fragile coastal areas can cause loss of scarce land, a culturally important and invaluable resource in many on these non-market oriented developing economies.

In it's 1997 flagship publication, *A Future for Small States: Overcoming Vulnerability*, the Commonwealth Secretariat, highlighted the fragility and susceptibility of many of these SIDS to natural disasters, including coastal hazards like sea-level rise and their associated effects, in particular, coastal erosion and coastal land loss. In turn, problems like coastal hazards, affect economic and social development in developing SIDS economies and make them economic vulnerable. This point was also highlighted and discussed in an Interim Report of a Joint World

Bank/Commonwealth Secretariat Task Force on *Small States: Meeting the Challenge in the Gobal Economy, 1999* and at the Commonwealth Heads of Government Meeting (CHOGM) 1999, Durban, South Africa.

The fragility and vulnerability of the PICs to coastal and sea level rise hazards have also been the subject of key thematic sessions at the recent Conference of Parties (COP-5) Meeting, Bonn, Germany, November 1999.

At the 10th Subsidiary Bodies on Scientific and Technological Advice (SBSTA), Bonn, Germany, June 1999, the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat also highlighted that coastal adaptation measures to sea-level rise are key issues which needs to be addressed, especially in the context of Small Island Developing States (SIDS). This sentiment was also echoed at the Alliance of Small Island States (AOSIS), July 1999 Meeting in Majuro, Republic of the Marshall Islands and the World Science Congress, Budapest, 1999 and by the UNFCCC Secretariat, Bonn, Germany.

To address current and future erosion problems and the possibly deleterious effects of sea-level rise in Pacific SIDS, requires assessment of site specific, local and regional environmental conditions. This also facilitates a rational approach to management of island resources.

It is also necessary to understand the factors, which influence erosion susceptibility on these islands through time and space. This can be achieved only through a systematic and integrated approach, with sound data collection, analysis and management exercises. Only then, can optimum environmental and sustainable development strategies be formulated. This approach also facilitates the development of appropriate coastal adaptation technologies for anticipated sea-level rise.

SOPAC, since it's inception in 1972, has worked on coastal and marine projects in the South and Central Pacific region. This includes work on coastal erosion and management, coastal natural hazards, bathymetry and hydrography and physical oceanography. In fulfilment of its mandate, to provide technical expertise and advice to Pacific Island Countries (PICs) on these and related issues, SOPAC has completed many projects in these technical areas, to address development initiatives of PICs and fill data gaps This is exemplified in the range of projects which are included in its current fiscal year's work programme. This includes projects on the assessment of the vulnerability to sea-level rise, assessment of shoreline change, assessment of coastal adaptation strategies for anticipated sea-level rise and evaluation of aggregate potential.

For many SOPAC member countries, technical know-how is generally unavailable, while technical guidelines and codes of professional practice are lacking. This lack of information can seriously impair effective management of coastal resources within PICs. In addition, lack of a sound skill base handicaps poverty alleviation and social and economic reforms and development.

By providing timely and technically-sound advice, SOPAC is able to contribute to the development of the skills base within countries and the Pacific region, paving the way for optimum management of island resources in Pacific SIDS, thereby contributing to the social and economic development of the region.

This project document, and the technical guidelines contained within, provides a sound base for the transfer of coastal technology and technical skills to island residents. This project is based on a coastal training module for Kiribati.

3.0 SCOPE OF THE TRAINING - SKILLS FOR DEVELOPMENT

To address the coastal erosion concerns and management needs of Pacific SIDS and AOSIS members, it is first necessary to evaluate the existing nature of the coastal environment.

As mentioned earlier, for many Pacific SIDS and SOPAC member countries, technical know-how is generally unavailable, while technical guidelines and codes of professional practice are lacking. In many cases, where these information do exist, they are sometime too technical for the general user, with responsibility for various aspects of the coastal environment, while in some cases, information may be over simplified.

Empowerment, by transfer of technical skills is one means of addressing national environmental problems and development issues in-country. To address this skill deficiency, a project was formulated by SOPAC Secretariat, with funding from the Commonwealth Secretariat (COMSEC) under the Commonwealth Fund for Technical Co-operation (CFTC) and the Government of the United Kingdon (UK) under the UK Small Grant Scheme to prepare guidelines for the collection, analysis and management of data on beaches, with emphasis on the effective management of island (= coastal) resources.

These guidelines is one of the outputs from this project. The target audience is the group of Government professionals, working in the various marine resources, natural resource, environmental and geological departments and environmental protection agencies in SOPAC small island developing countries with responsibility for the coastal and marine environments.

The content of the report is technical, but not complex nor over-simplified. It caters for the technician and non-specialised and/or beginning professional. It presents technical information in a logical and simplified format, with a focus on simple and important technologies and principles, which can be easily assimilated by the target audience. Simple, but practical and technically sound methodologies are also presented and discussed, to address the needs of personnel who may not have access to specific or complex, expensive and inaccessible monitoring equipment.

Information on more specialised technical evaluation methodologies, hydrodynamic boundary conditions, design criteria or risk evaluation methodologies, on any of the subjects described in the subsequent text, is available by contacting the author at SOPAC Secretariat, Fiji at, www.sopac.org.fj or rossi@sopac.org.fj

4.0 SOURCES OF INFORMATION

The ideas and rationale for these guidelines are based on the author's experience in the PIC's and in other SIDS in other regions of the world. This also stems from numerous discussions between the author and Governmental agencies throughout the SOPAC Member Countries.

Discussions were valuable with government departments in the Federated States of Micronesia (FSM), including the States of Yap, Pohnpei, Chuuk and Kosrae and island residents in more than twenty-five atoll islands in the FSM territorial waters.

In addition, valuable discussions were held between SOPAC and other Government representatives of Kiribati, Republic of Fiji Islands and the Cook Islands, on the need for these types of technical guidelines.

The technical material presented is based on the author's professional experience and consultation with state-of-the-art professional material available in the published literature. These literature, are cited at the end of the text, and for the keen and enthusiastic reader, should provide ample and valuable further reference on this and related subjects.

It is not the intention of the author to provide an exhaustive list of methodologies in these guidelines, but to provide representative and appropriate examples, which are valuable and useful within the framework of project development in Kiribati.

5.0 UTILISATION OF BEACHES AND THE COAST

Beaches and the shorelines in the PICs are used for a variety of purposes, ranging from social, recreational to industrial activities. The relatively large ocean and maritime space in each of the PICs makes it impossible to develop without affecting (positively or negatively) on the coast and shorefront. For that reason, shorefront and coastline development must be pursued in a carefully planned manner, so as to minimise negative impact of development activities.

Some of the uses of shorefront and the beach environment[1] in PICs include the following:

1. Mariculture (pearl and shellfish) e.g. in the Cook Islands,
2. Subsistence reef fishing, e.g. in all PIC's,
3. Fill sites, e.g. in mangrove systems throughout the PICs,
4. Liquid waste (effluent) disposal, e.g. in industrial areas like Lami, Fiji Islands,
5. Maritime and land defence, e.g. Fiji Navy, FSM Patrol in Kolonia, Pohnpei,
6. Recreation and tourism development, e.g. tourist resorts like Sheraton's Denarau Island Resort in Fiji Islands,
7. Land reclamation, fill and housing development, e.g. in parts of almost all mangrove areas throughout the PICs, like in Kosrae and Yap States, FSM,
8. Construction of cooling water inlets and outlets e.g. Nauru Power Facility, Nauru,
9. Construction of sewage outfalls/outlets, e. g. on the west coast of Nauru,
10. Construction of tidal inlets and river-mouth engineering works, e.g. Rewa River, Fiji,
11. Construction of coastal protection structures like seawalls, groynes, revetments, breakwaters, gabion baskets and bio-engineering protection, e.g. generally common throughout the PICs (Figures 5.1 and 5.2),
12. Construction of promenades and infrastructure facilities, e.g. coastal roads in Nauru, FSM, Fiji, Kiribati, Cook Islands and Solomon Islands,
13. Construction of jetties, boat channels and mooring facilities, e.g. Honiara, Solomon Islands and Port Vila, Vanuatu,
14. Construction of industrial and recreational ports and harbours (commercial ports and yacht clubs),e.g. Suva Yacht Club, Fiji Islands,
15. Construction and laying of undersea telecommunication cables, e.g. Cable and Wireless undersea fibre optic telecommunication cables, Laucala Bay, Fiji,
16. Construction and laying of pipelines for fluid transfer (oil and gas, water, industrial products and waste), e.g. Vuda Point, Fiji Islands and Kolonia, FSM,
17. Construction of residential and commercial buildings, e.g. throughout the PICs,
18. Marine aggregate[2] extraction (sand, gravel, boulders and coral-mining), e.g. throughout the PICs,
19. Onland quarry operations, e.g. Vanuatu, Fiji Islands and FSM,

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[1] The *beach environment* includes the area occupied by the back-reef, lagoons, adjacent mangroves and beach, including the back-beach area or landward limit. It is interpreted as the area between the high water mark and the reef crest, since that area is a complete system (nearshore or littoral zone) to which the *physical beach* belongs or is a sub-set of.

[2] *Aggregate* is the term used to describe various types of natural construction/civil engineering material of varying dimensions and form factors. It is a collective term, and should not be confused with gravel, as it is synonymous with in the Pacific region. Consequently aggregate, refers to all - sand, gravel, cobbles and boulders (of all sizes). Gravel is a type of aggregate. In most engineering literature, aggregate is also classified under the term, geomaterials or natural earth (geo) materials.

20. Metalliferous mining and hydrocarbon exploration and production, e.g. Papua New Guinea,
21. Agriculture and forestry, like timber and coconut production, e.g. in Fiji Islands and the Solomon Islands,
22. Protection and natural resource conservation (marine parks and protected areas), e.g. in New Caledonia and French Polynesia.

Some of these activities and uses of the coastline and shorefront will now be discussed in further detail, especially as it relates to shoreline monitoring and beach management. Human modifications of the natural coastline will be highlighted, as issues related to optimum management of the system.

Figure 5.1. Breakwater construction in Bairiki, Kiribati.

Figure 5.2. Seawall construction in Tarawa, Kiribati.

5.1 Beach Sand and Gravel Mining

Sand and gravel mining from a beach or shorefront and in back-reef lagoons usually presents itself as an attractive and cheap source for building materials. While in many cases it is so in PIC's, the environmental and engineering problems associated with its extraction are numerous, not to mention the immediate erosion of beaches and land during high water wave attack.

In PICs, sand is mined in all of the countries, especially the small atoll reef islands, where the reserves and supply of building aggregate is scarce. This sand, however, is part of the dynamic, natural coastal process in the littoral or nearshore zone.

Taking away sand at one location (Figure 5.3) can, and usually will, cause erosion at another location, usually downdrift of the extraction site. Other possible sources of sand have to be considered, e.g. from a nearby inland or offshore accretion sites.

Figure 5.3. Beach sand mining in Tarawa, Kiribati.

In cost comparison between the various sources of sand or gravel, not only are the costs of extraction, transportation and processing of the aggregate needs to be taken into account, but also, the costs of reducing or preventing erosion along the said coast (due to exacerbated erosion caused by mining). In addition, are the costs incurred during repair or replacement of infrastructure and domestic facilities which collapse and are washed away by waves because of mining activities. Only then, can a proper cost-benefit analysis be obtained for alternative options and sources of material.

This means that always some investigation/s into the availability of sand and gravel and the coastal hydrodynamic processes of the area will be necessary, in order to reach a decision where the sand should be sourced from. In addition, an environmental impact assessment should also be conducted to assess options before proceeding to mine the resource.

Basically sand mining should only be allowed at accreting coastlines where there are no downdrift coastal erosion or littoral problems. Where mining is allowed, there should also be monitoring guidelines for the activity to assess and remedy any negative impacts.

5.2 Coral Reef Mining

Coral reef mining, has for many years, been the main source of construction aggregate for the building industry in Pacific Island Countries (PICs). In coral reef and atoll environments, like those in the Pacific, mining of reef carbonates and extraction from storm ridge deposits, carbonate sandbanks, coral heads, reef rubble and reef sands and gravel is a huge economic activity.

Marine carbonates are mined from reef crests, back-reefs and lagoons, in water usually less than 10 m deep (Figure 5.4). Common species of corals, which are mined, are *Montastrea spp.*, in addition to *Acropora spp.*, and *Porites spp.*

Figure 5.4. Reef flat mining of sand and gravel, Tarawa, Kiribati.

Finely abraded gravel and sand are mined from shallow lagoons, and in commercial quantities. These finer materials contain many branching corals, especially *Acropora cervicornis*, Mollusca, benthic foraminifera, *Halimeda spp.*, *Rhodophyta spp.* and Echinoderm test fragments.

Much of this mining satisfies the demand for building aggregate, especially for domestic housing, which has evolved from the traditional thatched and palm dwellings to concrete and mortar structures. In addition, much aggregate is required for the commercial building industry, and for construction of critical facilities, like airports, roadways and bridges.

With changing societal trends in the region, which show a departure from traditional (bures and canoe houses) building techniques to more concrete and mortar structures, the demand for new homes, constructed facilities and civil infrastructure increases the demand for building aggregate. Consequently, there is a corresponding increase in mining of coral reef communities to satisfy this demand.

Field investigations in Pohnpei, FSM, have revealed fifty-one (51) reef mining sites, of which forty-seven (47) are dredge sites, with 13 recently active areas. These sites represent dredging and mining activities over the past two decades. Of the fifty-one (51) dredge sites, seven (7) are in the Nan Madol area, an archaeological treasure designated a United States National Historic Landmark and nominated to the World Heritage Convention of United Nations Educational Social and Cultural Organisation (UNESCO). Three (3) of these sites are actively dredged.

The mining of reef carbonates have caused many coastal environmental problems. Of these, coastal erosion and land loss are key impacts, due to the removal of natural coral barrier protection, by mining. Dredging results in significant deepening of nearshore bathymetry, altering hydrodynamics and causing the propagation of larger waves along shorelines. These cause significant scouring and coastal land loss, threatening coastal infrastructure and increasing erosion risks to coastal communities.

Dragline and clamshell dredging and mining using front-end loaders, which is common in FSM, also causes death of benthic reef dwellers, including non-calcareous biota, cause smothering of coral and decrease fin and shellfish population. These reduce biological productivity and affect subsistence fishing activities of the local population. The local fisheries authorities, in Pohnpei, have noted this decrease in recent years.

It is significant to note, that the use of modern and Holocene marine carbonates in construction, is also not without construction and engineering risks. These aggregates contain harmful chloride and sulphate ions (common and in high concentrations in seawater). These ions can cause chemical reactions with cement and steel (in steel-reinforced concrete), especially where concrete is mixed using normal/ordinary Portland cement (ASTM Type-I designation). Chloride ions also decrease the passivity of steel in concrete and increases the susceptibility of steel rebars (reinforcing bars) to corrosion in steel-reinforced concrete. This type of corrosion of rebars cause swelling of the outer corroded films of the rebar, by as much as 400 %. Such swelling results in high tensile stresses in casted concrete, which because of its low tensile strength cracks. Tension cracks produced by this process cause further ingress of moisture and cause further oxidation of rebars and more cracking. In addition, sulphate ions also react with calcium rich cement and leads to precipitation of expansive sulphate called ettringite. This also leads to swelling within the concrete and tensile stresses, also causing cracking.

Chemical reactions, like those described above, in this high pH and moisture-rich environment can result in deterioration of cement-aggregate and steel-aggregate-cement binding reactions in concrete. This can ultimately lead to collapse of the concrete structures. Steel-reinforced concrete casted with these aggregates, usually show ferrous oxide and hydroxide staining, due to rapid oxidation of the steel, on cracking of the concrete, and due to chemical attack by chloride ions usually present in the aggregate.

In addition, modern reef carbonates are usually of high porosity, with high void ratio, of low dry and wet density, with low specific gravity (less than 2.60) are of low compressive and impact strength and performs poorly under static or dynamic loads. Consequently, these geomaterial are of generally low quality for the construction industry. Where modern day marine carbonates must be used, due to the unavailability of alternative sources of geomaterial or engineered composites, amendments to and modifications of design criteria will have to be prescribed and made. This will facilitate the optimum performance of constructed facilities built with these aggregates and therefore, reduce the risk and likelihood of their failure through engineering time.

However, the range of environmental, engineering and cultural problems associated with reef mining can be addressed in some PICs, by seeking alternatives to coastal reef mining and by managing extraction in less sensitive habitats. Recent studies have shown that onshore quarrying of on-land volcanics can supply large volumes of superior quality aggregate for the construction industry in Pohnpei and FSM and therefore, this can be one viable alternative to mining reef carbonates.

Coral mining can also be attractive for cement raw material, e.g. Fiji Industries, Fiji Islands. The coral reefs however, form a natural beach protection and are analogous to coastal engineering equivalent of the submerged breakwater. As with a submerged breakwater, these reefs dissipate wave energy when offshore deepwater waves break on the reef crest, causing smaller waves to be propagate into the littoral zone. Once removed, this wave energy dissipater is “turned off” and erosion in the littoral zone starts or is exacerbated, which is usually manifested as beach erosion.

Tourist beaches behind coral reefs, can become narrower or vanish completely. Stability of hotels, residence and infrastructure near the coastline can also be endangered.

5.3 Shorefront Development

In PICs, building on the edge of the water or land is common. Since historical times, the seas and oceans have been of considerable value, as a source of food and livelihood for Pacific islanders. However, with steady population increase over the years, and with the corresponding demand for housing and infrastructure, there is further development along shorelines. Much of this development is again, at the water’s edge.

With social and economic development, many industries have developed. Tourism is one of these and is quite a big industry in the Pacific. With most of the land being owned by native island communities and the extended families, much private sector development is targeted at the shorefront, where reclamation, fill and development are feasible options to pursue for “land acquisition.” While these developments brings economic boom and social amenity to island nations, there are many deleterious impacts of building along the shorefront in small island states.

If you intend to build near the coastline, you should be aware that the position of the coastline is not fixed and is constantly changing. This is due to the dynamic nature of the coast, which is directly influenced by constantly changing hydrodynamic and morphological processes within the littoral zone. As processes occur, so they alter shoreline morphology and subsequent erosion and accretion patterns along the coast. While attempts are made to predict this change, it is significant to note, that every simulation is for a fixed set of parameters for a given time and three- or two-dimensional space, while those parameters in the natural open (system) environment are not.

Shorefront developers therefore, should also be reasonably sure that during the lifetime of their development (e.g. 10, 25, 50 or 75 years), no erosion problems will threaten the viability of the structure or facility. For that to be the case in development, structures should be set-back from the water edge, to a distance at least equal to the expected retreat of the coastline during the lifetime of the facility. If not, extra maintenance costs will have to be budgeted for protection of the facility against erosion (Figure 5.5).

In many engineering projects, this maintenance aspect is not usually considered, while anticipated erosion at the constructed facility is not catered for. Post-construction maintenance of the constructed facility is usually down played, even in a high-risk environment like the ocean. Usually, such follow-up is only entertained when damage or loss of the service of the facility occurs.

Figure 5.5. Failure of shorefront buildings due to wave action, Tarawa, Kiribati.

5.4 Inlets and Outlets/Outfalls

When making a seawater inlet, you should be aware that a coast is always a dynamic phenomenon. The inlet should be constructed at a location where there is no excessive erosion or sedimentation. Erosion can endanger the stability of the inlet, while sedimentation can block the water inlet.

The same is true for an outlet, but an extra complication is water quality. When the outlet is a sewer for municipal or industrial effluent, the sea can be polluted. This can be detrimental to fishery interests or to the bio-diversity in the region, but it can also contribute to coastal erosion in the long term. This is the case where coral reefs form a natural protection. These reefs can die because of pollution and lose their protective ability.

5.5 Cutting and Clearing of Mangroves

Mangrove forests or mangals[3] in PICs are cut or wood for timber or fuel and to make fish traps and even buildings. In some countries, like the FSM, mangroves are cut to provide space for aquaculture, like fish farming

But in all cases where a mangrove forest is removed, one should be aware of the consequences. First, mangroves can act as coastal defence and provide a buffer zone for the land against the harsh seas and waves. During storms and cyclones, these forests act as windbreaks and barriers and dissipate wave and tidal energy approaching shore.

Mangrove forests also act as filter for the sediment and biological waste products, being discharged by rivers to the coast. Cutting away a forest will then lead to more sedimentation at other locations, possibly having a negative influence on fishing grounds or corals.

Mangrove species include those of the *Rhizophoraceae* family. Mangrove systems in Fiji are used as important fisheries, reclamation and construction sites, a sources of firewood, housing material, timber, conversion to agricultural sites and as sites for urban development. In addition, they provide natural coastal protection against storms, and trap sediments from fluvial and littoral systems.

Estimates of mangrove systems for Fiji based on 1:50,000 aerial surveys, by the Lands Department was 45,288 ha (Watling, 1985). Studies by Watling (1985), using 1: 20,000 aerial photographs showed that the total mangrove area was 11% less than that estimated by the Lands Department or 40,306 ha.

The total mangrove area for Viti Levu was estimated at 23,463 ha, about 58% of the total area for the Fiji Islands (Watling, 1985). The larger systems are located in Ba, Rewa and Labasa Delta areas, with 3,714 ha, 5,130 ha and 1,473 ha respectively. These three systems represent about 40% of the mangrove area for Viti Levu.

In addition, much mangrove have been reclaimed for sugar cultivation (1,292 ha in Labasa) and construction activities, e. g. 750 ha in western Viti Levu (Watling, 1985). Watling (1985) also note that Lands Department indicated that at September 1987, 2,457 ha were reclaimed or 6% of the original area. Watling also indicated that at 1985, the remaining mangrove area for Fiji was approximately 38, 543 ha.

In terms of economic evaluation of mangal systems, Watling (1985), based on data from the Fiji Islands Fisheries Department, note that mangrove associated fisheries provided subsistence in the order of 8.76 Million kg of fish. This was 60% of the total subsistence fisheries for Fiji with a market price of FJ $17.52 Million in 1983. For 1983, the total mangrove fisheries in Fiji was estimated to have a total economic return of FJ $ 21.8 million, with mangrove contributing FJ $566/ha.

5.6 Mariculture

Ponds for seafish or shrimp are located in coastal areas, often in areas with mangrove forests. The

[3] *Mangals* is use to denote mangrove trees and other swamp or brackish water plant and animal species that may be associated with the mangrove wetlands. Mangals is a collective term, while mangroves is a type of plant group found in the mangal environment.

combination of mangroves and shrimps is quite natural, shrimps feed on the waste products of the trees. A very high intensity of shrimps, however, causes disruption of the ecological equilibrium. Pollution of the water and diseases of the shrimp are the result. Also the cutting away of the mangroves to make room for shrimp ponds, can cause several negative effects and may lead to additional work.

5.7 Construction of Coastal Protection Structures – Seawalls and Groynes

A groyne or breakwater perpendicular to the coast can be constructed to create quiet water (protection against waves) or to make a berthing or mooring for shipping or a runway for aircrafts (Figure 5.6). This can have an effect on the coastline, especially on a sandy coast.

There is a continuous transport along the coast of sand and the structure means interruption of this transport.

This will lead to accretion of the coast at one side and erosion at the other side (Figures 5.6 - 5.8). This means that always some investigation into the local sediment transport should be done before such a structure is constructed.

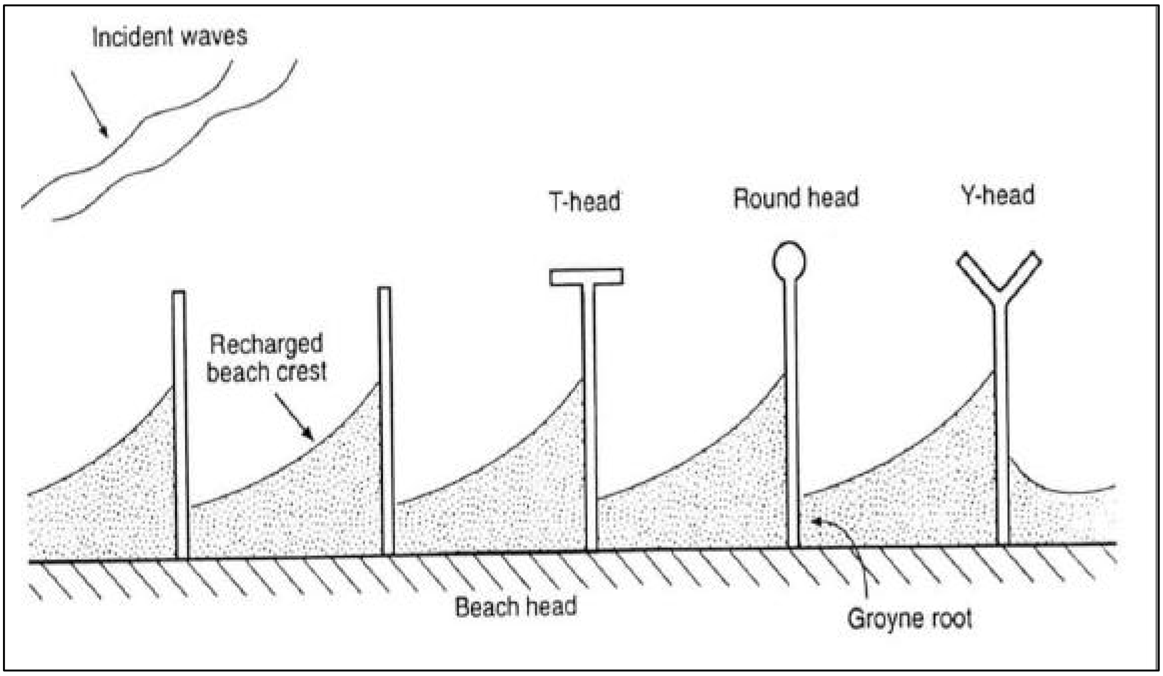


Figure 5.6. Groyne designs showing erosion on the downdrift side and accretion on the updrift side.

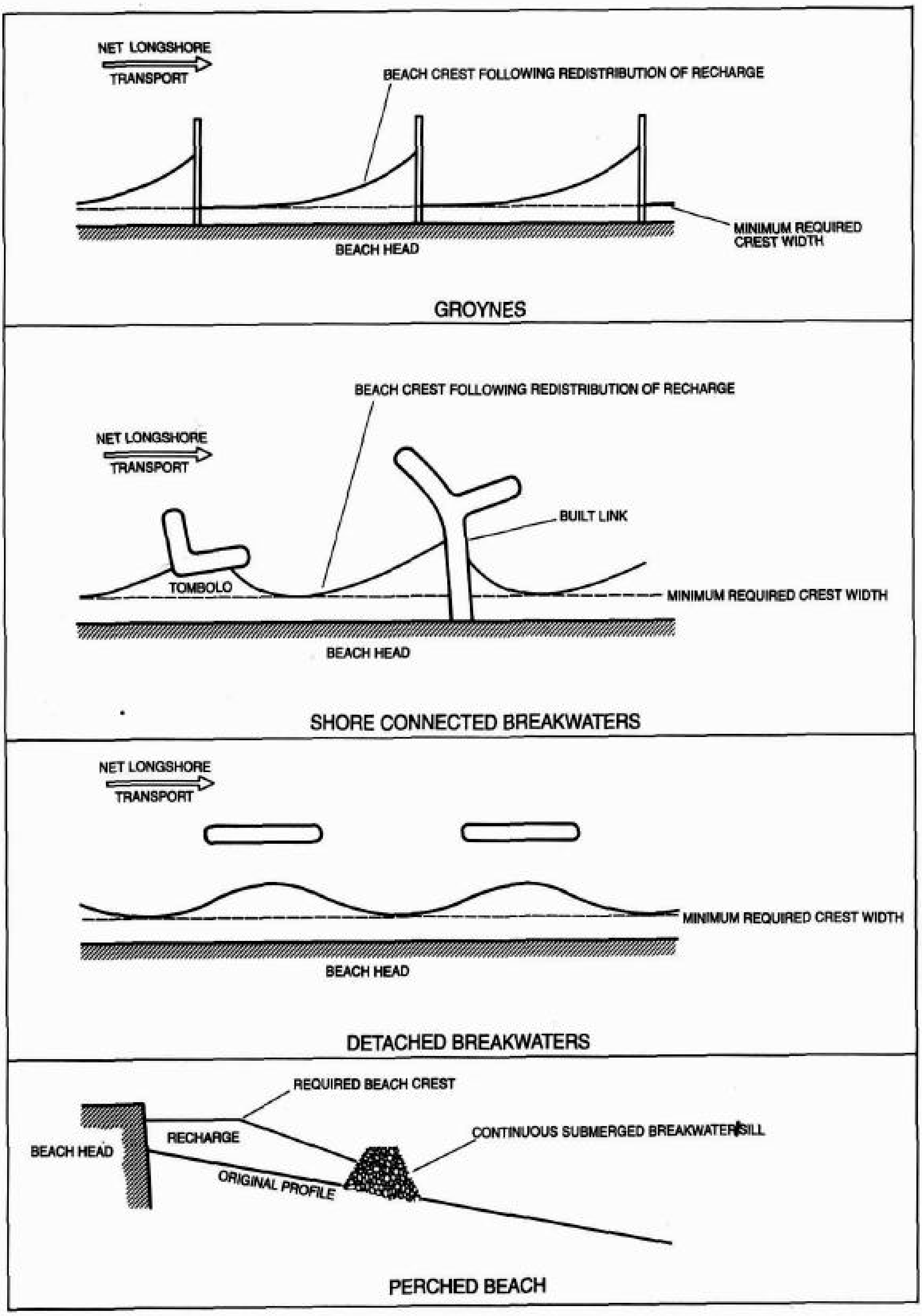


Figure 5.7. Erosion (downdrift) and accretion (updrift) patters with groynes, breakwaters and perched beaches.

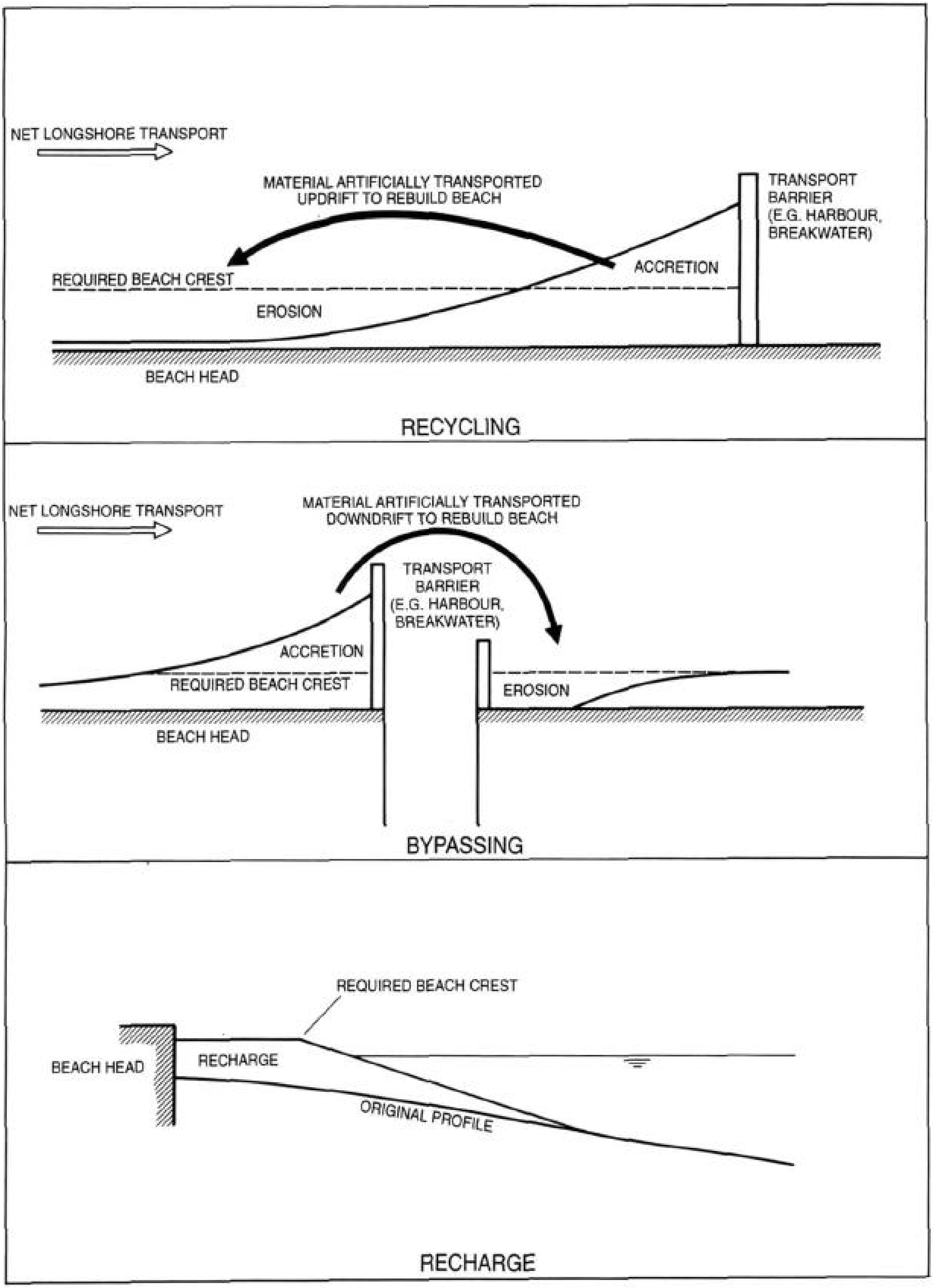


Figure 5.8. Preferential accretion updrift of structures and erosion on the downdrift aspect.

Very often shorefront development is done along the beach. From a coastal stability point of view this can be risky, because such developments fixes the position of the coastline. Because coastlines usually will fluctuate somewhat in time, the position of the development should be landward of the most expected position of the waterline.

Shorefront development like houses or hotels have the negative effect that they reflect waves. This may cause a somewhat higher wave in front of the structure, and due to that some erosion near the toe of the wall. Due to this erosion, the beach in front of the wall may get a deeper position (and consequently the beach will become narrower, or even disappear). In any case, a vertical wall will never stop chronic erosion. Sometimes, a wall is good in case of problems with acute erosion.

Seawalls and reclaimed or fill areas along the shorefront also act as groynes and cause similar erosion problems (Figure 5.9). In addition, seawalls cause significant erosion on the seaward face, especially at the base of the structure (Figure 5.10 and 5.11). This usually leads to failure of the structure (Figure 5.12)

Figure 5.9. Interlocking coral rubble seawalls along the coast in Tarawa, Kiribati.

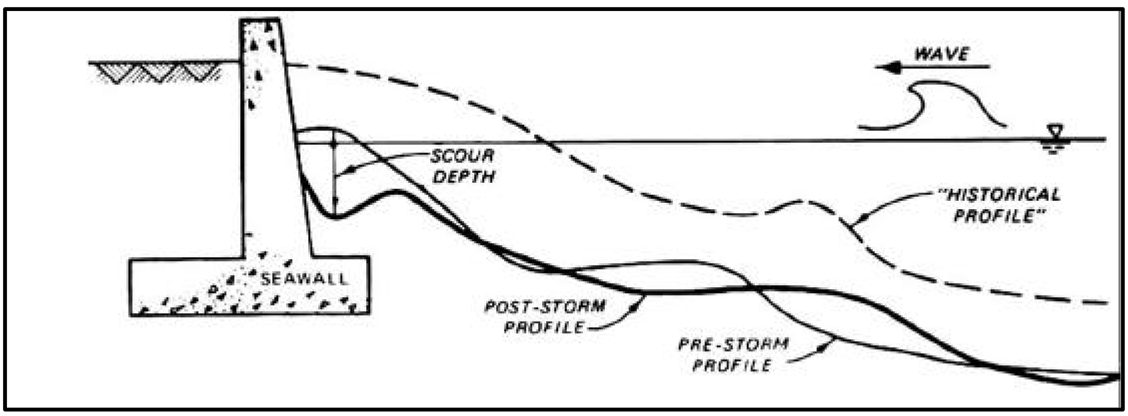


Figure 5.10. Scouring at the base of seawalls.

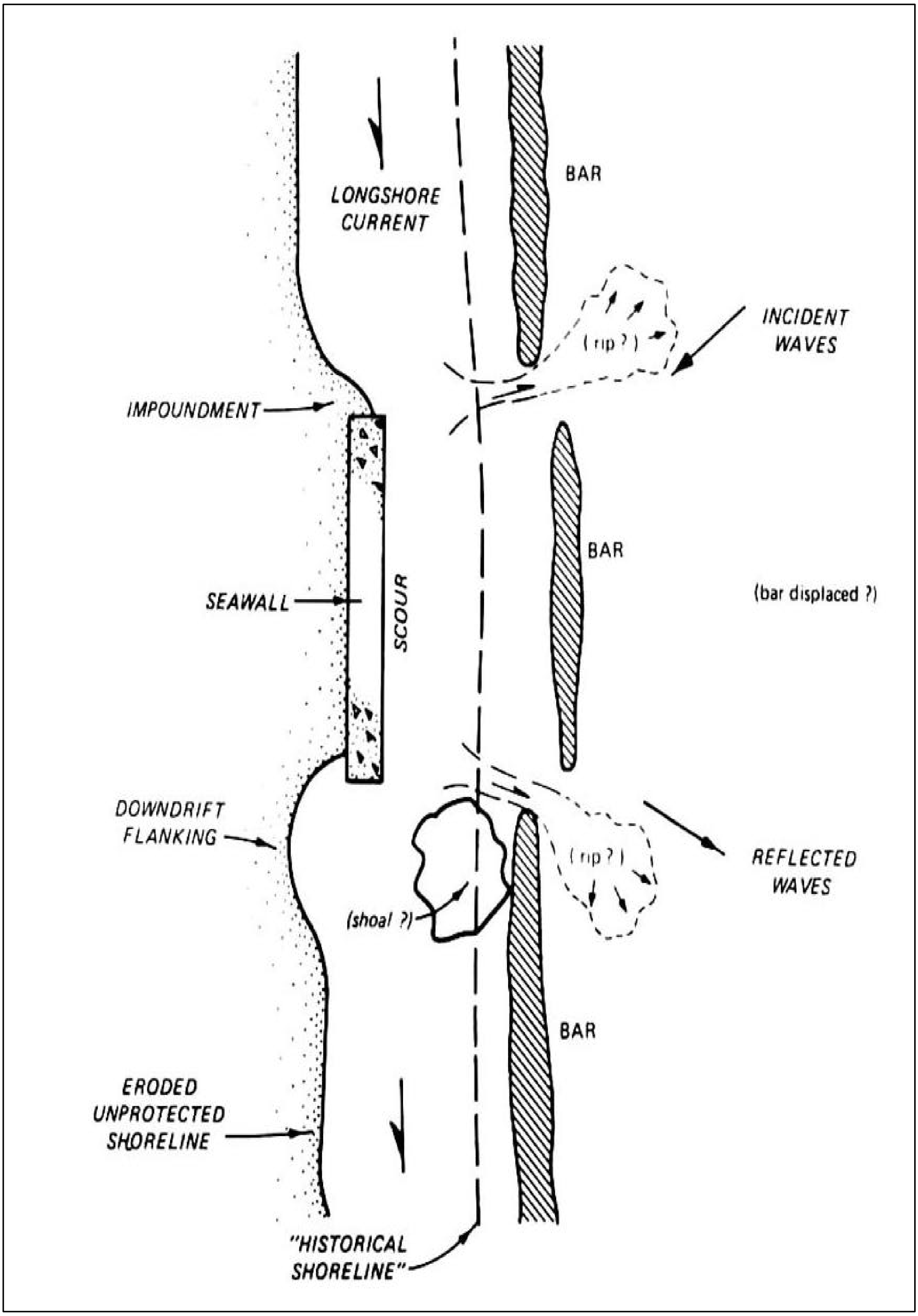


Figure 5.11. Plan view of erosion and accretion associated with non-flanked seawalls.

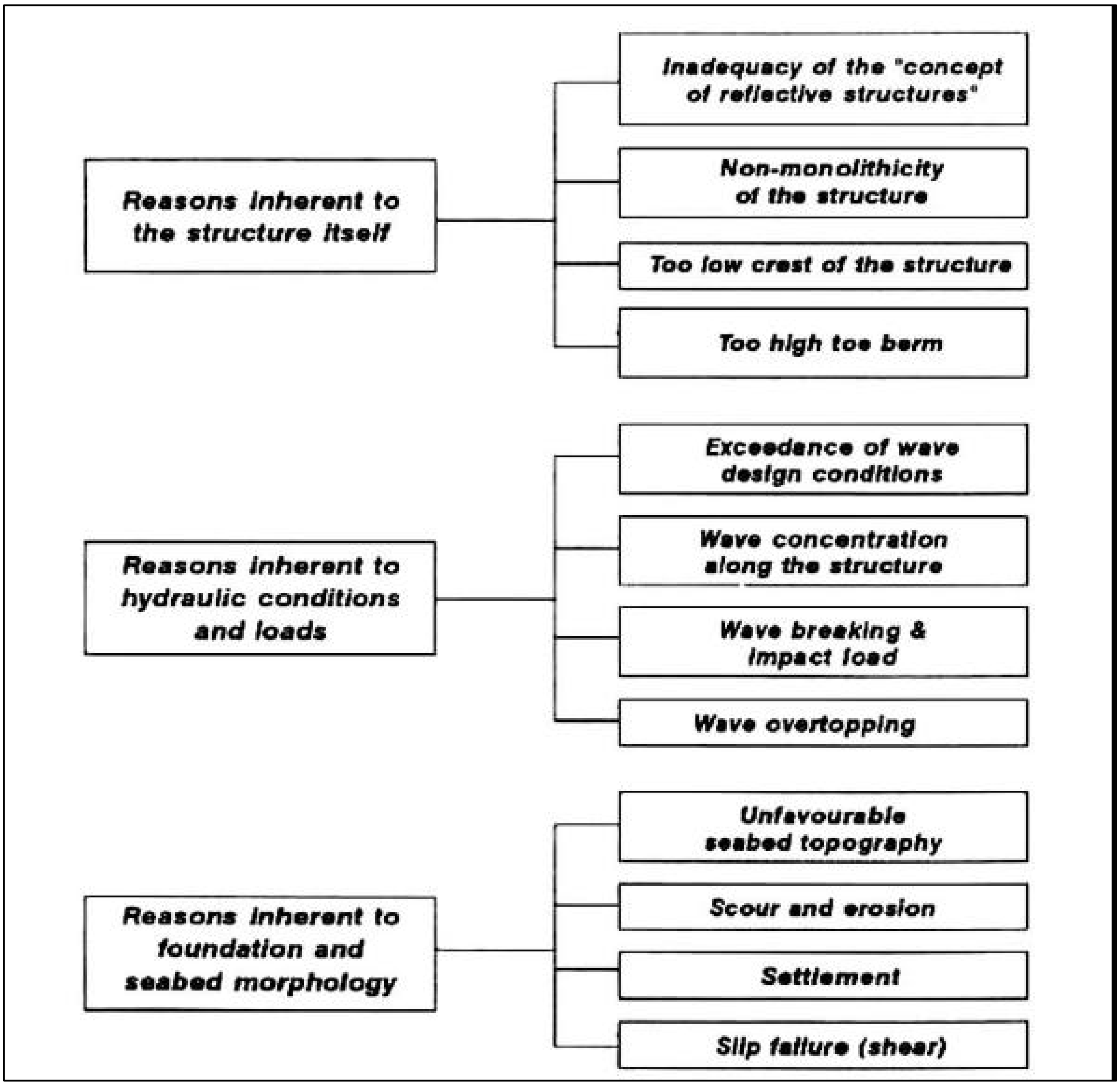


Figure 5.12. Reasons for failure of seawalls.

It is significant to note that coastal protection, by armouring such as rip-rap or concrete armour units also results in aggravated erosion, especiallly if they are poorly planned and constructed (Figure 5.13).

5.8 Land Reclamation and Fill

Especially in densely-populated areas, the need for more space can lead to an extension of land into the sea. Several questions will have to be answered before such an extension is really executed.

A lot of material to create land above sea-level will be needed. When this comes from the sea bottom, it should be dredged far enough from the shore in order to avoid interference with coastal processes, comparable to sand mining on a beach.

Another question is the height above sea level in order to avoid flooding or damage by waves. The design should take into account extreme water levels and waves.

Common concern	Assessment	Explanation of assessment
Coastal armouring placed in an area of existing erosional stress causes *increased* erosional stress on the beaches adjacent to the armouring	TRUE	By preventing the upland from eroding, the beaches adjacent to the armouring share a greater portion of the same total erosional stress
Coastal armouring placed in an area of existing erosional stress will cause the beaches fronting the armouring to diminish	TRUE	Coastal armouring is designed to protect the upland, but does not prevent erosion of the beach profile waterward of the armouring. Thus an eroding beach will continue to erode. If the armouring had not been placed, the width of the beach would have remained approximately the same, but, with increasing time, would have been located progressively landward
Coastal armouring causes an acceleration of beach erosion seaward of the armouring	PROBABLY FALSE	No known data or physical arguments support this
An isolated coastal armouring can accelerate downdrift erosion	TRUE	If an isolated structure is armoured on an eroding beach, the structure will eventually protrude into the active beach zone and will act to some degree as a groin, interrupting longshore sediment transport and thereby causing downdrift erosion
Coastal armouring results in a greatly delayed post-storm recovery	PROBABLY FALSE	No known data or physical arguments support this
Coastal armouring causes the beach profile to steepen considerably	PROBABLY FALSE	No known data or physical arguments support this
Coastal armouring placed well back from a stable beach is detrimental to the beach and serves no useful purpose	FALSE	In order to have any substantial effects on the beaches, the armouring must be acted upon by the waves and beaches. Moreover, armouring set well back from the normally active shore zone can provide "insurance" for upland structures against severe storms

Figure 5.13. Assessment of some concerns relating to coastal armouring.

When the reclaimed area protrudes into the sea, the extension can cause problems similar to those encountered when building a groyne.

The extension can change the salinity in the groundwater. The balance between salt and fresh water will shift seaward, influencing the vegetation in the coastal area.

6.0 WHAT TO DO IN CASE OF EROSION

6.1 Is the Coast Eroding?

In a number of cases, the coastline is not eroding at all. Because of some activities (for example after the construction of houses too near to the beach) the owner has a problem such as there is not enough beach any more in front of his property. In this case the problem is not stop erosion, but to create a new, artificial beach.

Also it may be that the position of the coastline is only fluctuating, because of variations in the weather. The problem may be solved by simply wait-and-see. Coastlines always fluctuate. Therefore one should also give the coast the room to fluctuate. This means that fixed structures *never* should be constructed too near to the waterline. That is asking for trouble.

6.2 Is It Acute or Chronic Erosion?

Acute erosion is the consequence of a single event, for example the erosion caused by a storm, a tsunami or by massive sand-mining operations (during a relatively short period). Chronic erosion is a type of erosion, which continues every year, the quantity per year is not so much, but the process always continues. Chronic erosion is not spectacular, and you seldom read something in the newspapers, while the press always covers acute erosion.

6.2.1 Chronic erosion

Chronic erosion is usually caused by a gradient in longshore transport and takes place in the breaker zone.

Chronic erosion as such cannot be stopped. In principle there are only three solutions for solving chronic erosion problems:

Stop the erosion effect by feeding the beach. This can be done by means of artificial beach nourishment. It is only useful when sand is available in the neighbourhood for a reasonable price.

Move the problems to a downstream location. Sometimes this is a very attractive solution. If downstream of the endangered site is a location where coastal erosion does not cause much trouble, it can be wise to move the erosion area to that spot. In the case that downstream of the troubled area is a rocky coastal section it can also be attractive. Several technical solutions might be relevant:

- Construction of groynes
- Construction of offshore breakwaters
- Construction of artificial headlands

It is sometimes useful to feed the beach at the upstream side, if the longshore transport is blocked by a construction (for example a harbour entrance) by the construction of a bypass plant.

6.2.2 Acute erosion

Acute erosion is caused by a sudden event. Usually it is one sudden storm or the effect of a Tsunami. In case there is *only* acute erosion, there is nothing to worry about for the long term. In that case, one has to make "only" a protection that, in case such an event happens, one should not have too much erosion endangering the structures on the coast. Such a protection can be:

- A heavy revetment

This can be constructed as:

- Riprap,
- Vertical wall or
- Sloping dike

Because natural coastlines always fluctuate, one has to allow sufficient space between the waterline and the structures (apply a set-back line).

In some situations it may be attractive to construct the protection as a "hidden structure". This means that normally you cannot see the structure, is completely covered by the sand of the beach and the first dune. Only in case of an extreme event, with much acute erosion, the structure will become visible and will prevent further erosion during that event. After the storm, one has to cover the structure again with sand, e.g. from extra sand extracted from alternative sites.

In case of acute erosion, it is absolutely necessary to verify that there is *only* acute erosion. Often there is a combination of acute and chronic erosion. This means that underwater there is a chronic erosion, which is may not be recognised at the beach itself (sometimes one sees only that the beach becomes somewhat steeper, and thus somewhat narrower). This chronic erosion in the sea area causes the water in the breaker-zone to becomes deeper. The beach slope becomes steeper, and the beach itself is no longer stable. A relatively small storm can then cause severe erosion, which is in fact, only an adaptation of beach profile to normal beach slopes.

In case of a combination of acute and chronic erosion, one has to take a number of steps:

1. First take measures against the chronic erosion.
2. Re-establish the desired beach width and the desired beach slope.
3. Check if the new beach is sufficiently stable against acute erosion. If not, an additional structure is needed.

6.3 When Did the Erosion Start?

Erosion never starts without a reason. In many cases the erosion always existed, but was never a problem. However, after buildings have been constructed near to the coast, coastal erosion became a problem. In fact, this problem should have considered, before starting the development. In some cases, some activities in the neighbourhood are probably initiating the erosion. For example sand mining, building structures upstream of the problem site, construction of revetments and beach walls.

6.4 How Much is the Coast Eroding?

For the analysis of the problem, and for designing solutions to erosion problems, it is necessary to quantify the erosion rate. This can be done in the easiest way by analysing beach measurements. Comparison of former coastal profiles with present day profiles is a valuable exercise. In a number of cases, no profiles may be available. In that case, one can use the former positions of coastlines, extracted from older maps, bathymetric charts and aerial photography or satellite imagery (of the appropriate scale), and compare them with the present day coastline and calculate the loss of sand using the present day profiles.

6.5 What are the Causes of Erosion?

The following causes of erosion can be recognised:

1. Less supply of sand because of an upstream structure;
2. The original source of sand is depleted (for example, by the upstream construction of a revetment, in front of an eroding beach or by a disappearing coral reef);
3. Sand is removed from the beach (sand mining);
4. Downstream transport of sand has increased;
5. Sand is lost in an offshore direction;

Sea-level rise can also result in a loss in the offshore direction, but this loss is usually too small for causing real engineering problems. Hard protections, are in this case, certainly not advisable.

In case of cause 1, 2 and 4, the best isto also try to stop the negative impact. However, this is in most cases extremely difficult.

Fundamentally, coastal erosion is caused by longshore or cross-shore losses. In case of a loss in longshore direction it is important to realise that the loss is always caused by gradient in the transport and that the magnitude of the longshore transport is not relevant at all.

The next step is to decide if one has to accept the erosion, or if one is willing to invest much in stopping the erosion. If one allows erosion, it is vital to devise a good system of set-back lines.

7.0 MANAGING BEACHES: DATA REQUIREMENTS

Managing a beach effectively requires data. Measurements or observations of the beach are obviously needed, data are required on the attributes of the beach.

Sometimes it is also necessary to include measurements of other factors, for example waves, tides and weather conditions which dominate beach development.

Data are required for three main reasons:

1. To identify spatial and temporal trends, determine their significance, and help to understand their causes,
2. To provide information to assist in the assessment and design of management strategies,
3. To appraise the performance and impacts of the adopted beach management methods.

A clear distinction must be made between an initial survey of the whole beach system at a particular moment in time, and monitoring of the beach system as it varies with time.

Monitoring is an ongoing exercise in data collection. It is important that data collection is cost-effective, i.e. that the value obtained justifies the effort involved. Measurement methods need to be chosen, bearing in mind the required accuracy, time and cost.

In order to design a suitable data collection system for any particular beach, the following key questions must be answered.

7.1 Why Collect Data?

The reasons to collect data can be summarised as follows:

- Understanding the past - short-term fluctuations and long-term trends in the behaviour of the beach and in the hydraulic regime need to be identified to understand the development of a beach. Without this information it is often difficult to identify precisely the causes of change and is certainly much more difficult to predict future changes.

- Identification of present problems - The present is the key to the past The past is the key to the future. Monitoring changes of the beaches allows the early identification of changes in the beach response. This may confirm the year-to-year stability or health of the beach and may provide reassuring confirmation of beach recovery or re-growth. Perhaps more importantly, data can be used to detect when beach levels have fallen to a critical level, which could lead to unwanted overtopping, damage to the backshore or undermining of sea walls. Monitoring may also be significant for the maintenance of other important beach attributes (e.g. to limit damage to important ecological habitats).

- Programming management operations - monitoring can assist in the timing of existing management schemes. Beach recharge schemes, for example, may be programmed with enhanced confidence if the beach is closely monitored.

- Predicting future solutions - data are required to calibrate and validate physical and numerical models, which may be used for predicting the future development of a beach, hence assisting in the design of appropriate solutions to any particular problem. Information may also help justify the expense of future beach management, for example, by quantifying numbers of tourists and the recreational use of beaches.

- Monitoring solutions - whatever their nature, soft beach management schemes will need to be monitored much more carefully and frequently than hard defences. The information will assist, for example in post-project evaluations and in understanding the environmental impacts of schemes. It may also suggest better methods of tackling problems in the future.

7.2 Which Data to be Collected?

In general, the precise details of the data that need to be collected as part of a beach management exercise will depend upon the specific site and its character. A preliminary assessment of the site is often necessary to design a suitable data-collection programme. This should identify the information already available, the further variables to be measured and the level of accuracy and resolution required. Accuracy and resolution will govern the choice of instruments and methodology that are appropriate. Possibilities for data collection will almost always exceed the budget available. As a consequence it is often necessary to set priorities and to concentrate effort on the most vital information.

It is important to consider what information is already being collected, or generated, which proposed monitoring might duplicate.

The following topics are presented in their likely order of priority for data collection:

1. Beach levels, sediments and attributes.
2. Geotechnical site investigation.
3. Land, underlying strata and nearshore seabed.
4. Tidal currents and wave conditions close to the beach.
5. Tidal levels, offshore waves, winds, etc.

7.3 When and Where to Collect Data?

Data have to be collected in a systematic and planned manner. The choice of sampling interval in time and space is dependent upon the process being studied. For example, to identify any seasonal variation in beach levels against a seawall, will be necessary to survey them at least four times a year, at regular intervals. In the longer term, once seasonal variations have been established, a twice-yearly monitoring regime is likely to suffice.

If, however, post-storm beach levels are of interest, a more flexible fast-response approach to survey will be required. Similarly, thought needs to be given to the locations at which data are gathered.

The locations of any previous surveys should also be considered; more reliable comparisons can be made when the data collection location is consistent. The frequency and location of environmental seabed and geotechnical surveys also need to be considered carefully.
It may be necessary to adjust the data collection programme over time if conditions change at the site, or more importantly if the survey programme adopted is not providing the information required. Analysing the data is a vital part of any data collection exercise, rather than a post-script to it.

7.4 How to Store and Analyse Data?

No universal consensus exists on the best way of storing beach-monitoring data. Data have a geographical location, so a Geographical Information System (GIS) is a powerful tool to store, collate and analyse information.

An important part of the analysis of the information gathered, therefore, involves time-series analysis, for example to separate the short-term fluctuations from any long-term trends. For such time-series data storage and analysis, personal computer (PC) storage systems such as spreadsheets, Computer Aided Design (CAD) and simple bespoke databases can perhaps be used more simply than GIS if the geographical referencing is less important.

Simplicity of storage, retrieval and analysis are key to effective data management.

It is important that analysis is carried out as new data are entered into the database, and up-to-date summaries of the results are made available to interested parties. Although the data should have been checked before being input, erroneous data can be identified after loading by prompt analysis, which will reveal surprising or unrealistic changes.

A vital part of any analysis of data is the presentation of results in a convenient form that can be appreciated by non-technical individuals and groups, as well as providing a summary for the beach managers themselves. The requirement for such output from the data collection programme needs to be defined in advance and developed in the light of experience.

7.5 How to Start a Data Collection Programme?

The practicalities of starting up and sustaining a data collection programme will be almost as site-specific as the beaches themselves. It is rarely possible to start a long-term monitoring exercise without prior justification, usually expressed in benefit-cost terms.

Several stages are normally needed before starting a beach-monitoring programme. First, the need for the information has to be established, usually to non-technical fund holders. Then it is important to review what information already exists and where the gaps are. This leads on to consideration of the needs for further information, and whether it can be obtained in a short-term programme of monitoring or whether longer-term monitoring is required.

Having set the objectives of a data collection programme, a decision will need to be made on the required accuracy and frequency of the information for the baseline and monitoring surveys. The methods for storing, analysing and disseminating the information also need to be specified at this stage.

It is then necessary to estimate the costs of the programme and ideally to place financial values on the likely benefits that will accrue. The benefits, of course, come from improving the efficiency, or cost, of beach management and thus avoiding losses or making economic gains as a result.

8.0 BEACH DATA COLLECTION

8.1 Programme Planning

CIRIA (1996) describes several methods for data collection. The following are adapted from those guidelines.

Beaches are constantly changing in response to the various processes and factors which control them. Successful management of a beach requires that the processes should be identified and changes should be monitored. The data should be analysed and appraised following a carefully planned ongoing data collection programme.

The aim of the programme should be to understand the beach responses and to identify potential problems, thereby allowing management to be proactive rather than reactive.

Monitoring should be undertaken on any coastline where there is a potential risk of flooding or erosion that threatens significant property or infrastructure and it is essential for the post-construction assessment of any new beach works or management scheme.

The programme should include:

1. Recording observations,
2. Taking fixed-aspect photographs,
3. Measurement of beach profiles and plan shapes,
4. Analysis of beach sediment samples,
5. Determination of the sediment budget,
6. Environmental data collection,
7. Aerial photography,
8. Bathymetric survey.

This work must be undertaken in conjunction with the monitoring of waves and water levels, as well as the collection of geotechnical, bathymetric and tidal current data.

Prior to establishing a field programme, a desk study should be undertaken. Information relating to the geological and historical development of the beach is vital to understanding present situation and therefore to the planning of the programme. Sources of information include:

1. Geological memoirs and maps,
2. Published research papers,
3. Universities theses,
4. Ordnance Survey sheets,
5. Admiralty Charts and Defence Mapping Agency Charts,
6. Previous beach surveys,
7. Engineering drawings and records,
8. Historic photographs, both aerial and ground,
9. Press reports and local knowledge and
10. Satellite imagery.

Particular attention should be paid to the nearshore and backshore geology, and to the impact of coastal structures and dredging.

Fieldwork must be undertaken often enough to reveal short-term variations as well as long-term trends. At the outset surveys should be undertaken monthly and immediately after any significant storm events.

This level of monitoring should be maintained until an understanding of the processes and factors controlling the beach has been developed and the potential for seasonal and storm related variations, the areas of particular concern, and the sediment sources and sinks have been identified. Once these requirements have been met, survey frequency and extent can be reduced.

8.2 Site Investigations

The simplest form of monitoring a beach is by regular inspection of the coastline. The use of photographs and pre-prepared checklists or record-sheets is a good way of increasing the value of such inspections. Inspections will vary according to the site and the particular concerns of the beach manager, but they should include the collection of information on:

1. *Beach changes, for example:*

   - Beach levels against sea walls, groynes, etc.
   - Evidence of erosion of dune faces, or steep scarps at the beach crest and
   - Exposure of the solid shore-platform in the inter-tidal zone.

2. *Beach texture, for example:*

   - Deposition or loss of sand covering a shingle upper beach;
   - Deposition of mud on the lower beach face.

3. *Damage to structures, for example:*

   - Missing groyne planking;
   - Spalling or abrasion of concrete walls;
   - Displacement of rock armour and
   - Exposure of structure foundations.

8.3 Beach Profiles and Coastal Hydrodynamic Boundary Conditions

Beach profiles comprise surveyed section lines perpendicular to either the shoreline or to a pre-determined baseline (Figure 8.1). They are used to quantitatively establish beach response to storm events, beach recovery rates, long-term volume changes, areas of potential flood or erosion risk and the potential envelope of cross-shore elevations (Figures 8.2 - 8.4).

If beach profiles are combined with nearshore bathymetric surveys, then morphological changes across the full zone of wave influence can be assessed.

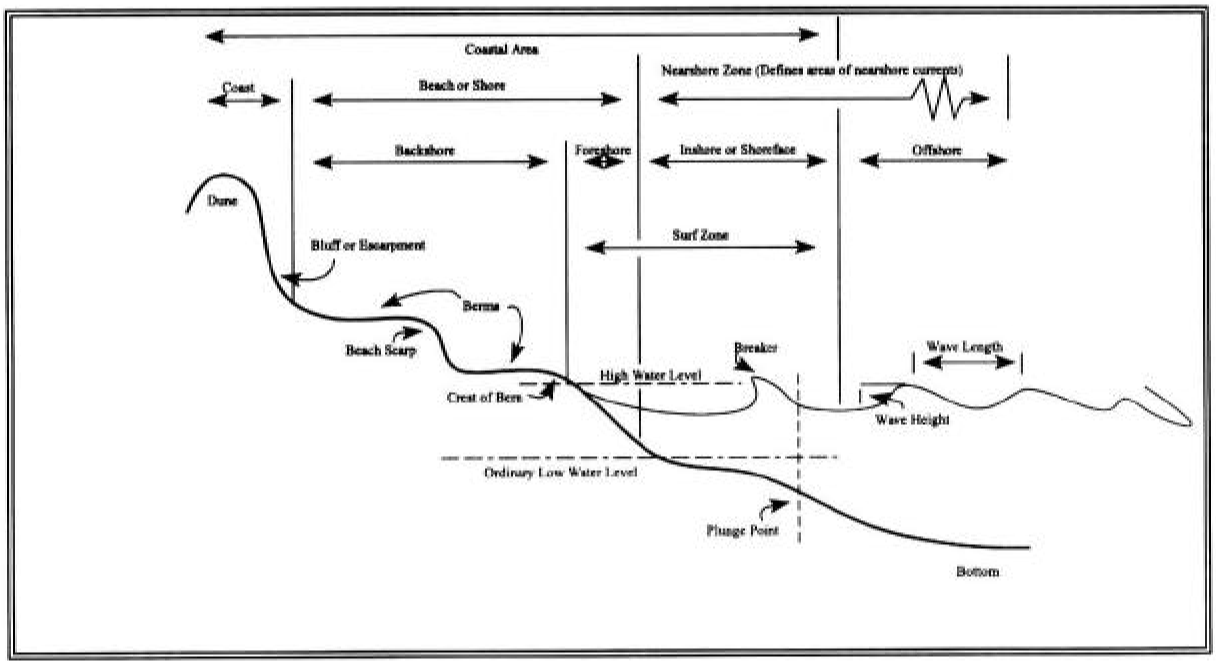


Figure 8.1. Beach terminology and morpho-dynamics.

BEACH PROFILE AND LITTORAL FIELD DATA SHEET

Project: Anibare Bay Fishing Harbour Development, Republic of Nauru
Objectives: Coastal Monitoring and Engineering Design Assessment

Profile Number:	AB-1, RON
Location of Profile:	North side of the Harbour Development, SM 43
Profile Direction:	090/270
Beach Orientation:	360/180
Time of Survey:	2nd. March, 2000
Date:	2nd. March, 2000
Surveyor/s:	Russell J. Maharaj, Geologist & Engineer
Tide:	Rising Neap
Wind Speed, m/s:	13.5-15.0. Sometimes up to 18.0.
Wind Approach/Direction:	East/090
Wave Height, m:	1.5-2
Wave Approach:	065-090
Wave Period, s:	5 to 8
Breaker Height, m:	1.5
Breaher Approach:	065-090
Breaker Depth, m:	NA
Longshore Current Direction:	South/180
Longshore Current Speed, m/s:	To compute using CRESS/ACES
Remarks:	Moderately sloping sandy beach.
Photograph:	Roll N1- 05 to 15
Drawing:	See Notes book.

SOPAC

Figure 8.2. Example of a littoral data sheet for field data collected at a beach profile station.

BEACH PROFILES - FIELD MEASUREMENTS

Profile Number: AB-1, RON

Horizontal Distance, m	*Vertical Staff Reading, m*	*Remarks*
0	5.61	Benchmark
7.5	4.5	
10	4	
15	2.5	
16.5	2	
23.5	1.5	
71.5	1.5	
102	1.5	
120	1	
130	0.5	
143.5	-0.5	
155	-1.5	
158.5	-2.5	
165	-4	
176	-9.5	

SOPAC

Figure 8.3. Example of a beach profile data sheet for the same site shown in Figure 8.2.

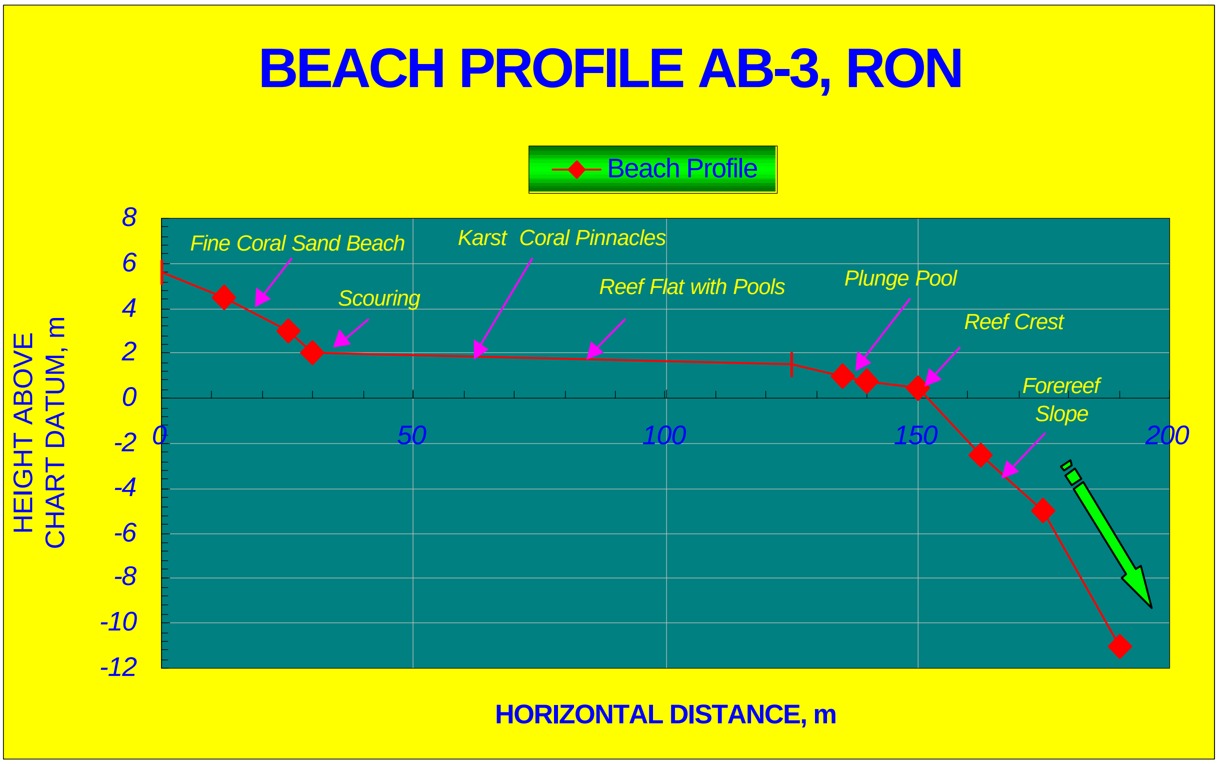


Figure 8.4. Example of a processed beach profile for the site shown in Figures 8.2 and 8.3.

Rapid appraisal of profile data is vital for determining whether coastal management works are required and for establishing some of the design constraints for the works.

When establishing profile lines or station points it is vital to ensure that they can be easily re-established for successive surveys. The profiles must have a defined bearing and must be tied to independent control points.

Control points should be established inland of areas which might be subject to erosion during the course of the monitoring programme. It is desirable, but not always possible, to set out a common baseline for adjacent profile lines.

Beach profiles can be surveyed using traditional precise levelling, a total station or Global Positioning System (GPS) set of tools. Line and level surveys may provide distorted results due to the methods of measuring the change on steep-faced beaches.

Total stations provide undistorted X-Y-Z data in an easily processed format. GPS technology is in use for a number of regular monitoring programmes and will become more widespread.

The location of the profile lines should be carefully considered. The density of the lines should be sufficient to provide adequate coverage of the beach. On long open beaches, the lines may be spaced at intervals of a kilometre or more with allowance made for nearshore features, such as bars, banks and troughs, which may result in localised variations. On groyne beaches it may be necessary to survey lines on either side of the groynes and at the centre of the bays.

Profile lines for general monitoring should not be taken immediately adjacent to structures, as localised scour can mask the more general beach form; a separation of about 5-10m is normally sufficient. Profiles taken adjacent to structures may be of value if information is needed on scour.

Supplementary shore parallel profiles are of great value, particularly at the toe and crest of the beach if Digital Terrain Models (DTMs) are to be used in data analysis. It should be noted that DTM analysis will require a much greater density of survey points to prevent the apparent accuracy of the displayed data from masking the limited coverage of the actual data.

Surveys should identify boundaries between the mobile beach toe and bedrock and the crest and sea wall/cliff, if appropriate. The landward end should reach beyond the expected point of storm wave influence. On natural coastlines this may require the surveying of sand dunes, the backs of shingle ridges or the top of eroding cliffs. The seaward end should extend to at least the level of MLWS, or further if conditions allow the staff person to enter the surf zone safely.

Bathymetric surveys should overlap the beach profile and extend it out to a depth below which wave induced transport is negligible, typically below Chart Datum (CD). Bathymetric surveys generally require the use of specialist equipment and are therefore, completed less frequently than beach profiles. However, they are valuable in defining long term and storm induced transport patterns.

Photographs of the beach should be taken from fixed positions in conjunction with surveys. Photographs are particularly useful for identifying small-scale features, such as cusps or other changes in beach material type, which might influence the data interpretation. They can also be used to record beach development adjacent to structures or in areas not covered by the fixed profile lines.

During survey analysis, and particularly volume calculation, it must be remembered that vertical accuracy is usually +20 mm for topographic surveys and +150 mm for bathymetric surveys. Plan position is usually +0.2 m and +1 m respectively (based on the trapezoidal rule).

The beach plan shape is normally characterised by one or more longshore lines defined by tidal levels (i.e. MHWS, MSL, MLWS) by the beach crest. Beach plan shapes can be used to monitor storm response and long-term volume changes and to determine areas of potential risk. This is of course bearing in mind the dynamics of the beach (Figure 8.5).

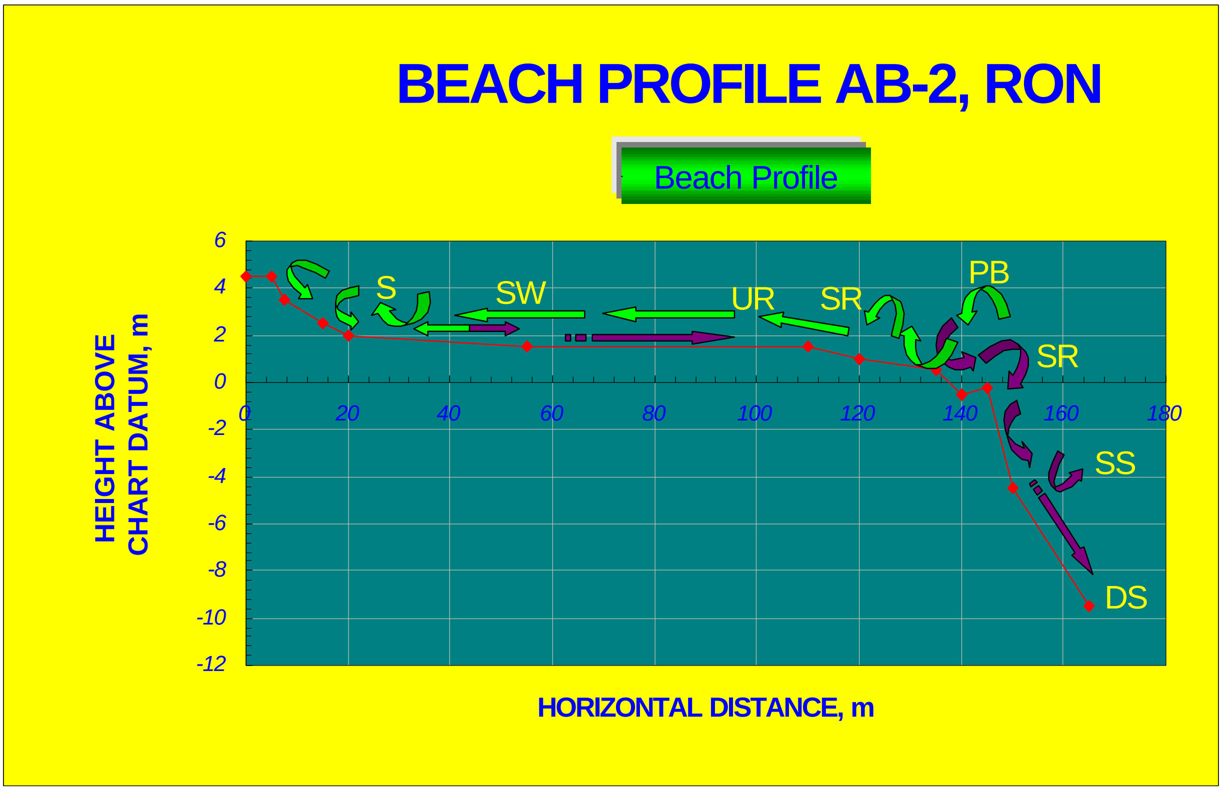


Figure 8.5. Surf zone dynamics. SW-swash; S-scouring; UR-uprush; PB-plunging breakers; SR-sediment re-suspension and surging; SS-sediment suspension; DS-deep sea sediment transport.

Monitoring techniques depend on the length of coastline to be considered and the types of beach. Aerial photographs can be very useful in obtaining a general understanding of long lengths of coastline and photogrammetric analysis of stereo pairs can provide data for volume calculations or mapping, though they cannot be used to identify changes below water level.

Photogrammetry can be accurate provided that good ground control is established, and the photography is at a suitable scale. Aerial photography is useful for examination of long-term trends where several years of photography are available.

Surveys conducted before and after major work would be sufficient to provide a qualitative record of beach development.

Satellite imagery is another source of plan shape data. Plan shape definition can also be derived from beach profile data, though profiles at fixed locations may miss important longshore features. Ideally high-density topographic survey data should be used to form digital terrain models, however, this method is very time consuming and expensive. A compromise is to use beach profile data supplemented by surveys of particular points of interest, such as the positions of severe beach crest cutback or accretion.

A critical aspect in beach dynamics assessment is hydrodynamic boundary conditions. These include several hydraulic parameters (Figure 8.6). Of particular importance are waves, breakers, winds, tsunamis, swells and storm surges. Significant wave and breaker heights are critical elements, as are extreme conditions such as swell wavelength and period. Associated with these parameters are wind speed and direction, wave and breaker heights, wave approach, water depth at breaker zones, wave period (including swells and smaller/normal waves), longshore current speed and direction and cross-shore sediment transport.

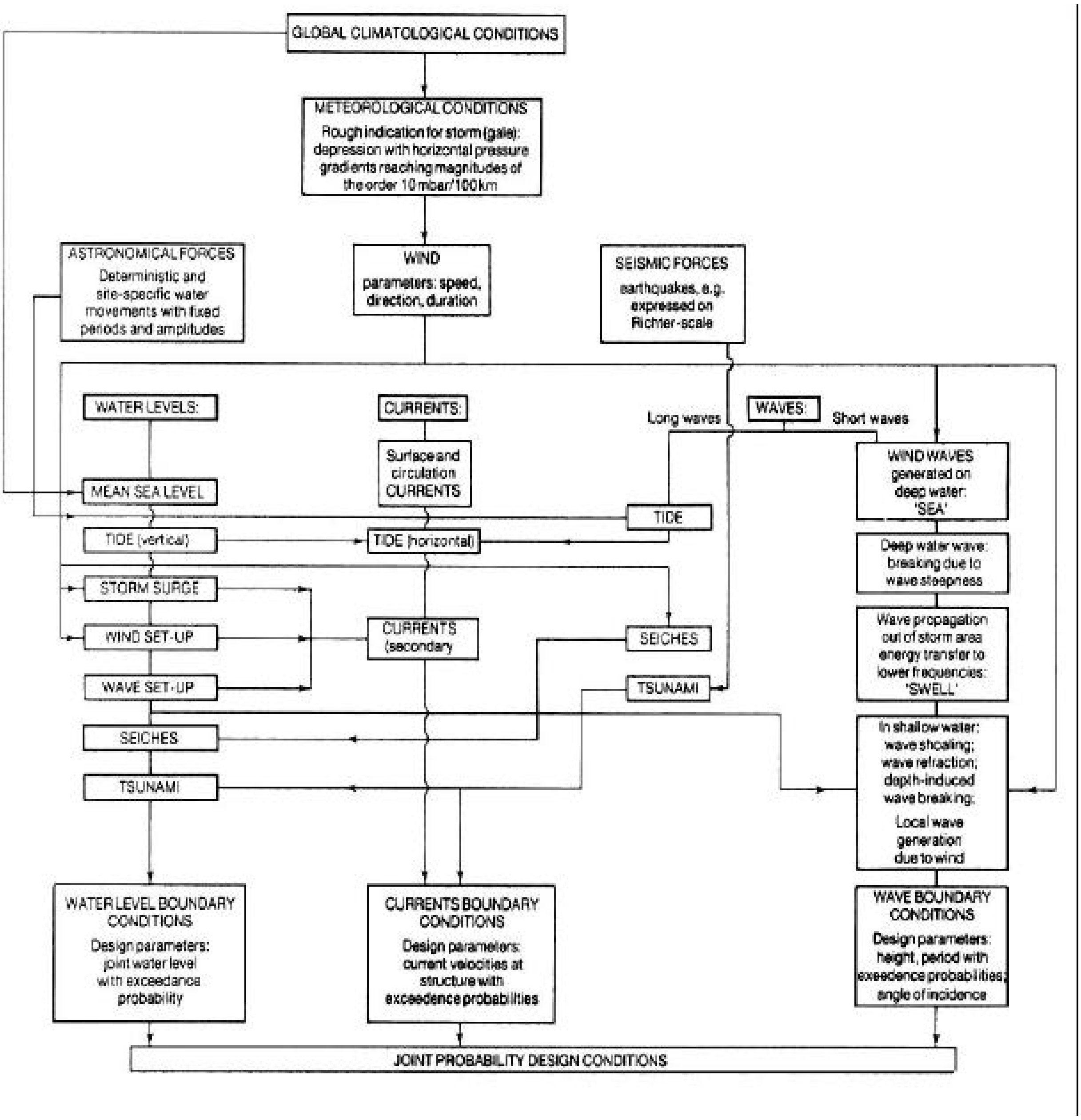


Figure 8.6. Hydraulic boundary conditions.

8.4 Beach Response Near Structures

Beaches in the immediate vicinity of groynes, breakwaters and seawalls are subject to rapid change as a result of wave and current interactions with the structures. Scour can cause unexpectedly high rates of scouring, littoral drift and cross-shore sediment transport. During extreme events this can cause catastrophic damage by undermining the foundation s of coastal structures and buildings.

Figure 8.7. Collapse of a shorefront building due to foundation scouring in Tarawa, Kiribati.

Figure 8.8. Scouring alongside a gabion basket seawall in south Tarawa, Kiribati.

8.5 Beach Modification Near Structures

Beaches in the immediate vicinity of groynes, breakwaters and seawalls are subject to very rapid change as a result of wave and current interactions with the structures (Figures 8.9 and 8.10).

Scour on the seaward face and toe can cause unexpectedly high rates of littoral drift and during extreme events, can cause catastrophic damage by undermining foundations of structures (Figure 8.8). This is usually the cause of frequent seawall and other coastal engineering structure failure along the coast.

Damage of beach control structures by wave action, such as during storms and cyclones, can cause the removal of armour units from the crest of protection rubble-mound structures. These can also modify beach response to littoral drift and hydrodynamic processes.

These impacts can be minimised, if appropriate data collection and design processes are followed. Figure 8.11 presents some examples of mitigation of beach structure impacts during construction and post-construction stages.

Mitigation options can be optimised if the advantages and disadvantages of various beach control works are highlighted, e.g. Figure 8.12.

8.6 Beach Sediment Sampling

Beach material sampling is undertaken to determine seasonal or long-term and spatial changes in beach composition, sources of materials and appropriate recharge materials where beach nourishment programmes are in place. It is also used to provide design information for coastal models and selection of coastal protection alternatives.

A beach sampling programme must be planned to cover potential variations cross-shore and onshore, longshore and also, vertical and seasonal changes. Vertical and seasonal variations are particularly important. There is little to be gained from frequent surveys after the beach composition has been satisfactorily defined.

Observations and photographs taken in conjunction with other fieldwork will normally provide sufficient information to detect any long-term changes in beach sediment composition.

The exception to this is in the case of post-recharge monitoring, for which regular sampling may help to identify whether the recharge material was appropriate, or whether a finer or coarser material should be used for future maintenance. It is also useful to monitor the rate and severity of abrasion, where crushed rock has been selected for nourishment.

Samples should be collected from the surface and from depths of up to 1m below the surface, depending on the beach sediment thickness. For most practical purposes, near-surface samples of 0-30 cm will do, with samples described and analysed at different depth. If the beach sediment is very thick, and there is significant variation in beach elevation, deep samples should be collected. Deeper samples may also be required, depending on the seasonal change in beach elevation. The size of sample depends on the particle size and the need to obtain statistical validity.

Several standards are available, which advises on the size of samples for different grain sizes, e.g. the American Society for Testing Materials (ASTM; Table 8.1). ASTM provides the most widely used and accessible international guidelines for material testing available today. For sands (0.0625-2.00 mm), the most common sediment on beaches, at least 115 g of dry samples is required, for silt (less than 0.0625 mm), 65 g and for gravel, at least 500 g of dry sample.

Scaled photographs of a 1 m or 30 cm square scale lying on the beach are useful as supporting evidence for analysis. Care should be taken not to disturb the sample area during sample collection. Sample location, position along the beach, depth, colour, texture, smell, angularity, composition should be noted. The date and time of sampling, the tidal cycle at the time of sampling, the sea-state (wave dynamics) and the person/s doing the sampling must also be documented at all sample stations. The method of sampling, handling and storage of samples must be documented, in addition to the standards used in the field and in the laboratory for analysis and testing.

The laboratory tests and analysis should provide a description of the material using standard terminology, a grading curve, the median particle size *(D_{50})* and the spread *(D_{85} and D_{15})*. Mean and particle size limits should be noted. For most practical purposes millimetre scales are best for description of particle sizes.

Table 8.1. Grain-size parameters for sediments and soils. The phi scale is based on powers of 2 mm, which yields a linear logarithmic scale via the phi-parameter (F) defined as, F = $^{-2}$ log. d, where d is in mm.

GRAIN SIZES	*MILLIMETERS, MM*	*MICROMETERS, mM*	*PHI VALUES, F*
Boulders	> 256		< -8
Cobbles	256 – 64		-8 to -6
Gravel	64 - 2		-6 to -1
Very coarse sand	2.0 – 1.0	2000 – 1000	-1 to 0
Coarse sand	1.0 – 0.50	1000 - 500	0 to +1
Medium sand	0.50 – 0.25	500 – 250	+1 to +2
Fine sand	0.25 – 0.125	250 – 125	+2 to +3
Very fine sand	0.125 – 0.0625	125 - 62	+3 to +4
Coarse silt	0.062 – 0.031	62 – 31	+4 to +5
Medium silt	0.031 – 0.016	31 – 16	+5 to +6
Fine silt	0.016 – 0.008	16 – 8	+6 to +7
Very fine silt	0.008 – 0.004	8 - 4	+7 to +8
Coarse clay	0.004 – 0.002	4 – 2	+8 to +9
Medium clay	0.002 – 0.001	2 – 1	+9 to +10
Fine clay	0.001 – 0.005	1 – 0.5	+10 to +11
Very fine clay	0.0005 – 0.00024	0.5 – 0.24	+11 to +12
Colloids	< 0.0024	< 0.24	> +12

POTENTIAL IMPACTS[1][2] DURING CONSTRUCTION	BEACH CONTROL STRUCTURES	Groynes	Detached Breakwater	Shore Connected Breakwater	Modified Seawalls/Revetment	Sills	Beach Drainage Systems
Natural Environment							
Disruption to fauna and flora due to machinery use, trampling and excavation		—		—	—	—	—
Smothering of fauna and flora due to deposition of material		—	—	—		—	
Smothering of fauna and flora due to increase in suspended sediment		—	—	—		—	
Destruction of habitat		—	—	—	—	—	
Noise disturbance to birds		—	—	—	—		
Impact on timber source		—					
Human Environment							
Restricted area for beach use		—	—	—	—	—	—
Restricted access onto or along beach		—	—	—	—	—	—
Public safety during plant movements		—	—	—	—	—	—
Unsightly and unconfined sites		—	—	—	—	—	—
Restricted access to inshore fishing ground		—	—	—		—	
Local economy, conflict with holiday tourist season		—	—	—	—	—	—
Disruption to commercial activities (e.g. local concessions)		—	—	—	—	—	—
Local employment generation		+	+	+	+		
Inshore navigational hazard		—	—	—		—	
Damage to designated archaeological sites		—	—	—	—	—	
Environmental Quality							
Increase in turbidity		—	—	—		—	
Accidental spillage of polluting material		—	—	—	—	—	—
Physical Environment							
Damage to designated geological sites		—	—	—	—	—	—

Notes: [1] Impacts will be dependent on the sensitivity of the resource
[2] — Adverse impact + Beneficial impact

Figure 8.9. Impact of beach control structures during construction.

POTENTIAL IMPACTS[1][2] DURING SCHEME LIFE — BEACH CONTROL STRUCTURES	Groynes	Detached Breakwater	Shore Connected Breakwater	Modified Seawalls/Revetment	Sills	Beach Drainage Systems
Natural Environment						
Change in wave climate and sedimentation rates affecting fauna and flora	±	±	±	±	±	
Erosion downdrift of works caused by disruption to natural sediment supply	—	—	—	—	—	
Barrier to passage of fish and invertebrates	—	—	—		—	
Creation of new habitat	+	+	+			
Disruption to benthos		—	—			—
Human Environment						
Restriction of access on to or along beach	—		—	—	—	
Creation of amenity facility				+		
Safety of beach users and swimmers	—	±	—		—	
Visual intrusion	±	±	±	±	±	
Reduction in inshore fishing grounds	—	—	—	—		
Reduced risk of flooding/coastal erosion	+	+	+	+	+	+
Nearshore navigation hazard	—	—	—		—	
Environmental Quality						
Litter and debris trap	—	—	—	—	—	
Substrate for algae	—	—	—	—	—	

Notes: [1] Impacts will be dependent on the sensitivity of the resource
[2] — Negative + Positive ± Positive or negative

Figure 8.10. Impact of beach control structures during the post-construction phase.

Structure type[1]	Situation	Advantages[2]	Disadvantages[2]
Groynes	- Shingle - any tidal range - Sand - micro-tidal only - High gross drift, but low net - Low vertical sided structures suitable for low wave energy - Large mound type structures suitable for high wave energy	- Allows for variable levels of protection along frontage	- Can induce local currents which increase erosion, particularly on sand beaches - Vertical structures potentially unstable with large cross-structure beach profile differences - Requires recharge to avoid downdrift problems
Detached breakwaters	- Shingle - any tidal range - Sand - micro-tidal only - Dominant drift direction - Constant wave climate, not storm dominated - Creation of amenity pocket beaches or salients	- Allows for variable levels of protection along frontage	- Large visual impact particularly with macro-tides - May cause leeward deposition of fine sediment and flotsam - Strong inshore tidal currents may be intensified - May cause hazardous rip currents - Difficult to construct due to cross-shore location - Difficult to balance impact under storms and long-term conditions - Difficult to balance impact on both shingle and sand transport
Shore connected breakwaters	- Shingle - any tidal range - Sand - limited effect with macro-tides - Dominant drift direction - Any wave climate - Strong shoreline tidal currents ("fishtails" only) - Creation of amenity pocket beaches	- Allows for variable levels of protection along frontage - Can be used to create amenity features - Longshore and cross-shore control	- May cause leeward deposition of fines and flotsam - Little design guidance at present
Seawall/ Revetments	- Sand or shingle - Any tidal range, any wave climate - Low gross drift rate - Provides secondary line of defence where beach can not be designed to absorb all wave energy during extreme events	- Well developed design methods - Provides equal protection along frontage - Can be designed to support a sea front development	- No drift control - May become unstable if erosion continues
Sills	- Shingle or sand - Low wave energy - Low and variable drift - Submerged with micro-tides, regularly exposed with macro-tides	- Creates perched beach - Reduces shoreline wave climate	- Storms may remove beach irreversibly - Level of protection reduces during storm surge events
Beach drainage systems	- Sand beaches, normally up to the high water line - Any tidal range - Any wave climate or drift rate	- Responds to beach developments	- Limited experience of use - Long-term maintenance may be expensive - Risk of failure during short duration, extreme storms

Notes:

(1) The guidelines given above assume that the structures are either built in conjunction with a beach recharge or that downdrift frontages are not dependent on continued longshore transport

(2) In addition to the above considerations a range of other environmental issues, described in Section 8.8, need to be taken into account

Figure 8.12. Guidelines for the application of beach control structures: advantages and disadvantages.

Other variables, such as mineralogy, geotechnical, hydraulic and hydrodynamic parameters can be subsequently evaluated from proven mathematical formulae and test procedures.

Beach sampling should be undertaken in conjunction with nearshore sampling and a study of the underlying nearshore and onshore geology. This will help in identifying the relationships, if any, which exists between the beach sediments and local coastal geology.

8.7 Beach Sediment Budget

A sediment budget is the sediment transport volume balance for a coastline. Sediment quantities can be categorized according to the sources, sinks, sediment-types and processes involved.

Definition of a sediment budget will assist in:

1. Identifying the relevant conditions, processes and factors affecting the beach,
2. Estimating transport volumes and rates and
3. Monitoring the success of beach management schemes.

The methods for estimating the sediment budgets combine predictive techniques, with desk studies and field measurements. All of the methods are subject to large uncertainties and require the involvement of specialist assistance. Generally, it must be indicated that the budget determined are only indications and not absolute and therefore should be treated with discretion.

Desk studies involve analysis of available records such as Ordnance Survey maps, existing beach surveys, satellite imagery and aerial photographs. This allows the investigator to build up a time series of beach positions, allowing long-term development of the beach plan-shape to be analysed.

Field measurements of plan and profile shape can be more reliable, particularly at sites where a monitoring programme has been in place for a number of years. Comparisons of successive beach plan shapes measured near crossshore structures can be used to estimate longshore and crossshore sediment drift.

Another more reliable approach, is to deploy tracers to identify sediment transport paths. In the past radioactive, fluorescent, coloured or metallic tracers have been used. Other techniques include the use of magnetic sand particles and electronic pebbles.

9.0 ENVIRONMENTAL DATA COLLECTION

The following types of environmental data are needed in order to assess, evaluate, or monitor the environmental characteristics of' the existing beach for the purpose of a beach management initiative.

Since the beach is part of a larger coastal ecosystem, characterising and understanding the bio-physical characteristics (of both natural and man-made systems) are important for successful implementation of any beach management plan. This serves to minimise the negative impacts of development initiatives in the coastal/littoral environment.

Parameters of importance include the following:

1. Flora/invertebrates/birds/fish/fauna,
2. Recreation activities (informal and formal),
3. Safety,
4. Topography and geomorphology,
5. Fishery activities,
6. Commercial industrial activities,
7. Tourism,
8. Land use,
9. Archaeology and heritage,
10. Navigation and shipping,
11. Coastal engineering infrastructure,
12. Water quality (beaches, tidal inlets, river mouths and adjacent offshore areas),
13. Sediment quality (beaches, tidal inlets, river mouths and adjacent offshore areas),
14. Coastal hydrodynamics,
15. River outflow - hydrological processes and
16. Geological characteristics.

Some of the data types are presented in Figure 9.1. If insufficient information exists within the study area, baseline surveys and assessment may be required. This survey work should be carried out in advance of any management or construction activity and should, ideally, take place over a number of years prior to any major change being planned.

These surveys and assessments should be part of the planning processes, and should facilitate optimum site selection and environmental and developmental planning decisions. This period of survey enables an impact assessment to be made of any natural fluctuations in population, community structure, abundance, distribution in response to developmental changes. The detail of survey work required is, however, site specific and will depend to some extent on the nature and scale of the proposed activities.

Figure 9.2 show the Impact Assessment (IA) process. This can take the form of development of an Environmental Assessment (EA), EIA and/or Strategic Environmental Impact Assessment (SEA). EA’s are general impact assessment, while the EIA is a comprehensive impact analysis, based on an inter-disciplinary study of the total environment (human and natural), with various options and remedial measures proposed. SEA’s are policy documents and guidelines, that supports the decisions and recommendations produced in an EIA.

TYPE OF DATA	COLLECTION	PROCESSING	ANALYSIS	BOUNDARY CONDITIONS
GENERAL Geography Infrastructure Legislation	Section 2.2.4 Geographical maps Maps, local authorities Local authorities		Capacity assessment Matching study	Distances, orientation Distances, class of road Restrictions for project
HYDRAULIC	Sections 4.2.1–4.2.9, Appendix 6, Section A6.4.1	Section 4.2.4.3, Appendix 6		
Wind	National meteorological office measurements, correlations	Recording of means over a time interval	Statistical analysts	Wind speed characteristic
Currents	Charts, registrations Tracers	Recording of a continuous signal Plotting	Modelling Movement analysis	Velocity characteristic
Storm surges	Historical data of extreme water levels, tides (local harbour) authorities	Sampling Recording of continuous signals or extremes	Decomposition, filtering Statistical analysis	Water level distribution
Waves	Existing data (harbour, coast authorities, ships) Hindcasting		Spectral analysis Refraction analysis Diffraction analysis Shoaling and breaking	(Distributions of) wave height, period and direction Local wave height and direction Local wave height and direction Impact velocities/forces Wind and wave set-up Draught of construction vessels
Bathymetry Morphology	(Admiralty) charts Measurements	Mapping, plotting	Differential analysis Slope analysis Extreme value analysis	Water depths, slopes
GEOTECHNIC	Section 4.3, Appendix 7	Sections 4.3, 5.2		
Soil density Grain size Compressibility Permeability Composition Friction	Sampling, weighing, measuring Sampling, sieving Sampling and tests Sampling and tests Sampling Sampling and tests	Mathematical operation Plotting Recording of continuous signals Recording of continuous signals Photographing Recording of continuous signals and plotting	Weighing, measuring Distribution analysis Differential analysis Differential analysis Comparison Numerical/graphical analysis	Soil weight Mobility Permeability Friction angle
MATERIALS	Sections 3.2, 3.3			
Engineering characteristics Production cost Transport cost Environmental impact	Handbooks Project evaluation Handbooks Standards, handbooks Project evaluation Measurements, experience Materials specifications Environmental conditions	Billing of quantities Data sampling	Interpretation Validity analysis Handbooks Validity analysis Project evaluation Correlation analysis Risk analysis Environmental conditions	Strength, weight Cost figures Cost figures Acceptability Risk level
PERFORMANCE	Section 4.1.12, Appendix 2, Section A2.9			
Damage and failures of existing structures	Monitoring measurements Repair records	Sampling of data on structure(s) after construction	Statistical analysis of loadings and damage	Level and frequency of damage and failure Cost and risk level

Figure 9.1. Some physical environmental parameters needed for planning and optimum decision making.

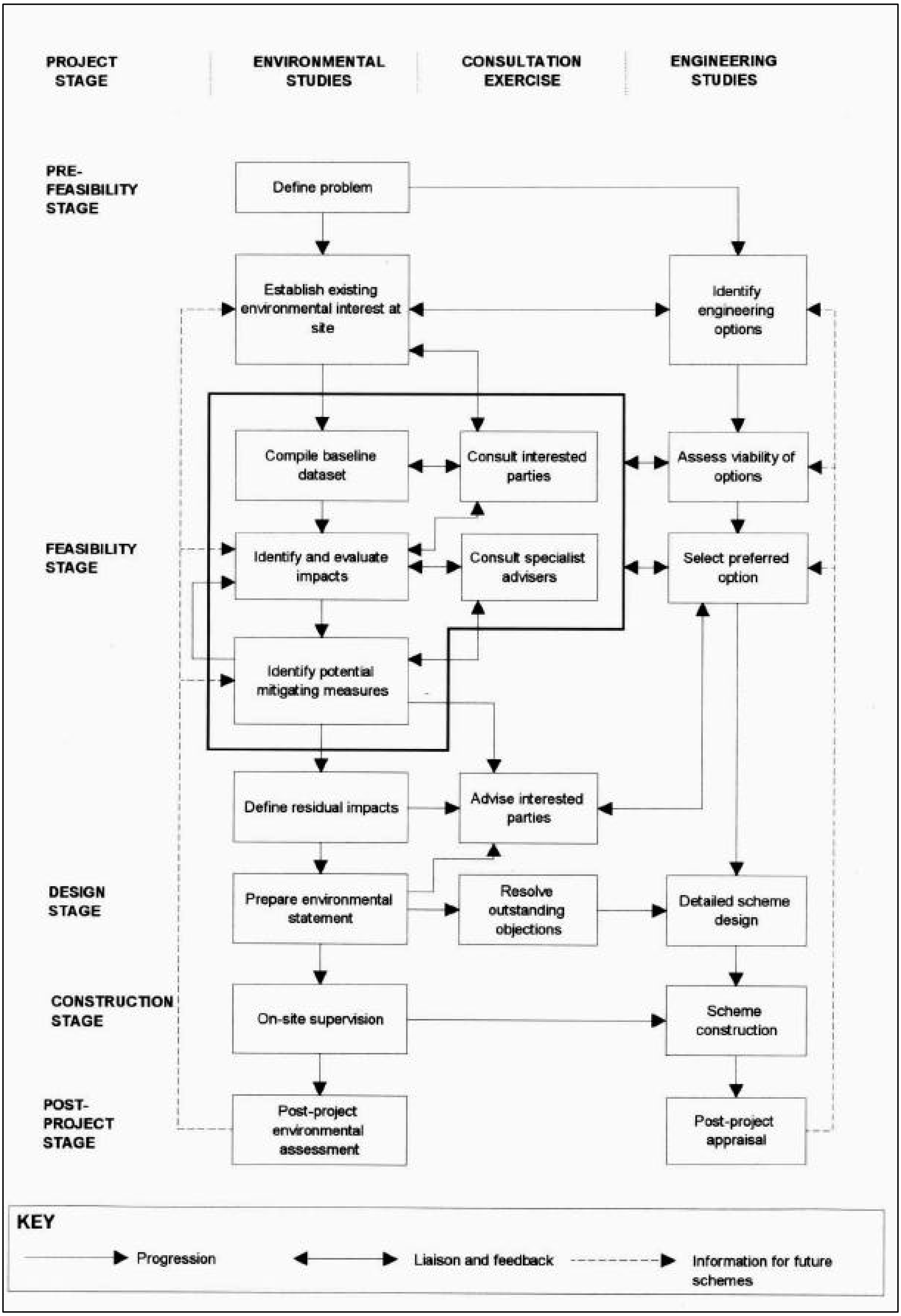


Figure 9.2. The environmental impact assessment (EIA) process.

Once impacts have been identified and predicted, it may be necessary to continue the survey work as a monitoring exercise during the management or construction activity, that any damage to the environment is indeed minimised or that environmental benefits are, in fact, being realised. This will facilitate a rational approach to project planning and environmental management.

On completion of any management or construction activity, it is important to carry out subsequent monitoring of some or all of the parameters previously surveyed. Such monitoring serves as a basis for comparison with pre-construction conditions. It is also important for assessing the recovery of a site, following the construction process and/or for assessing any beneficial impacts, which may have resulted.

10.0 NEARSHORE SEABED CHARACTERISTICS

10.1 Introduction

There are a number of features of the nearshore/littoral environment which affect the beach. There are three main areas of interest, namely the bathymetry of the nearshore zone, the sediments and their disposition over that zone and finally any evidence for the transport (longshore and cross-shore) of those sediments (CIRIA, 1996).

10.2 Bathymetry

The bathymetry of the nearshore zone is of interest to the beach manager for a number of reasons. First, many beaches extend to a considerable distance below the lowest tidal level. For the purposes of calculating beach material volumes, it is necessary to carry out hydrographic surveys of the submerged part of the beach profile (CIRIA, 1996).

Other features of the nearshore seabed may also be important, such as the gradual lowering of the level of the shore platform suspected as being a cause for long-term beach erosion.

Many beaches are also affected by the presence and movement of banks of seabed sediment, or of channels produced by tidal currents, the latter particularly in the vicinity of the mouths of estuaries or tidal inlets.

10.3 Seabed Sediments

Examining the nature and disposition of sediments on and beneath the nearshore seabed will often assist understanding the origins and development of a beach. Investigations of sediment deposits in the nearshore zone will sometimes show quite a close similarity to the local beach material. In addition, differences in composition and texture will also be brought out.

Some of the sediments forming beaches and the seabed offshore may have formed due to accretion over the past few thousand years or during Pleistocene to Holocene post-glacial, glacial or pre-glacial times. The conditions under which these sediments were laid down may have been very different from modern conditions, though their lithology may be similar to modern sediments.

Care must therefore be exercised when evaluating sediments from beaches or from offshore, to ensure that the sampled unit is part of the modern sedimentary regime and not part of all older or relic unit. Anomalous grain size, colour, lithic content and consolidation may be indicators of an older relic unit.

It is therefore important to distinguish between relic and present day material. Both exist and their relative importance at a particular site needs to be assessed.

10.4 Sediment Transport

The presence of sediment on the seabed does not necessarily imply that it is mobile. Sand, gravel and coarser material on the seabed may be lithified into an immobile mass by a matrix of finer sediments and biological organisms. Consequently, the threshold of motion is high and may not be reached even during severe storms and tidal flows.

Often large areas of the seabed are colonised by marine flora and fauna and the presence of such wildlife gives a good indication of the lack of mobility of the seabed sediments.

Sediment shows evidence of its mobility by being moulded into sedimentary structures on the seabed. The smallest of these are ripples, as commonly observed on the foreshore of a sandy beach. As the mobility of sediment increases, the size and persistence of the bedforms also increases.

The smaller of the more persistent bedforms may reflect only recent sediment transport conditions, such as those present during part of the tidal cycle or during the most recent storm. The larger forms indicate a longer-term sediment transport pattern and, usually, the net direction of that transport. Care has to be taken since these bedforms may, like the sediment be relic features and hence not indicate present day sediment transport patterns.

Sediment transport can be interpreted from good quality aerial photography or high-resolution satellite imagery. Sediment plumes or lobes of sediment deposits are easily discerned on such remotely sensed imagery, e. g. Figure 10.1.

Figure 10.1. Brown sediment plumes generated by cross-shore transport (to the top centre of the photo), Tarawa, Kiribati, 1998 aerial photography.

These data can guide ground surveys and are key for interpreting regional patterns of sediment transport in nearshore areas. Figure 10.2 show a similar phenomena, but for longshore transport in Bikenibeu, Tarawa, Kiribati. Note the dominant sediment transport to the left of the photo, to the west, with ridges of sand aligned perpendicular to that direction of longshore sediment transport. Note also the plumes of dispersed sediments (lighter brown colour) in the deeper areas to the top of the photo (the lagoon).

Figure 10.2. Longshore transport on a 1998 verical aerial photo of Bikenibeu, Tarawa, Kiribati.

11.0 SEA STATE AND OCEANOGRAPHIC DATA COLLECTION

11.1 Introduction

The importance of the hydraulic processes of waves, winds and tides on the development of beaches is clearly essential. These are key boundary conditions that affect the development of erosions forces, which cause stress to develop in the littoral environment, causing erosion and land loss. Therefore, characterising these parameters are key items which must be incorporated in any beach monitoring programme.

The initial step is always to establish what information is already available and what information is likely to be available in future (CIRIA, 1996).

In addition, for the interpretation of beach profile data, the lack of these boundary conditions do not allow proper assessment of the reasons for beach changes, through time and space. This is essential, especially in light of the fact that beach hydraulics is an important element, which affect the equilibrium of beaches (Figures 11.1 and 11.2). The key processes to note here are follows.

Breaking waves impact and run-up on the beach. Some of it drains downslope, on the beach, due to gravity, while some of the water seeps into the sediments, also under the influence of gravity. Seepage contributes to the shallow beach water table and then adds to shallow groundwater flow, below the beach, or interflow/thoroughflow. This thoroughflow, will drain downslope, also towards the sea, and into the surf zone. However, some of it will also seep to the surface of the seabed. This process is facilitated by high pore-water pressure within the sediments, especially as it is below the seawater level and saturated. This reduces the effective stresses between the sediment grains and causes some buoyancy of the sediment grains and lift forces to develop, eventually resulting in exfiltration of the thoroughflow and dislodgement of sediment particles. This dislodgement causes erosion and removal of sediment in the water column.

11.2 Wave and Current Measurements Near Structures and the Nearshore

The interaction, between waves, currents and coastal structures are complex (see Section 5.7) and not well-defined in theory. Local beach response is, therefore difficult to predict, even with the use of numerical or wave tank bed physical models. It is significant to note that models, which are development, must be a true analogue of the actual physical conditions and corresponding boundary condition. In addition, models must be validated to ensure that they represent true conditions. This of course can only be done with appropriate site specific data and validation programmes. In the absence of such validation, model results may not be useful.

Bearing in mind that the beach is a continuously evolving dynamic environment and is difficult to predict and part of an open system, models which are run for specific temporal and spatial coverage, are valid only for those coverage. Should site conditions and processes change, then new boundary conditions must be specific and used to re-run the model to obtain the new predictive analysis. For that very reason, when not validated, model test results have very limited applications.

The experienced practitioner and professional should exercise expert judgement when using model test results, especially those derived from commercial modelling software (written for “global” use).

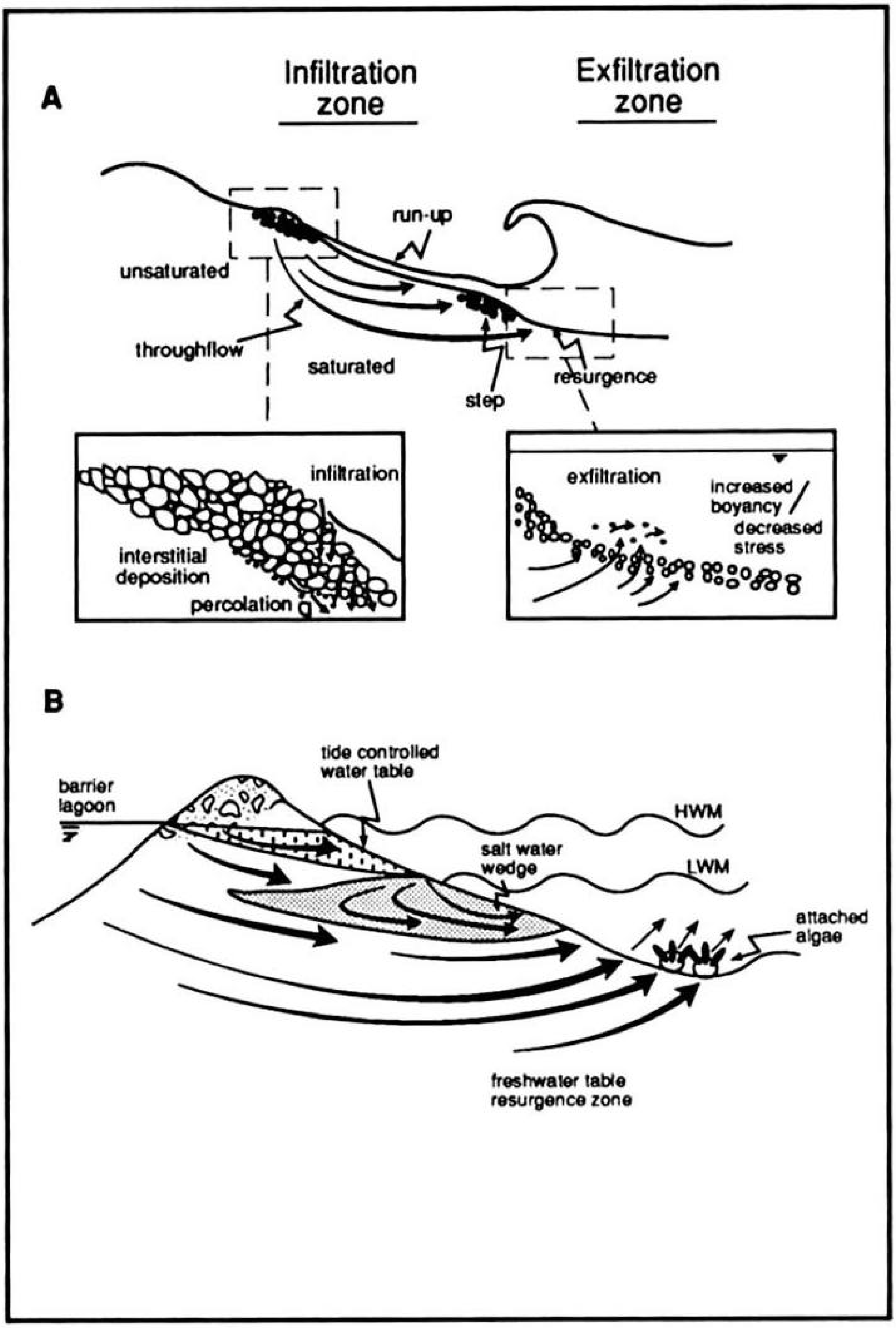


Figure 11.1. Hydraulics of beach sediments on an atoll.

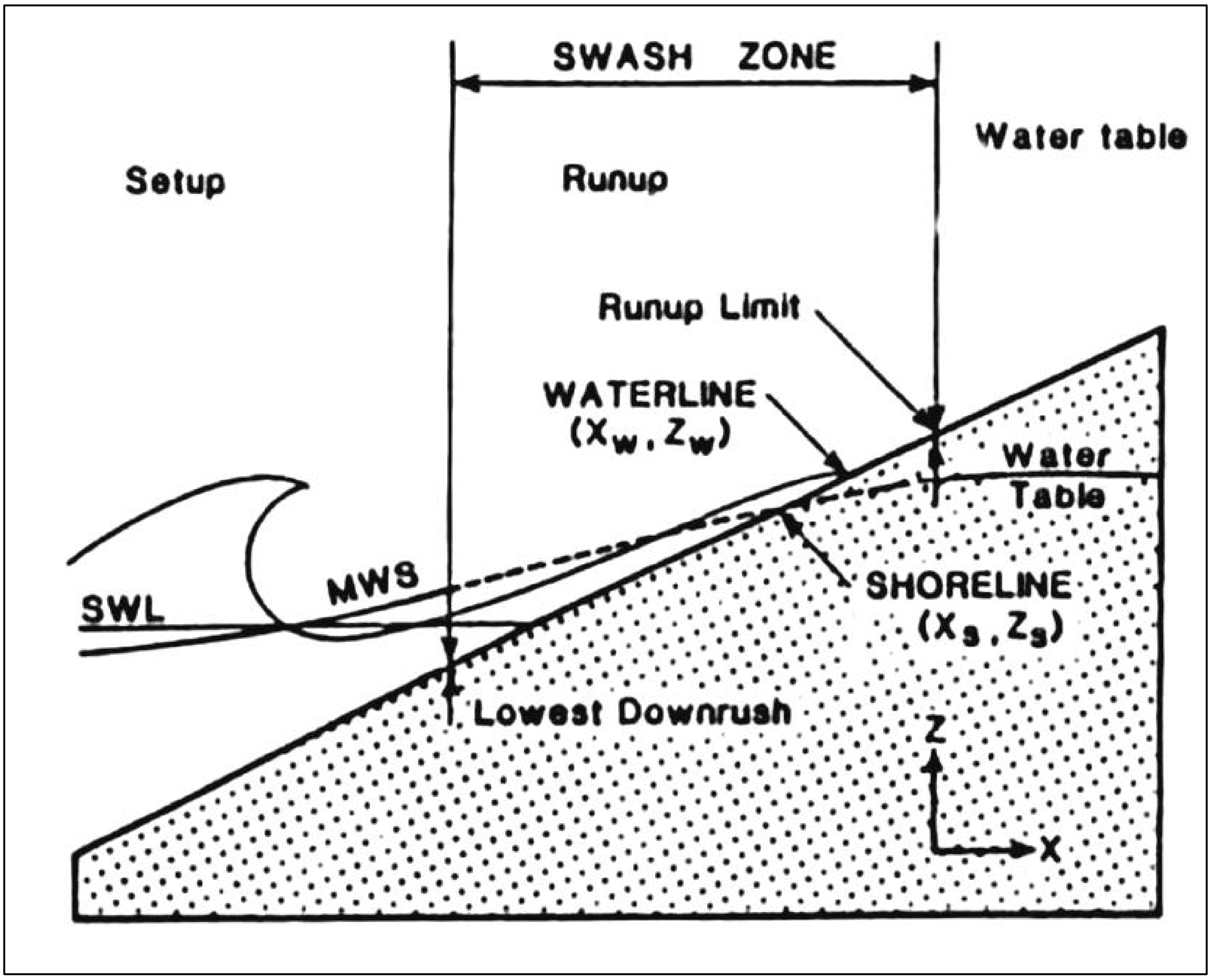


Figure 11.2. Hydraulics of the seawater-beach-land interface.

Good quality records of' waves and currents near and adjacent to structures, in conjunction with beach response monitoring, will improve the reliability of the prediction models and also provide useful data on the design, construction and maintenance of coastal protection works. This approach will help in reducing the risk to constructed facilities along the shorefront.

Wave processes near structures include diffraction, refraction, reflection, transmission, impact and overtopping. Of key importance is reflection of an impact/incoming refracted wave at the base or toe of the structure. This results in significant sediment scouring and erosion at the toe of an unprotected structure (Figure 5.10). The removal of sand, by scouring at the base of coastal structures usually lead to loss of beach volume in the vicinity of the structure and also, undermining of the foundation of the structure. In many cases, where the foundation is shallow, the structure undergoes settlement, and eventually topples.

Reflection also causes a smaller wave (than the incoming impacting wave) to be generated. Where the incoming wave is perpendicular to the structure, the reflected wave is transmitted in the opposite direction. Transmission of a reflected wave, from the structure, into the breaker zone usually lead to the development of “freak waves”[4], due to interaction with the subsequent

[4] Abnormal wave approach and transmission direction. Different from the significant wave approach and heights.

incoming waves. These cause the development of eddys and bottom currents near the seabed, leading to scouring and erosion of loose sediment. Reflecting waves cause the subsequent impact/incoming wave to be much larger waves, causing greater scouring when they impact on coastal structures. Examination of the seaside aspect of coastal structures reveal large sediment plumes and sediment entrained backwash.

Overtopping is also important, as is run-up, as these phenomena affect coastal flooding, splash and spray way beyond the shorefront. These also cause damage to adjacent structures and infrastructure by abrasion and scouring (Figure 5.1). In addition, spray and splash lead to damage and deteroriation of concrete structures along the shorefront. This usually results, due to ingress of seawater into the concrete. Most concrete cast with Portland cement (ASTM Type I) are not resistant to chemical attack by sulphate and chloride ions. These ions which are common in seawater, react with cement and cause the precipitation of ettringite, an expansive sulphate, within the concrete matrix. This leads to swell pressure/tensile stress within the concrete, which due to its very low/no tensile strength, causes cracking and eventually spalling[5] of the concrete (See Section 5.2). Many coastal concrete structures in the Pacific are affected by this process.

Important information on wave processes can also be gathered from direct observation. This applies particularly to overtopping and wave transformation around and through structures. The use of digital filed video recording is also very useful. These types of observation are best taken during high spring tides, or if possible during storm events. Since it is extreme conditions which cause the most damage, the collection of data during these events are crucial.

If such data is being collected the time of the day, the date, tidal cycle and compass direction of the view of the photography should be recorded. In addition, all photographs should have a clear scale. If photography is being taken at different times of the month, of different seasons and years, then the same view direction (compass direction) must be maintained, unless it is impossible, due to a significant change in the shoreline morphology.

Coastal protection works, which are damaged, should be instrumented and damage intensities noted. Failure analysis/forensic engineering is an important tool for optimising design in the future. In addition, learning from missed predictions and oversights in design is one of the best ways of improving the effectiveness of coastal protection works. Instrumentation can be from simple scour and abrasion measurements, including surface area, depth, volume and location along the structure to more complex structural cross sections and profiles of the structure. In addition, settlement and tilting of structures, like large breakwater and wharf segments can be instrumented with inclinometers and settlement gauges. Displacement in the X and Y planes can be surveyed with precise levels, theodolites or high-resolution differential GPS.

Measuring and observing currents around structures can be undertaken more easily than wave measurements. They can be measured over time at discrete points or as flow paths. A measurement programme that combines both methods is most appropriate in the presence of structures (CIRIA, 1996).

Flow paths can be monitored by deploying surface floats, drifters or sub-surface drogues. These can be anything from oranges to PVC buoys to sophisticated devices which can be tracked by radar or other electronic pulse signalling systems.

As the purpose of monitoring is to provide flow velocity and corresponding vector data for predicting beach response, then sub-surface drogues are more useful as they follow near-seabed

[5] Flaking of the surface of concrete after cracking.

current flow, rather than surface flow. For deeper nearshore areas, like atoll reef lagoons (greater than 15 m), there are in many cases clearly differentiated surface, mid-water and bottom current flows. It is important to identify from early on, which currents are crucial to your program design. Not all measurements may be needed.

Apart from drifter and drogue studies, current metres may be used to assess flow velocities and direction. If a large array of meters are available for deployment at various depths in the water column and for a full spatial coverage, a good representation of 3-D flow can be obtained. However, where this is commonly not the case, then drogue and drifter studies are crucial for adequate spatial and temporal tidal coverage. In many cases, one of two current metres deployed in atoll lagoons cannot give good representation of current flow vector and magnitude. In those instances, it is more desirable to use a large array of drogues than one or two metres only. That spatial and temporal coverage will more than likely produce better results, than the data from a single metre. This is bearing in mind the varied nature of seawater flow in surface, mid and bottom layers, under rising and falling tides and under varied wind and wave set-up.

Single-point measurements can be made by deploying directional current meters for one or two or more (depending on needs) spring and neap-tidal cycles. Current monitoring must be combined with measurements of incident wave heights, approach and period (storm waves, swells and wind waves), water levels, wind velocities and directions.

In almost all cases, a combination of current metres and drogues and drifter is desirable. Where current metres are not available, as in many Pacific islands; excellent data can be procured from drifter and drogue studies. For such programmes, it is necessary to obtain accurate position and time and the various trajectories the drogue or drifter takes. This can be done with the aid of a high-resolution differential GPS and proper timer. Where GPS is not available a theodolite is excellent. In addition, navigation equipment can be used for more remote offshore locations.

It is important to consider that the accuracy of positioning depends on the model and resolution of the survey equipment. For high-resolution studies, it is necessary to use high-resolution survey equipment. For regional and general studies, lesser accuracy is tolerable, though not desirable.

Site-specific studies using equipment with low resolution in the X and Y planes (like 100 m) may not be very useful. It is important to select the appropriate tools for the particular job. Too often, this is a major problem in project execution and yields poor-quality results and interpretation. The frequent problem of trying to solve site-specific problems with regional and general or low resolution data can be avoided, if these aspects are considered at the project planning stage.

For the above mentioned reasons, the field programme must be extensive enough to allow tidal currents to be monitored over complete ebb and flood-cycles, on both spring and neap tides, and must allow observation of currents over a “substantial area.” The “substantial area” is ideally the circulation cell of the littoral environment being investigated. This represents the system approach to process studies. For that reason, it is important to identify the extent of coastal circulation cells or the discreteness of littoral systems in the area of interest. If this is not identified, then the instrumentation programme will not be optimised.

Where possible, the programme should also attempt to monitor wave-induced currents, which are generally only of interest close to the structure. The adoption of such a process will facilitate a rational approach to understanding the dynamics of the area of interest.

12.0 GEOTECHNICAL DATA COLLECTION

12.1 Introduction

The principal objective in undertaking geotechnical data collection for a beach management project is to derive a comprehensive understanding of the engineering-geological and geomorphological make up of the coast, beach and foreshore areas.

Such information will be used to:

1. Facilitate analysis of coastal processes (e.g. to assess engineering performance of soils or the nature of processes that contribute to their distribution),
2. Aid in the assessment of coastal erosion and deposition patterns,
3. Assessment of the hydraulic properties of sediments and soils, and
4. Provide input parameters and geotechnical boundary conditions for the design of foundations, reclamation and fill works.

Some geotechnical parameters are presented in Figure 9.1.

12.2 Site investigation

Good site/ground investigation practice follows standard procedures[6]. These guidelines can be summarised to four easily definable steps which are now described in turn.

12.2.1 Desk study

The purpose of' a desk study is to assemble all the available existing and published data on a particular site for the project. This is the first part of the data collection exercise for any project which is done. Of particular interest in the preliminary phases of an investigation for a beach management project are:

1. Published technical papers, journals, books, reports and theses,
2. Present-day and historical Ordnance Survey topographic maps
3. Cadastral maps (showing property ownership and layout),
4. Geological maps and memoirs,
5. Soil survey reports and maps,
6. Admirality and hydrographic charts,
7. Recent and historical aerial photographs,
8. Satellite imagery (high-resolution, appropriate to the project needs),
9. Consultant reports from previous engineering developments,
10. Any geotechnical model data from previous studies,
11. Local Government information (library and museum records) and
12. Existing ground investigations.

[6] There are several standards available. Use internationally accepted guidelines which can be repeated by anyone in the future e.g. ASTM.

12.2.2 Site Reconnaissance

A rigorous visual examination of the site should be undertaken at the earliest opportunity and be carried out by a suitably qualified and experienced geotechnical engineer or engineering geologist.

A site reconnaissance is best performed on foot and it is essential to carry a site or district plan which can be marked with observations as the reconnaissance progresses.

Particular attention should be paid to omissions or alterations to the features described on maps or plans, including topographical, geological or man made. Photographs taken during a site reconnaissance often identify details missed by the naked eye and are always more cost effective than a return visit.

Detailed observations should be made of the nature and characteristics of the exposed strata on the beach, foreshore or coastal cliff and a preliminary judgement made on the susceptibility of the foreshore strata to erosion. Any evidence of surface water, springs or groundwater flow should be recorded.

12.3 Detailed Examination and Special Studies

Based on the results of the site reconnaissance and the data available from the desk study, an evaluation will be made of the need for a more detailed examination or special study of the ground conditions, geology or geomorphology. The most appropriate methodology will be determined by the scope of the project, problems to be addressed and available budget.

Further detailed examination might include, topographic surveys, geological mapping, aerial photography, and more rarely, geophysical surveys.

The desk study and site reconnaissance may have revealed that a more detailed ground investigation is required with field work incorporating the drilling, logging and sampling of boreholes and trial pits.

12.4 Interpretation

The final step of the investigation is to assimilate, review, correlate and interpret all the recovered data. The key factors that may affect design decisions will be:

1. The lateral extent and depth of beach deposits,
2. The geotechnical properties of the beach deposits and underlying material,
3. Characteristics of beach substrata, their origin and weathering profile,
4. Coastal cliff or beach stability and rates of erosion,
5. Beach water table, and
6. Tidal lag in the variation in groundwater levels, saline intrusion and groundwater conditions.

13.0 DATA STORAGE AND ANALYSIS

13.1 Introduction

To manage a beach successfully, an accurate picture of the actual response of the coastal processes is required.

Data are required in four (4) key areas:

1. Understanding the past: data are required to identify short-term variability and long-term trends,
2. Identification of present problems: data are required to monitor alarm levels
3. Predicting the future solution: data are required to calibrate and validate physical and numerical models for future solutions and
4. Monitoring the future solution: data are required to monitor the solution, particularly with soft engineering schemes (CIRIA, 1996).

The collection of data in a dynamic system, such as a beach, is necessarily a continuous task as the system state and response are continuously changing. It involves measuring a large number of variables over a larger geographic area than of immediate concern to the present-day manager. The result is that, in well planned monitoring programmes, a large amount of data will be collected from a variety of sources. It is, therefore, essential to plan carefully the storage of these data in a form which makes further query and analysis most efficient. The following is based on guidelines from CIRIA (1996).

13.2 Software

Many people are familiar with spreadsheet programs, such as *Microsoft Excel*, and it is possible to develop worksheets to perform required tasks. Visualisation of the data is extremely easy, however numeric and report analysis is more difficult. The disadvantage is that spreadsheets are not optimised to manipulate large amounts of data. As the database increases in size the speed of the spreadsheet may be reduced. In addition, spreadsheets lack some of the functionality associated with database programs.

CAD programs can be used to store information with geographical locations plus details of' attributes. The presentation of geographical data is very easy. Other types of display, such as time series and comparison between variables is more difficult. The database functionality of CAD programs may be limited.

Both spreadsheet and CAD programs are simple and flexible; however they are more limited in functionality that a bespoke database with routines written specifically to analyse and present beach data. This may also include simple predictive models to allow the identification of alarm levels and forecasting of future beach response, such as future beach volumes and level.

13.3 Geographical Information Systems (GIS)

A GIS is a software package for the acquisition, storage, retrieval, manipulation and analysis of spatially referenced data. The most sophisticated GISs are expensive and require considerable processing power and storage capacity, whilst basic systems are also available for use on desktop PCs at a modest cost.

Despite this wide cost range, all systems are based on two essential components:

1. A database capable of' storing and retrieving information about the mapped data, which is referenced by (geographical position and other search criteria. Some systems include an internal database but most now include interfaces to external relational database (RDBMS).
2. A visualisation system capable of displaying spatially-referenced data (e.g. maps) and interrogating the mapped data for co-ordinate information. Other graphics, such as graphs, photographs and video images may also be displayed.

It is important to distinguish how a GIS represents data, either as raster or vector, and also to distinguish whether the data are structured or unstructured. The method of representation is fundamental to the type of information that can be recorded and the analysis that is possible.

The functionality of the GIS must be considered when selecting a GIS system. Again, there must be a clear understanding of the proposed use before a system is purchased and of how, and by whom, the system will be maintained, updated and accessed.

13.4 Data input

There is a large number of different data storage and transfer formats, both for raster and vector data. It is essential that the input and output formats supported by the selected GIS are compatible with those used by external suppliers of data (e.g. OS map format). Similarly, the ability to input and output Data Exchange Format (DXF) files allows a direct interaction with Computer assisted Design (CAD) packages.

The GIS must also provide efficient methods for inputting data derived from site surveys and modelling studies. This information could be in the form of figures, photography, maps, tables, text as well as computer files.

13.5 Data management and processing

Before data input to a GIS can be analysed for a particular purpose it is usually necessary to perform some type of pre-processing. This may include co-ordinate transformation, rescaling, joining, clipping and edge-matching of polygons, conversion to raster data or to vector data.

13.6 Data analysis

Examples of standard GIS spatial analysis functions based on vector data are:

1. Area and perimeter calculations,
2. Overlaying and merging of polygons,
3. Summing of spatially coincident values,
4. Generation of Thiessen polygons (assigning area characteristics using point data),
5. Buffering of features (defining zones of influence around a point, line or area) and
6. Point-in-polygon (the geographical occurrence of one feature within another).

13.7 Database operations

The ability to carry out spatial queries is what differentiates a GIS from conventional databases. These processes include simple data retrieval using spatial delimiters (windows or proximity measures) and Boolean operators (AND, OR, NOT, etc.) to locate, display and tabulate cases where particular conditions are satisfied.

The following questions are typical of the types of queries a GIS may be used to perform:

1. Are there any wave measurements within 10 km of this location?
2. What are the seabed surface deposits at this location?
3. Where is survey station 24-B?
4. What type of sea wall is at this location?
5. What type of sediments are found near revetments?

13.8 Three-Dimensional Surface Modelling

Surface modelling can provide three-dimensional representation of recorded data or model output. This may be used for further analysis such as contouring, slope analysis and volume estimation (e.g. volume above some threshold such as (MHWS) or for visualization purposes.

13.9 Applications

It is vital to recognise that whatever GIS product is selected, for whatever application, that the basic GIS functions, described above, must be used to build the specialist processes needed to meet the requirements of that application. This may involve building links between the GIS and external software and numerical models. It may also be necessary to develop completely new functions tailored to a particular application.

14.0 APPRAISAL OF MONITORING RESULTS

14.1 Introduction

The principal objective of the monitoring described above is to provide information of value in the efficient management of a beach. More precisely, this involves:

1. Reviewing, the information obtained,
2. Deciding what further monitoring is necessary and
3. Deciding whether any (different) management of the beach is necessary.

14.2 Review of information obtained

A first step in appraising a monitoring exercise is to decide whether the required information has actually been collected and whether it has then been analysed and the results made available to the correct audience. In this context, it is important to have a clear statement of the requirements of a monitoring exercise beforehand, by means of a pre-determined set of quality criteria. In many cases, specialist advice on the initial specification of surveys should be sought before starting monitoring.

It is equally important that any information collected should be analysed promptly and the results of that analysis stored safely, as well as the information itself. The former requirement allows possible re-surveying to be carried out if results are unusual (e.g. in comparison to other surveys.). The latter is often neglected, but it is important in the context of beach management since it may be many years before the full value of a data set can be appreciated.

Long-term trends in beach levels, for example, may be effectively masked by the effects of a few years of untypical weather. As already noted, therefore great care is required in selecting appropriate baseline and monitoring beach profile "envelopes".

It is therefore best to set up, at the same time as setting up the monitoring programme and as part of' the beach management strategy, a clearly-defined approach to analysis of results.

Finally, as with many other aspects of beach management, it is likely that the cost effectiveness of a monitoring exercise will come under scrutiny from time to time. Much of the value in monitoring lies in its ability to demonstrate the behaviour of a beach to a wide audience, perhaps to provide reassurance that a particular management strategy is succeeding, or to show that other action needs to be taken.

14.3 Deciding on further monitoring

If a beach is being actively managed, for example by periodic nourishment or recycling, some beach monitoring is likely to be carried out indefinitely. In a few other situations, however, a monitoring campaign may only need to last for a limited period. For example, with pocket beaches; although this does not eliminate the possibility of repeating such a campaign at some stage in the future.

In practice, the decision about the nature and frequency of further monitoring will depend both on what is monitored and the specific character of the site.

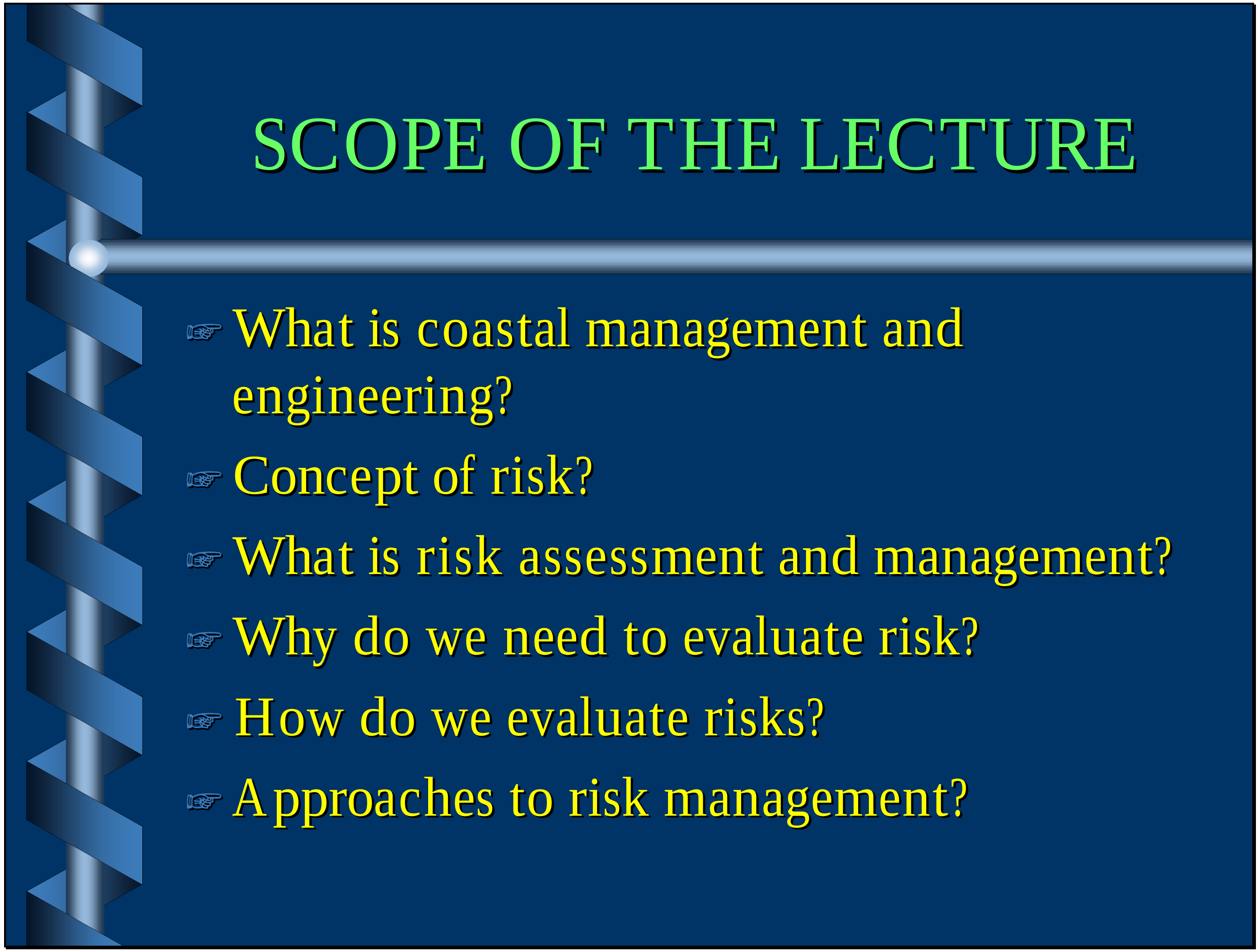
15.0 LECTURES

15.1 Appraisal and Management of Erosion Risks in Coastal Engineering and Management

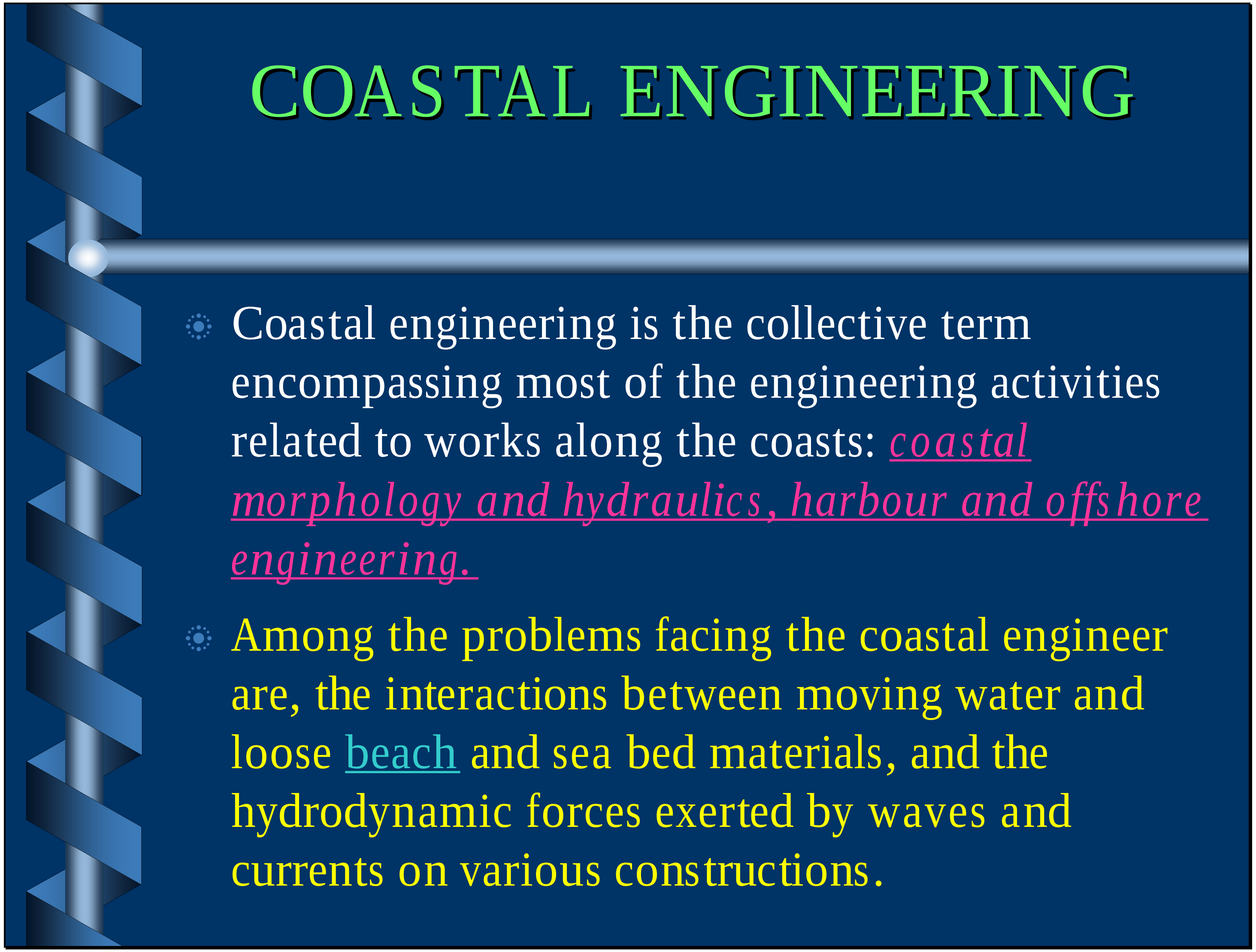
Slide 1


APPRAISAL & MANAGEMENT OF EROSION RISKS IN COASTAL ENGINEERING AND MANAGEMENT
Russell J. Maharaj, Geologist & Engineer
Commonwealth Secretariat /CFTC Expert
South Pacific Applied Geoscience Commission (SOPAC)
Suva, Fiji
MS 211- USP, Fiji
Nearshore Environment
and Coastal Engineering
27th-31st March 2000
SOPAC

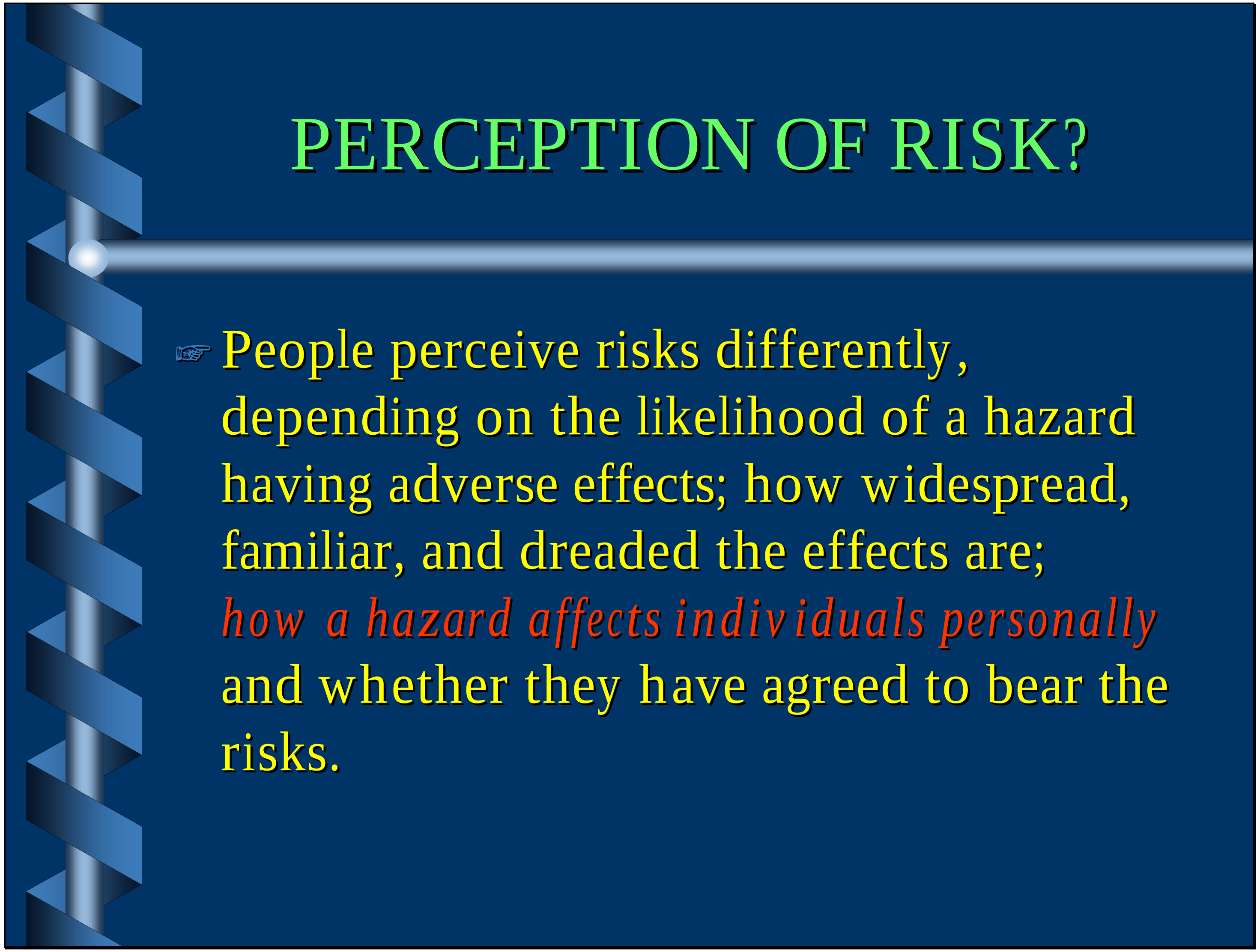
Slide 2


SCOPE OF THE LECTURE
What is coastal management and engineering?
Concept of risk?
What is risk assessment and management?
Why do we need to evaluate risk?
How do we evaluate risks?
Approaches to risk management?

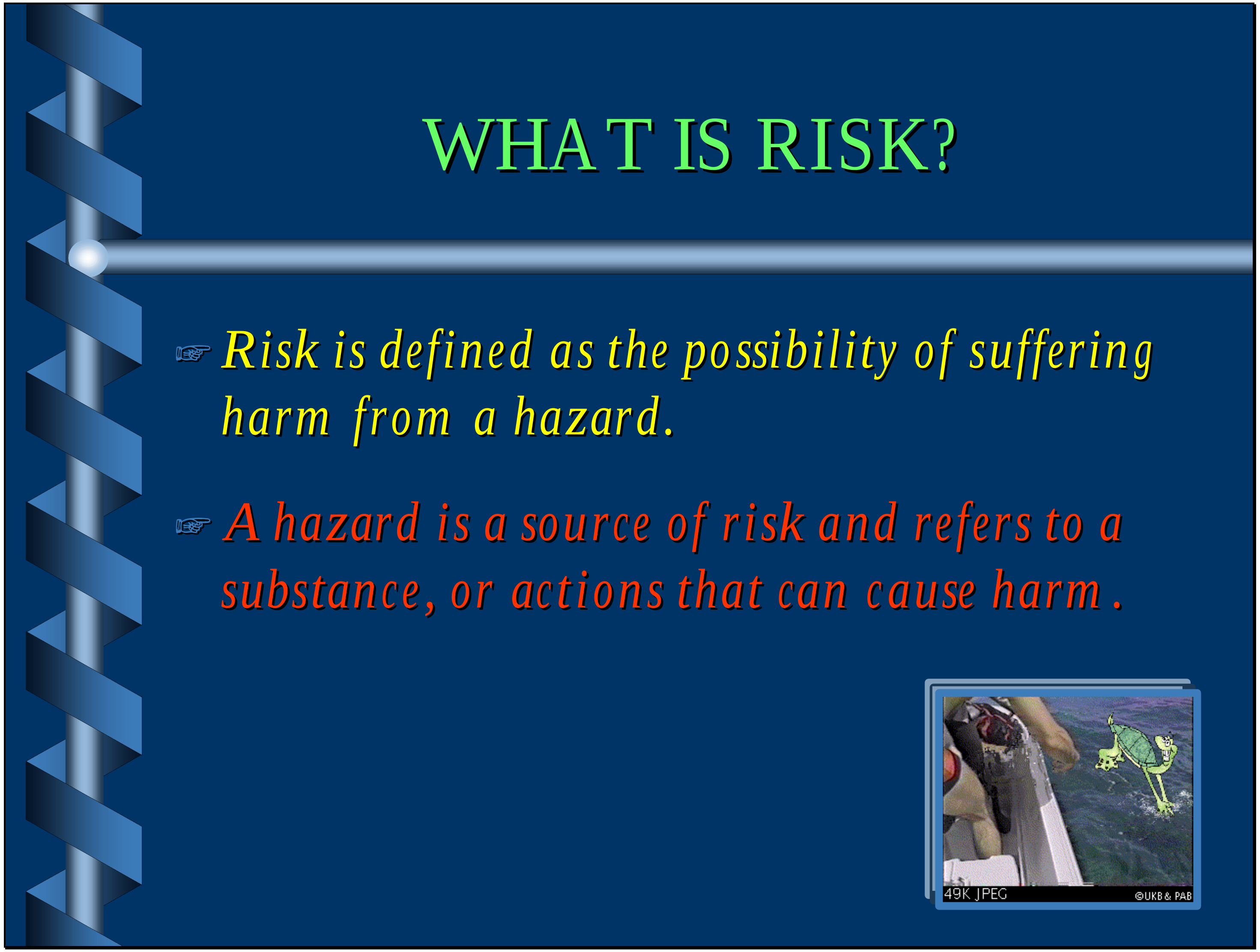
Slide 3


COASTAL ENGINEERING
Coastal engineering is the collective term encompassing most of the engineering activities related to works along the coasts: coastal morphology and hydraulics, harbour and offshore engineering.
Among the problems facing the coastal engineer are, the interactions between moving water and loose beach and sea bed materials, and the hydrodynamic forces exerted by waves and currents on various constructions.

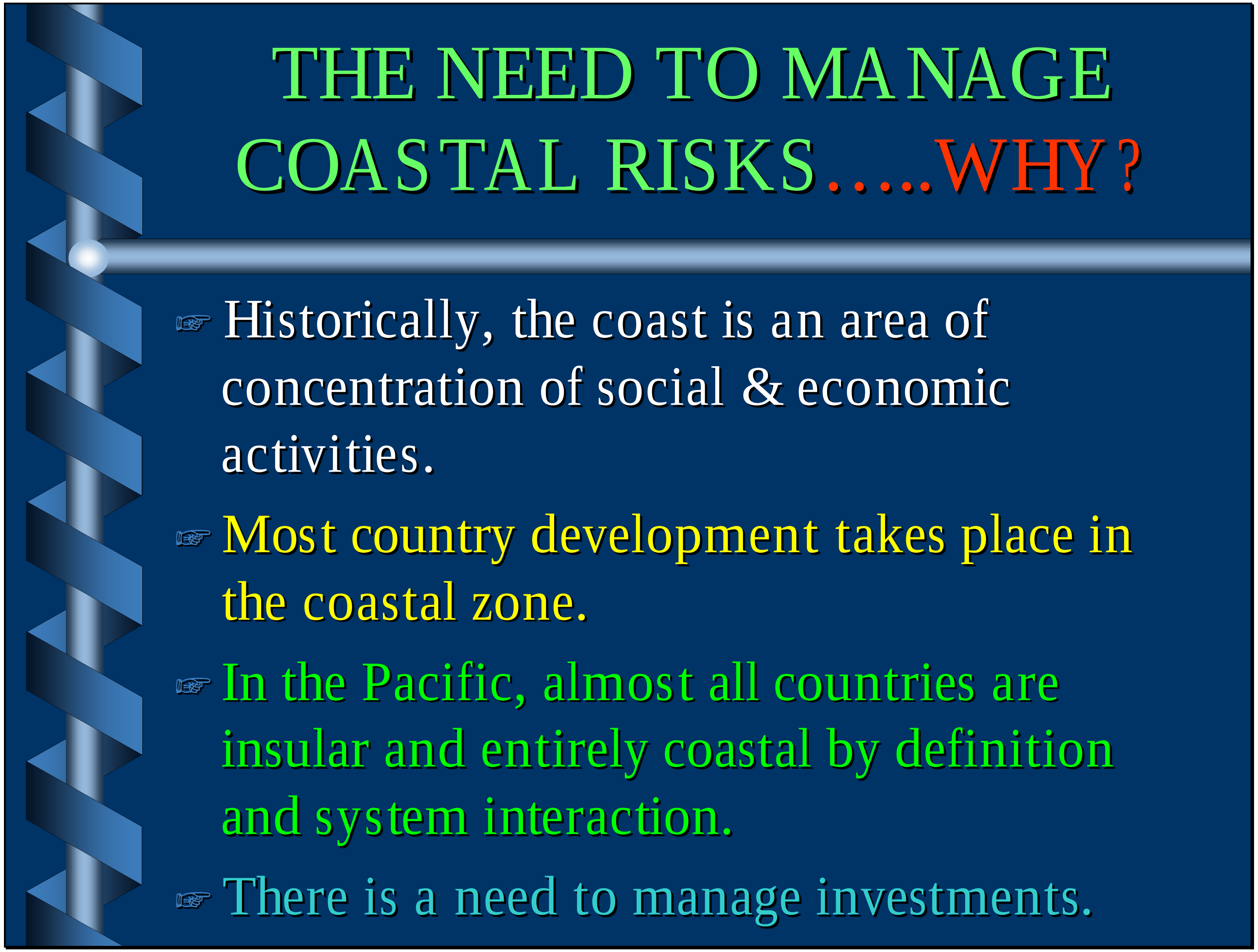
Slide 4


PERCEPTION OF RISK?
People perceive risks differently, depending on the likelihood of a hazard having adverse effects; how widespread, familiar, and dreaded the effects are; *how a hazard affects individuals personally* and whether they have agreed to bear the risks.

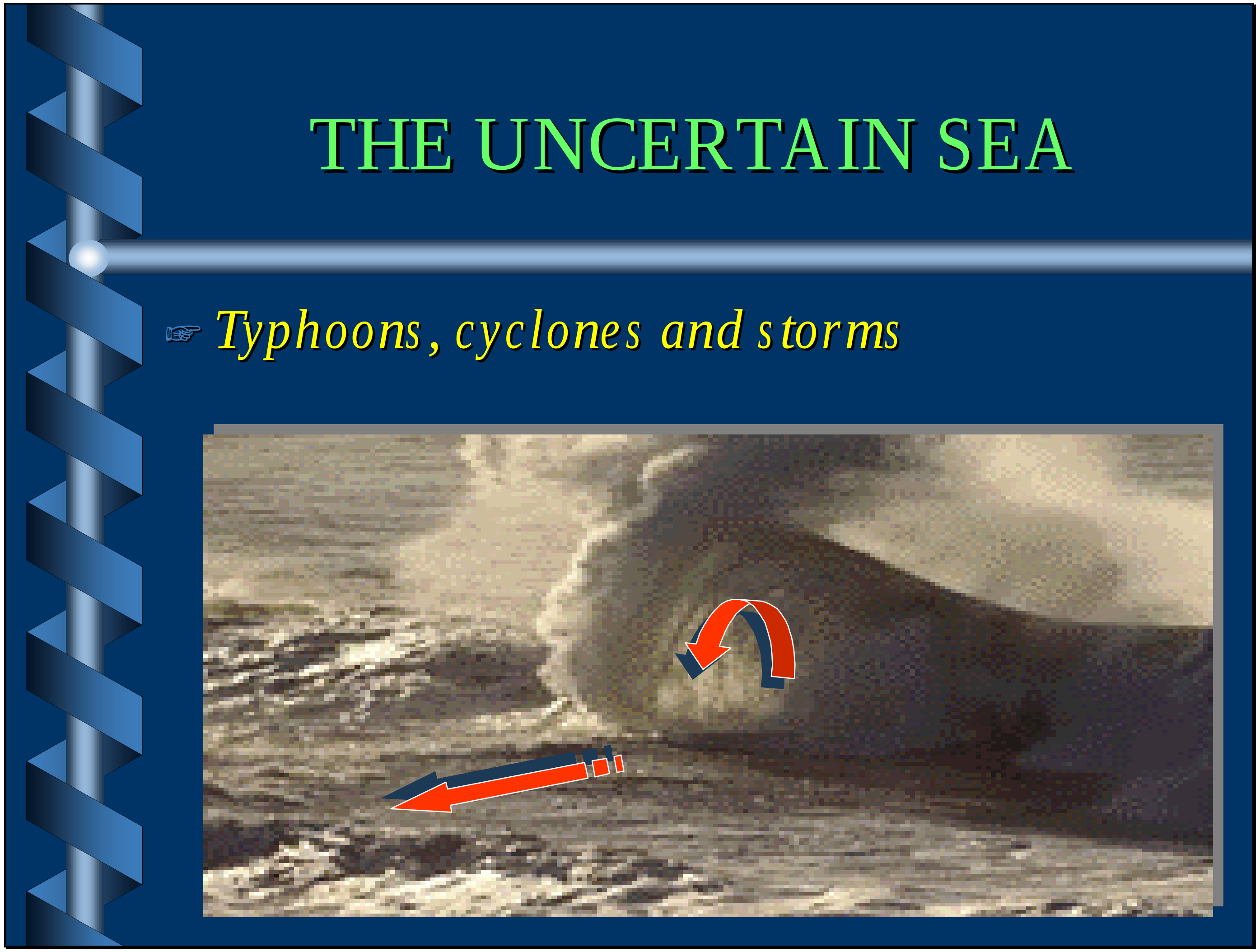
Slide 5


WHAT IS RISK?
Risk is defined as the possibility of suffering harm from a hazard.
A hazard is a source of risk and refers to a substance, or actions that can cause harm.
49K JPEG
©UKB & PAB

Slide 6


THE NEED TO MANAGE
COASTAL RISKS.....WHY?
Historically, the coast is an area of concentration of social & economic activities.
Most country development takes place in the coastal zone.
In the Pacific, almost all countries are insular and entirely coastal by definition and system interaction.
There is a need to manage investments.

Slide 7



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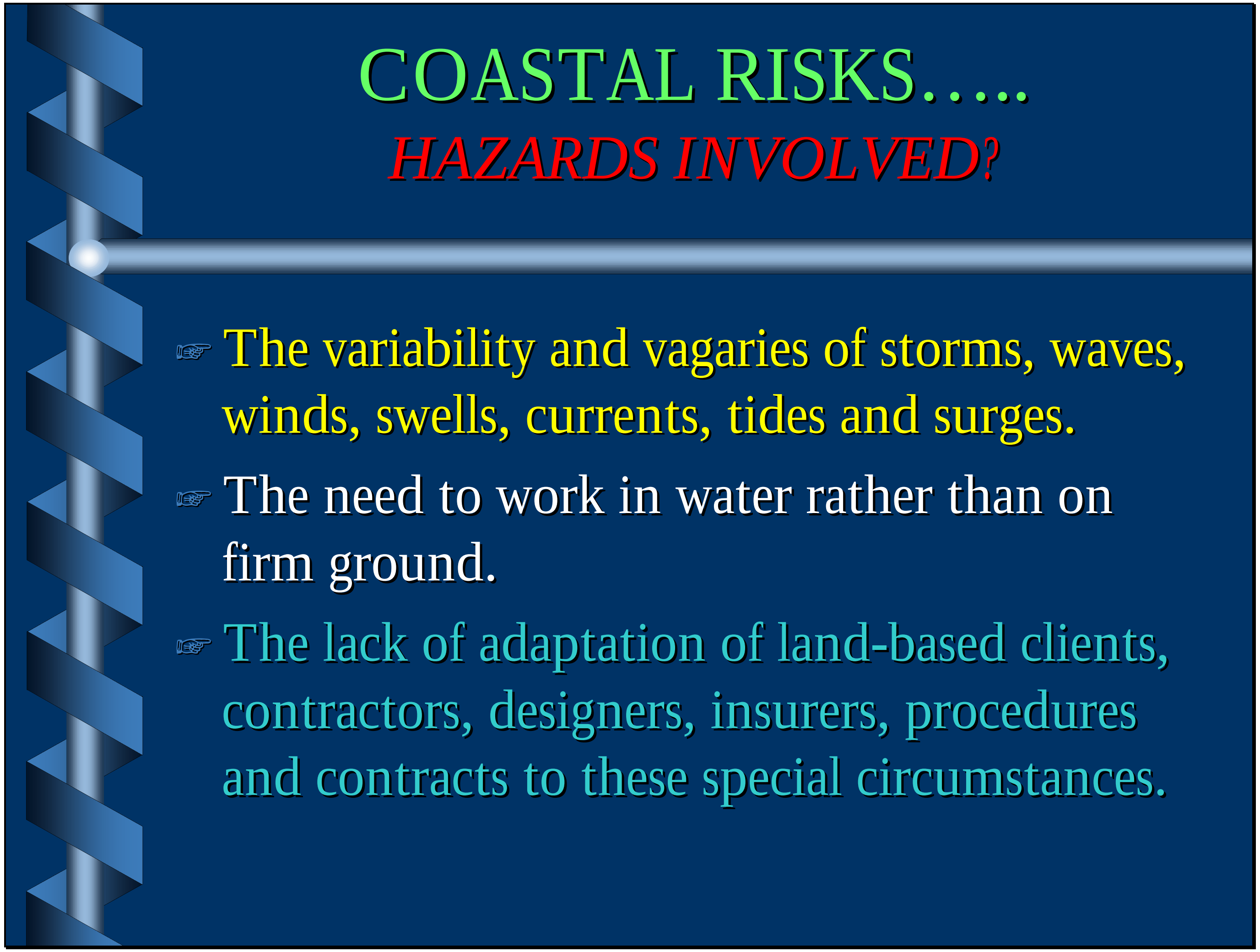
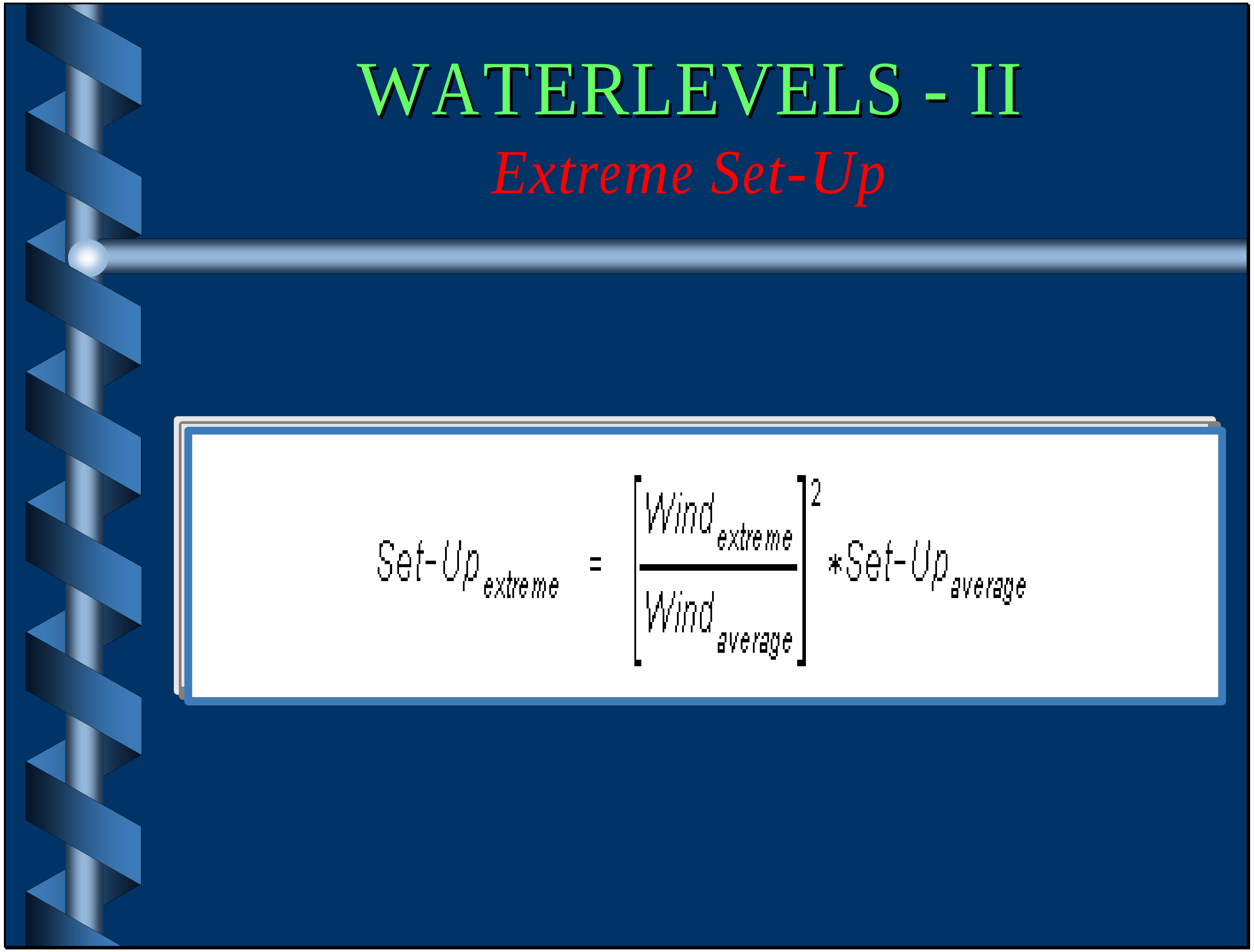

COASTAL RISKS…..
HAZARDS INVOLVED?
The variability and vagaries of storms, waves, winds, swells, currents, tides and surges.
The need to work in water rather than on firm ground.
The lack of adaptation of land-based clients, contractors, designers, insurers, procedures and contracts to these special circumstances.

Slide 9

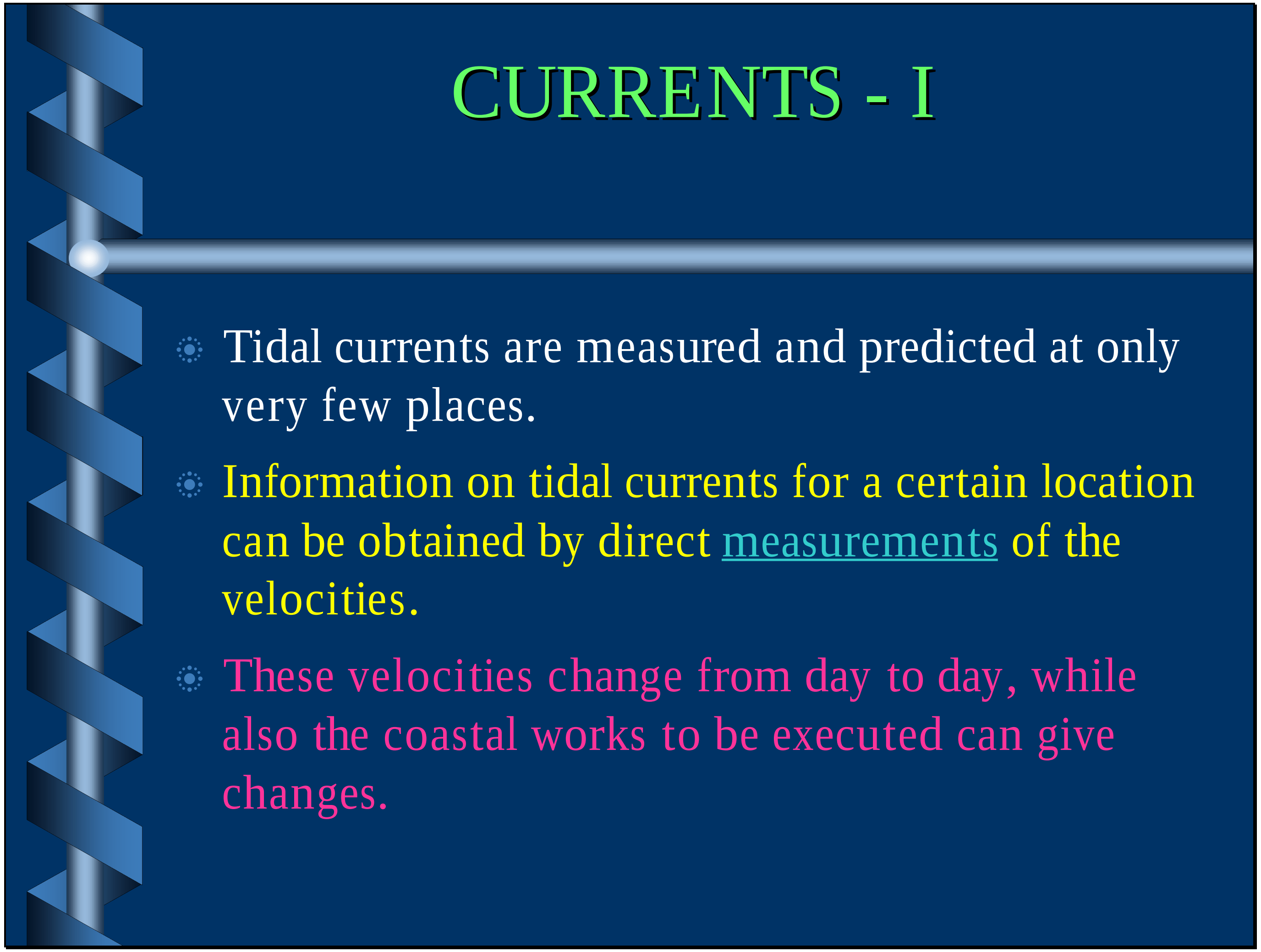
WATERLEVELS - I

- Fluctuations of the water levels (vertical tide) can be computed from the predictions made by country Hydrographic Services.
- For estimation of extreme high (or low) levels, the same tidal constants as used.
- An extreme tidal level is given by adding the amplitudes of the known tidal constituents with regard to Mean Sea Level (MSL).

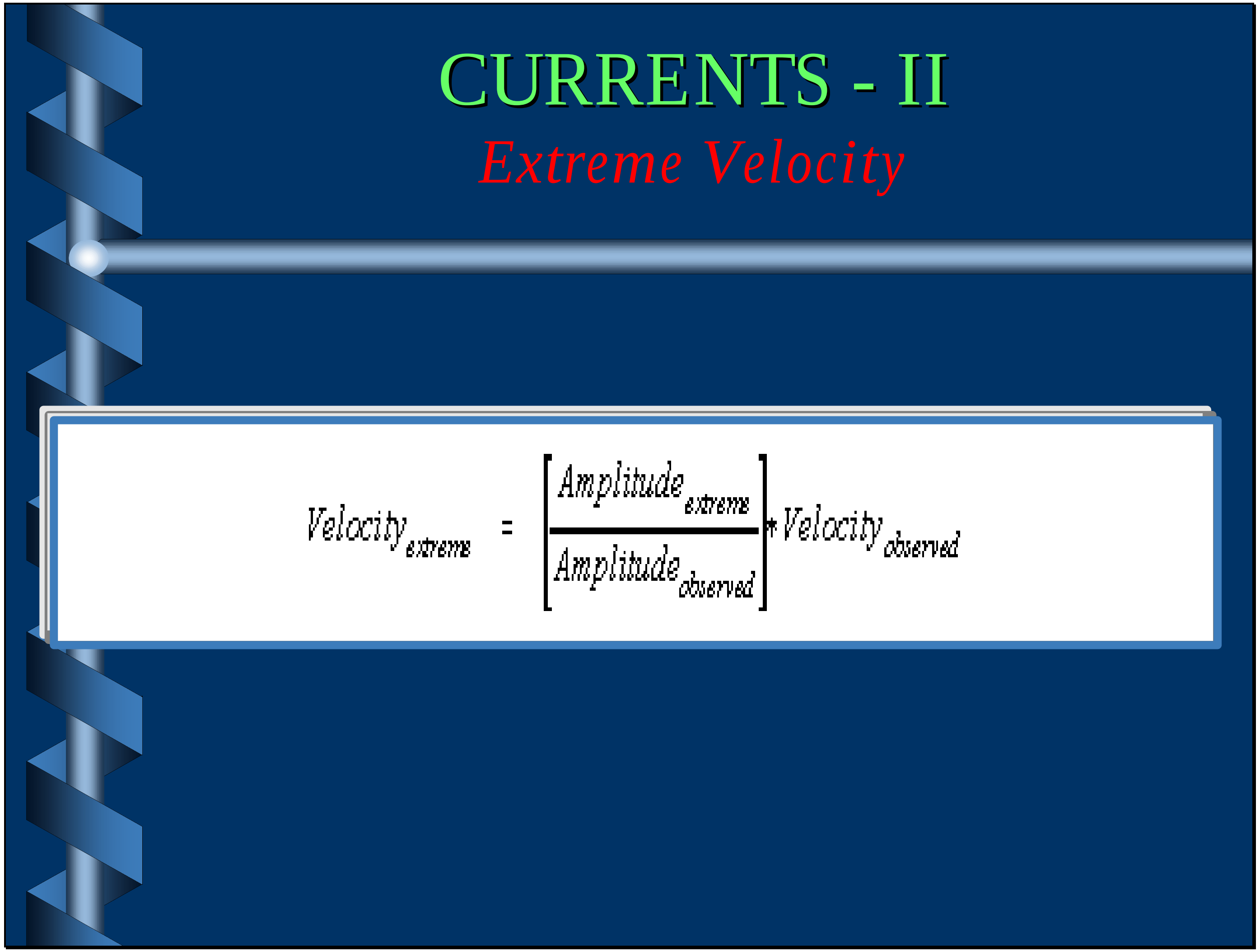
Slide 10


WATERLEVELS - II
Extreme Set-Up
$$\text{Set-Up}_{extreme} = \left[\frac{\text{Wind}_{extreme}}{\text{Wind}_{average}}\right]^2 * \text{Set-Up}_{average}$$

Slide 11


CURRENTS - I
Tidal currents are measured and predicted at only very few places.
Information on tidal currents for a certain location can be obtained by direct measurements of the velocities.
These velocities change from day to day, while also the coastal works to be executed can give changes.

Slide 12

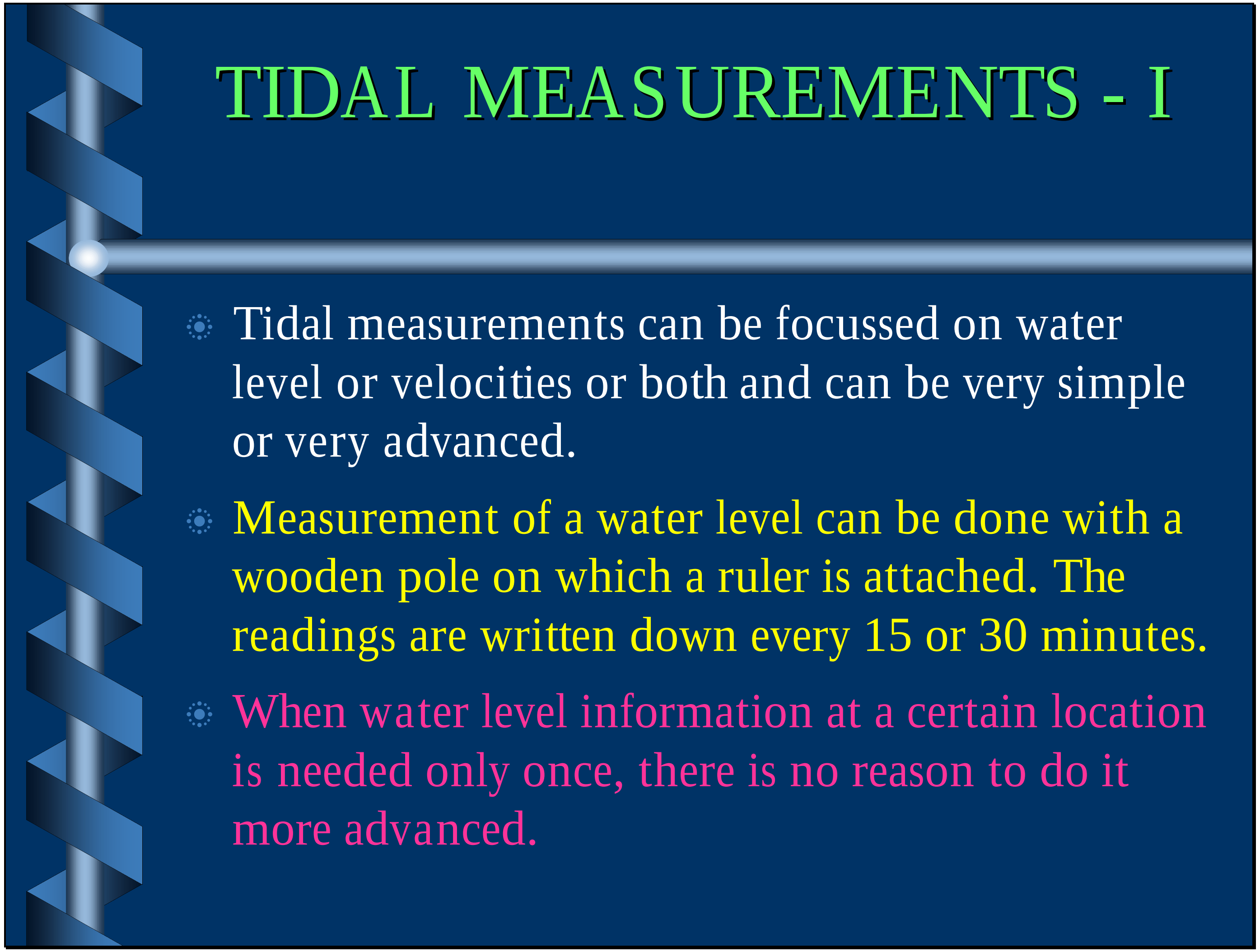

CURRENTS - II
Extreme Velocity
$Velocity_{extreme} = \left[\frac{Amplitude_{extreme}}{Amplitude_{observed}}\right] * Velocity_{observed}$

Slide 13

TIDAL COMPUTATIONS

- In this section the meaning of tidal computations is that one computes water levels, especially currents using some kind of mathematical model.
- Tidal computations can be used to calculate water levels and velocities for existing or for new situations. They are based on a numerical solution of the so-called long wave equations. *A tidal model always has to be calibrated* with measured data in order to proof that the model is reliable.

Slide 14

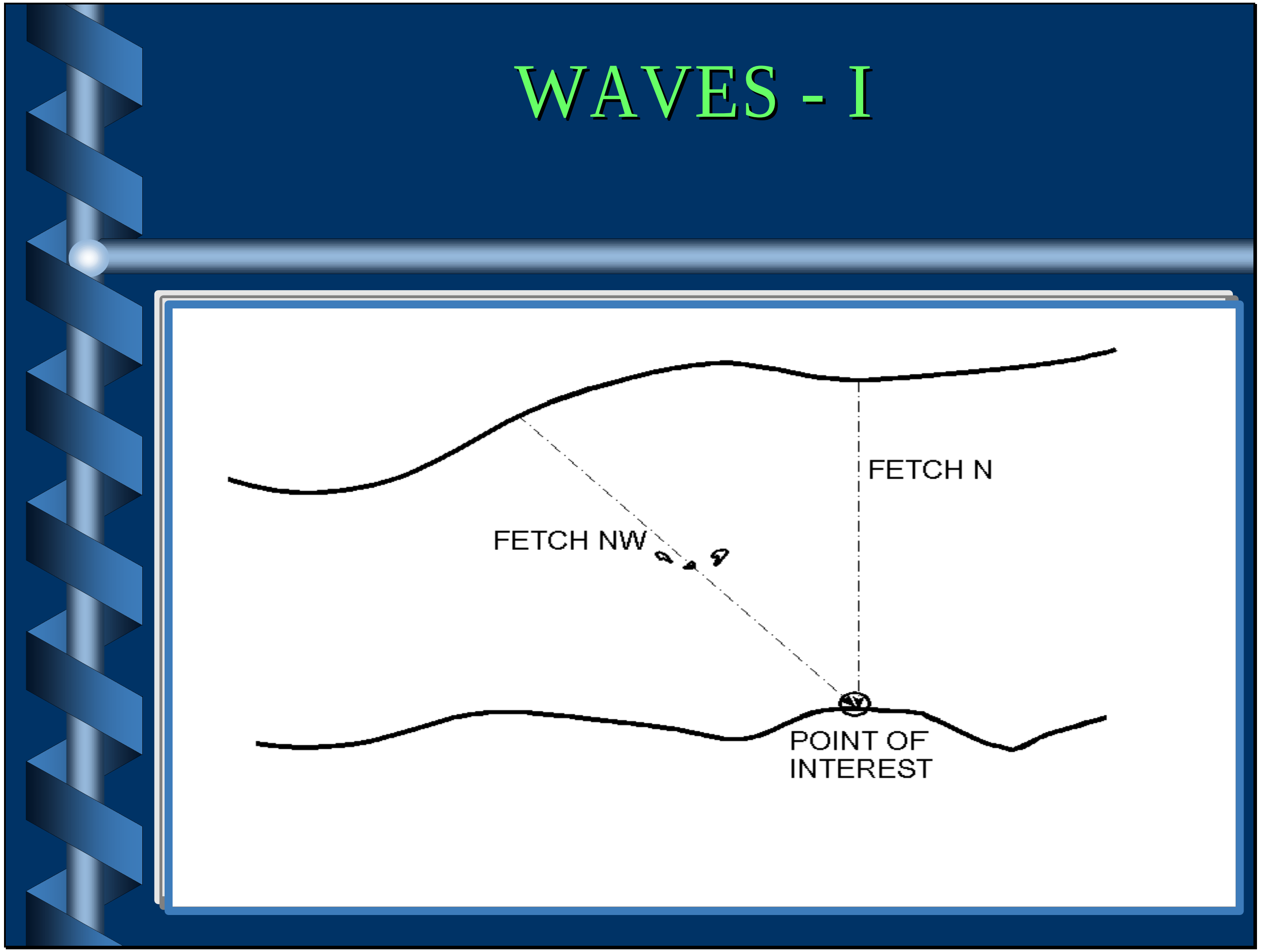

TIDAL MEASUREMENTS - I
Tidal measurements can be focussed on water level or velocities or both and can be very simple or very advanced.
Measurement of a water level can be done with a wooden pole on which a ruler is attached. The readings are written down every 15 or 30 minutes.
When water level information at a certain location is needed only once, there is no reason to do it more advanced.

Slide 15

TIDAL MEASUREMENTS - II

- When statistical information on water levels is needed, an automatic device can be applied which records the water level over a long period.
- HWST, HWNT, MSL, LWNT, LWST, LAT/DATUM…Extreme events.
- Velocities can be measured with a floating piece of wood and a stopwatch or a electronic gauge.

Slide 16



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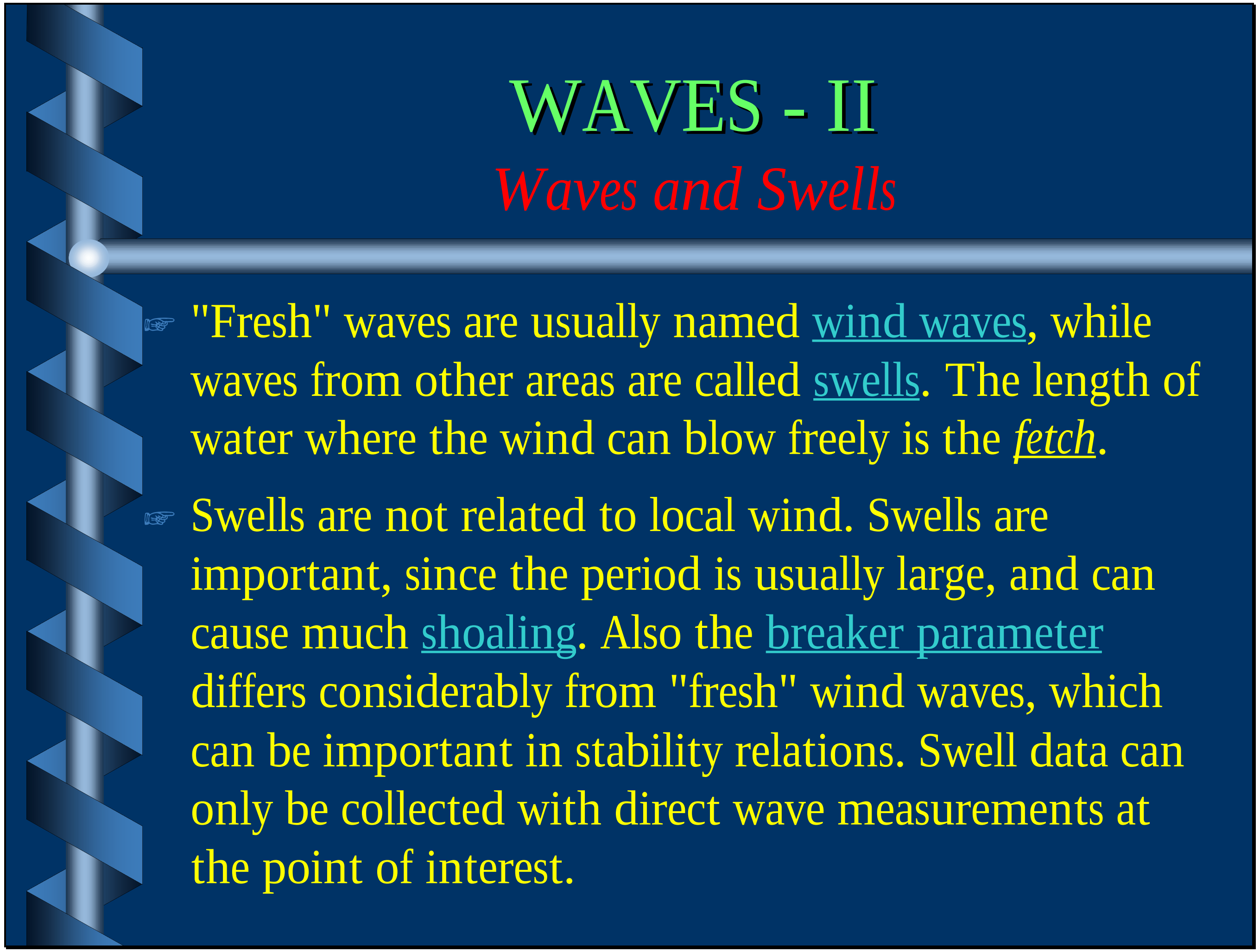
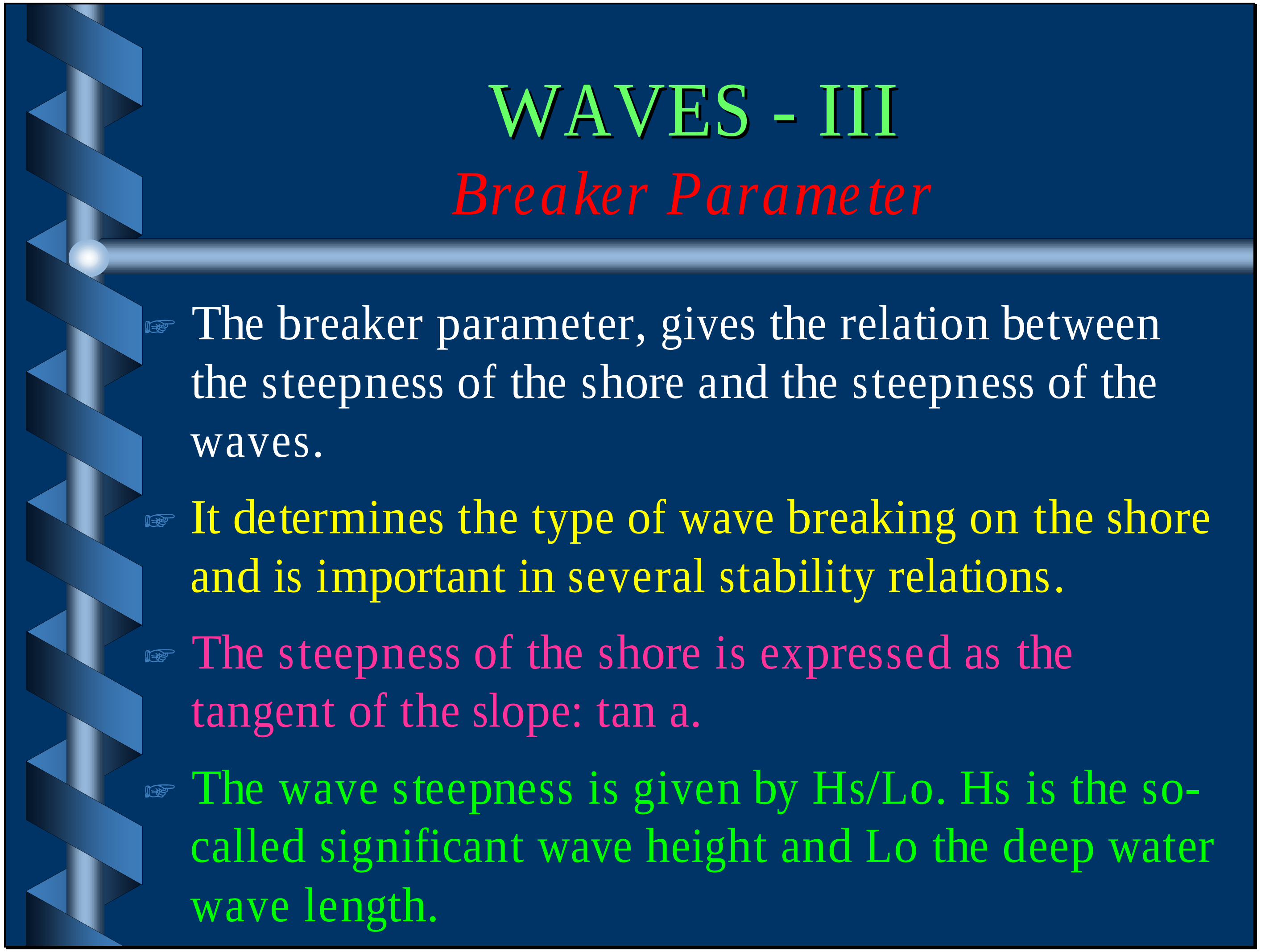
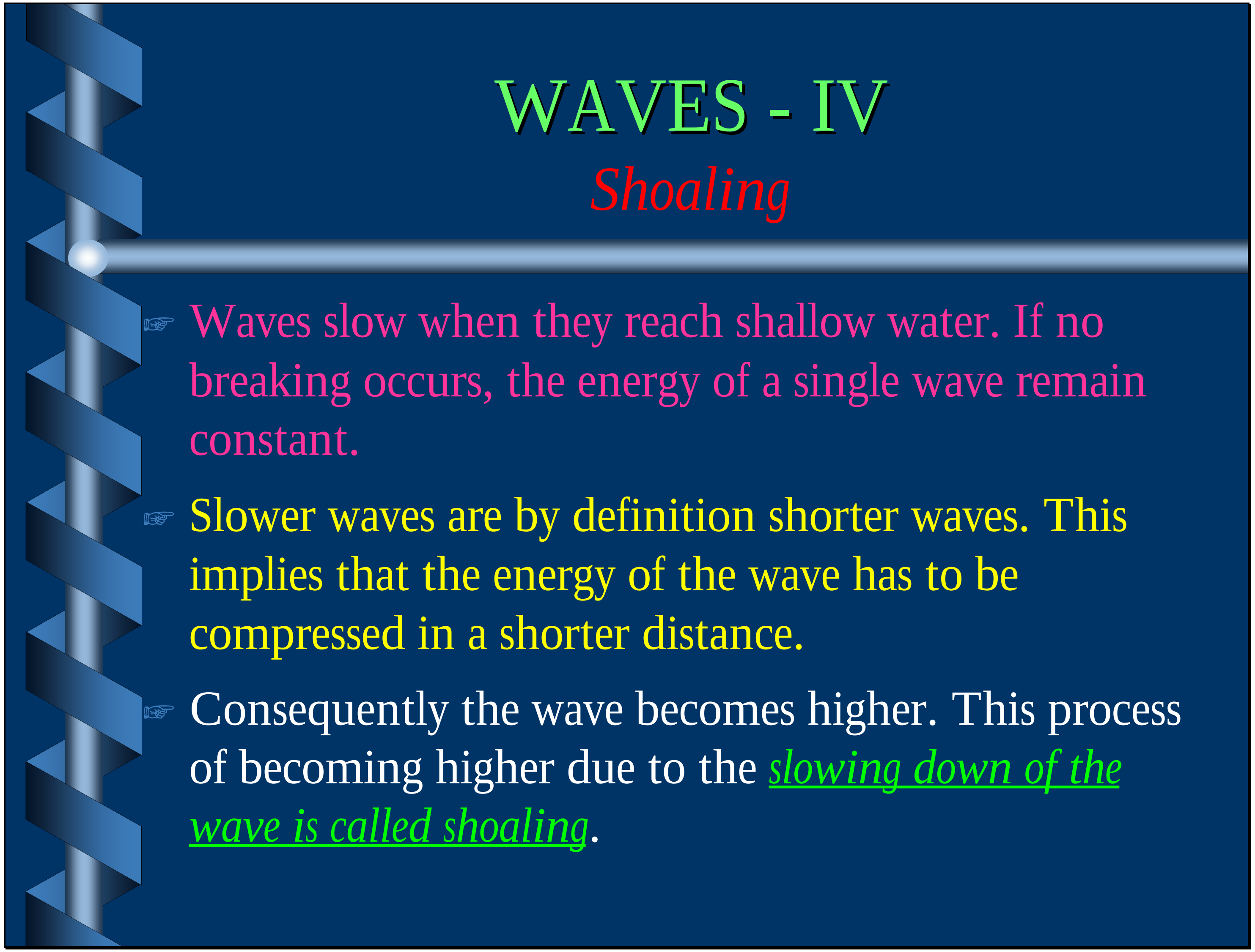

WAVES - II
Waves and Swells
"Fresh" waves are usually named wind waves, while waves from other areas are called swells. The length of water where the wind can blow freely is the fetch.
Swells are not related to local wind. Swells are important, since the period is usually large, and can cause much shoaling. Also the breaker parameter differs considerably from "fresh" wind waves, which can be important in stability relations. Swell data can only be collected with direct wave measurements at the point of interest.

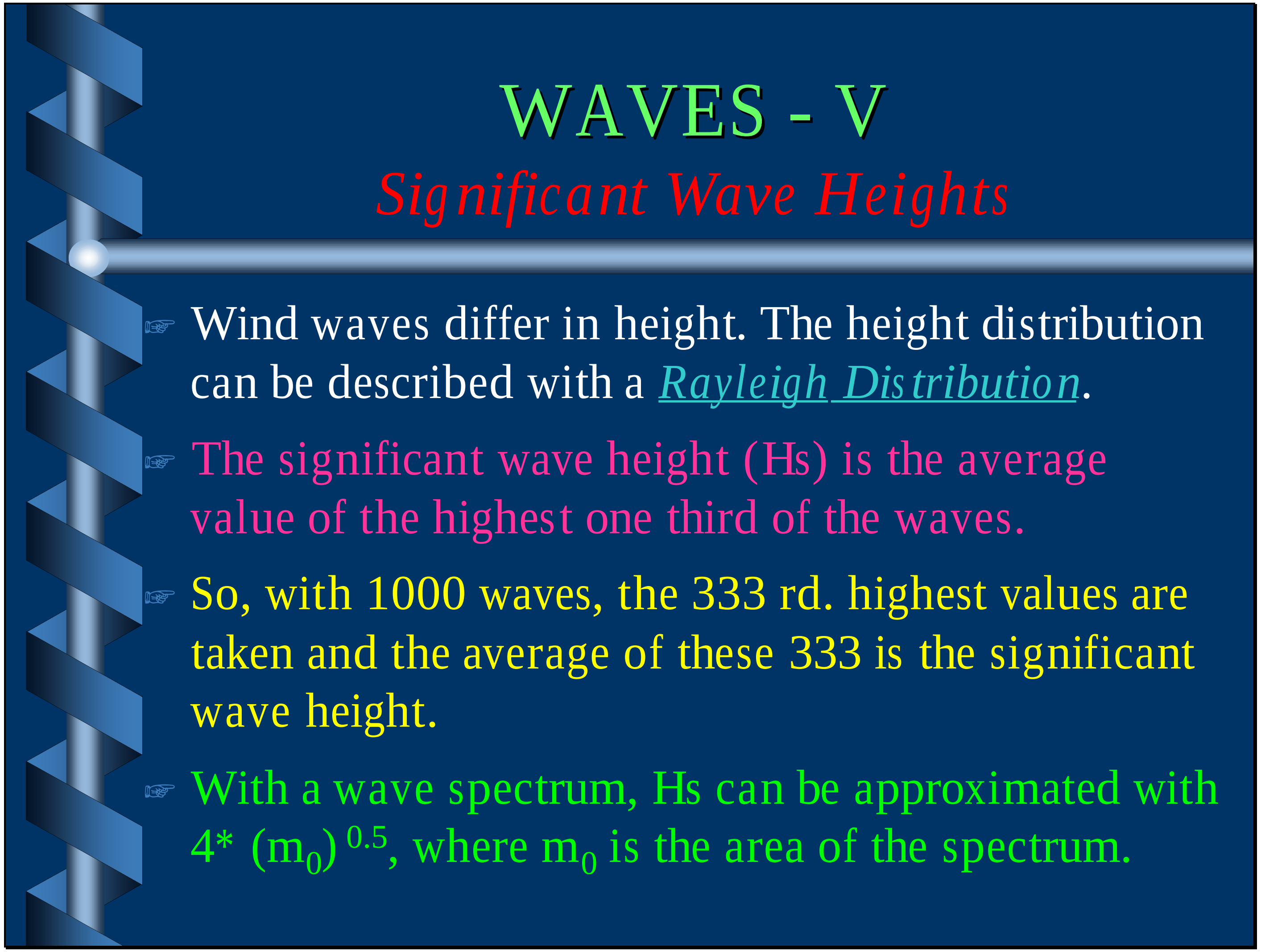
Slide 18


WAVES - III
Breaker Parameter
The breaker parameter, gives the relation between the steepness of the shore and the steepness of the waves.
It determines the type of wave breaking on the shore and is important in several stability relations.
The steepness of the shore is expressed as the tangent of the slope: tan a.
The wave steepness is given by Hs/Lo. Hs is the so-called significant wave height and Lo the deep water wave length.

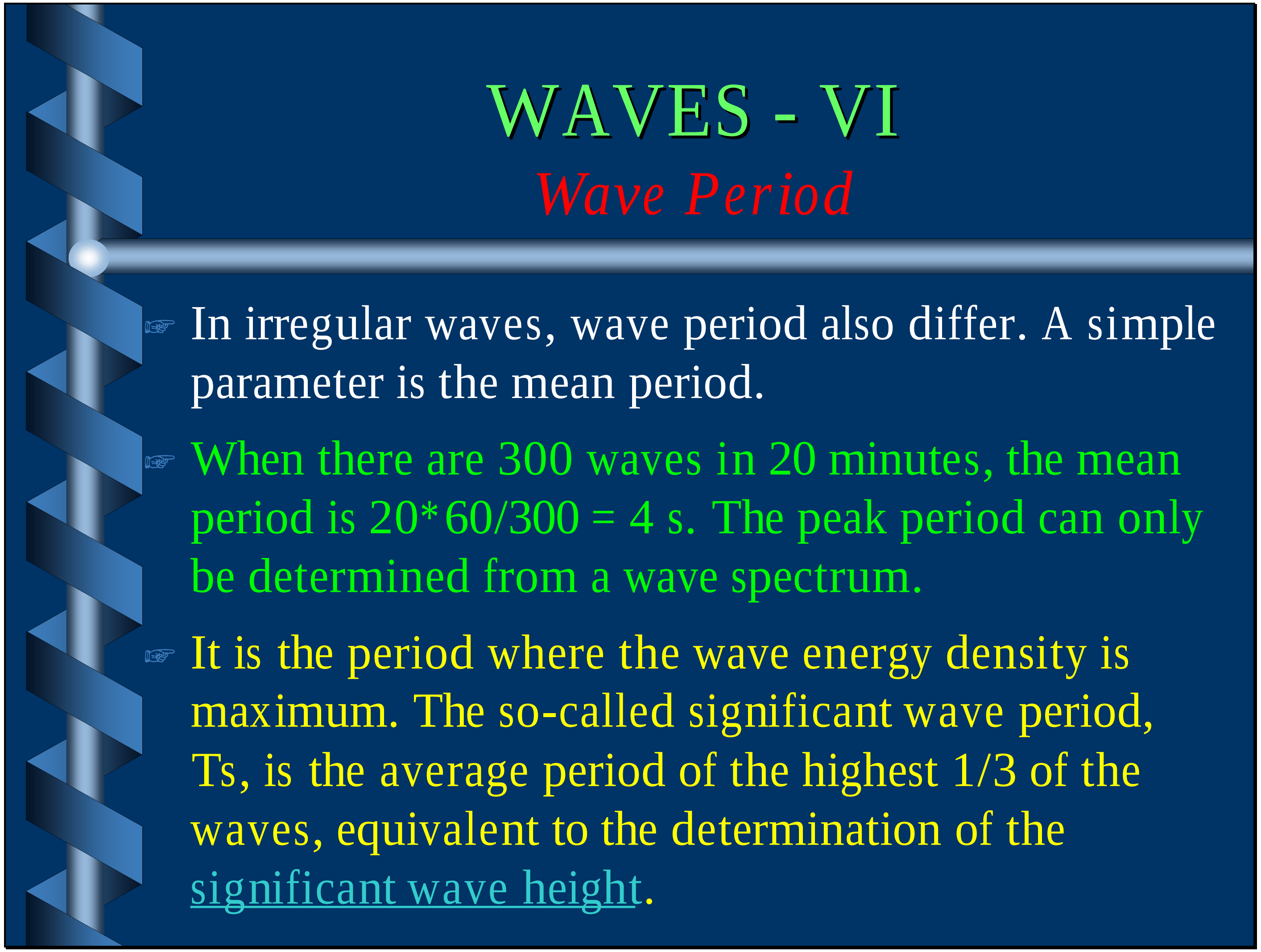
Slide 19


WAVES - IV
Shoaling
Waves slow when they reach shallow water. If no breaking occurs, the energy of a single wave remain constant.
Slower waves are by definition shorter waves. This implies that the energy of the wave has to be compressed in a shorter distance.
Consequently the wave becomes higher. This process of becoming higher due to the slowing down of the wave is called shoaling.

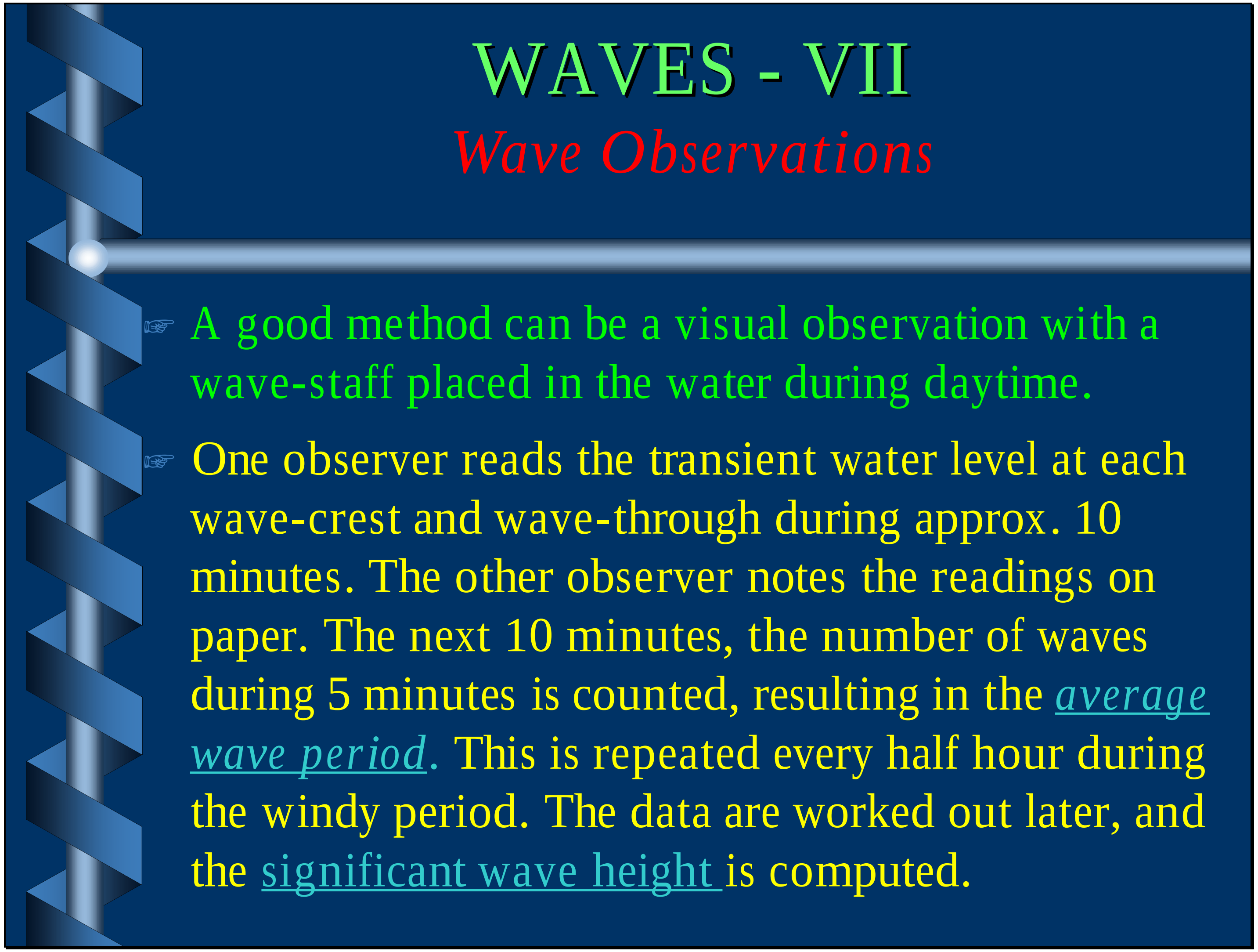
Slide 20


WAVES - V
Significant Wave Heights
Wind waves differ in height. The height distribution can be described with a Rayleigh Distribution.
The significant wave height (Hs) is the average value of the highest one third of the waves.
So, with 1000 waves, the 333 rd. highest values are taken and the average of these 333 is the significant wave height.
With a wave spectrum, Hs can be approximated with $4* (m_0)^{0.5}$, where m_0 is the area of the spectrum.

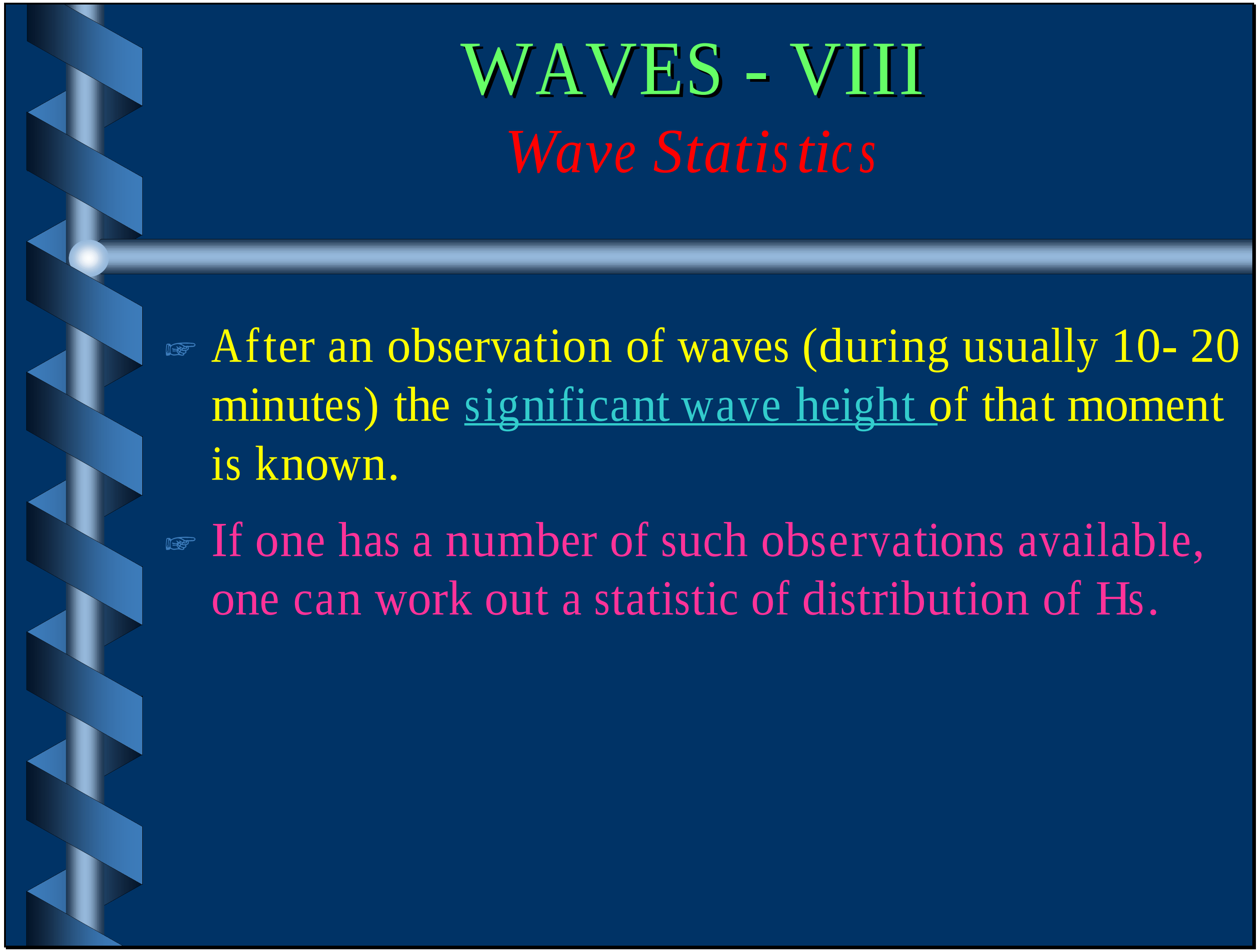
Slide 21


WAVES - VI
Wave Period
In irregular waves, wave period also differ. A simple parameter is the mean period.
When there are 300 waves in 20 minutes, the mean period is 20*60/300 = 4 s. The peak period can only be determined from a wave spectrum.
It is the period where the wave energy density is maximum. The so-called significant wave period, Ts, is the average period of the highest 1/3 of the waves, equivalent to the determination of the significant wave height.

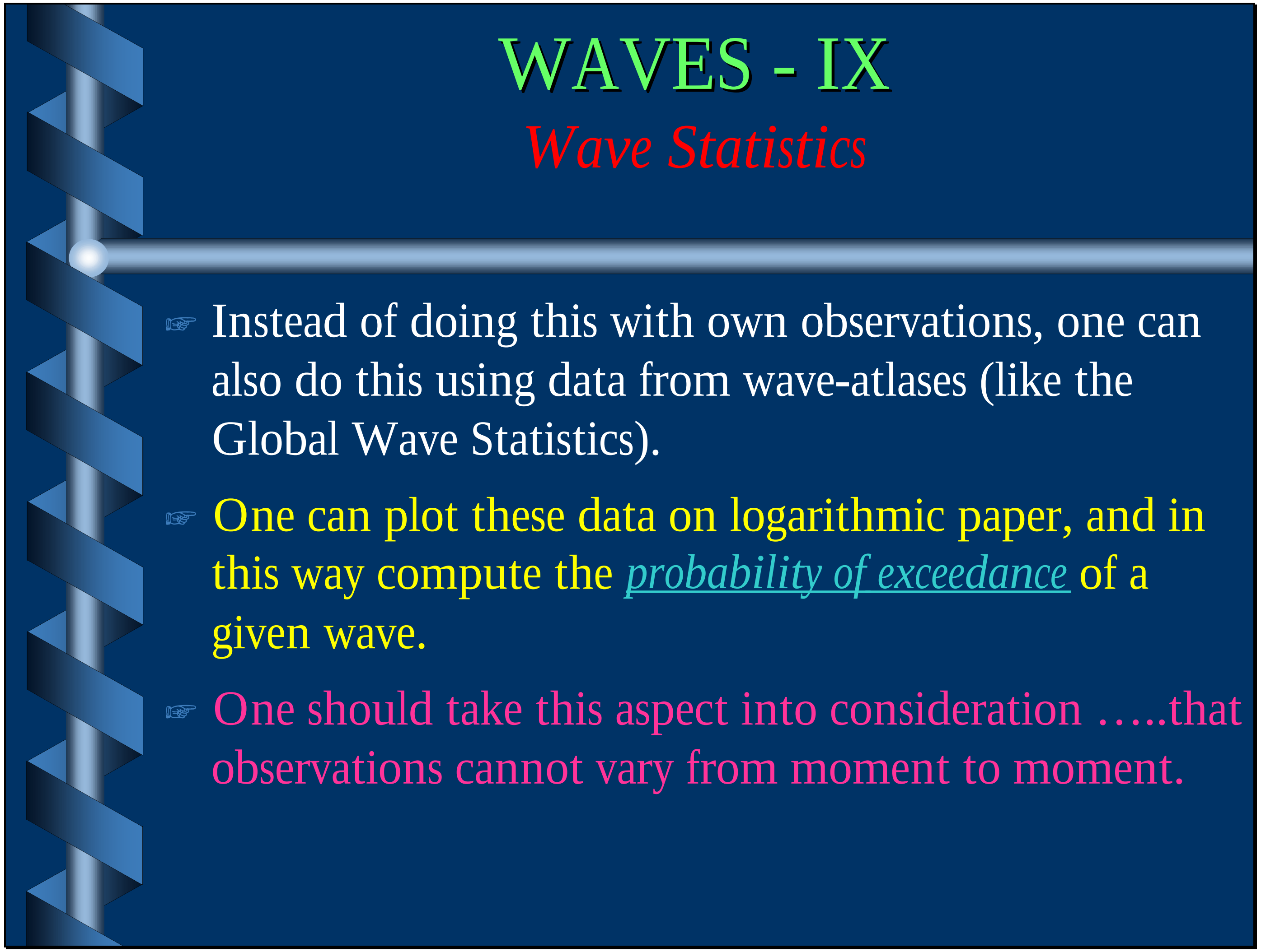
Slide 22


WAVES - VII
Wave Observations
A good method can be a visual observation with a wave-staff placed in the water during daytime.
One observer reads the transient water level at each wave-crest and wave-through during approx. 10 minutes. The other observer notes the readings on paper. The next 10 minutes, the number of waves during 5 minutes is counted, resulting in the average wave period. This is repeated every half hour during the windy period. The data are worked out later, and the significant wave height is computed.

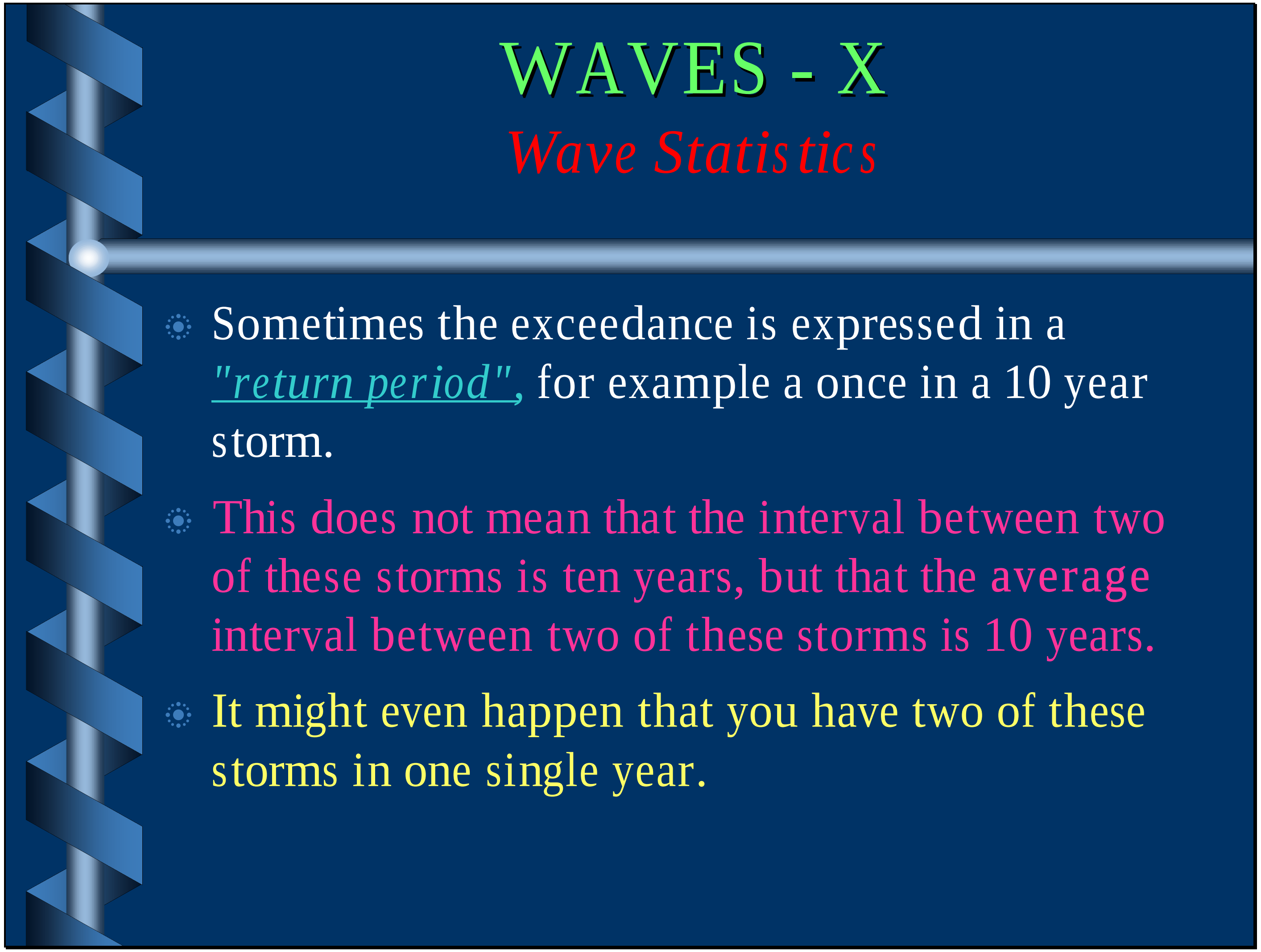
Slide 23


WAVES - VIII
Wave Statistics
After an observation of waves (during usually 10- 20 minutes) the significant wave height of that moment is known.
If one has a number of such observations available, one can work out a statistic of distribution of Hs.

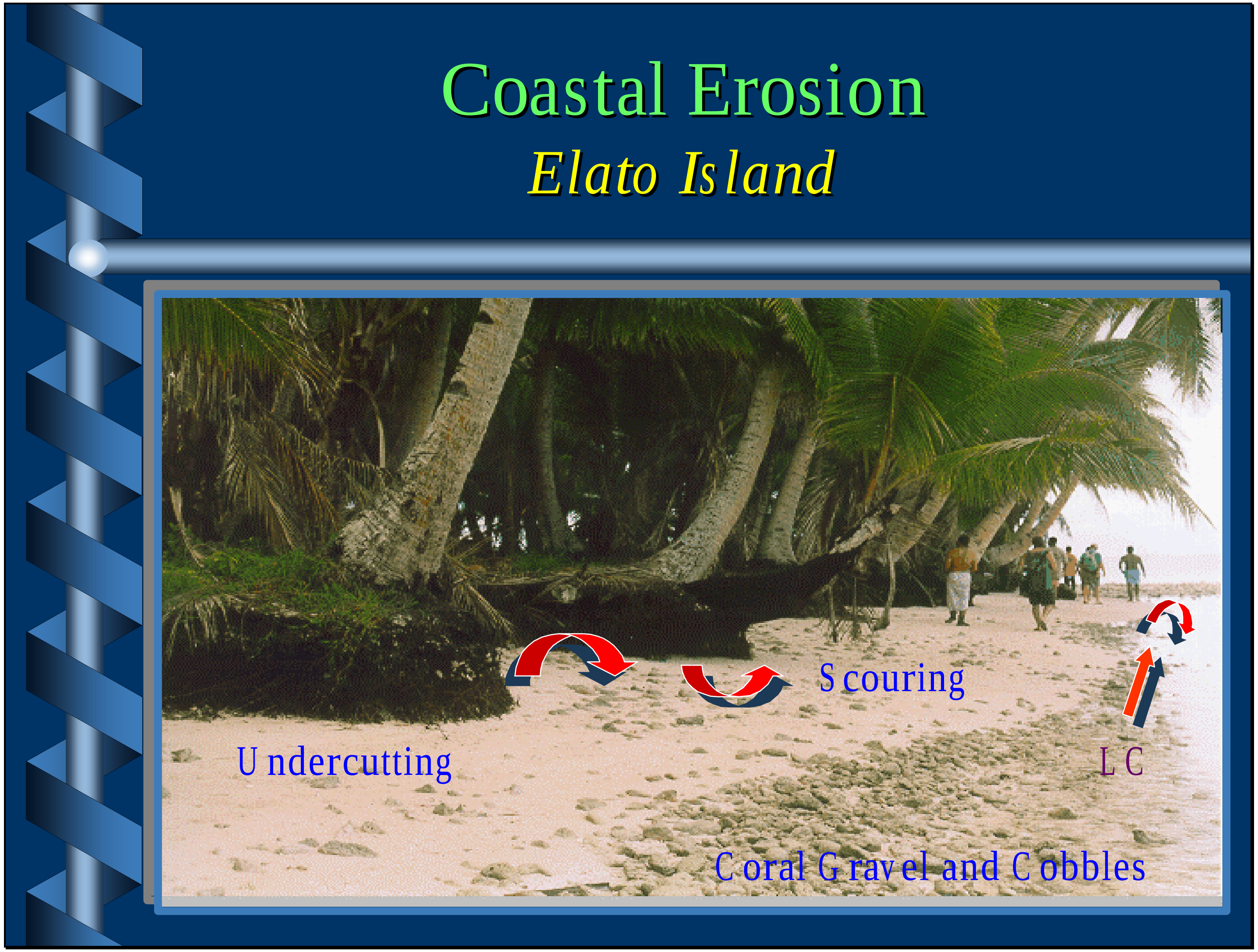
Slide 24


WAVES - IX
Wave Statistics
Instead of doing this with own observations, one can also do this using data from wave-atlases (like the Global Wave Statistics).
One can plot these data on logarithmic paper, and in this way compute the probability of exceedance of a given wave.
One should take this aspect into consideration …..that observations cannot vary from moment to moment.

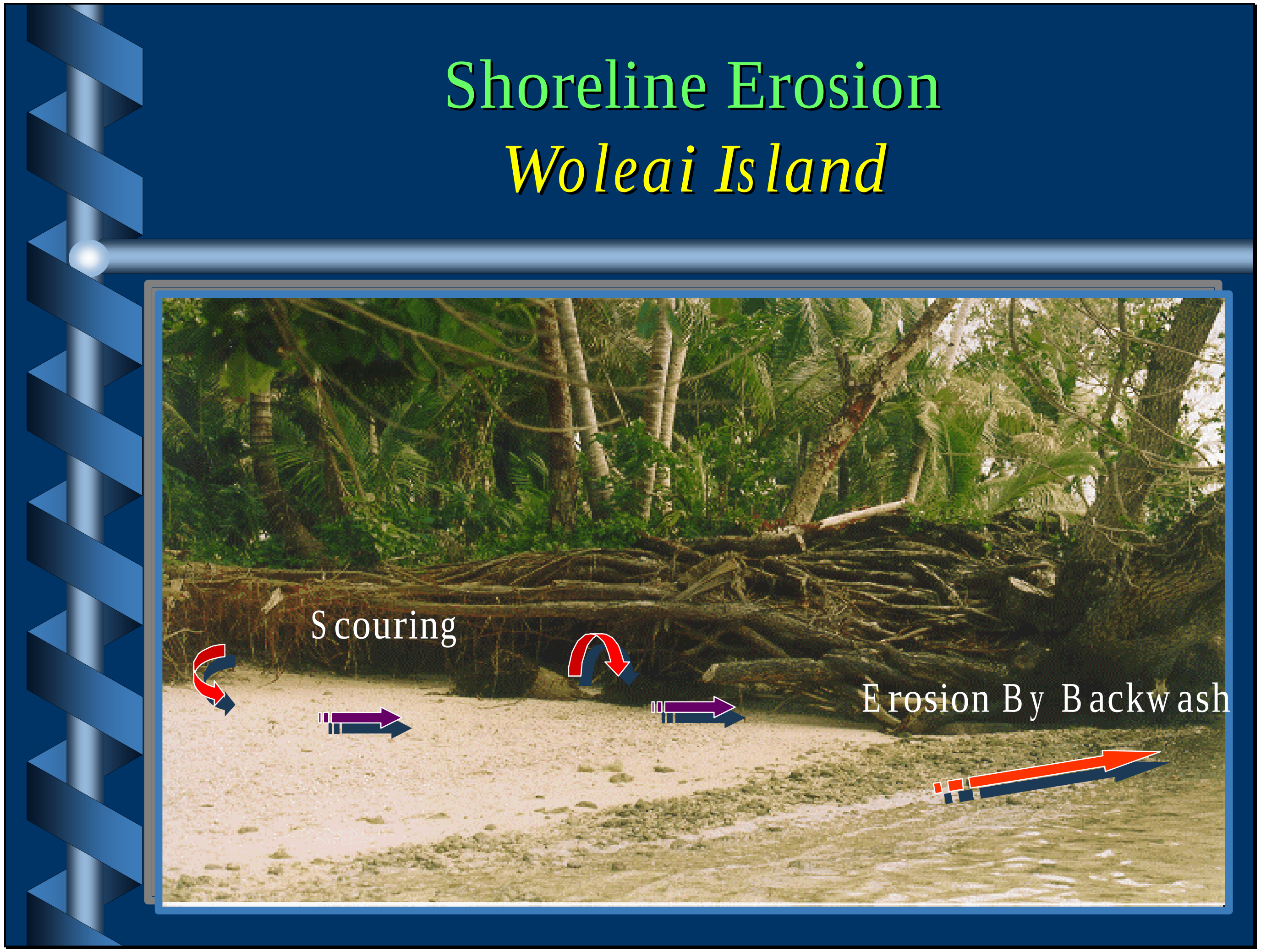
Slide 25


WAVES - X
Wave Statistics
Sometimes the exceedance is expressed in a "return period", for example a once in a 10 year storm.
This does not mean that the interval between two of these storms is ten years, but that the average interval between two of these storms is 10 years.
It might even happen that you have two of these storms in one single year.

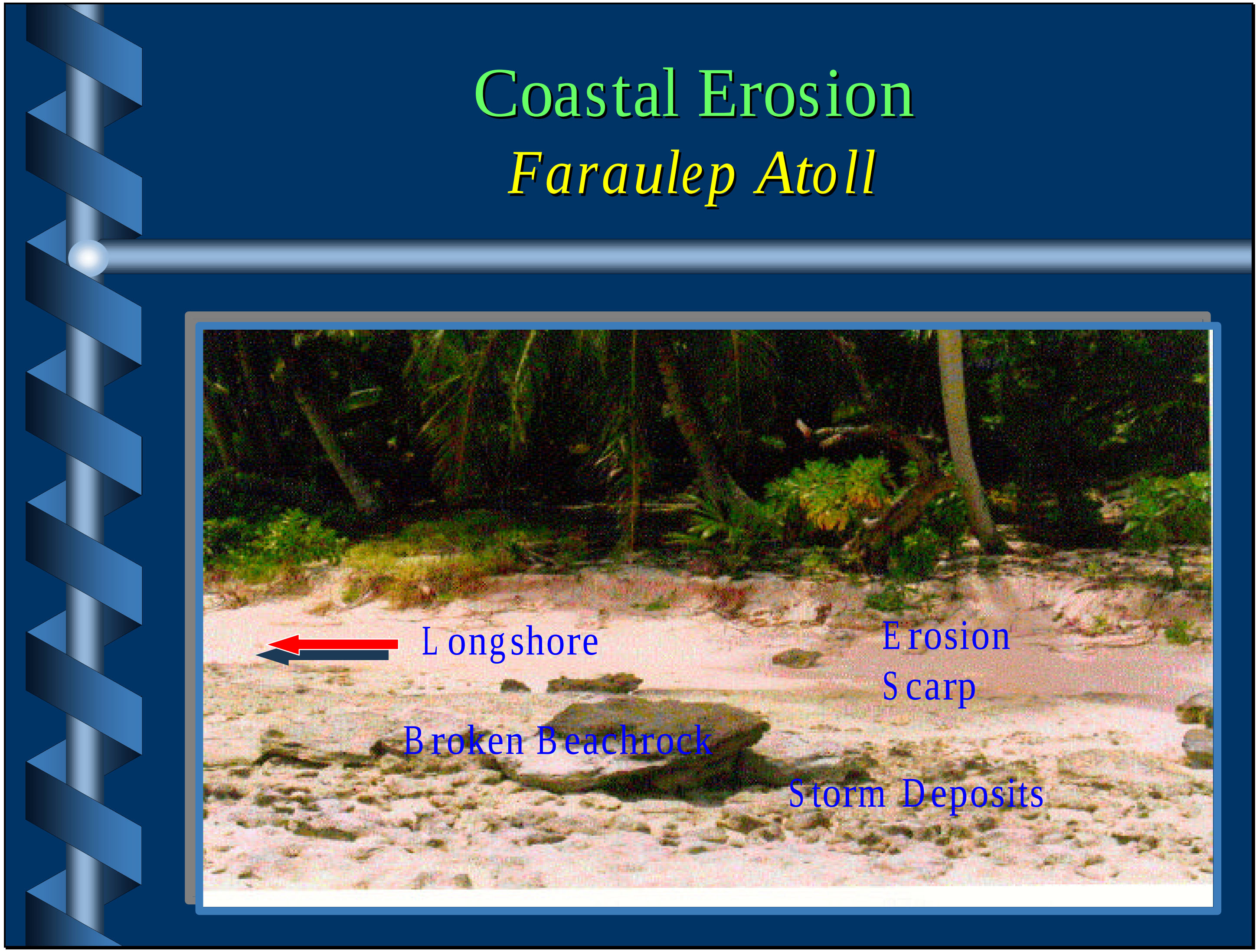
Slide 26


Coastal Erosion
Elato Island
Scouring
Undercutting
LC
Coral Gravel and Cobbles

Slide 27


Shoreline Erosion
Woleai Island
Scouring
Erosion By Backwash

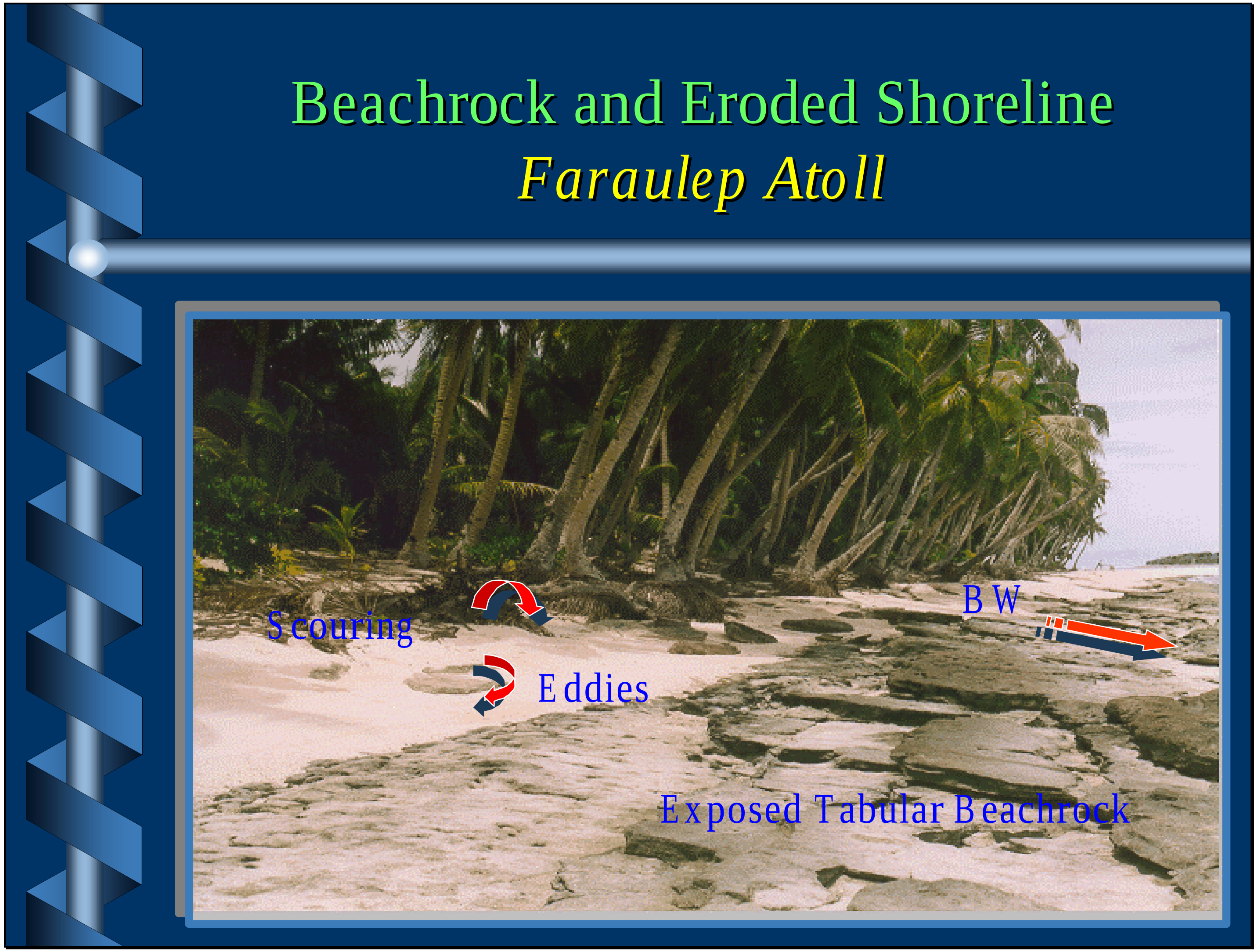
Slide 28


Coastal Erosion
Faraulep Atoll
Longshore
Erosion
Scarp
Broken Beachrock
Storm Deposits

Slide 29


Beach Erosion
Utagal Atoll
Beach Scarp
LC
Temporary Accretion By Sediment Re-distribution

Slide 30


Beachrock and Eroded Shoreline
Faraulep Atoll
Scouring
Eddies
BW
Exposed Tabular Beachrock

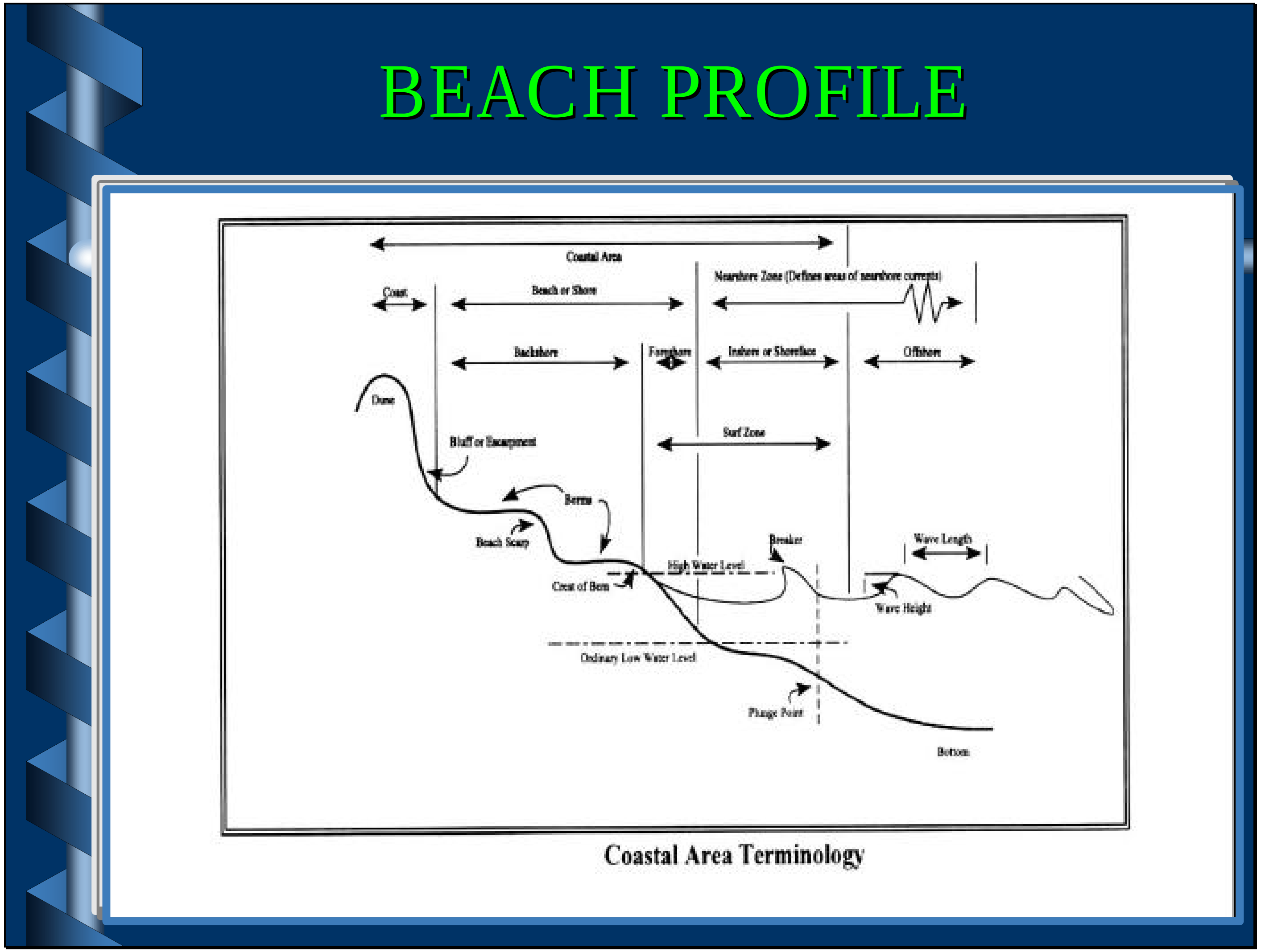
Slide 31

Slide 32

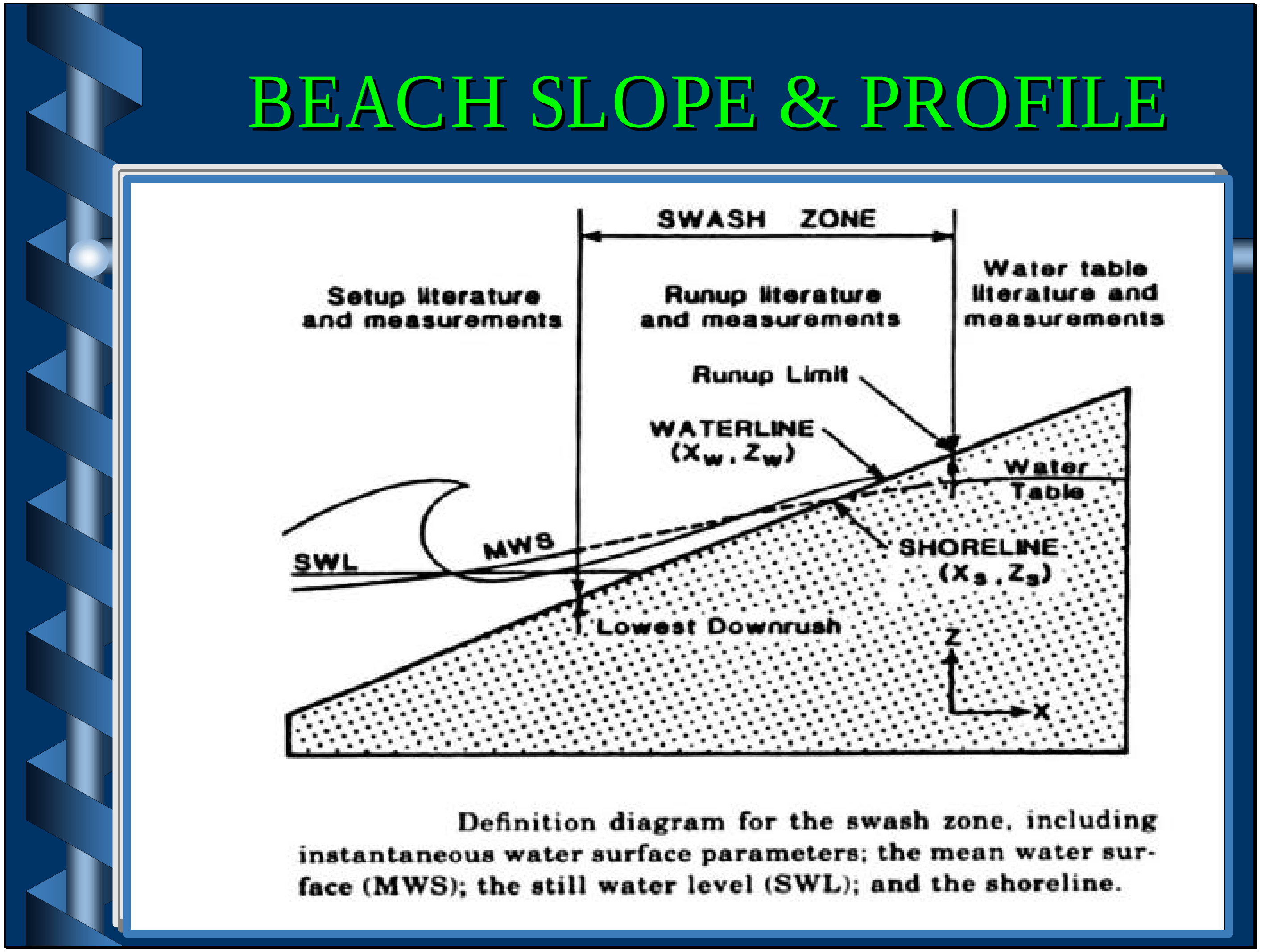
HOW DO WE EVALUATE RISKS?

- ☞ Site evaluation through data optimization and integrated assessments.
- ☞ Site selection following risk analysis.
- ☞ Sound design and construction QA & QC.
- ☞ Monitoring and maintenance programmes.
- ☞ Remedial measures.
- ☞ Further monitoring.

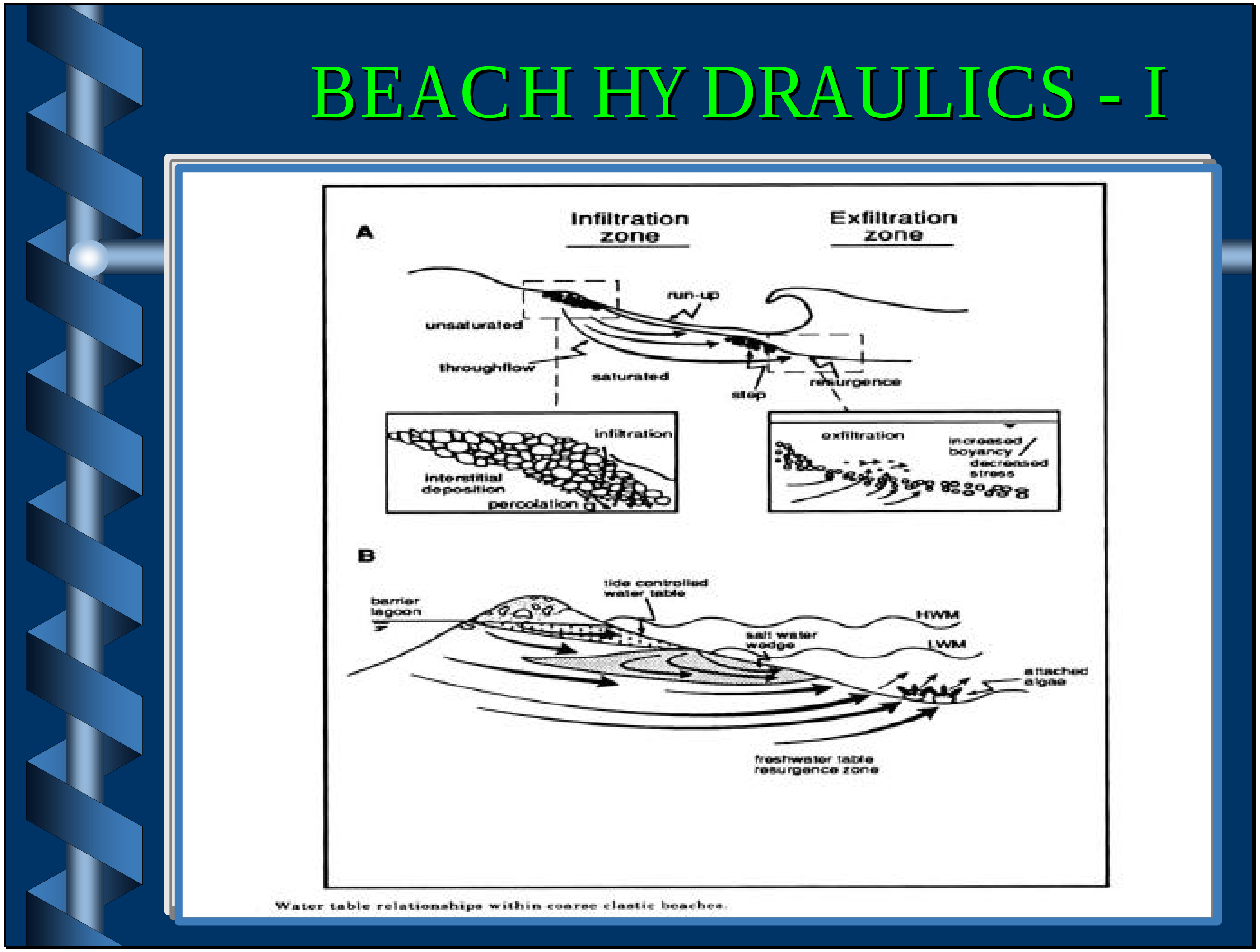
Slide 33


BEACH PROFILE
Coastal Area
Nearshore Zone (Defines areas of nearshore currents)
Coast
Beach or Shore
Backshore
Foreshore
Inshore or Shoreface
Offshore
Dune
Bluff or Escarpment
Surf Zone
Berms
Beach Scarp
Breaker
Wave Length
High Water Level
Crest of Berm
Wave Height
Ordinary Low Water Level
Plunge Point
Bottom
Coastal Area Terminology

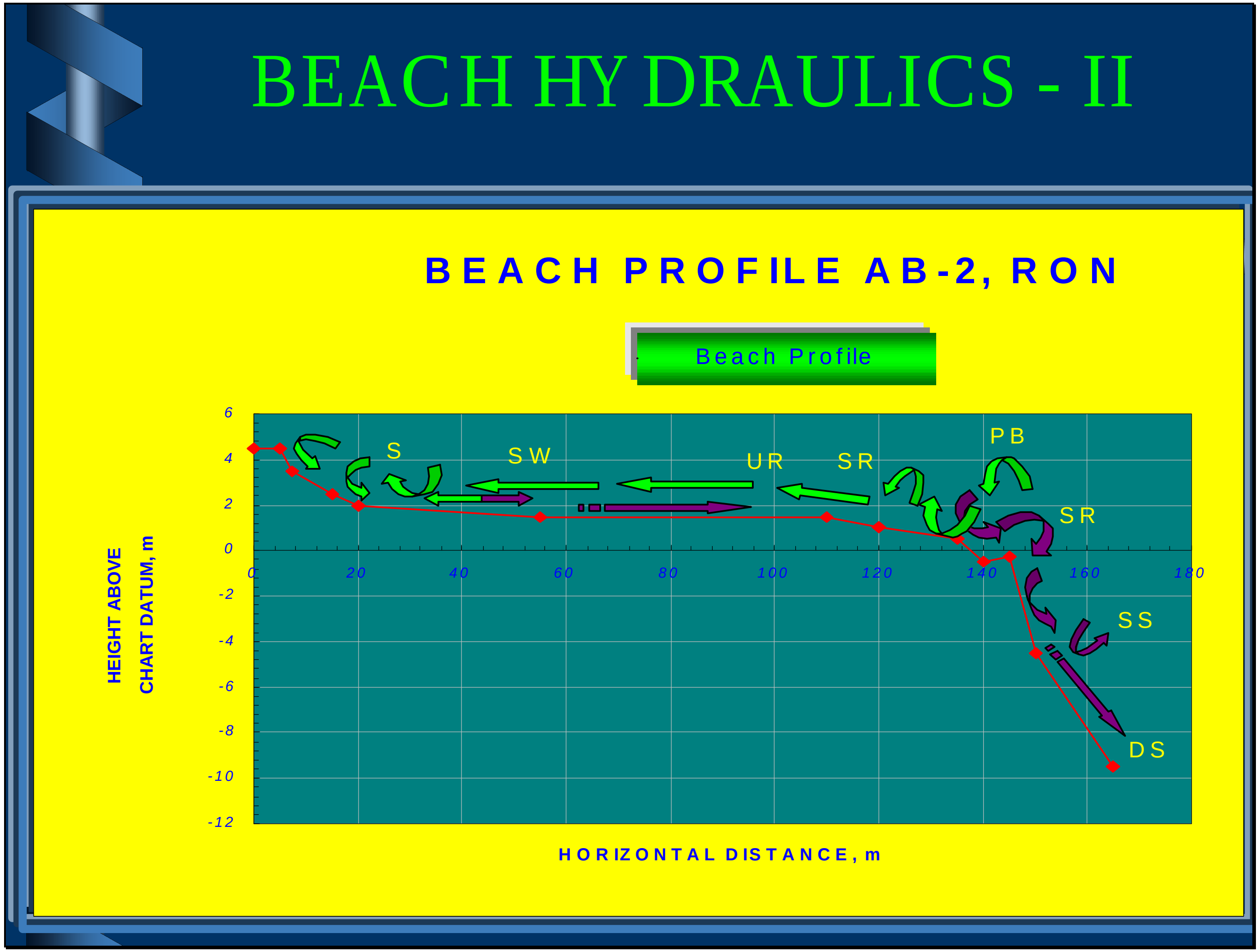
Slide 34


BEACH SLOPE & PROFILE
SWASH ZONE
Setup literature and measurements
Runup literature and measurements
Water table literature and measurements
Runup Limit
WATERLINE (Xw, Zw)
Water Table
MWS
SWL
SHORELINE (Xs, Zs)
Lowest Downrush
Z
X
Definition diagram for the swash zone, including instantaneous water surface parameters; the mean water surface (MWS); the still water level (SWL); and the shoreline.

Slide 35


BEACH HYDRAULICS - I
A
Infiltration zone
Exfiltration zone
run-up
unsaturated
throughflow
saturated
step
resurgence
infiltration
interstitial deposition
percolation
exfiltration
increased boyancy
decreased stress
B
tide controlled water table
barrier lagoon
HWM
salt water wedge
LWM
attached algae
freshwater table resurgence zone
Water table relationships within coarse clastic beaches.

Slide 36


BEACH HY DRAULICS - II
BEACH PROFILE AB-2, RON
Beach Profile
HEIGHT ABOVE CHART DATUM, m
HORIZONTAL DISTANCE, m
S
SW
UR
SR
PB
SR
SS
DS
6
4
2
0
-2
-4
-6
-8
-10
-12
0
20
40
60
80
100
120
140
160
180

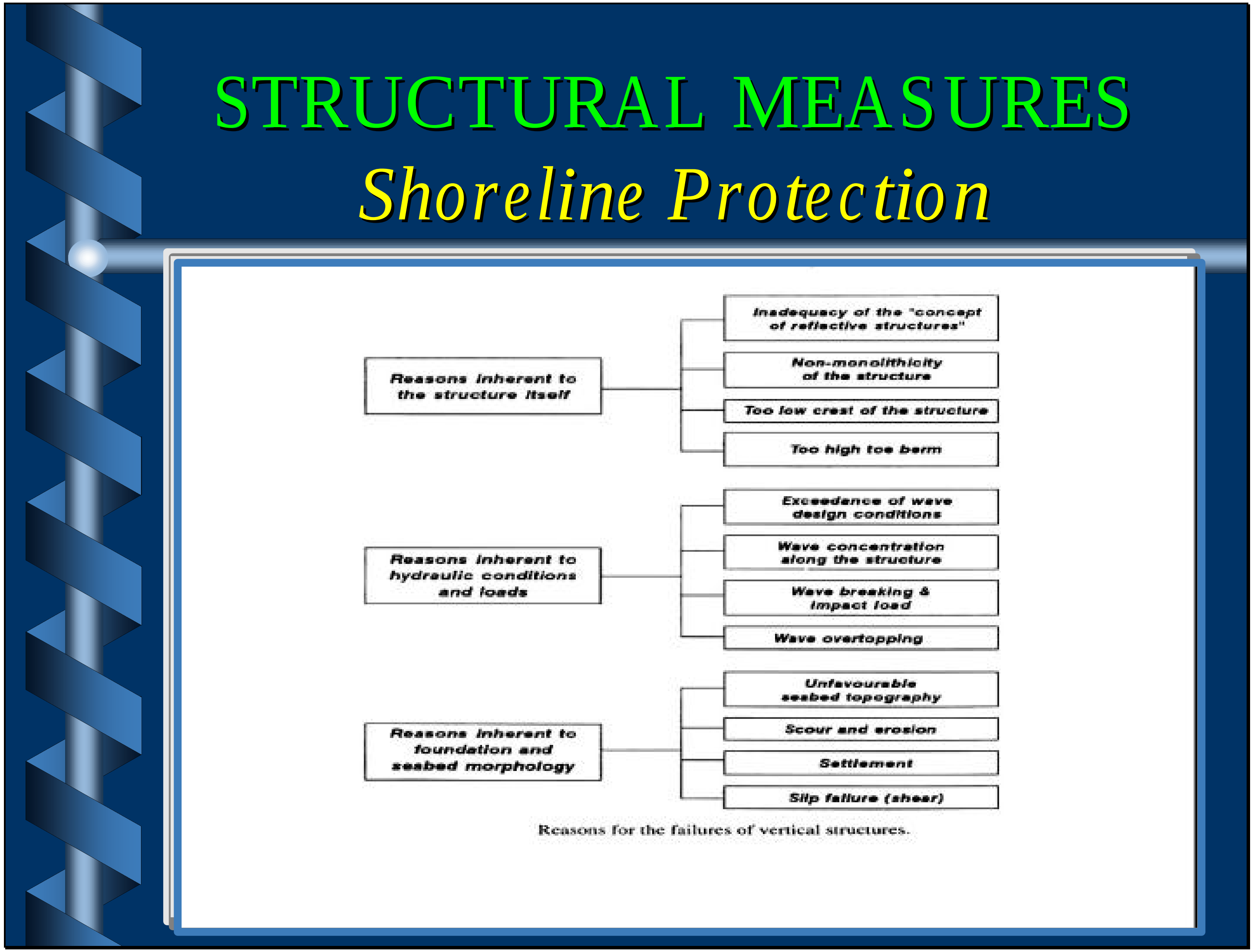
Slide 37

SCOPE OF ENGINEERING

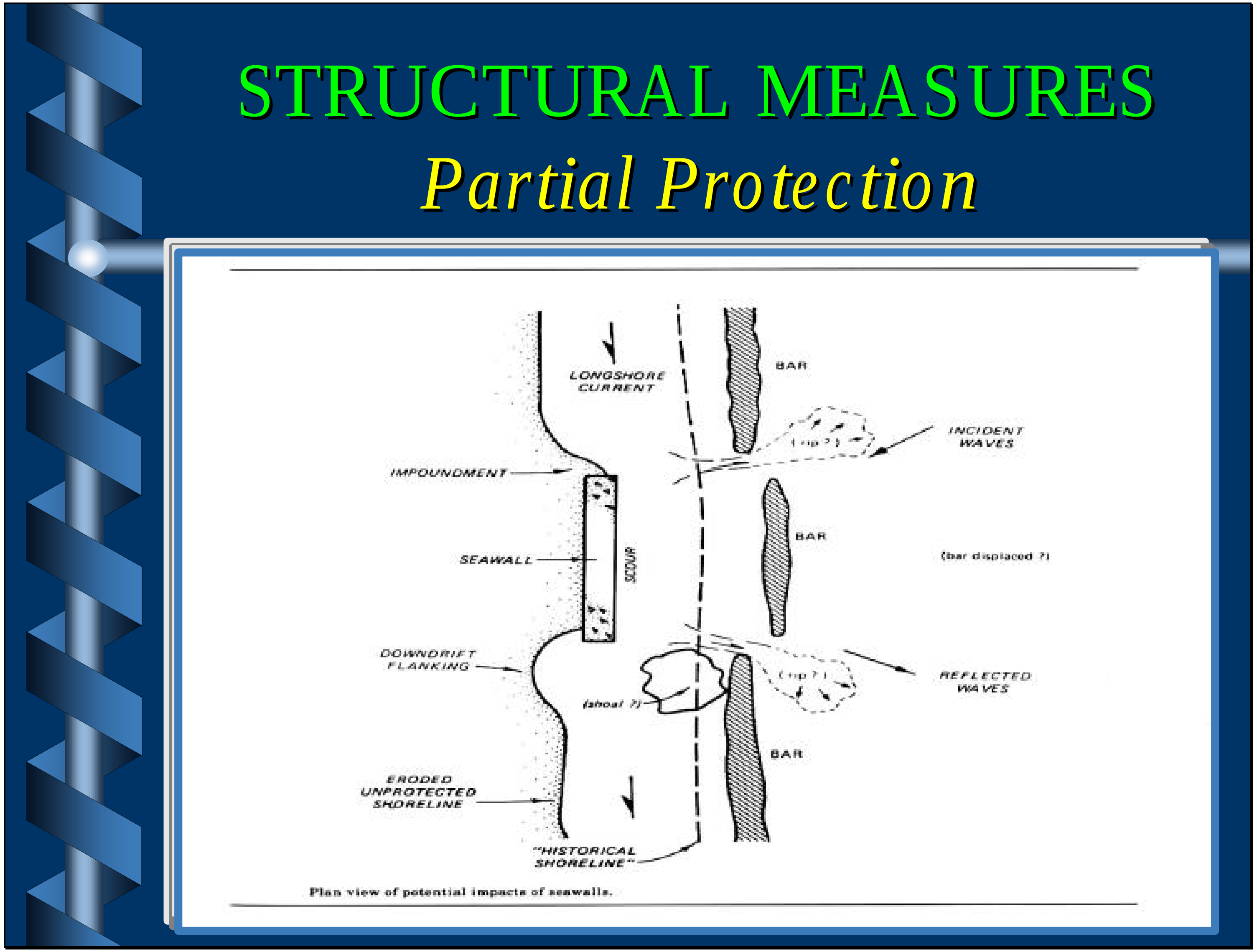
WORKS AND MATERIAL

- Rock works; concrete armour protection units;concrete sea walls & revetments; beach recharge works; navigational dredging; ports & harbours; caisson & piles; foundation improvement; outfalls and intakes; infrastucture and residential development.

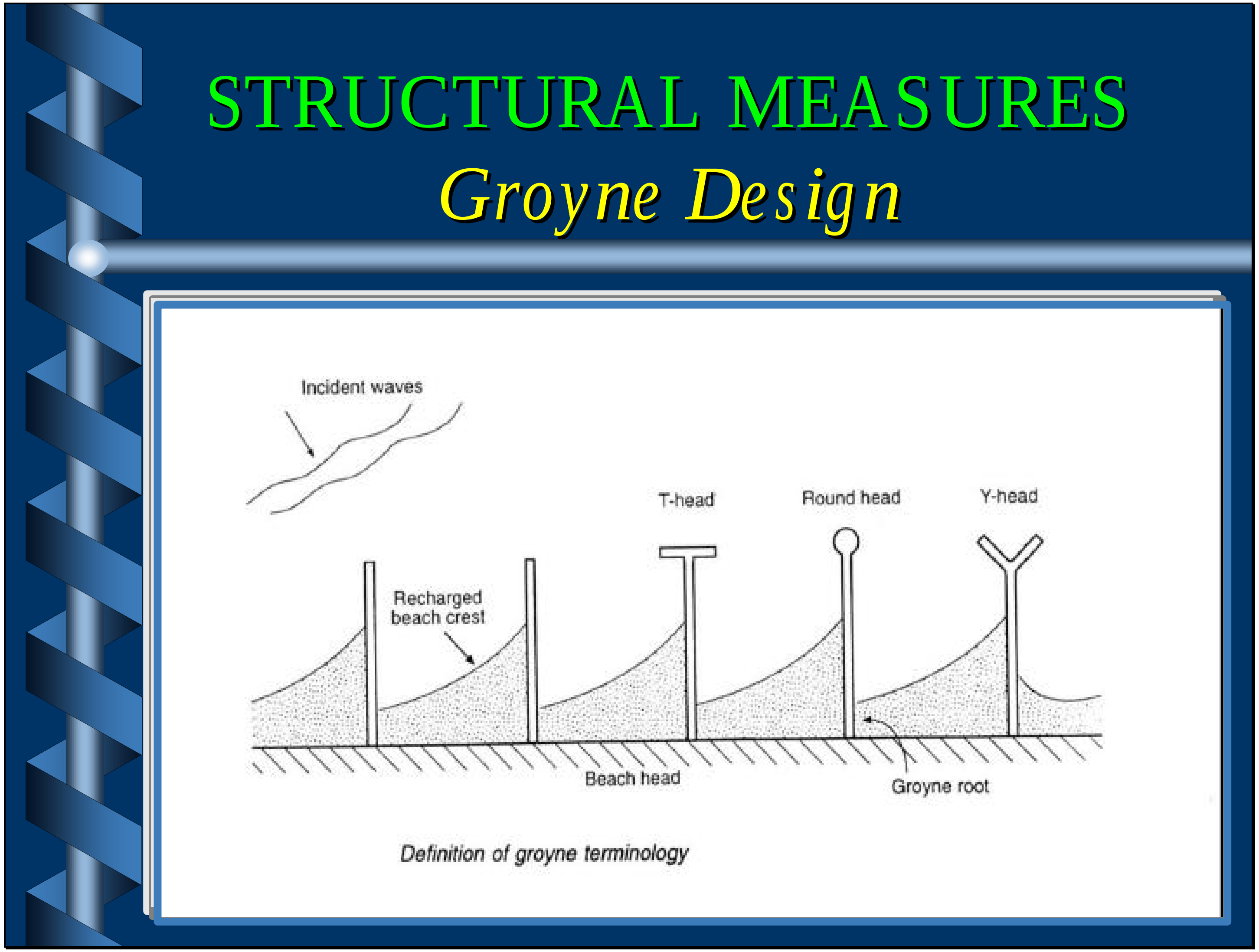
Slide 38


STRUCTURAL MEASURES
Shoreline Protection
Reasons inherent to the structure itself
Inadequacy of the "concept of reflective structures"
Non-monolithicity of the structure
Too low crest of the structure
Too high toe berm
Reasons inherent to hydraulic conditions and loads
Exceedence of wave design conditions
Wave concentration along the structure
Wave breaking & impact load
Wave overtopping
Reasons inherent to foundation and seabed morphology
Unfavourable seabed topography
Scour and erosion
Settlement
Slip failure (shear)
Reasons for the failures of vertical structures.

Slide 39

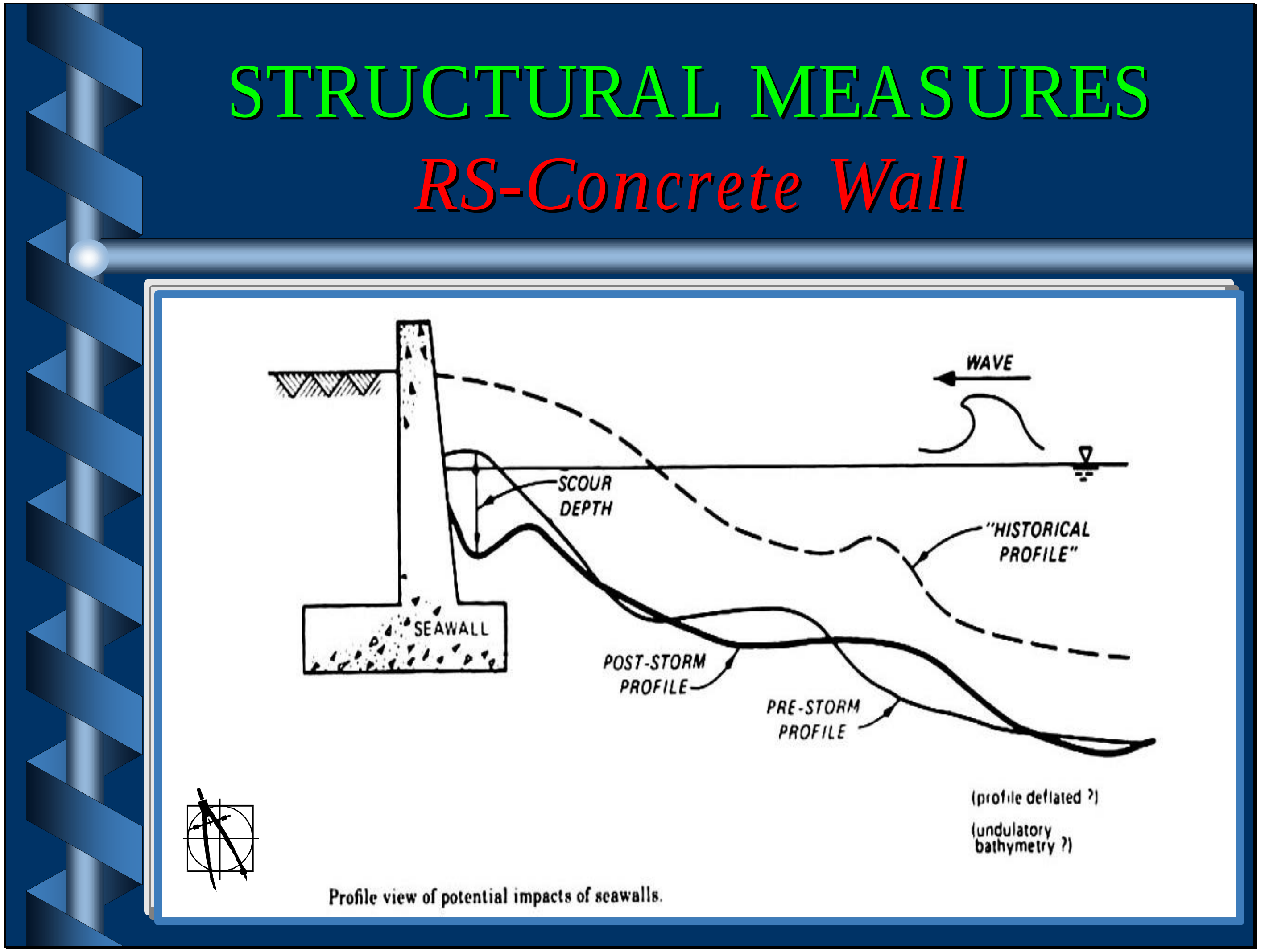

STRUCTURAL MEASURES
Partial Protection
LONGSHORE CURRENT
BAR
INCIDENT WAVES
(rip ?)
IMPOUNDMENT
BAR
SEAWALL
SCOUR
(bar displaced ?)
DOWNDRIFT FLANKING
(rip ?)
REFLECTED WAVES
(shoal ?)
BAR
ERODED UNPROTECTED SHORELINE
"HISTORICAL SHORELINE"
Plan view of potential impacts of seawalls.

Slide 40


STRUCTURAL MEASURES
Groyne Design
Incident waves
T-head
Round head
Y-head
Recharged beach crest
Beach head
Groyne root
Definition of groyne terminology

Slide 41

Slide 42


STRUCTURAL MEASURES
RS-Concrete Wall
WAVE
SCOUR
DEPTH
"HISTORICAL
PROFILE"
SEAWALL
POST-STORM
PROFILE
PRE-STORM
PROFILE
(profile deflated ?)
(undulatory
bathymetry ?)
Profile view of potential impacts of seawalls.

Slide 43

RISKS ASSOCIATED WITH
CONCRETE SEAWALLS AND REVETMENTS

- Concrete seawalls and revetments share many risks, common in narrow tidally influenced strips of land or coastal areas.
- The objectives in providing these facilities are executed through contract drawings and specifications.
- There should not be any compromise in achieving the design objectives, without the clients approval.

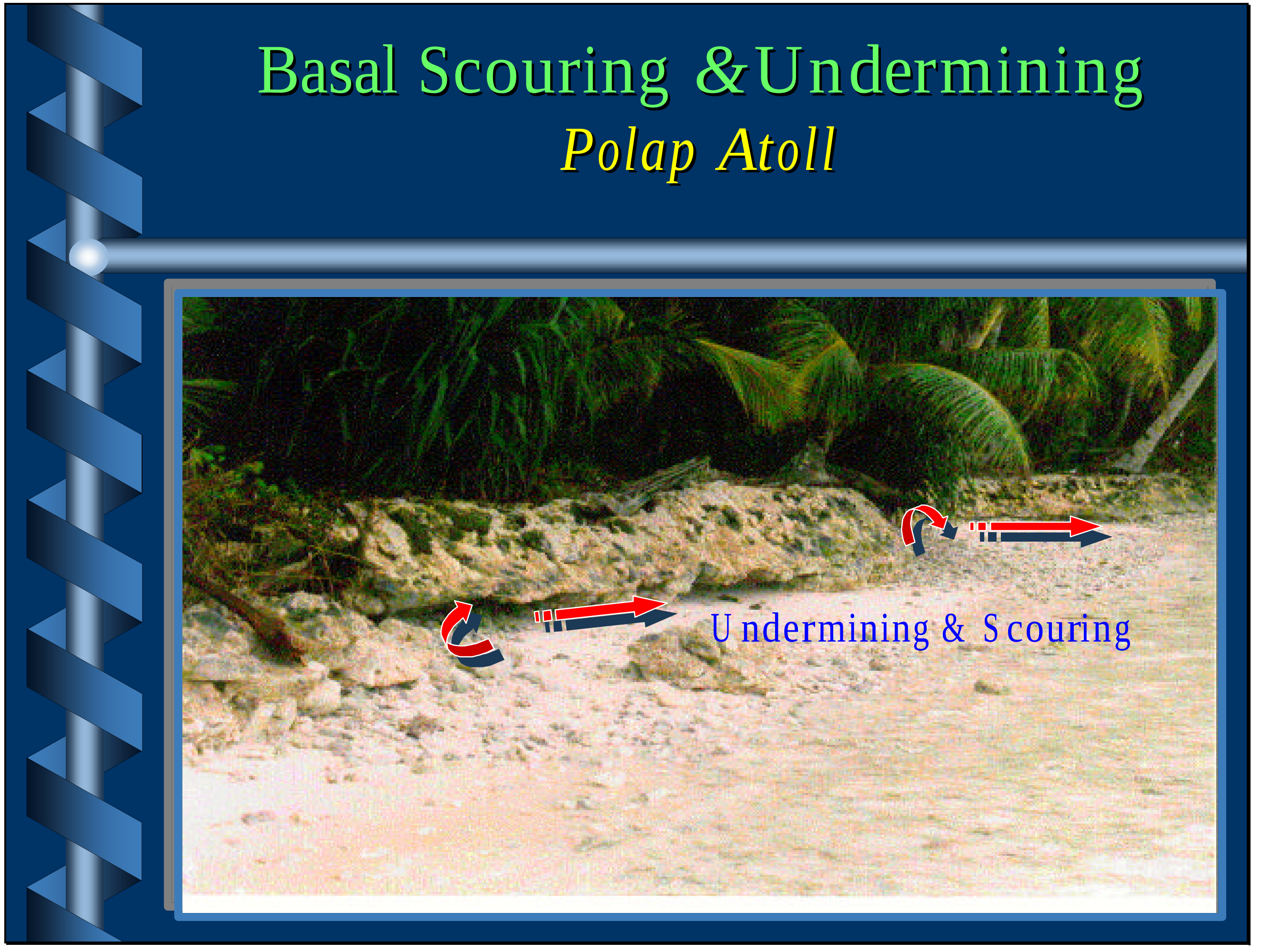
Slide 44


SEAWALL DESIGN
Interlocking coral rubble; masonry walls and steel-reinforced concrete

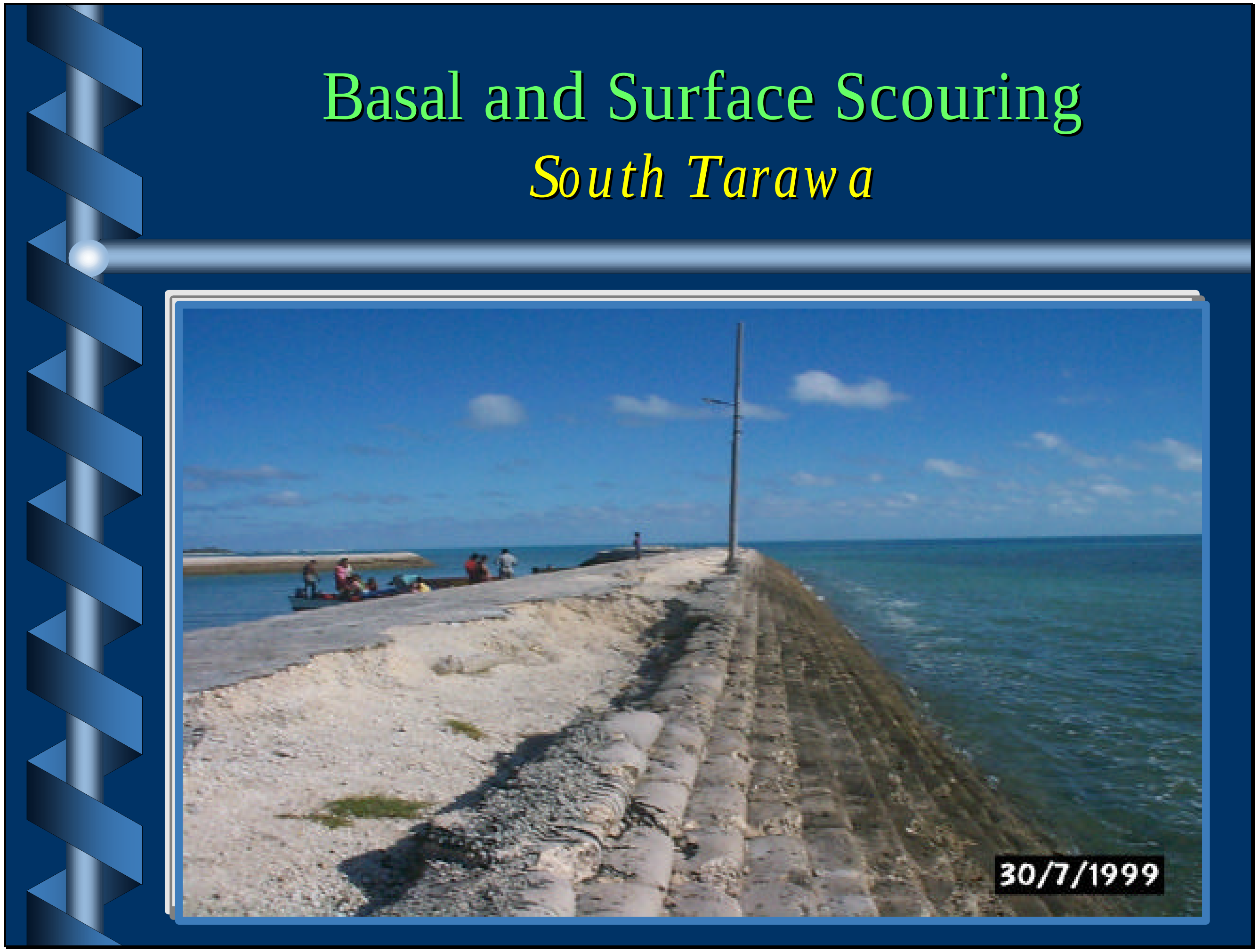
Slide 45

Slide 46

Slide 47


Basal Scouring & Undermining
Polap Atoll
Undermining & Scouring

Slide 48



Slide 49


RISK CONTROL STRATEGIES
Variations in Beach Level & Sea State
Can meteorological, hydraulic and beach dynamics be supplied?
Can additional ground/geotechnical investigations help in optimum design?
Can additional interpretations be made with limited data?
Can predictive modelling be reliable and can variability be predicted?
Can structures remove the risk of the sea/wave action?
Can we vary material specifications e.g. early hardening and sulphate-resistant concrete?

Slide 50


APPROACHES TO
RISK MANAGEMENT
The systems approach to environmental management
Criteria?
Levels of investigations required?
Problem solving
Recommendations

Slide 51


BENEFITS AND AIMS OF RISK MANAGEMENT
Risk management should make risks explicit, formally describing them and making them easier to manage.
Reduce the possible impacts (cost, time, quality, safety and environmental aspects) associated with uncertainty.
Present mitigation strategies, from inception, development, construction and post-project evaluation.

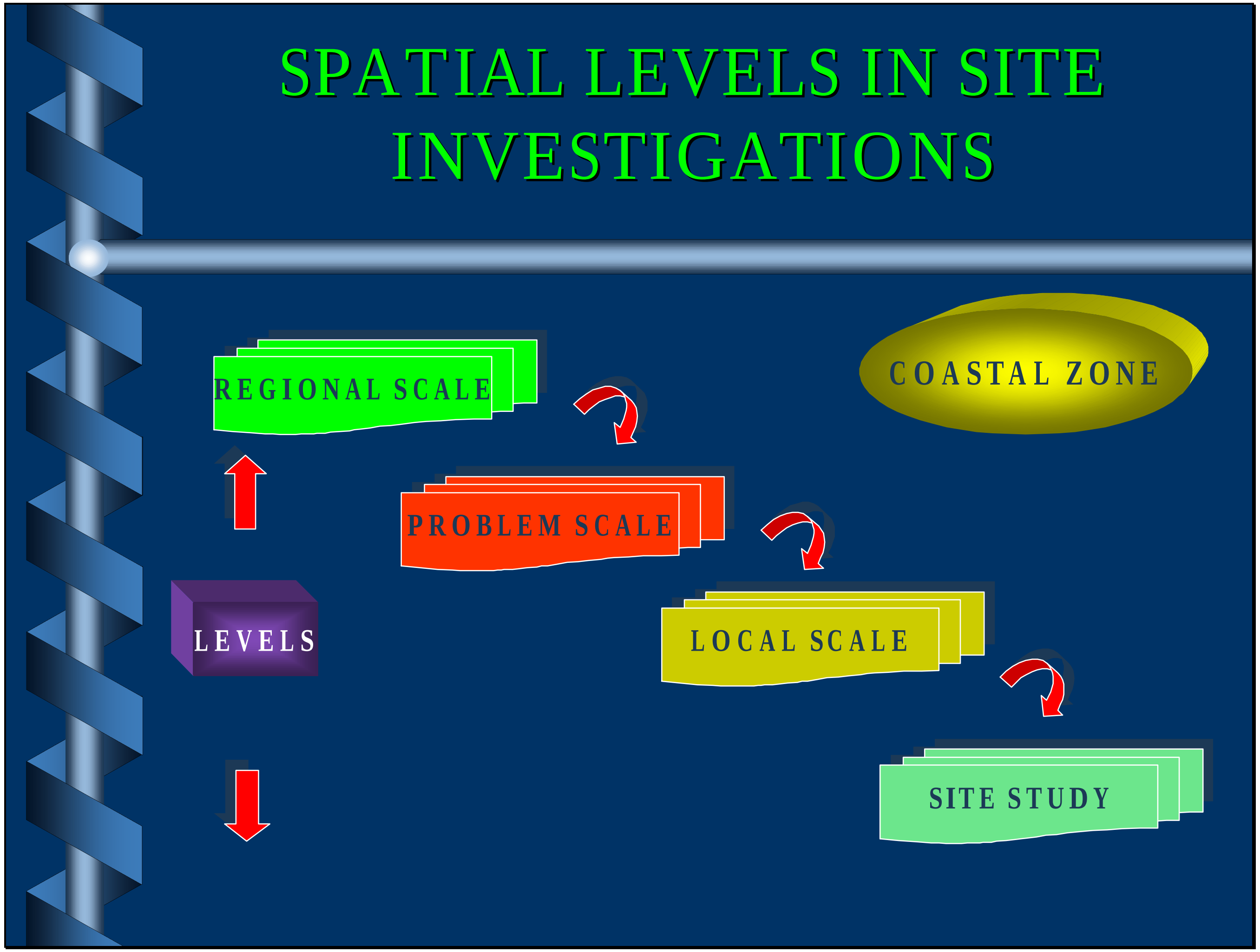
Slide 52


RISK MANAGEMENT
HELPS TO
Identify and question the assumptions that affects the success of the project.
Concentrate the efforts into controlling the risk through risk prioritisation, including:
Commercial risks and
Technical risks
Balance the cost and benefits of risk controlling measures.

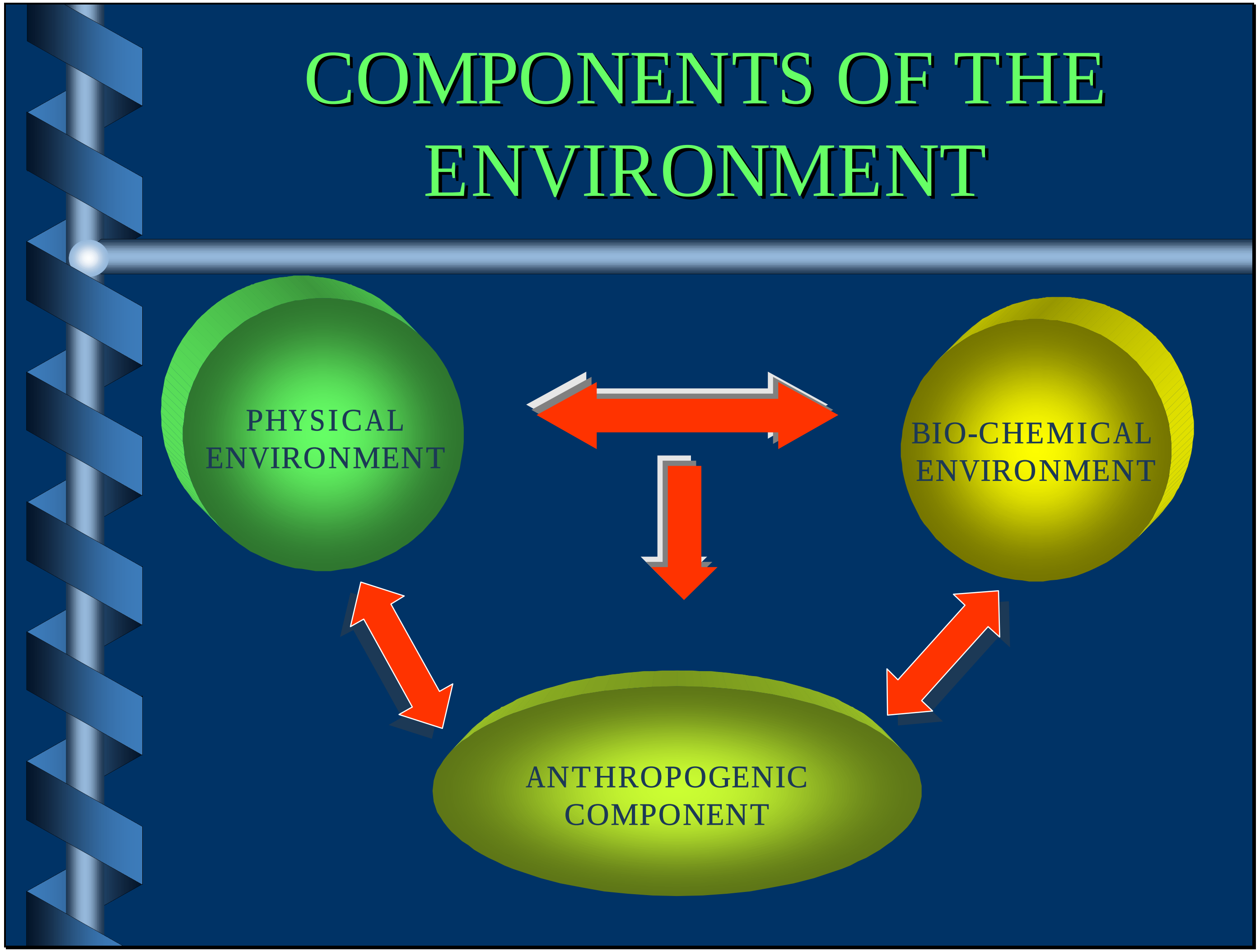
Slide 53

RISK MANAGEMENT
THE SYSTEMS APPROACH
ENVIRONMENTAL PARAMETERS
DATA
INTERPRET
EVALUATE
MAKE DECISIONS

Slide 54


SPATIAL LEVELS IN SITE INVESTIGATIONS
REGIONAL SCALE
COASTAL ZONE
PROBLEM SCALE
LEVELS
LOCAL SCALE
SITE STUDY

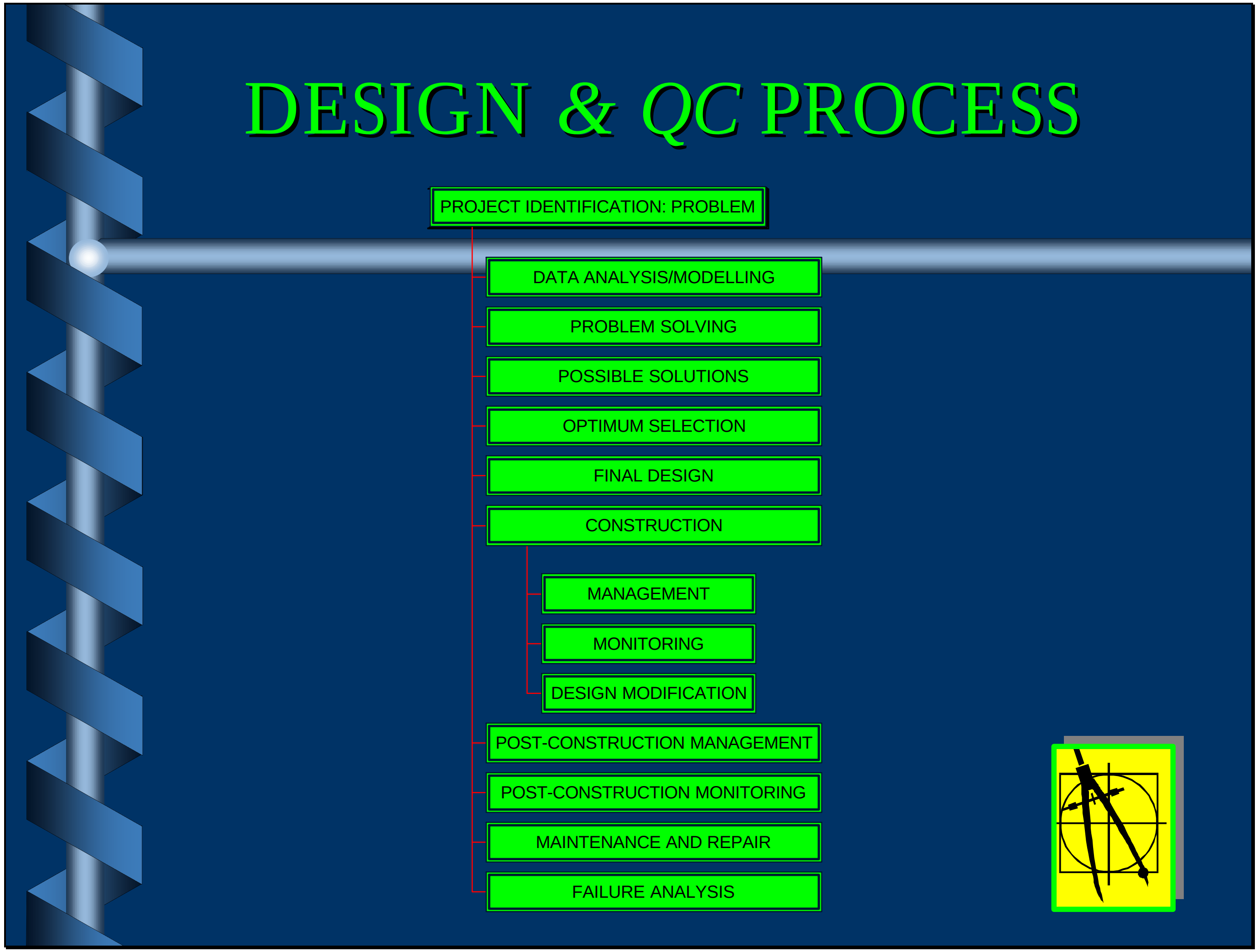
Slide 55


COMPONENTS OF THE ENVIRONMENT
PHYSICAL ENVIRONMENT
BIO-CHEMICAL ENVIRONMENT
ANTHROPOGENIC COMPONENT

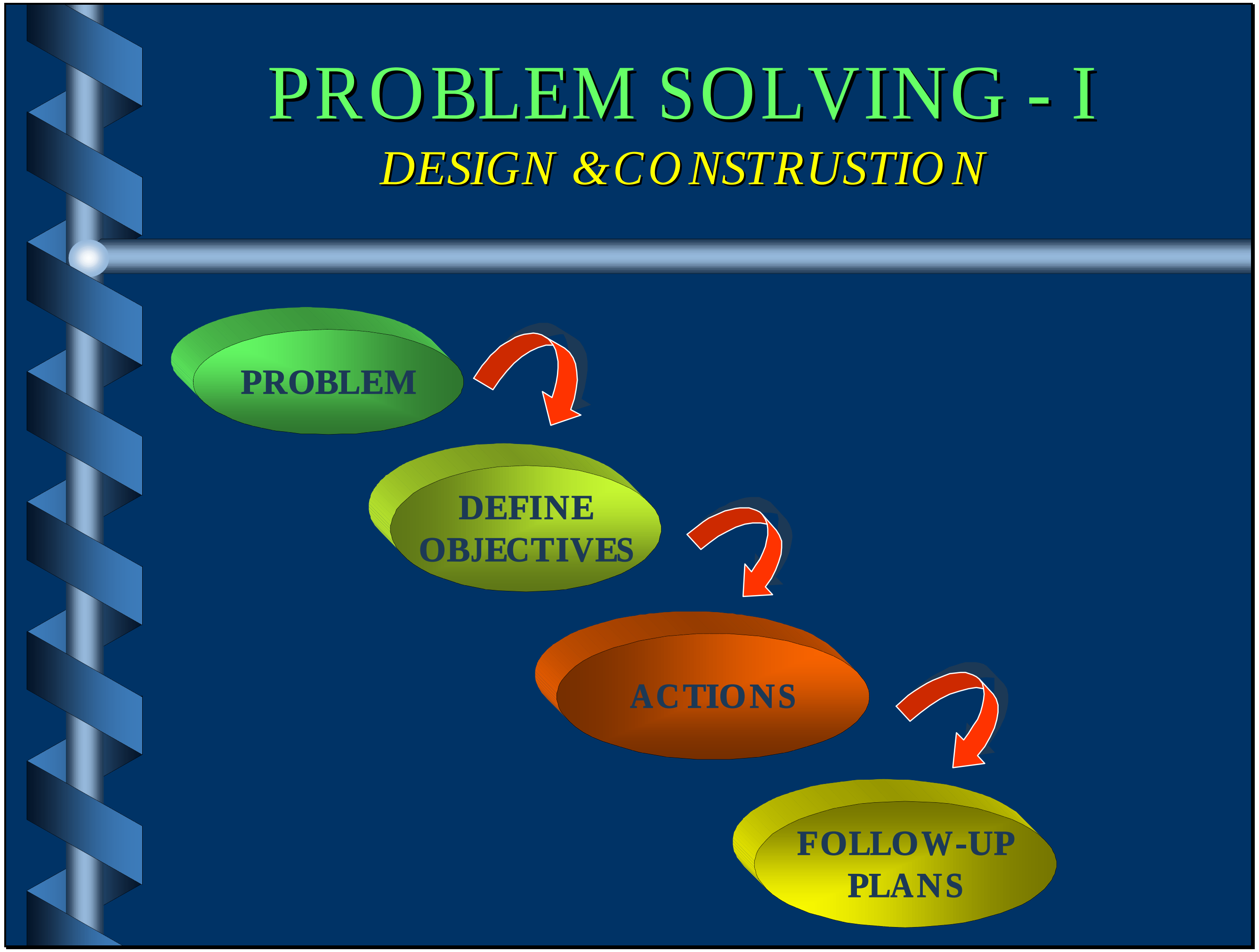
Slide 56


CRITERIA
QUALIFICATION
CRITERIA
PARAMETERS
DATA
SOLUTION

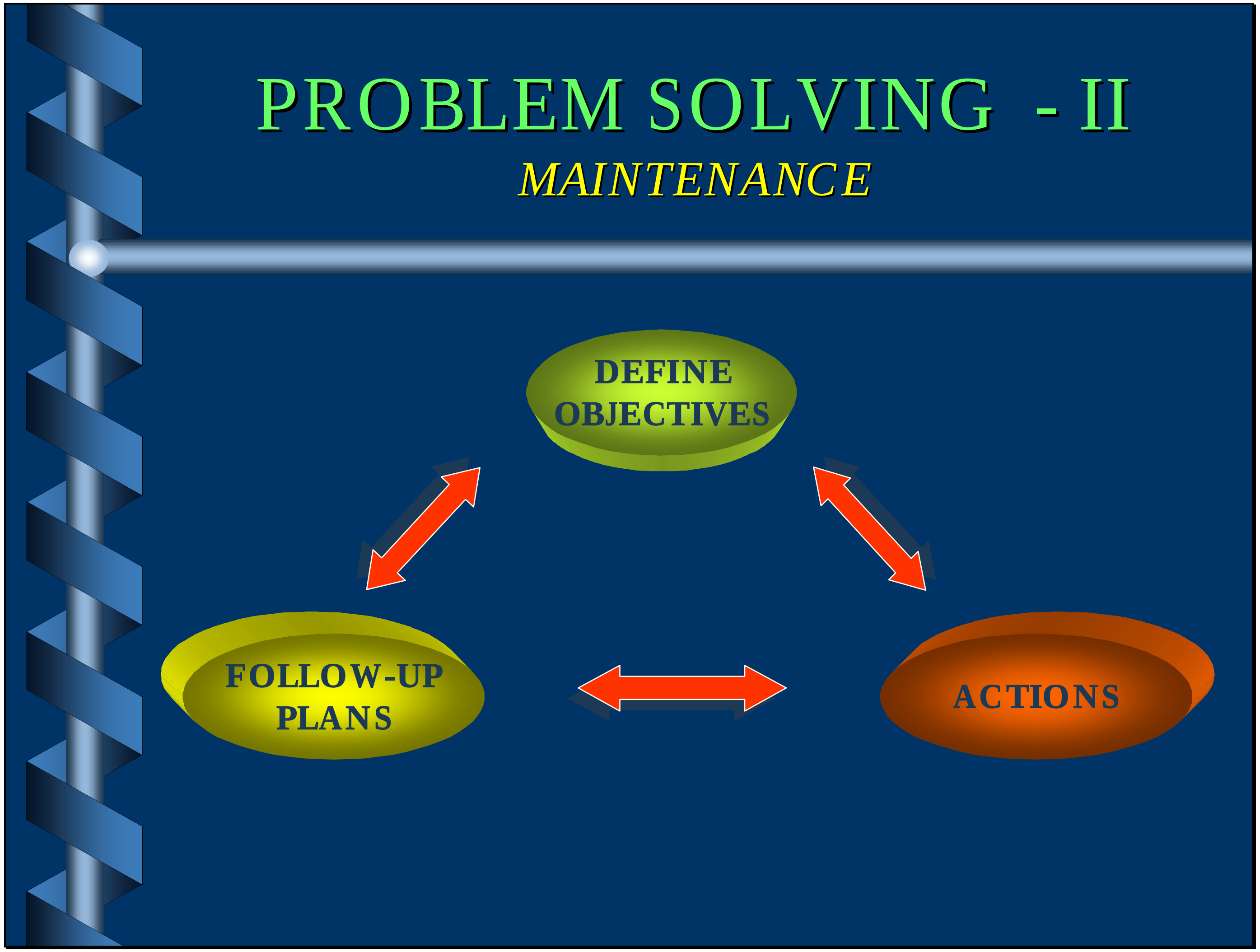
Slide 57


DESIGN & QC PROCESS
PROJECT IDENTIFICATION: PROBLEM
DATA ANALYSIS/MODELLING
PROBLEM SOLVING
POSSIBLE SOLUTIONS
OPTIMUM SELECTION
FINAL DESIGN
CONSTRUCTION
MANAGEMENT
MONITORING
DESIGN MODIFICATION
POST-CONSTRUCTION MANAGEMENT
POST-CONSTRUCTION MONITORING
MAINTENANCE AND REPAIR
FAILURE ANALYSIS

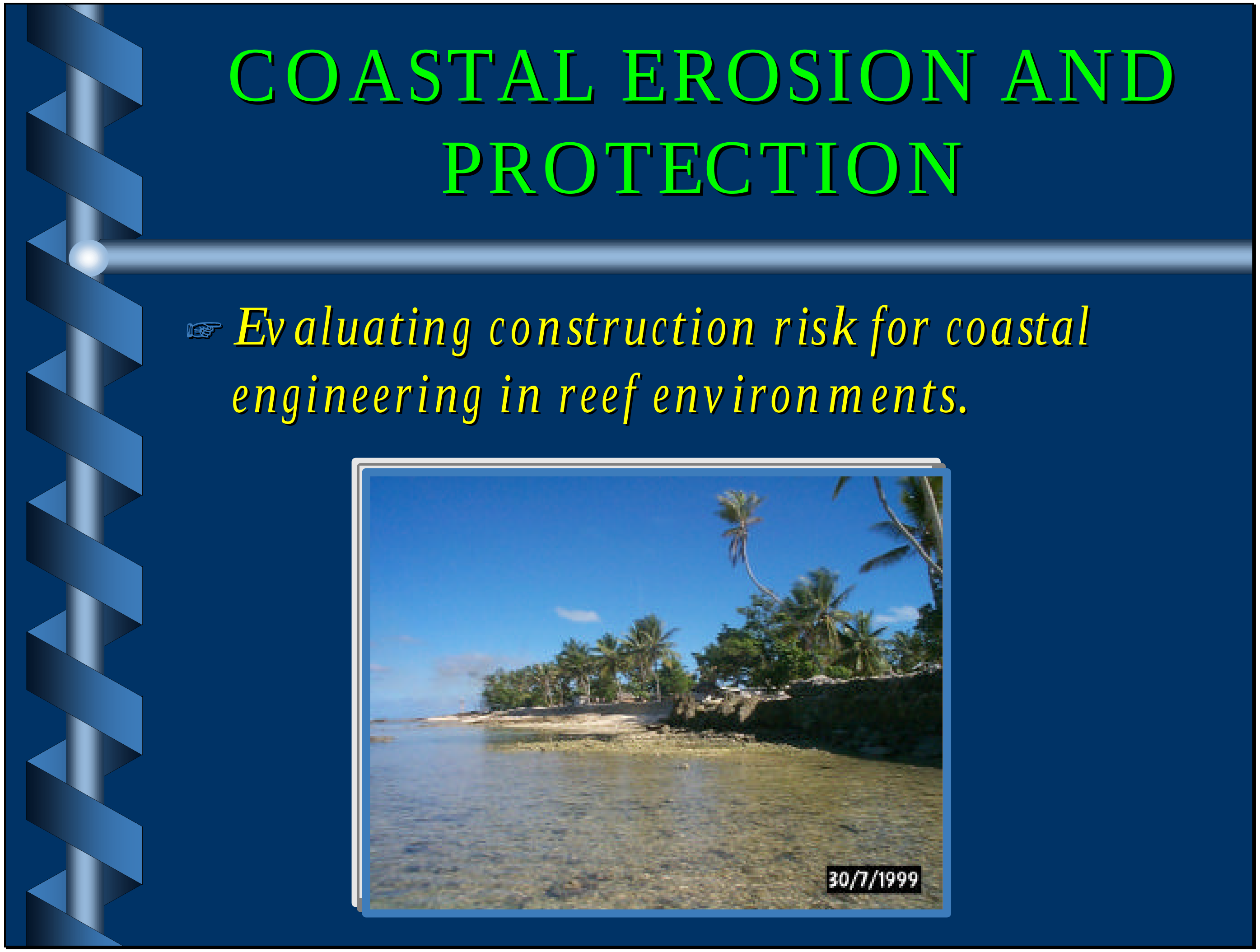
Slide 58


PROBLEM SOLVING - I
DESIGN &CONSTRUSTION
PROBLEM
DEFINE OBJECTIVES
ACTIONS
FOLLOW-UP PLANS

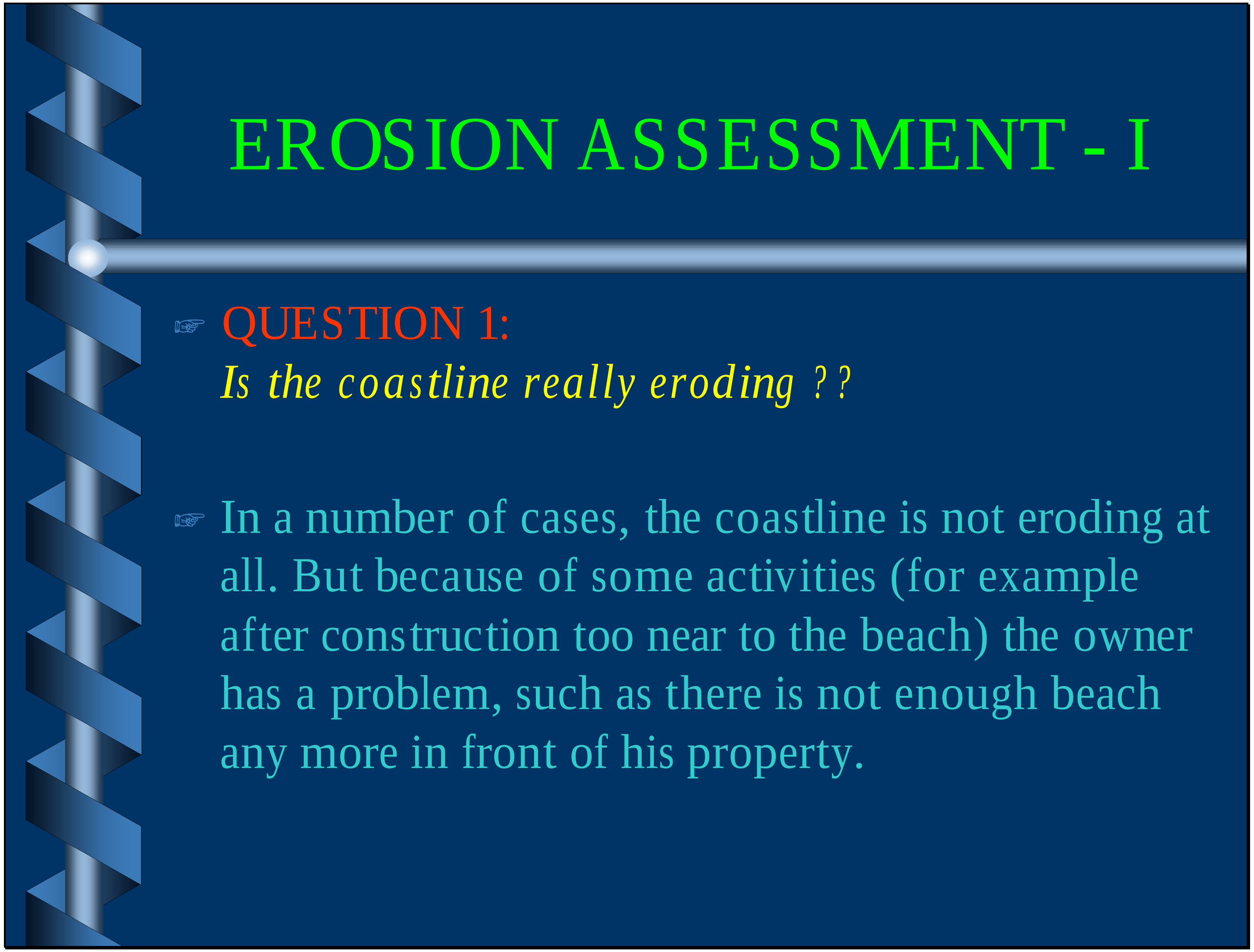
Slide 59


PROBLEM SOLVING - II
MAINTENANCE
DEFINE OBJECTIVES
FOLLOW-UP PLANS
ACTIONS

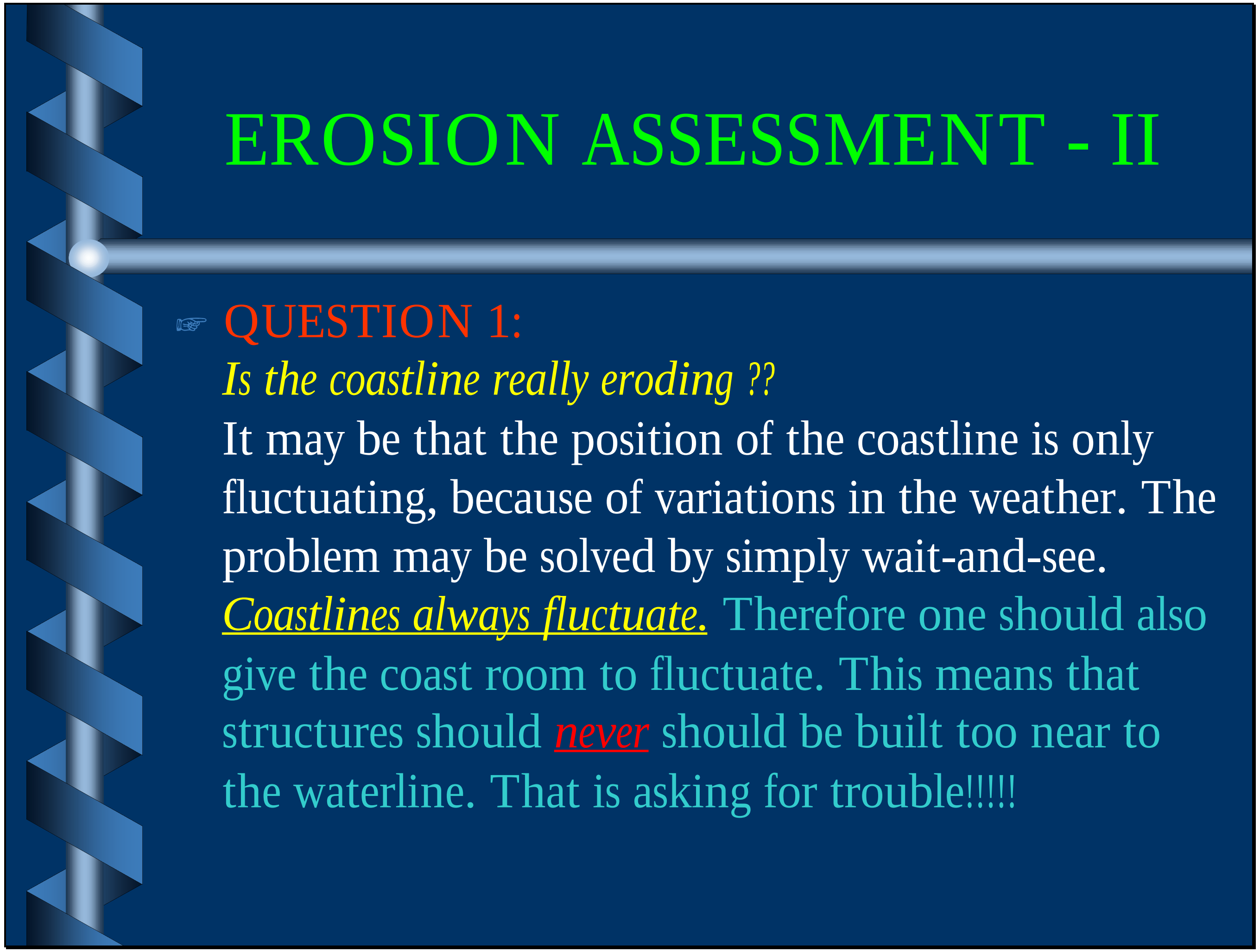
Slide 60


COASTAL EROSION AND PROTECTION
Evaluating construction risk for coastal engineering in reef environments.
30/7/1999

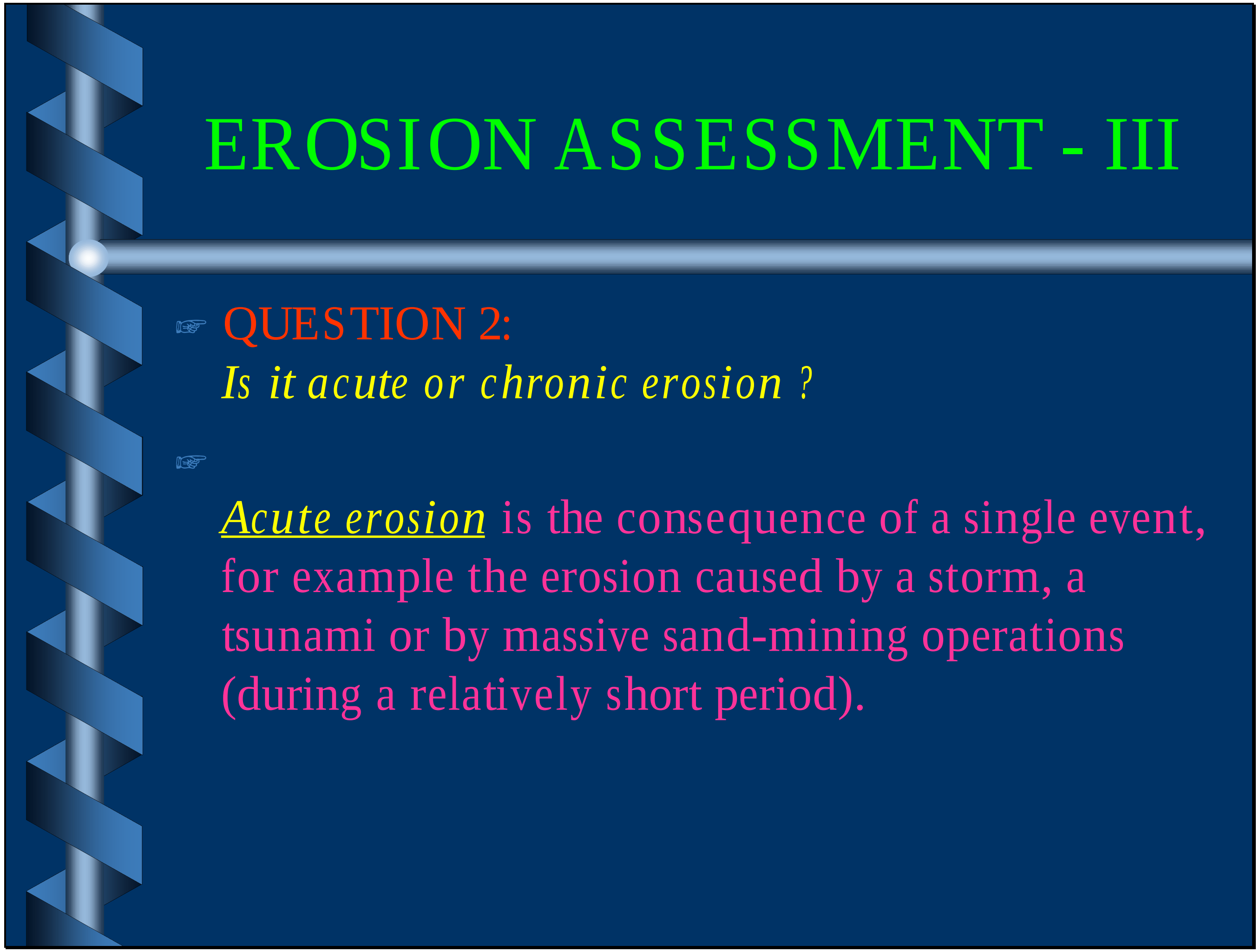
Slide 61


EROSION ASSESSMENT - I
QUESTION 1:
Is the coastline really eroding ??
In a number of cases, the coastline is not eroding at all. But because of some activities (for example after construction too near to the beach) the owner has a problem, such as there is not enough beach any more in front of his property.

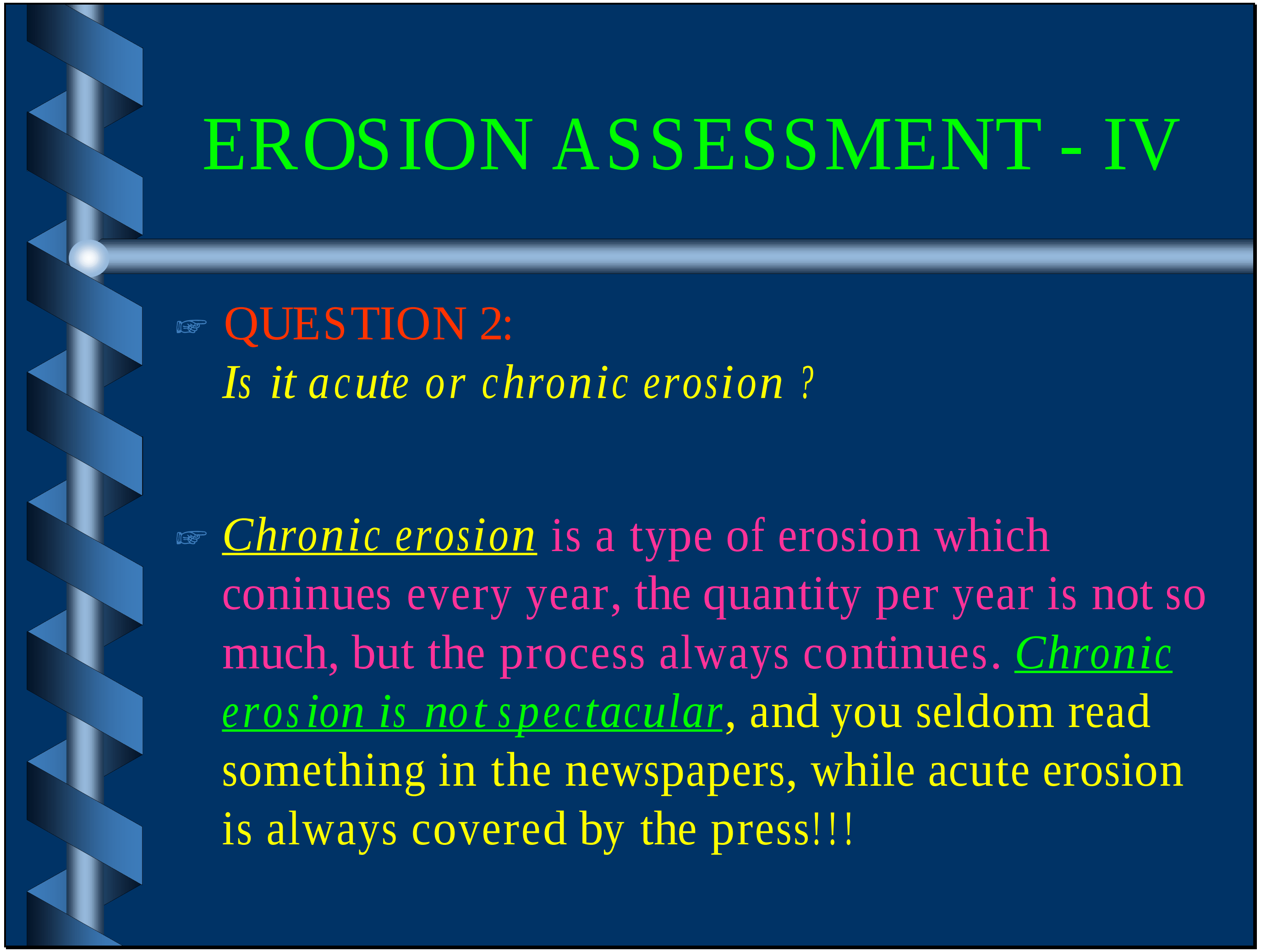
Slide 62


EROSION ASSESSMENT - II
QUESTION 1:
Is the coastline really eroding ??
It may be that the position of the coastline is only fluctuating, because of variations in the weather. The problem may be solved by simply wait-and-see.
Coastlines always fluctuate. Therefore one should also give the coast room to fluctuate. This means that structures should *never* should be built too near to the waterline. That is asking for trouble!!!!!

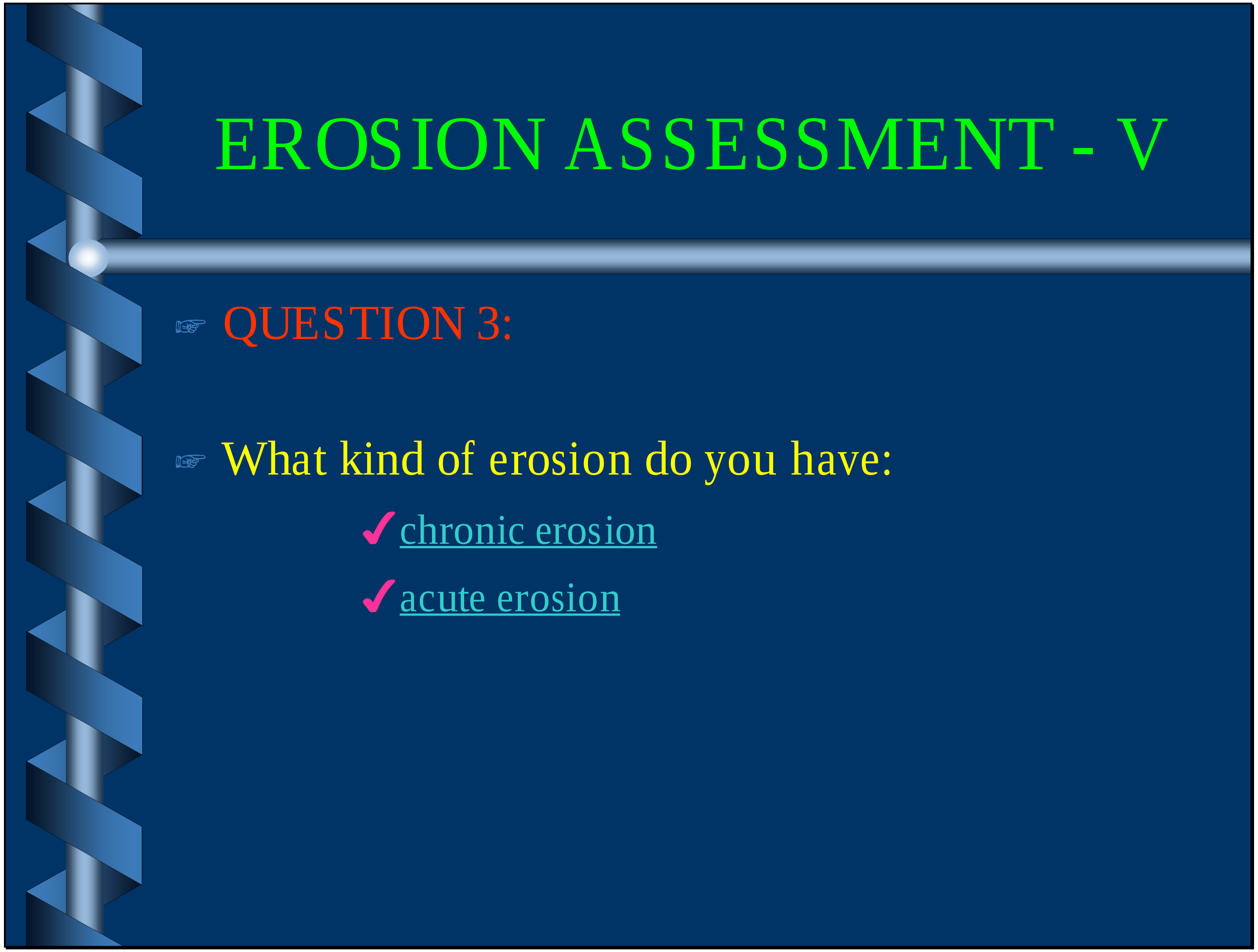
Slide 63


EROSION ASSESSMENT - III
QUESTION 2:
Is it acute or chronic erosion ?
Acute erosion is the consequence of a single event, for example the erosion caused by a storm, a tsunami or by massive sand-mining operations (during a relatively short period).

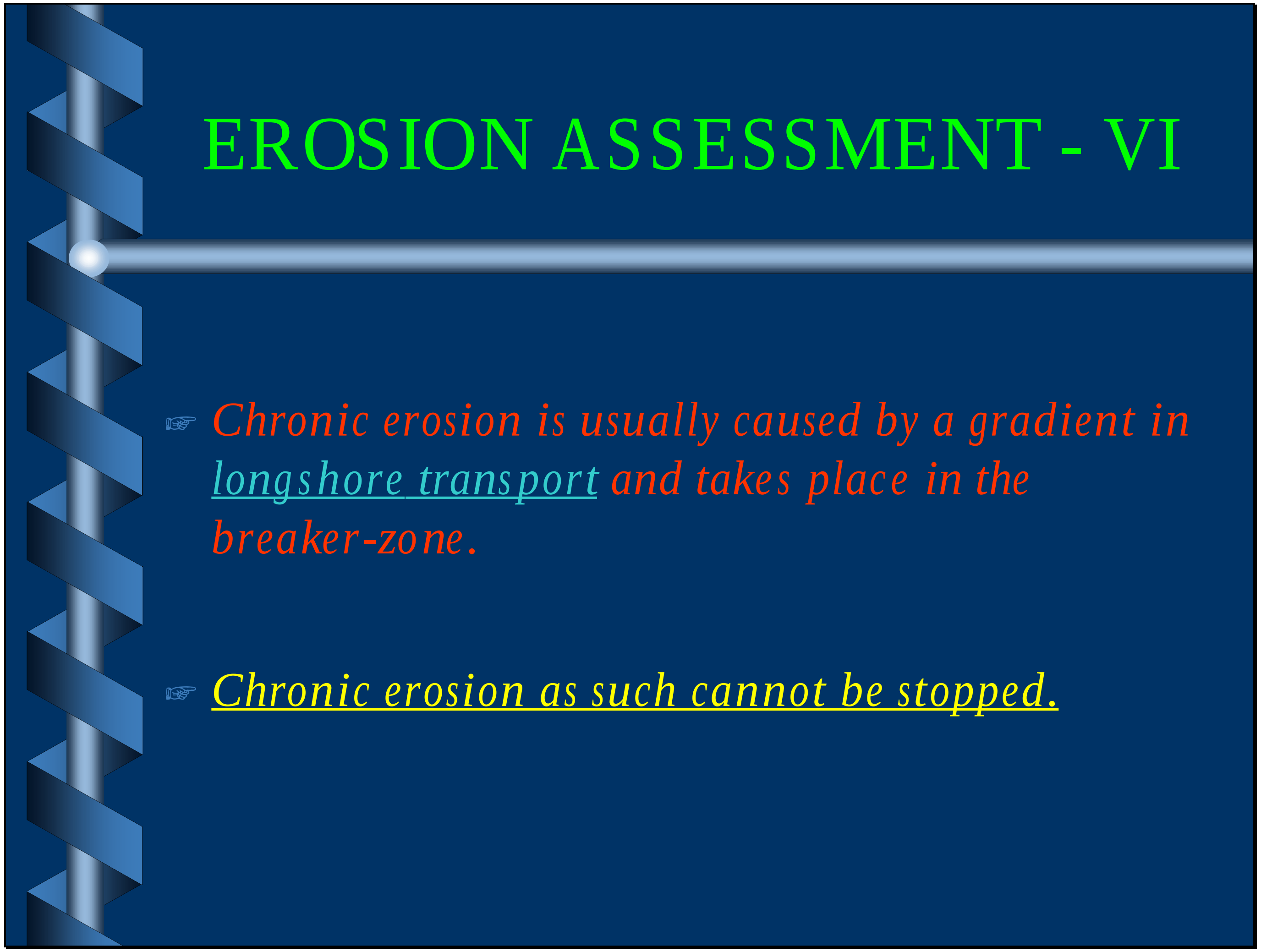
Slide 64


EROSION ASSESSMENT - IV
QUESTION 2:
Is it acute or chronic erosion ?
Chronic erosion is a type of erosion which coninues every year, the quantity per year is not so much, but the process always continues. Chronic erosion is not spectacular, and you seldom read something in the newspapers, while acute erosion is always covered by the press!!!

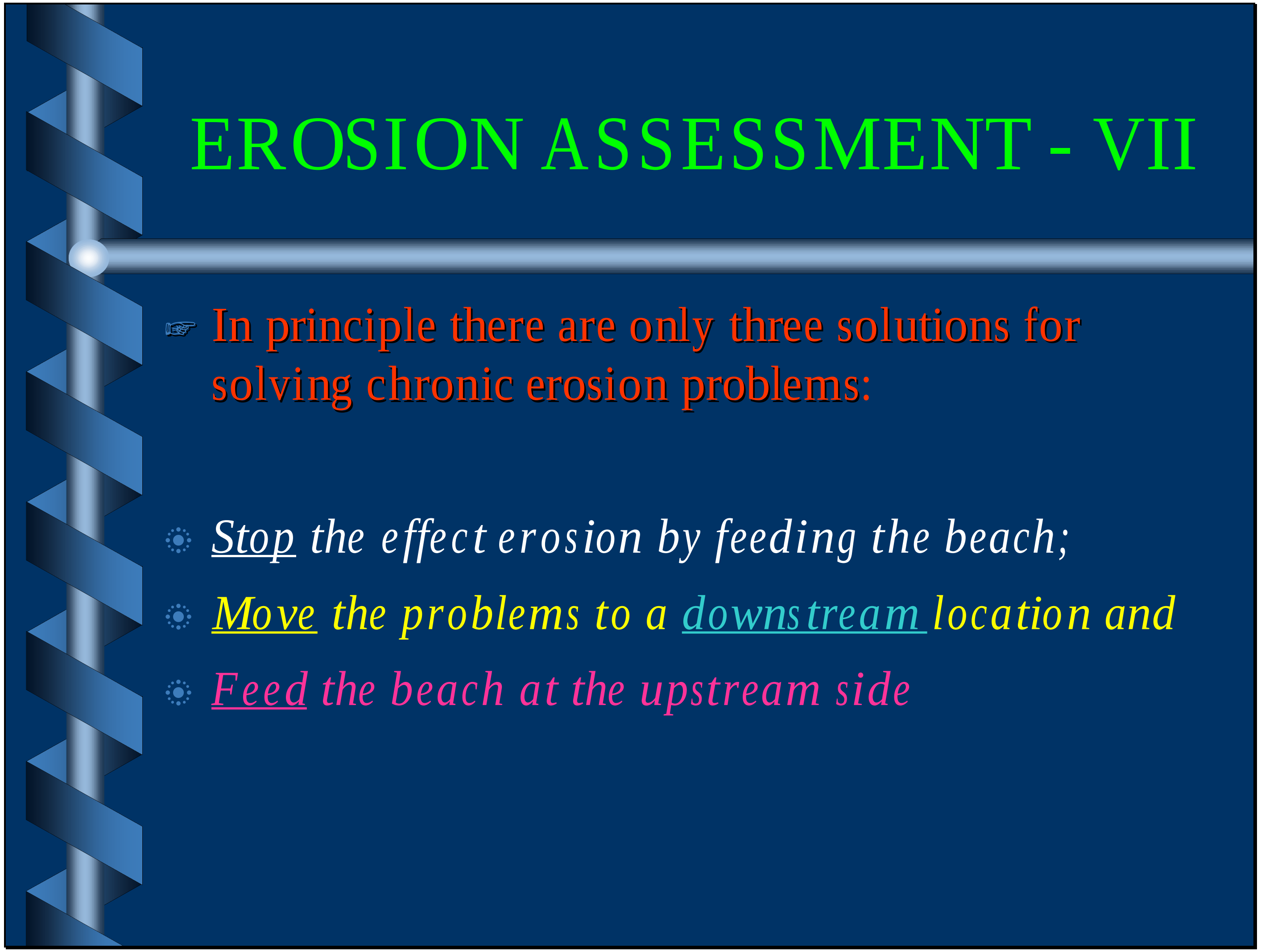
Slide 65


EROSION ASSESSMENT - V
QUESTION 3:
What kind of erosion do you have:
chronic erosion
acute erosion

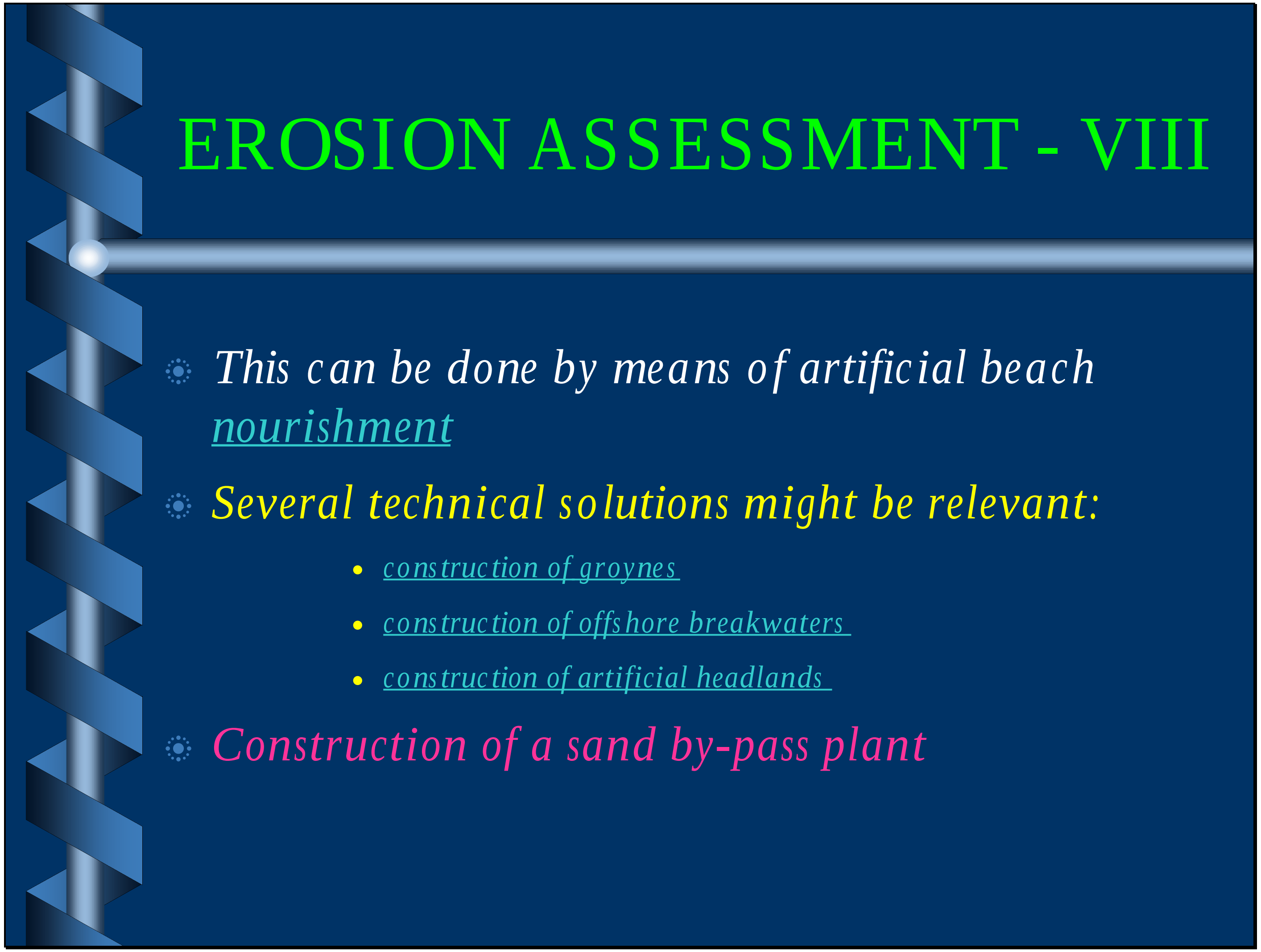
Slide 66


EROSION ASSESSMENT - VI
Chronic erosion is usually caused by a gradient in longshore transport and takes place in the breaker-zone.
Chronic erosion as such cannot be stopped.

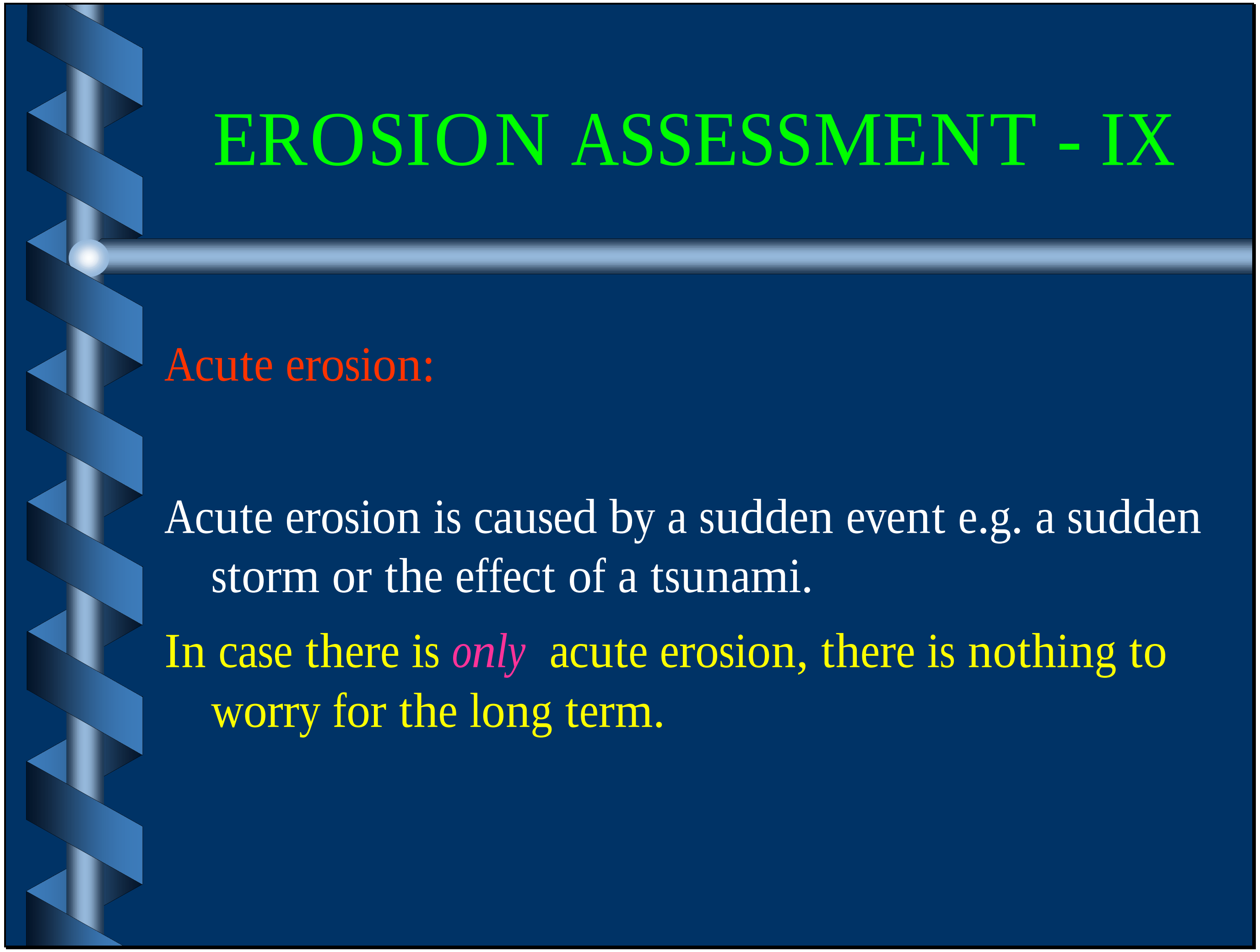
Slide 67


EROSION ASSESSMENT - VII
In principle there are only three solutions for solving chronic erosion problems:
Stop the effect erosion by feeding the beach;
Move the problems to a downstream location and
Feed the beach at the upstream side

Slide 68


EROSION ASSESSMENT - VIII
This can be done by means of artificial beach nourishment
Several technical solutions might be relevant:
construction of groynes
construction of offshore breakwaters
construction of artificial headlands
Construction of a sand by-pass plant

Slide 69


EROSION ASSESSMENT - IX
Acute erosion:
Acute erosion is caused by a sudden event e.g. a sudden storm or the effect of a tsunami.
In case there is *only* acute erosion, there is nothing to worry for the long term.

Slide 70

EROSION ASSESSMENT - X

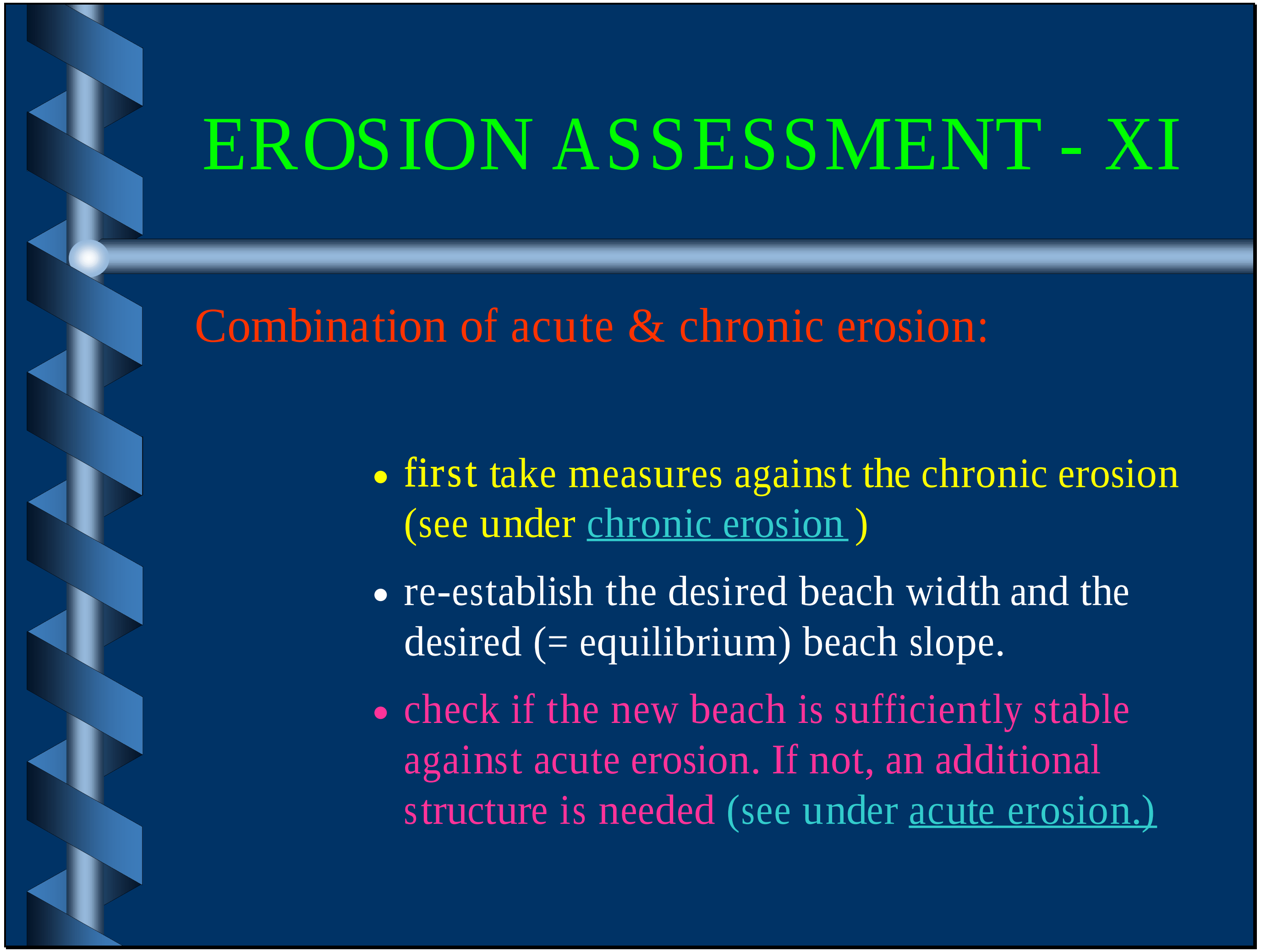
Acute erosion protection can be:

- a heavy revetment constructed as
  - *rip-rap*
  - *vertical wall,*
  - *sloping dike*

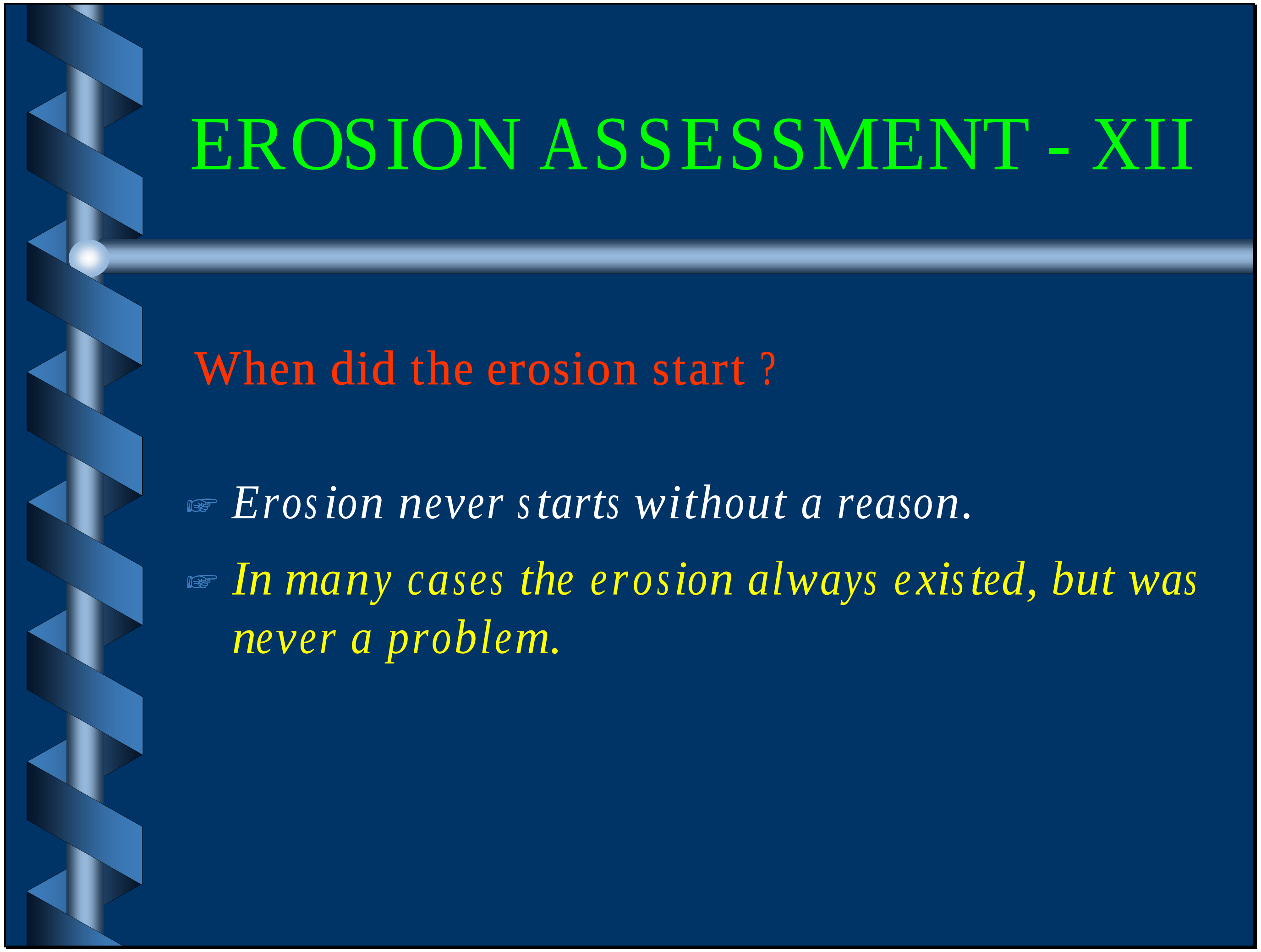
– Because natural coastlines always fluctuate, one has to allow sufficient space between the waterline and the structures (set-back line).

– However, in case of acute erosion, it is absolutely necessary to verify if there is *only* acute erosion.

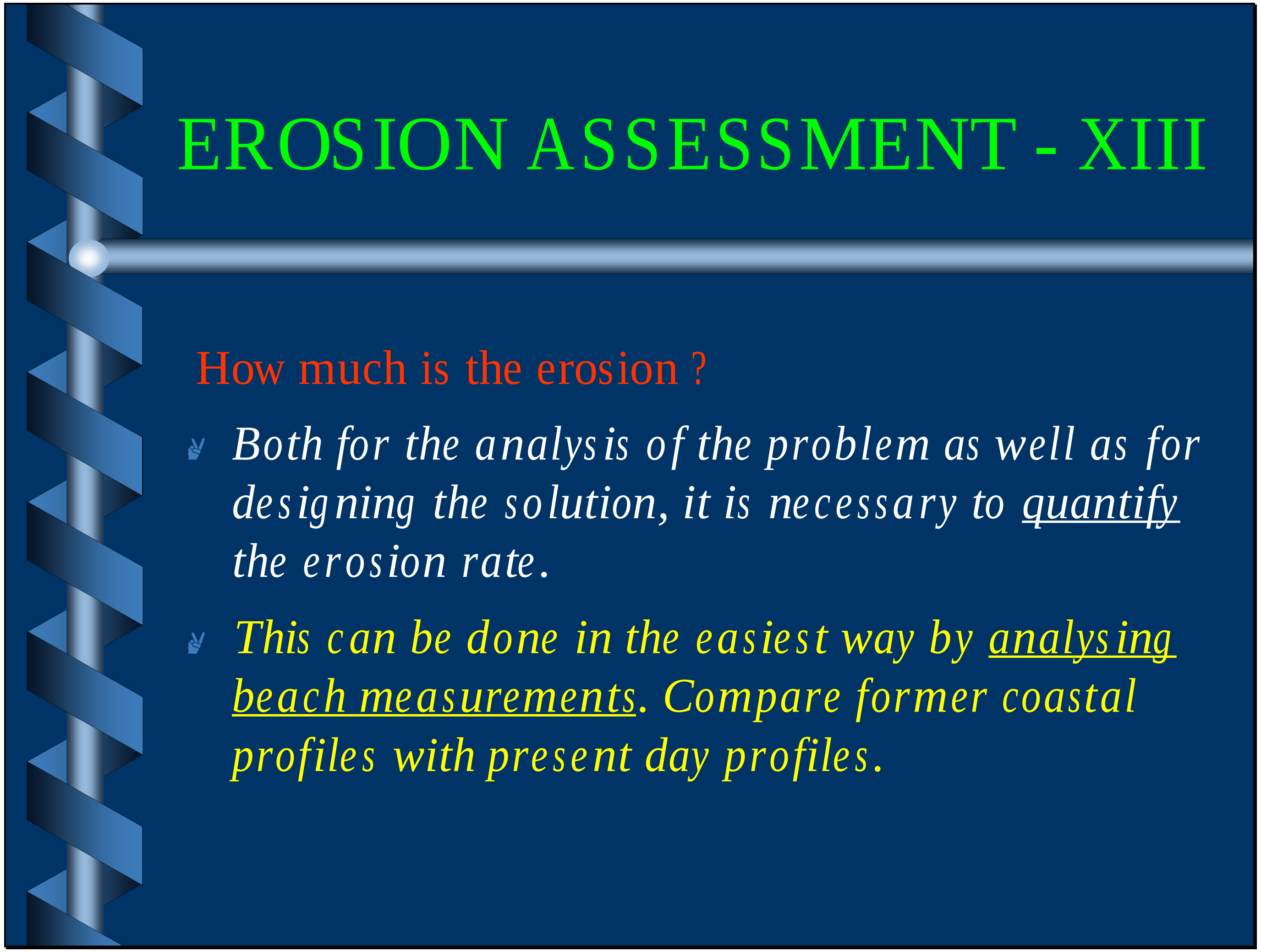
Slide 71


EROSION ASSESSMENT - XI
Combination of acute & chronic erosion:
• first take measures against the chronic erosion (see under chronic erosion)
• re-establish the desired beach width and the desired (= equilibrium) beach slope.
• check if the new beach is sufficiently stable against acute erosion. If not, an additional structure is needed (see under acute erosion.)

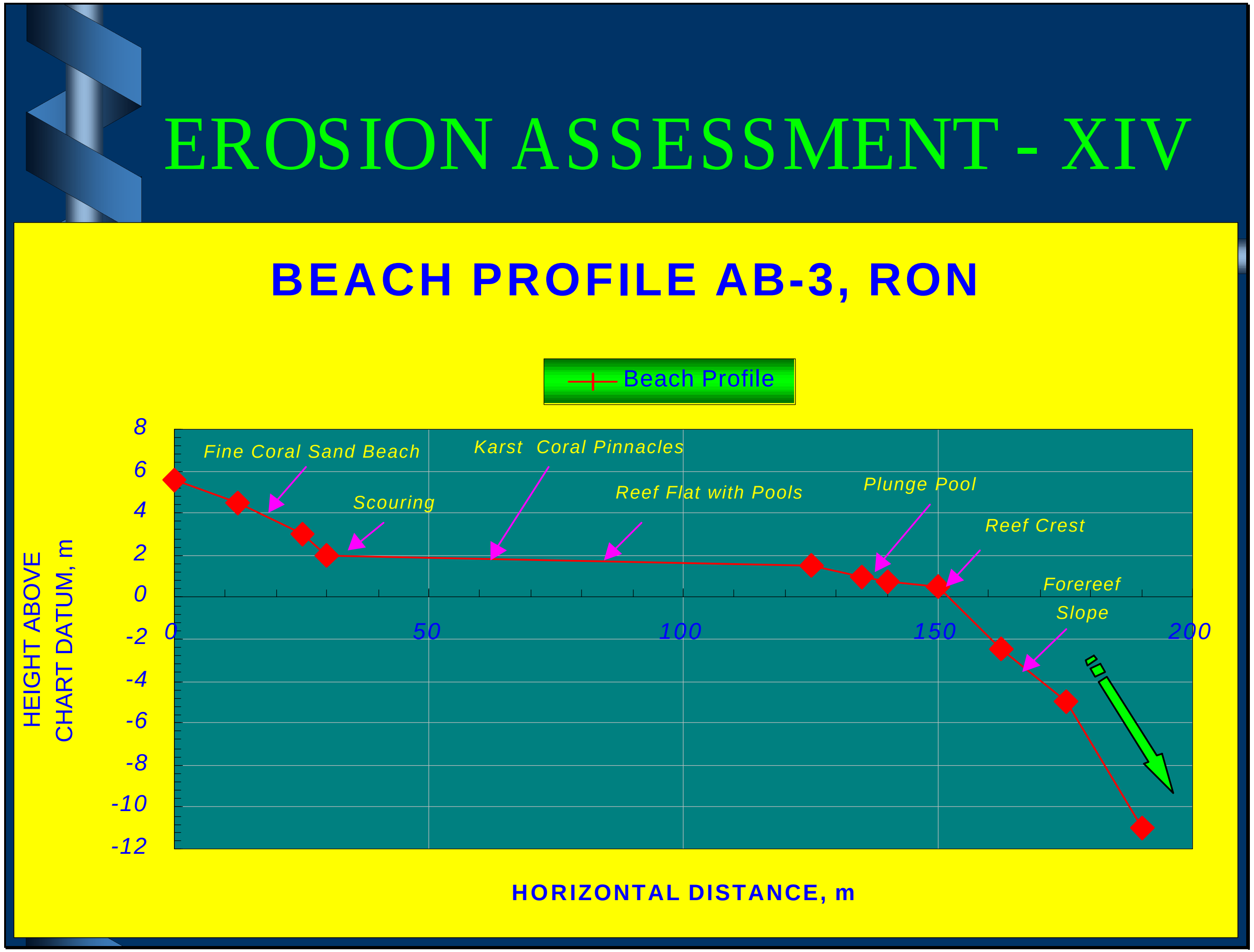
Slide 72


EROSION ASSESSMENT - XII
When did the erosion start ?
Erosion never starts without a reason.
In many cases the erosion always existed, but was never a problem.

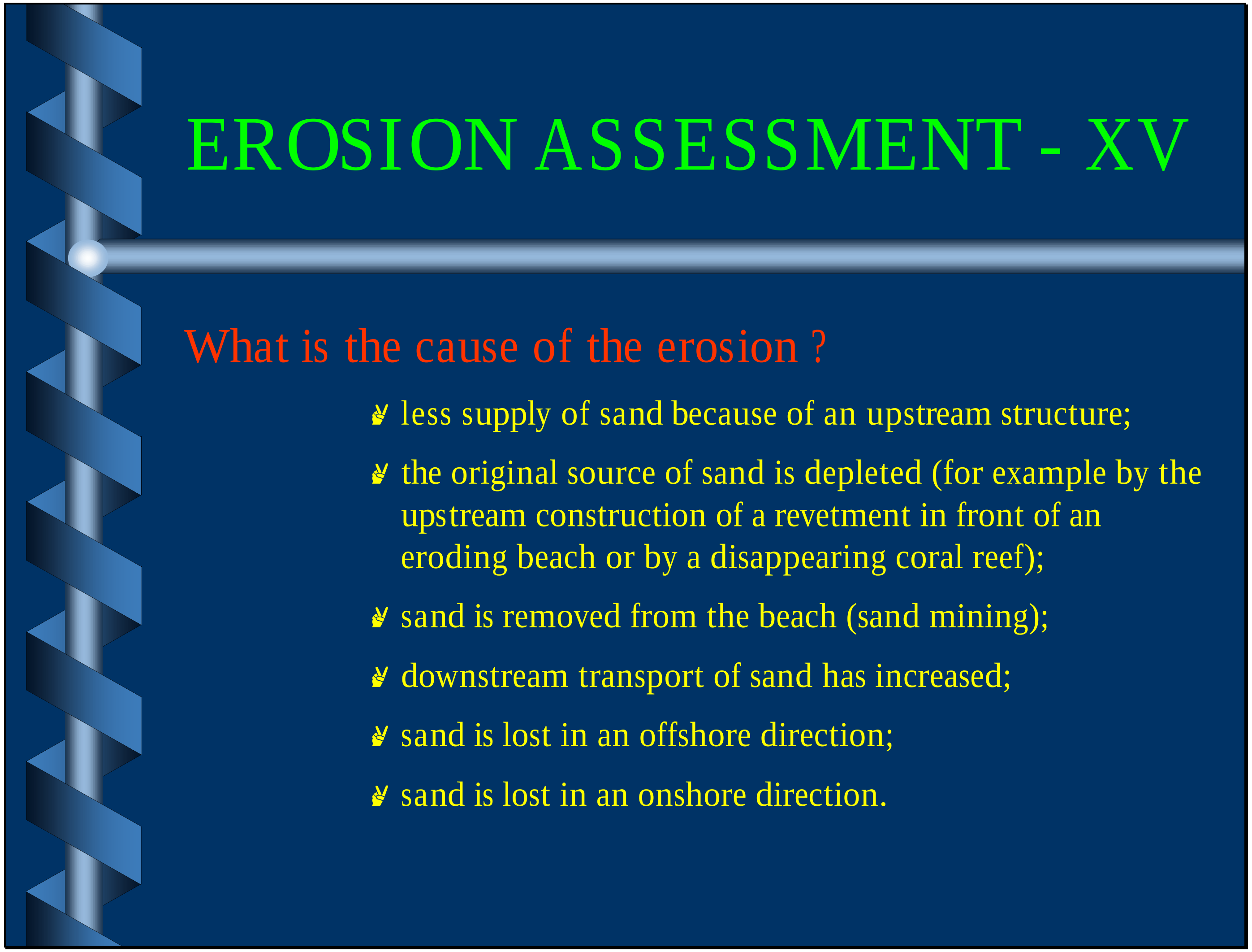
Slide 73


EROSION ASSESSMENT - XIII
How much is the erosion ?
Both for the analysis of the problem as well as for designing the solution, it is necessary to quantify the erosion rate.
This can be done in the easiest way by analysing beach measurements. Compare former coastal profiles with present day profiles.

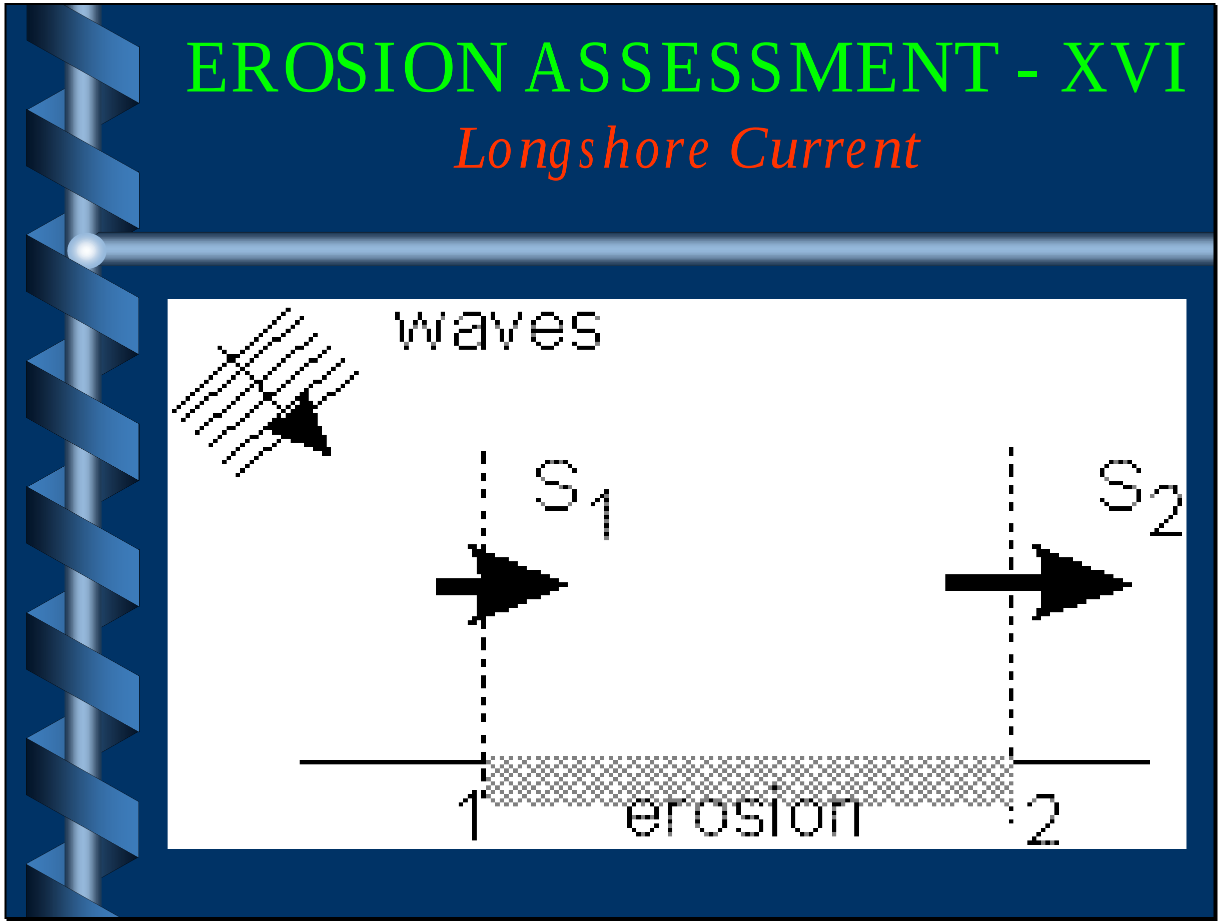
Slide 74


EROSION ASSESSMENT - XIV
BEACH PROFILE AB-3, RON
Beach Profile
Fine Coral Sand Beach
Karst Coral Pinnacles
Scouring
Reef Flat with Pools
Plunge Pool
Reef Crest
Forereef
Slope
HEIGHT ABOVE
CHART DATUM, m
8
6
4
2
0
-2
-4
-6
-8
-10
-12
0
50
100
150
200
HORIZONTAL DISTANCE, m

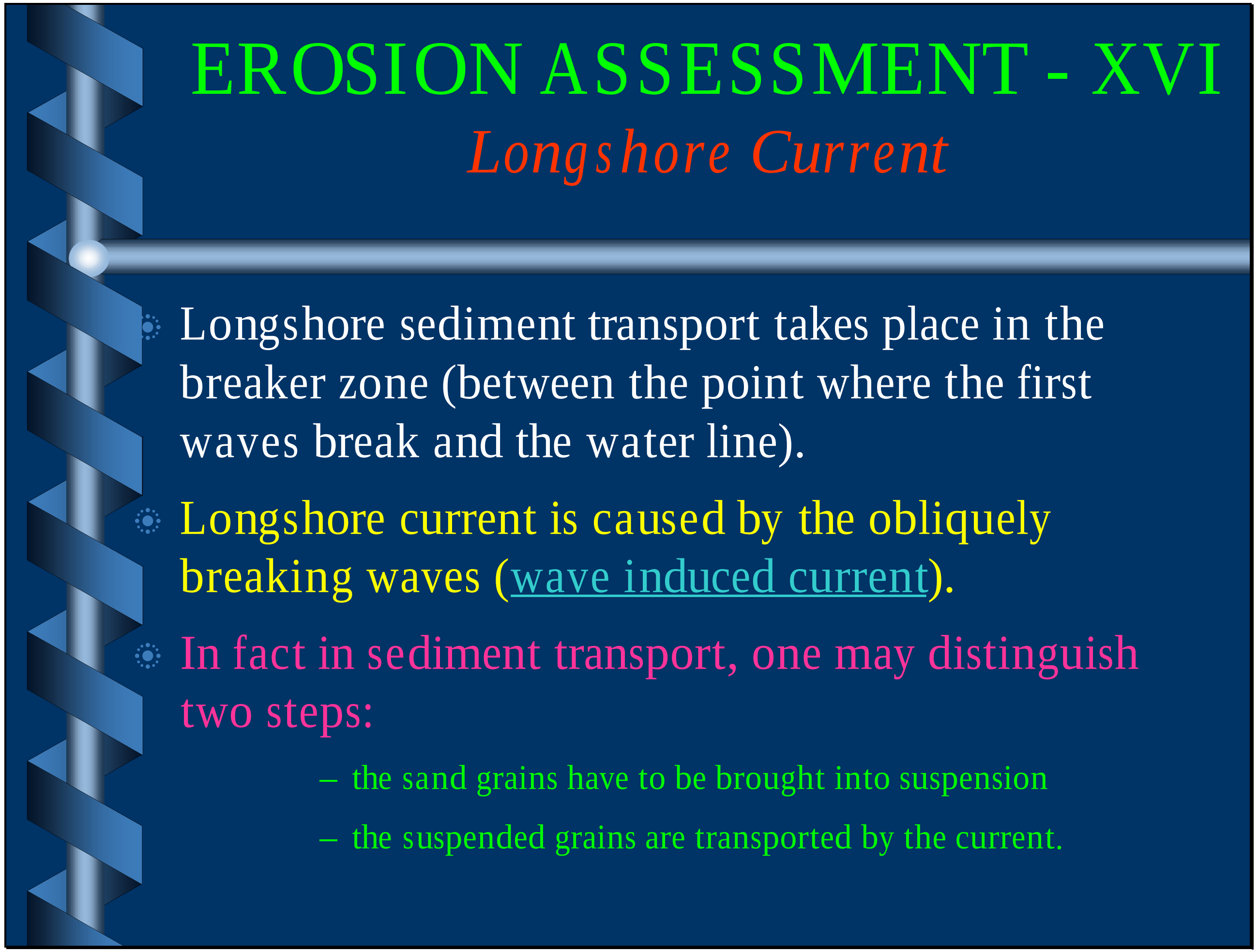
Slide 75


EROSION ASSESSMENT - XV
What is the cause of the erosion ?
less supply of sand because of an upstream structure;
the original source of sand is depleted (for example by the upstream construction of a revetment in front of an eroding beach or by a disappearing coral reef);
sand is removed from the beach (sand mining);
downstream transport of sand has increased;
sand is lost in an offshore direction;
sand is lost in an onshore direction.

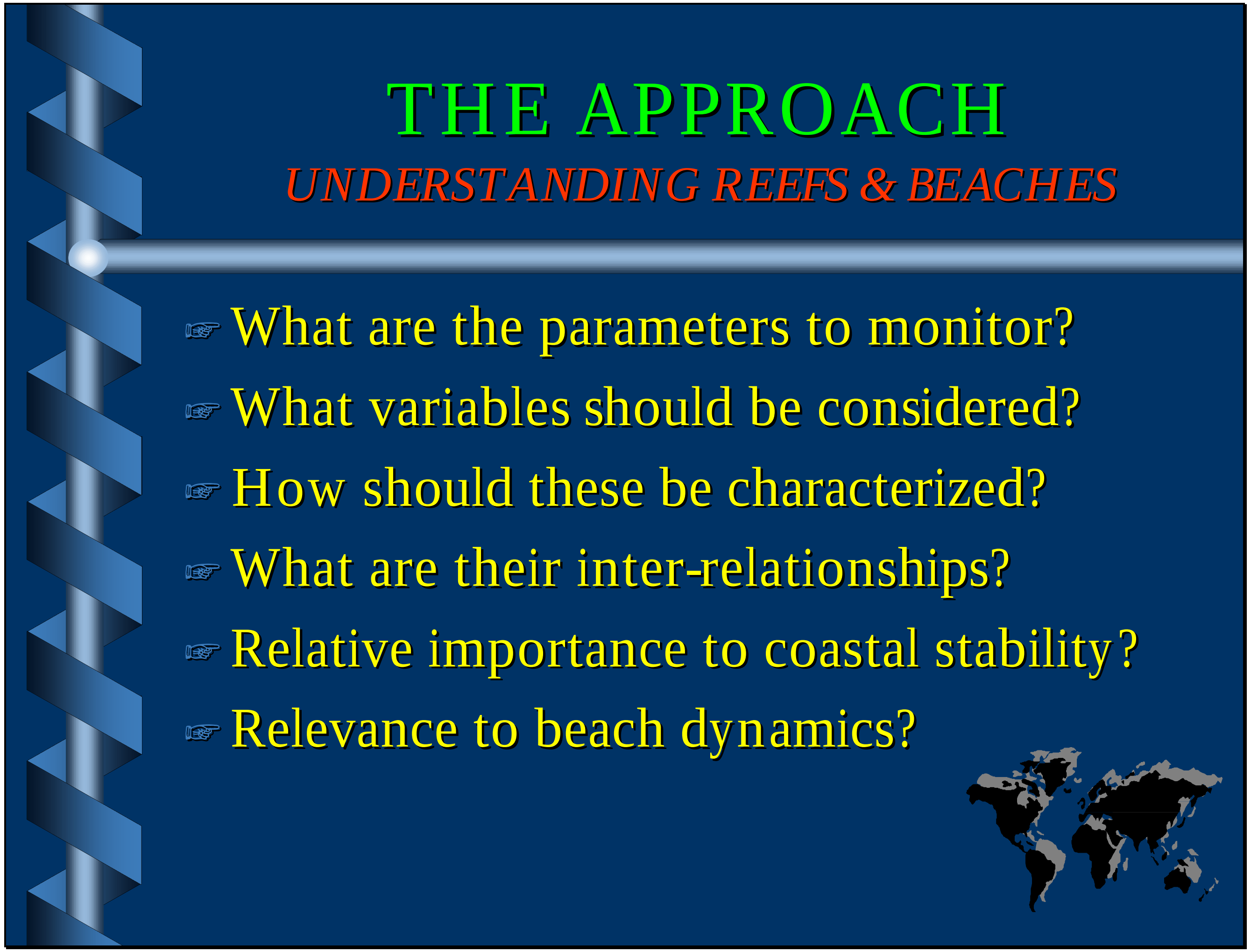
Slide 76


EROSION ASSESSMENT - XVI
Longshore Current
waves
S1
S2
1
erosion
2

Slide 77

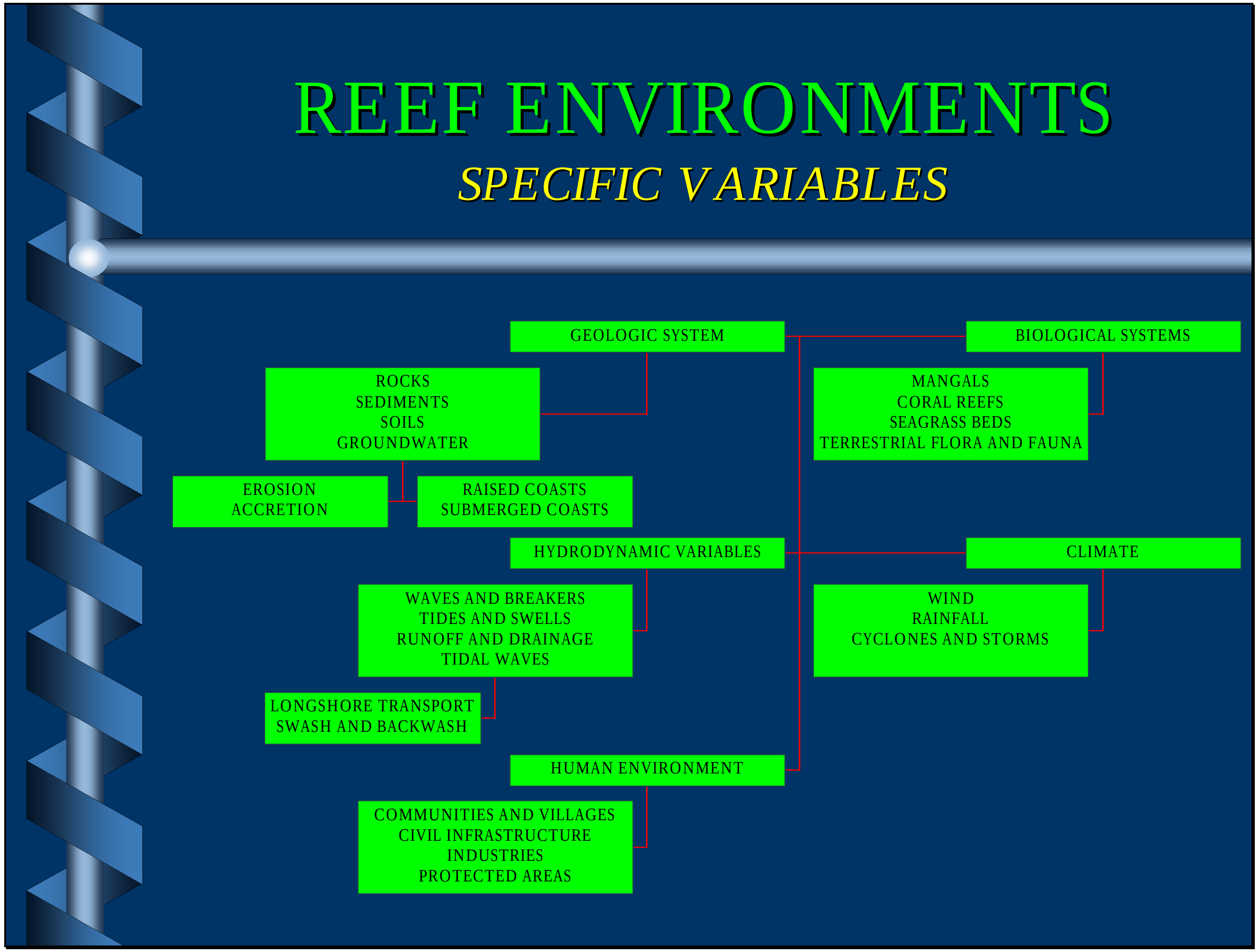

EROSION ASSESSMENT - XVI
Longshore Current
Longshore sediment transport takes place in the breaker zone (between the point where the first waves break and the water line).
Longshore current is caused by the obliquely breaking waves (wave induced current).
In fact in sediment transport, one may distinguish two steps:
– the sand grains have to be brought into suspension
– the suspended grains are transported by the current.

Slide 78


THE APPROACH
UNDERSTANDING REEFS & BEACHES
What are the parameters to monitor?
What variables should be considered?
How should these be characterized?
What are their inter-relationships?
Relative importance to coastal stability?
Relevance to beach dynamics?

Slide 79

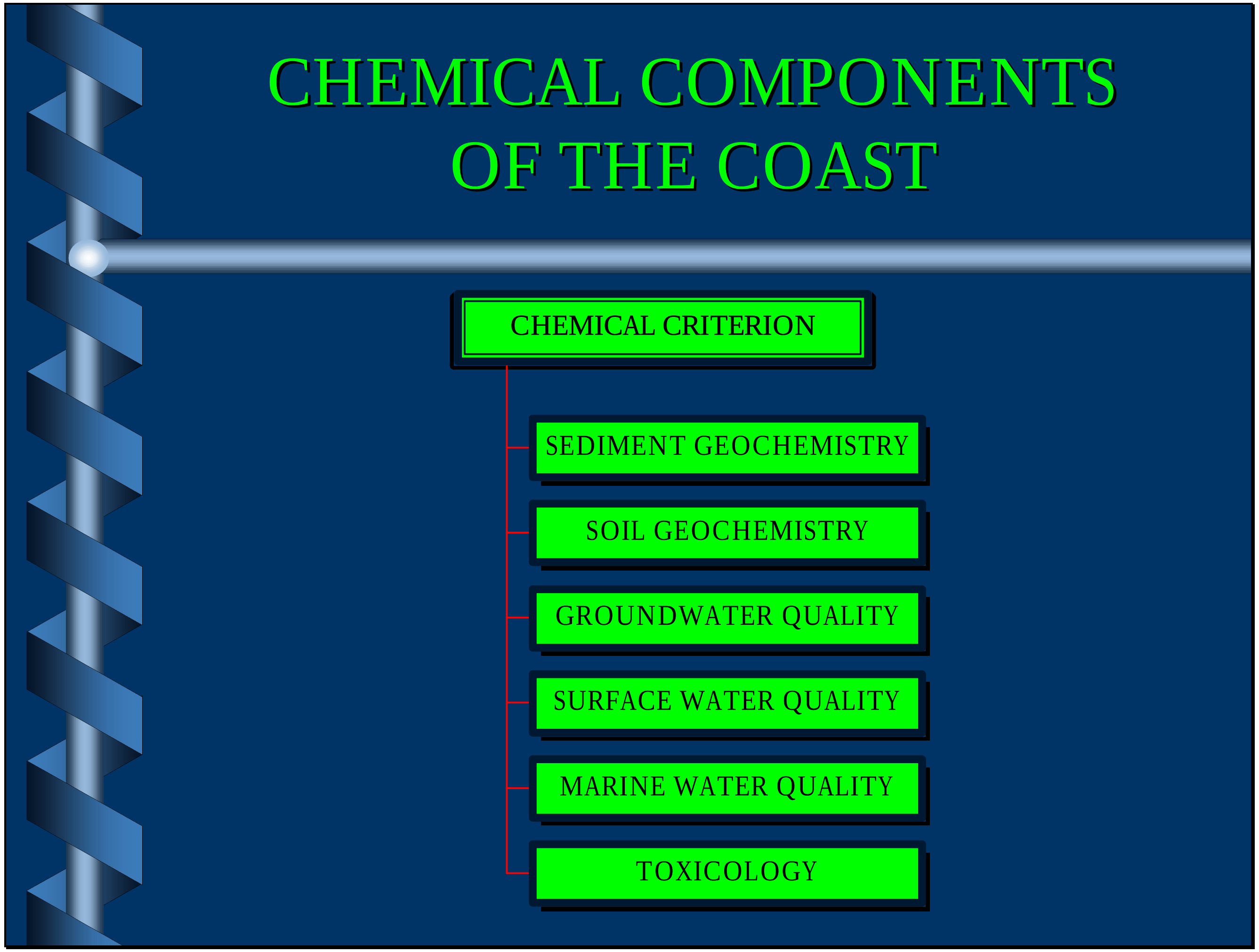
Slide 80


REEF ENVIRONMENTS
SPECIFIC VARIABLES
GEOLOGIC SYSTEM
ROCKS
SEDIMENTS
SOILS
GROUNDWATER
EROSION
ACCRETION
RAISED COASTS
SUBMERGED COASTS
BIOLOGICAL SYSTEMS
MANGALS
CORAL REEFS
SEAGRASS BEDS
TERRESTRIAL FLORA AND FAUNA
HYDRODYNAMIC VARIABLES
WAVES AND BREAKERS
TIDES AND SWELLS
RUNOFF AND DRAINAGE
TIDAL WAVES
LONGSHORE TRANSPORT
SWASH AND BACKWASH
CLIMATE
WIND
RAINFALL
CYCLONES AND STORMS
HUMAN ENVIRONMENT
COMMUNITIES AND VILLAGES
CIVIL INFRASTRUCTURE
INDUSTRIES
PROTECTED AREAS

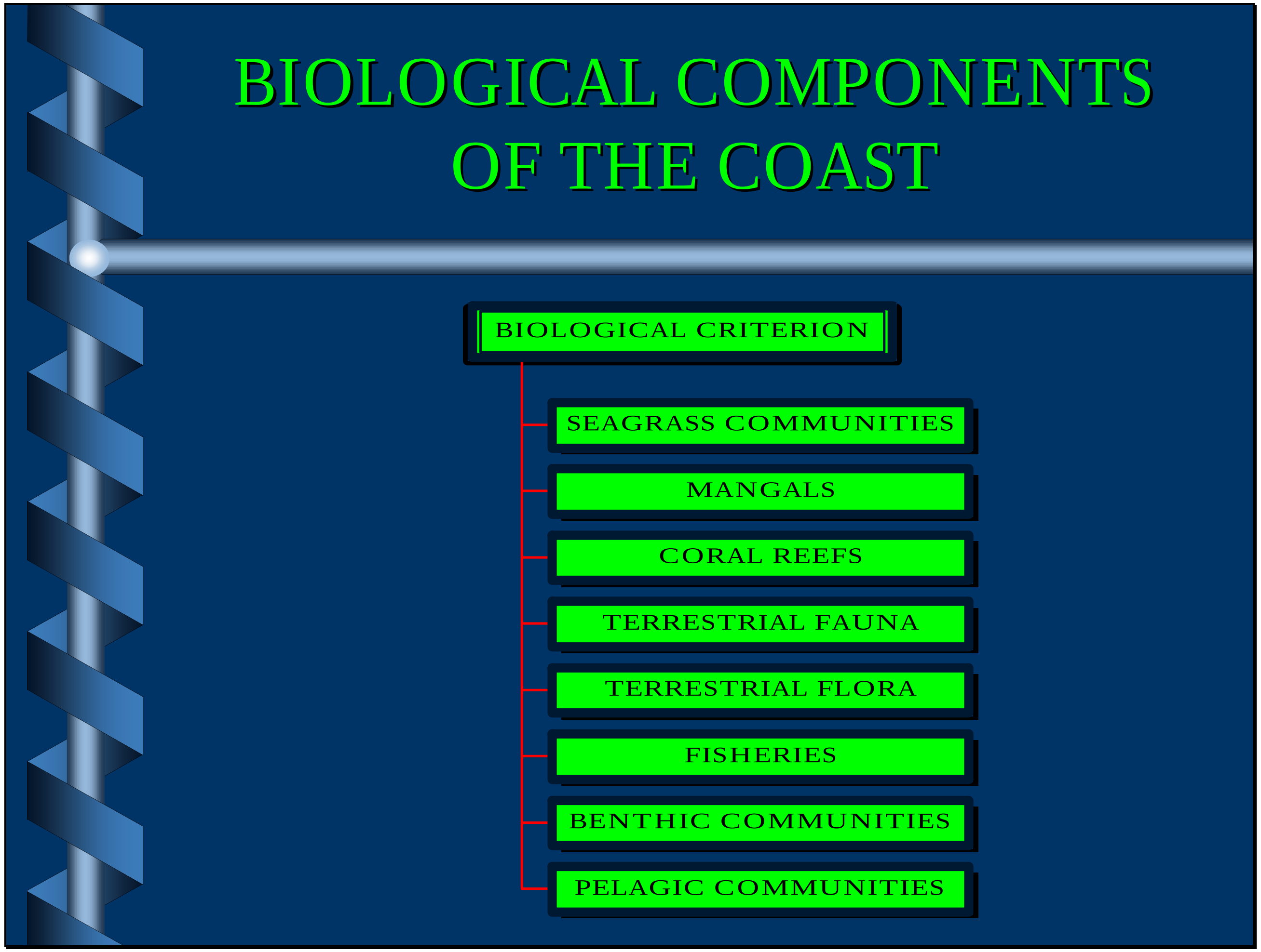
Slide 81


PHYSICAL COMPONENTS OF THE COAST
PHYSICAL CRITERION
GEOLOGY
GEOMORPHOLOGY
HYDRODYNAMIC
CLIMATOLOGY
WEATHER
SOILS AND SEDIMENTS
HYDROGRAPHY
HYDROGEOLOGY
HYDROLOGY

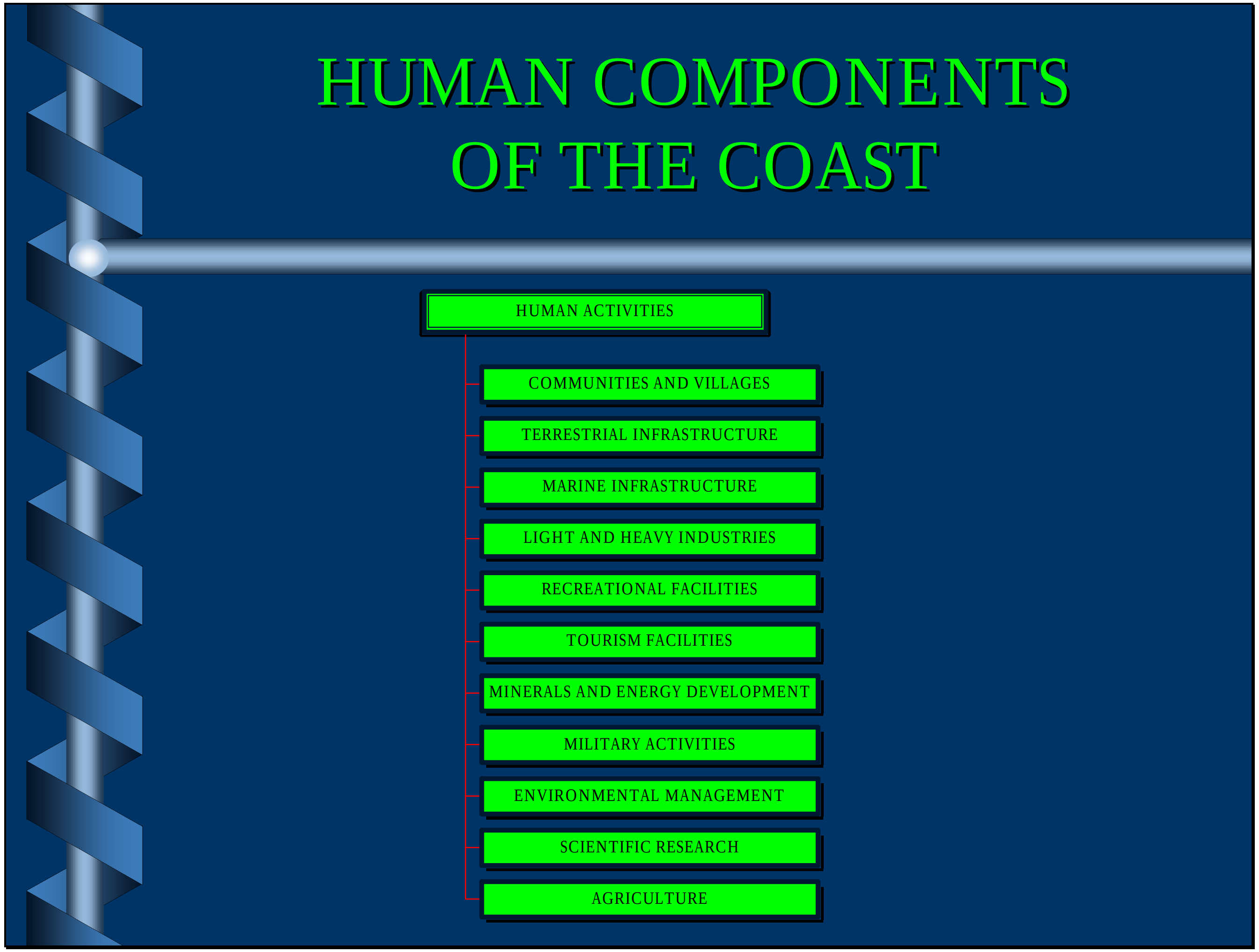
Slide 82


CHEMICAL COMPONENTS
OF THE COAST
CHEMICAL CRITERION
SEDIMENT GEOCHEMISTRY
SOIL GEOCHEMISTRY
GROUNDWATER QUALITY
SURFACE WATER QUALITY
MARINE WATER QUALITY
TOXICOLOGY

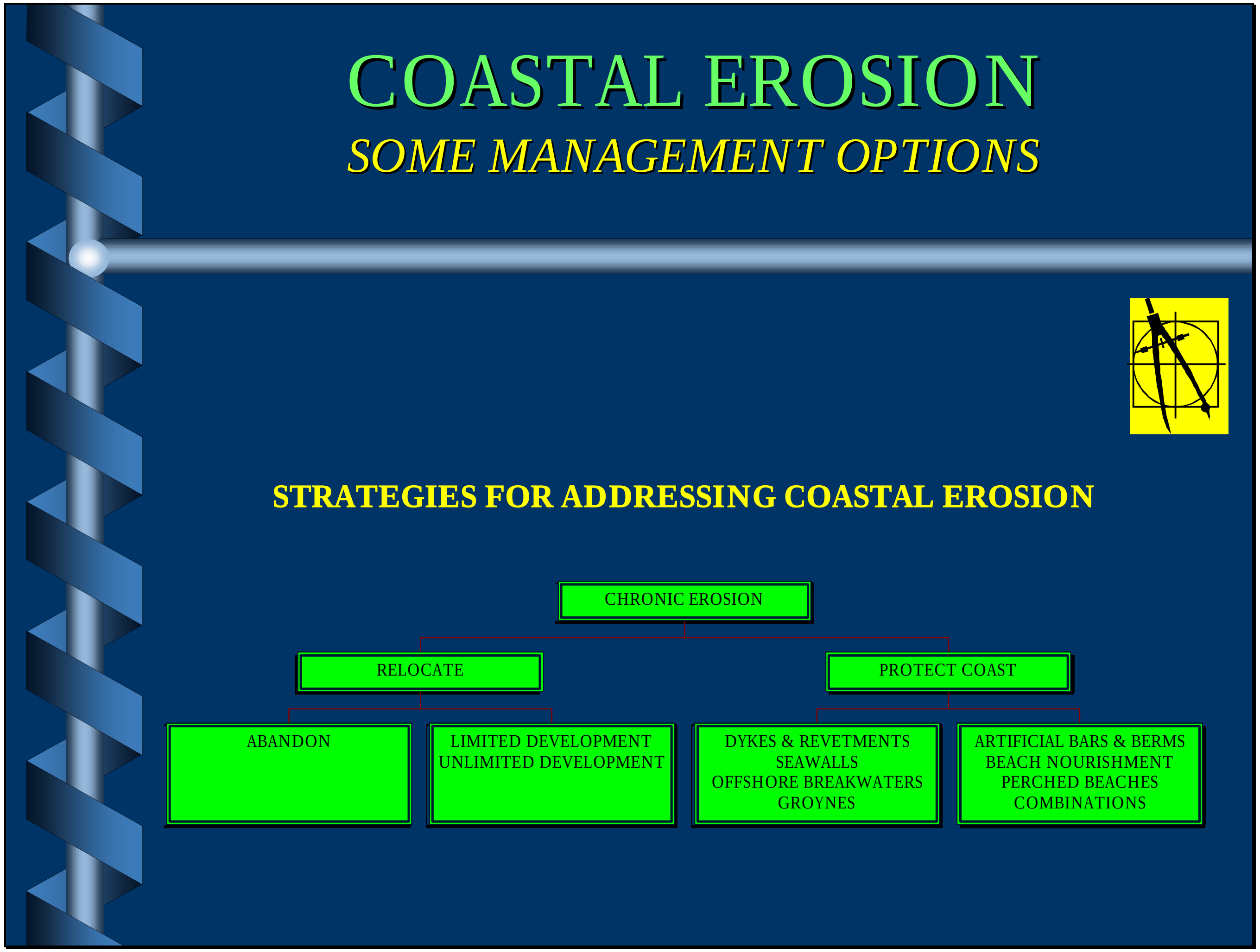
Slide 83


BIOLOGICAL COMPONENTS OF THE COAST
BIOLOGICAL CRITERION
SEAGRASS COMMUNITIES
MANGALS
CORAL REEFS
TERRESTRIAL FAUNA
TERRESTRIAL FLORA
FISHERIES
BENTHIC COMMUNITIES
PELAGIC COMMUNITIES

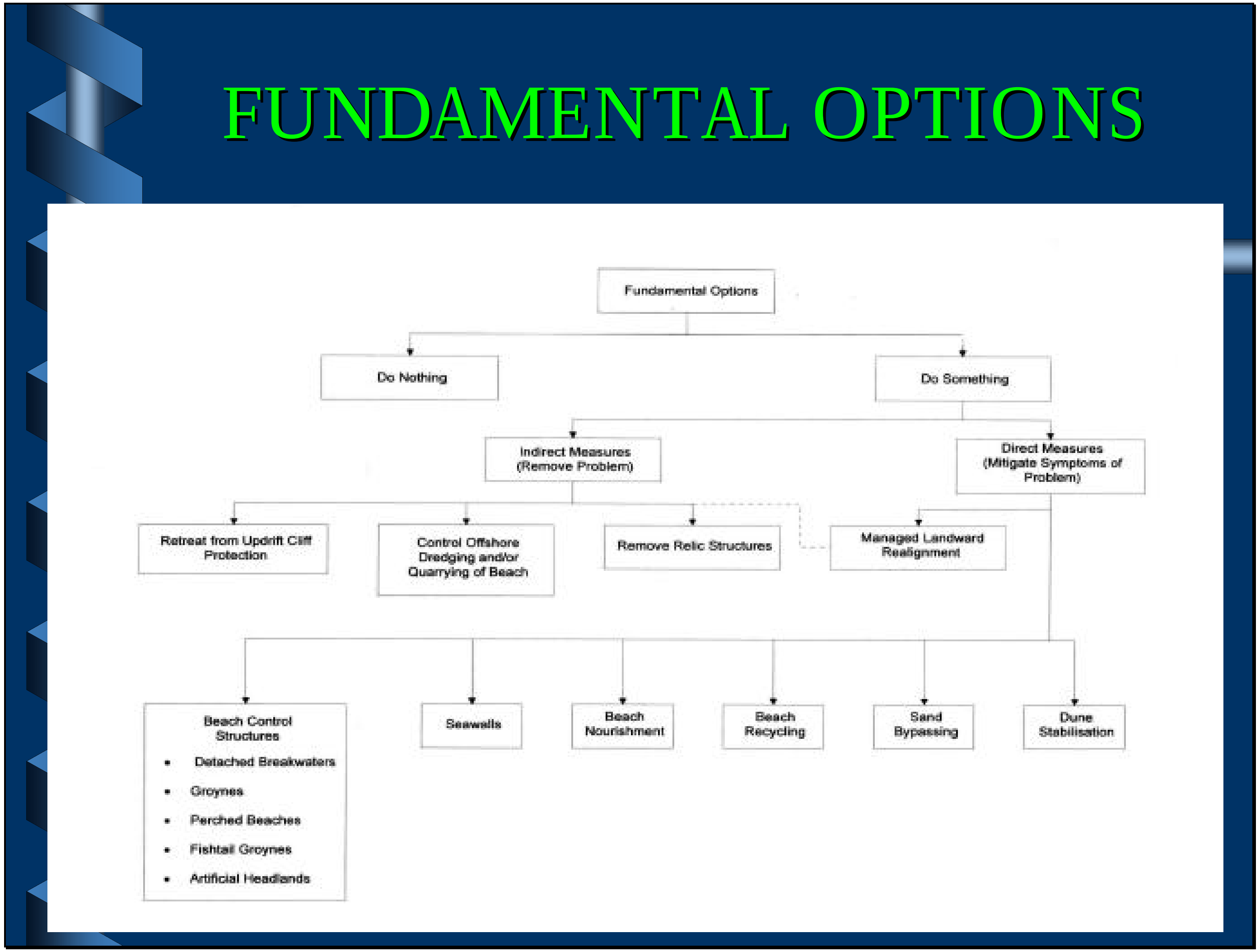
Slide 84


HUMAN COMPONENTS
OF THE COAST
HUMAN ACTIVITIES
COMMUNITIES AND VILLAGES
TERRESTRIAL INFRASTRUCTURE
MARINE INFRASTRUCTURE
LIGHT AND HEAVY INDUSTRIES
RECREATIONAL FACILITIES
TOURISM FACILITIES
MINERALS AND ENERGY DEVELOPMENT
MILITARY ACTIVITIES
ENVIRONMENTAL MANAGEMENT
SCIENTIFIC RESEARCH
AGRICULTURE

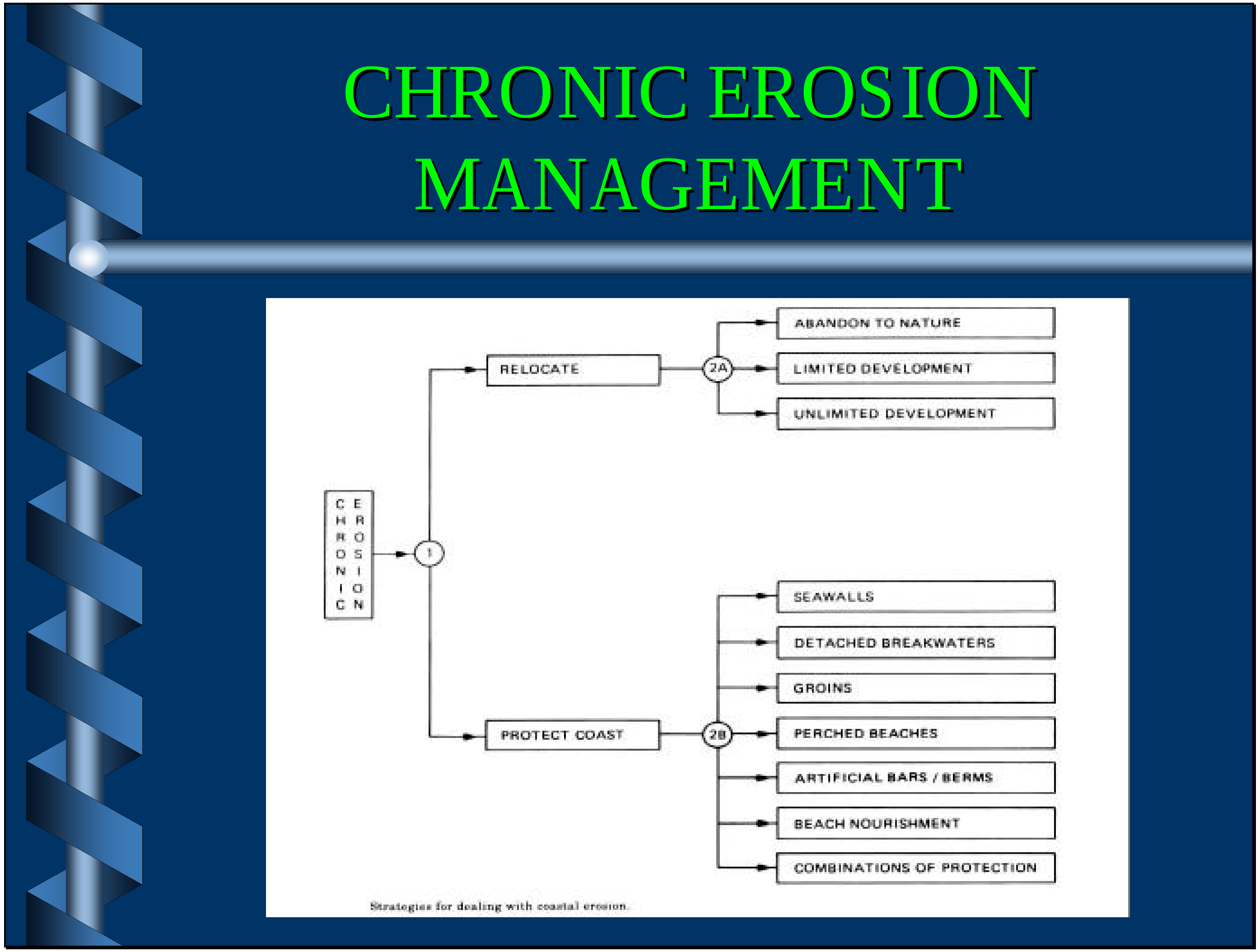
Slide 85


COASTAL EROSION
SOME MANAGEMENT OPTIONS
STRATEGIES FOR ADDRESSING COASTAL EROSION
CHRONIC EROSION
RELOCATE
PROTECT COAST
ABANDON
LIMITED DEVELOPMENT
UNLIMITED DEVELOPMENT
DYKES & REVETMENTS
SEAWALLS
OFFSHORE BREAKWATERS
GROYNES
ARTIFICIAL BARS & BERMS
BEACH NOURISHMENT
PERCHED BEACHES
COMBINATIONS

Slide 86


FUNDAMENTAL OPTIONS
Fundamental Options
Do Nothing
Do Something
Indirect Measures (Remove Problem)
Direct Measures (Mitigate Symptoms of Problem)
Retreat from Updrift Cliff Protection
Control Offshore Dredging and/or Quarrying of Beach
Remove Relic Structures
Managed Landward Realignment
Beach Control Structures
• Detached Breakwaters
• Groynes
• Perched Beaches
• Fishtail Groynes
• Artificial Headlands
Seawalls
Beach Nourishment
Beach Recycling
Sand Bypassing
Dune Stabilisation

Slide 87


CHRONIC EROSION MANAGEMENT
CHRONIC EROSION
RELOCATE
PROTECT COAST
ABANDON TO NATURE
LIMITED DEVELOPMENT
UNLIMITED DEVELOPMENT
SEAWALLS
DETACHED BREAKWATERS
GROINS
PERCHED BEACHES
ARTIFICIAL BARS / BERMS
BEACH NOURISHMENT
COMBINATIONS OF PROTECTION
Strategies for dealing with coastal erosion.

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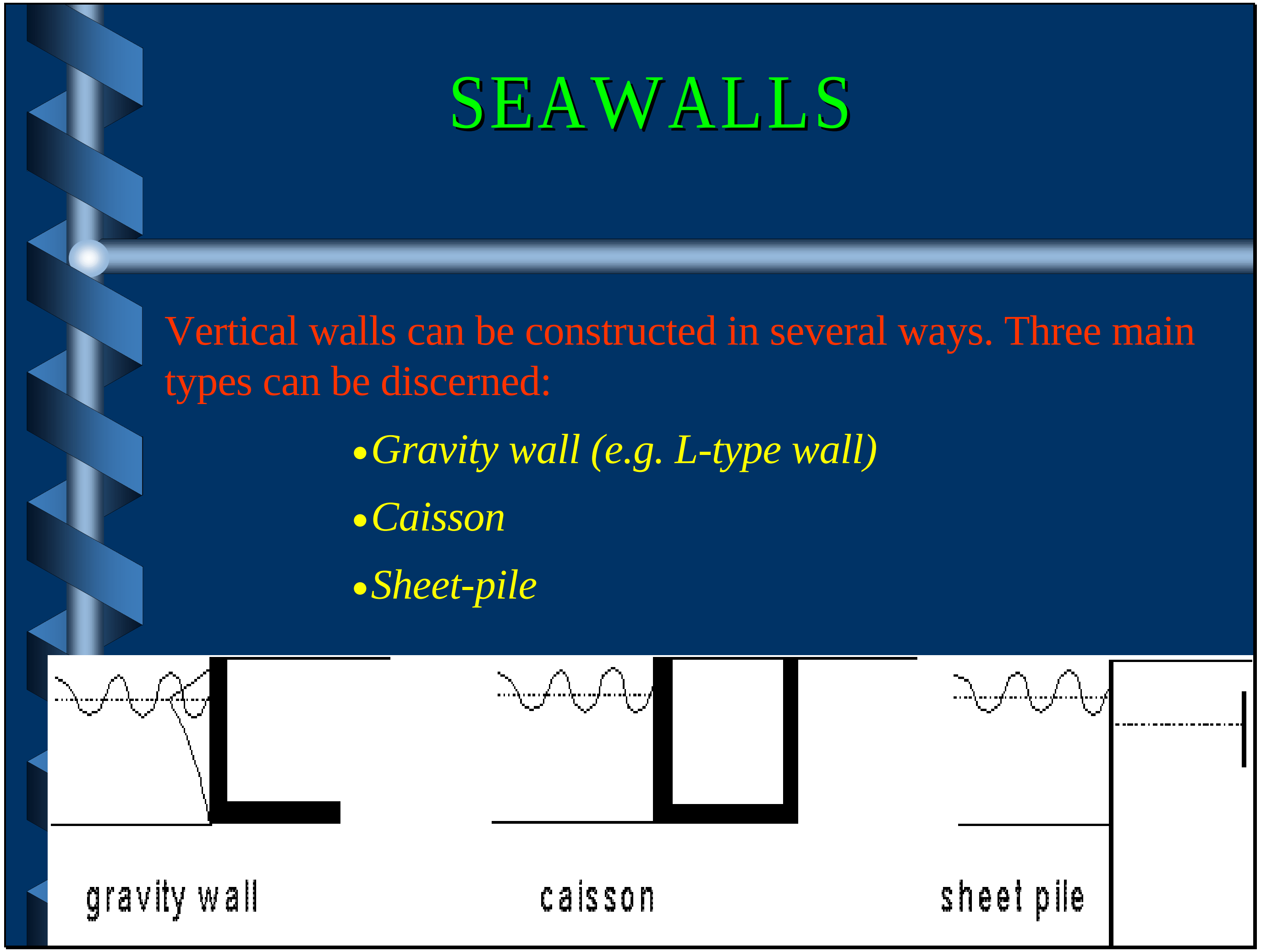
SEAWALLS
Vertical walls can be constructed in several ways. Three main types can be discerned:
•Gravity wall (e.g. L-type wall)
•Caisson
•Sheet-pile
gravity wall
caisson
sheet pile

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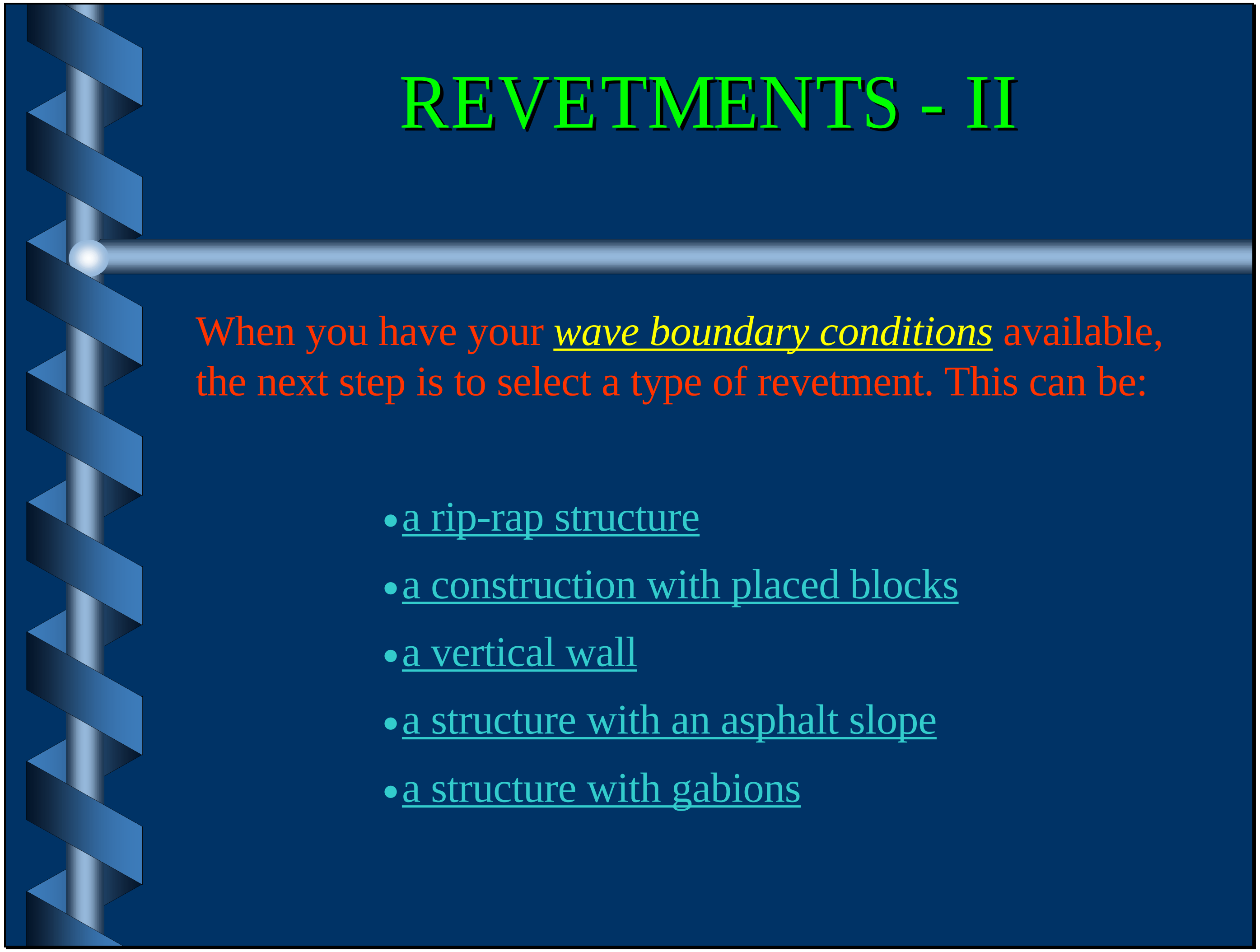
REVETMENTS - I

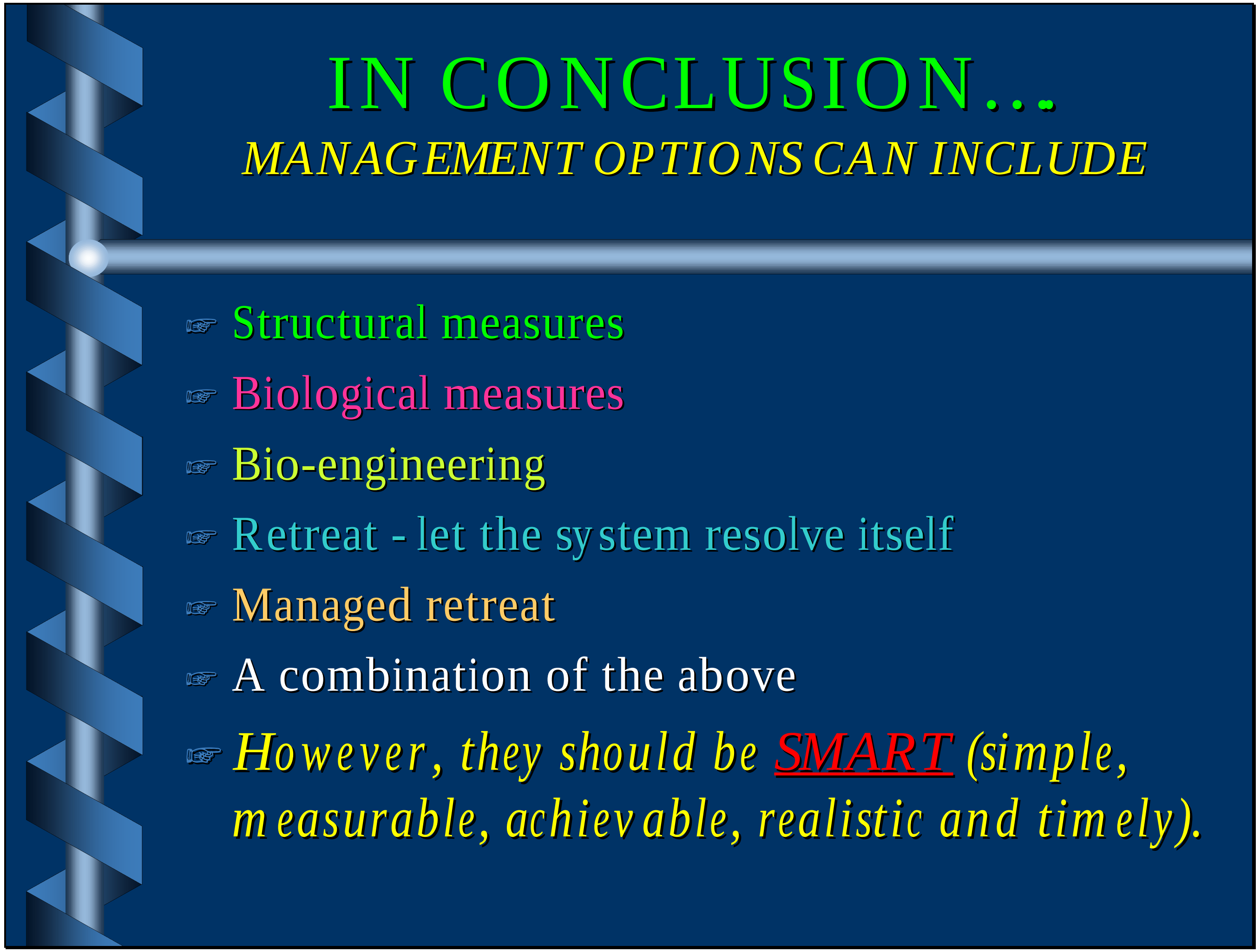
Revetments for protection against wave action:

- There are many types of revetment-structures for the protection against waves.
- For all types of protection, one has to determine the boundary conditions. Basically this is the design wave condition.
- For most revetment-structures you need to know the significant design wave height (Hs) and the accompanying wave period.

Slide 90


REVETMENTS - II
When you have your wave boundary conditions available, the next step is to select a type of revetment. This can be:
• a rip-rap structure
• a construction with placed blocks
• a vertical wall
• a structure with an asphalt slope
• a structure with gabions

Slide 91


IN CONCLUSION...
MANAGEMENT OPTIONS CAN INCLUDE
Structural measures
Biological measures
Bio-engineering
Retreat - let the system resolve itself
Managed retreat
A combination of the above
However, they should be SMART (simple, measurable, achievable, realistic and timely).

Slide 92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☞Clark, J. 1995. Coastal Zone Management Handbook. CRC Press, USA.
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☞Science, Vol. 239, 1986, 280-285.
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☞ T M Willimas Int. J. Proj. Mangt., Vol, 14, 1996, 129-130 & 185-186.
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☞ Simon et al, 1997. Project risk analysis and management (PRAM) guide. APM, High. Wycombe.
THE COMMONWEALTH FUND FOR TECHNICAL CO-OPERATION
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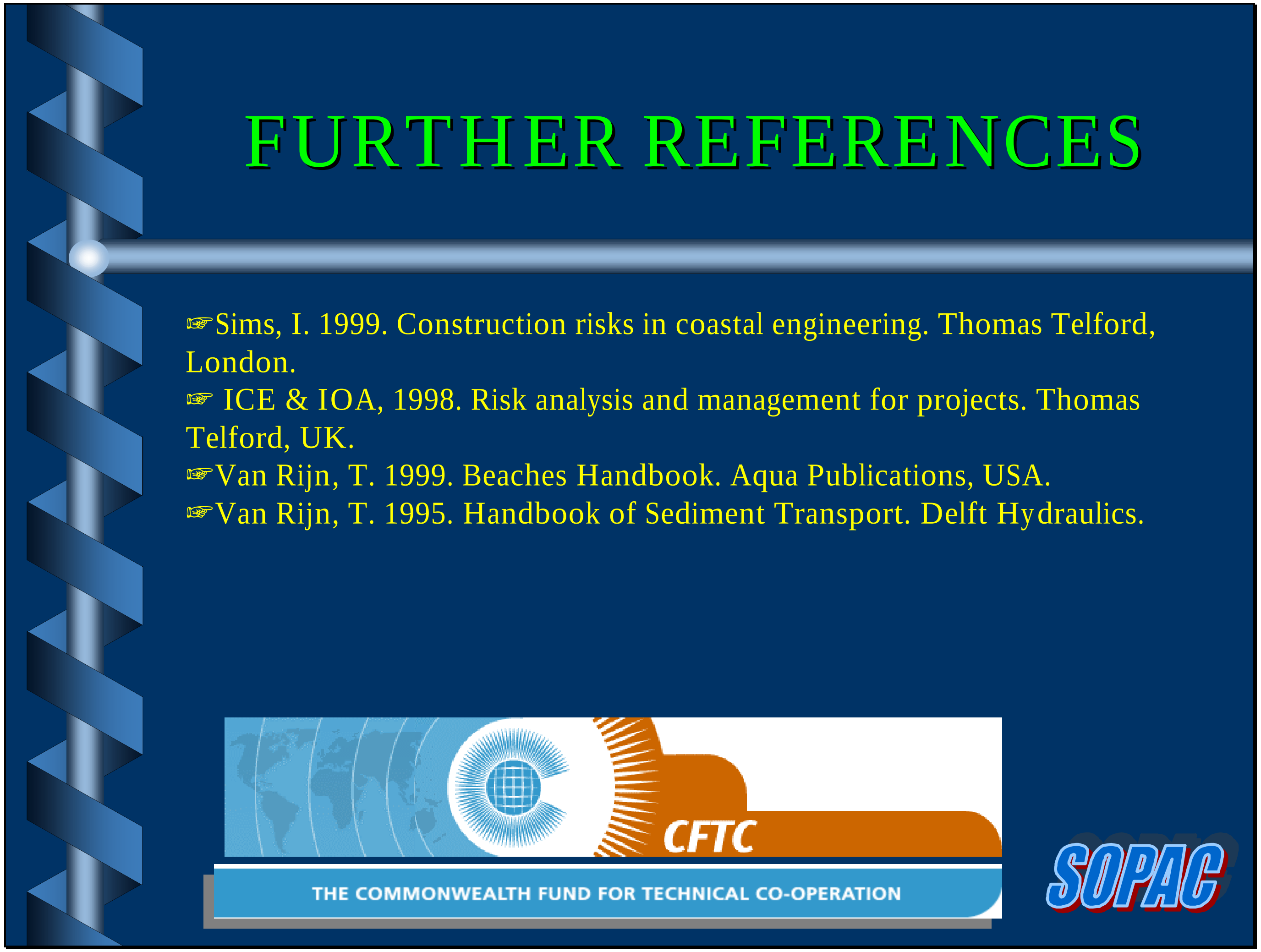
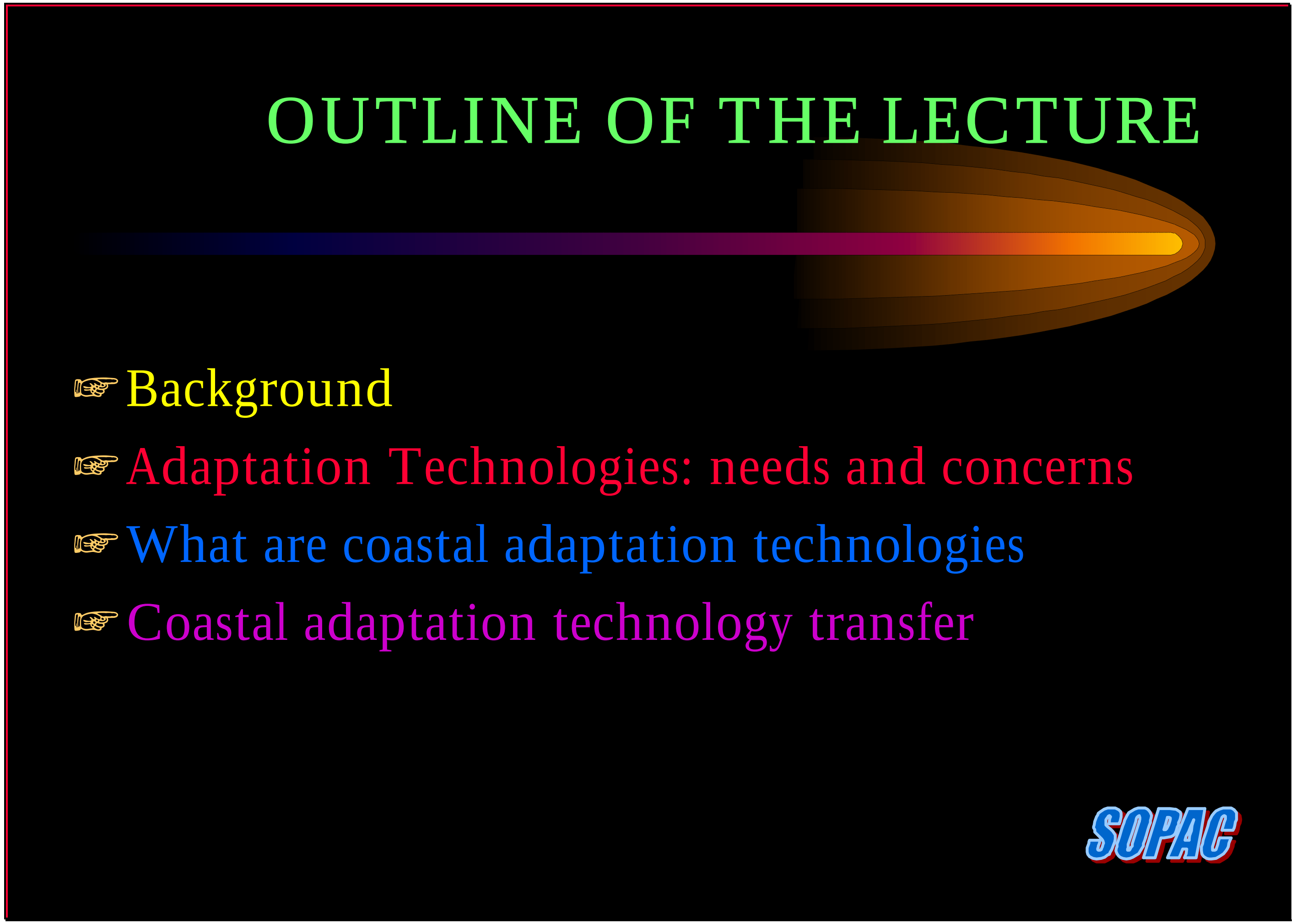
Slide 93



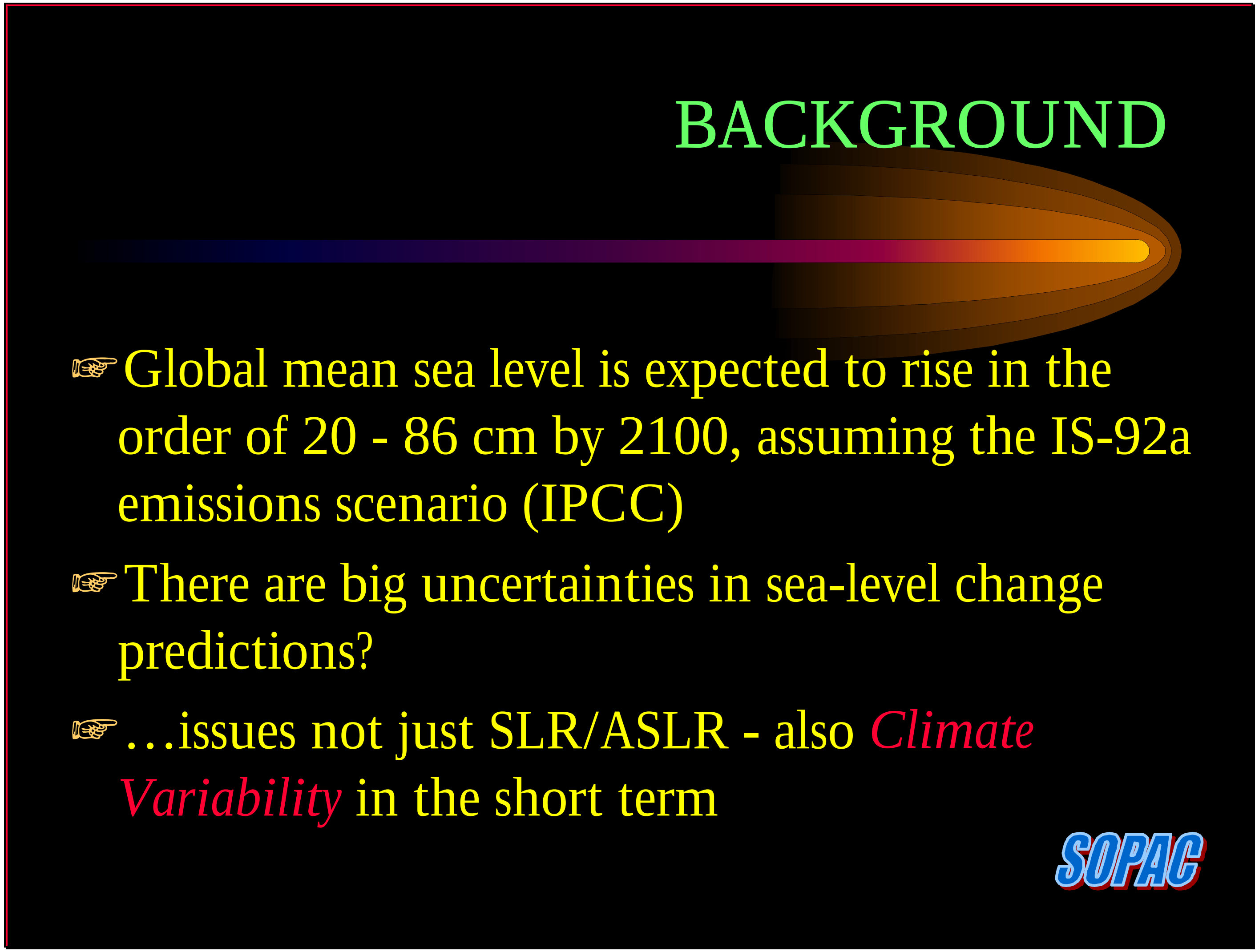
15.2Coastal Adaptation Technologies: Response to Sea-Level Changes

Slide 1

Slide 2


OUTLINE OF THE LECTURE
Background
Adaptation Technologies: needs and concerns
What are coastal adaptation technologies
Coastal adaptation technology transfer
SOPAC

Slide 3


BACKGROUND
☞Global mean sea level is expected to rise in the order of 20 - 86 cm by 2100, assuming the IS-92a emissions scenario (IPCC)
☞There are big uncertainties in sea-level change predictions?
☞…issues not just SLR/ASLR - also *Climate Variability* in the short term
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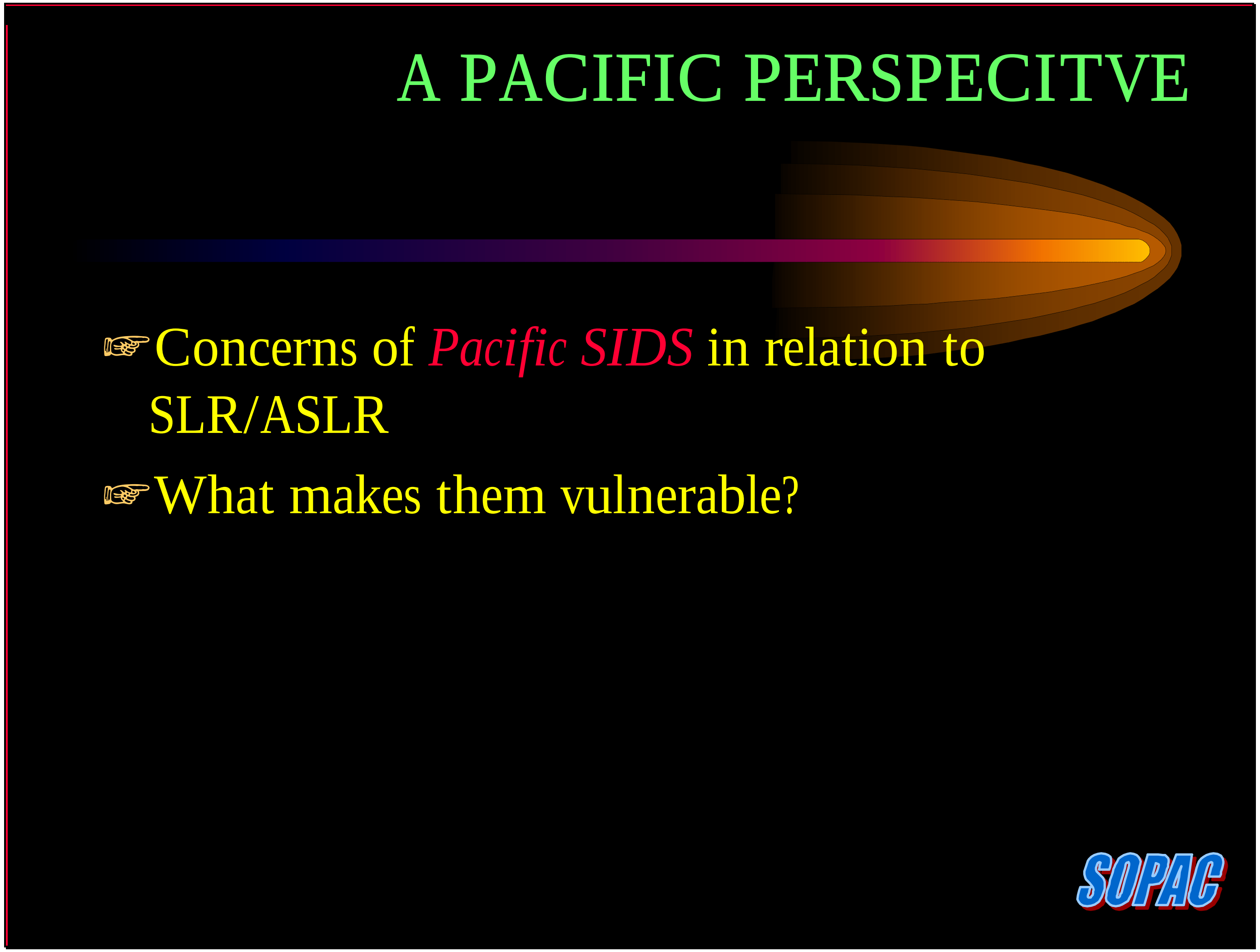
Slide 4


A PACIFIC PERSPECITVE
Concerns of Pacific SIDS in relation to SLR/ASLR
What makes them vulnerable?
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Slide 5

PACIFIC CONCERNS - PEOPLE & ENVIRONMENT

- ☞ Population/communities, industries and infrastructure located along the coastline and on small oceanic islands.
- ☞ Pacific SIDS are small, flat, low-lying, geologically young, affected by frequent natural hazards and face severe erosion problems: *Communities are vulnerable to sea-level changes*

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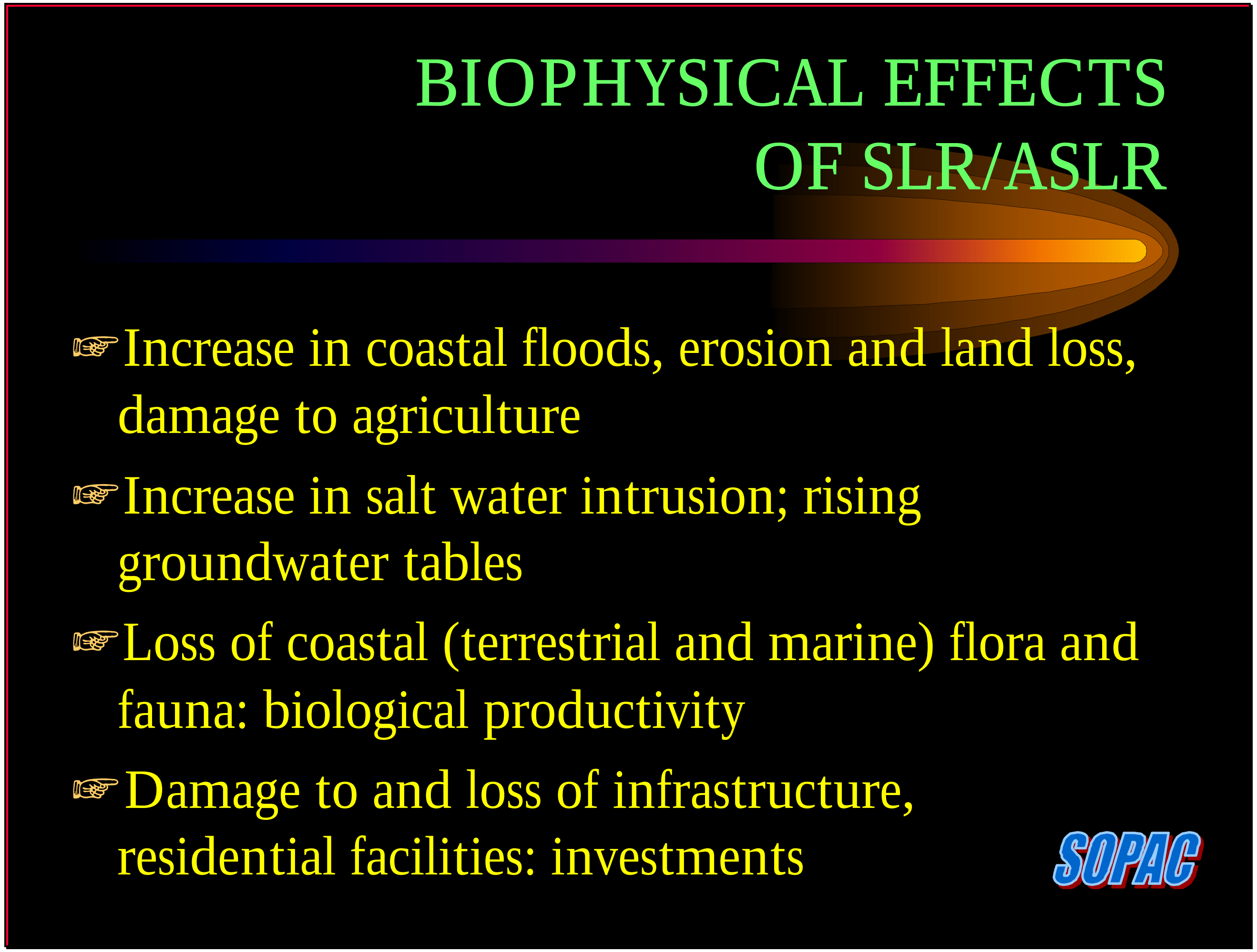
Slide 6


BIOPHYSICAL EFFECTS
OF SLR/ASLR
☞Increase in coastal floods, erosion and land loss, damage to agriculture
☞Increase in salt water intrusion; rising groundwater tables
☞Loss of coastal (terrestrial and marine) flora and fauna: biological productivity
☞Damage to and loss of infrastructure, residential facilities: investments
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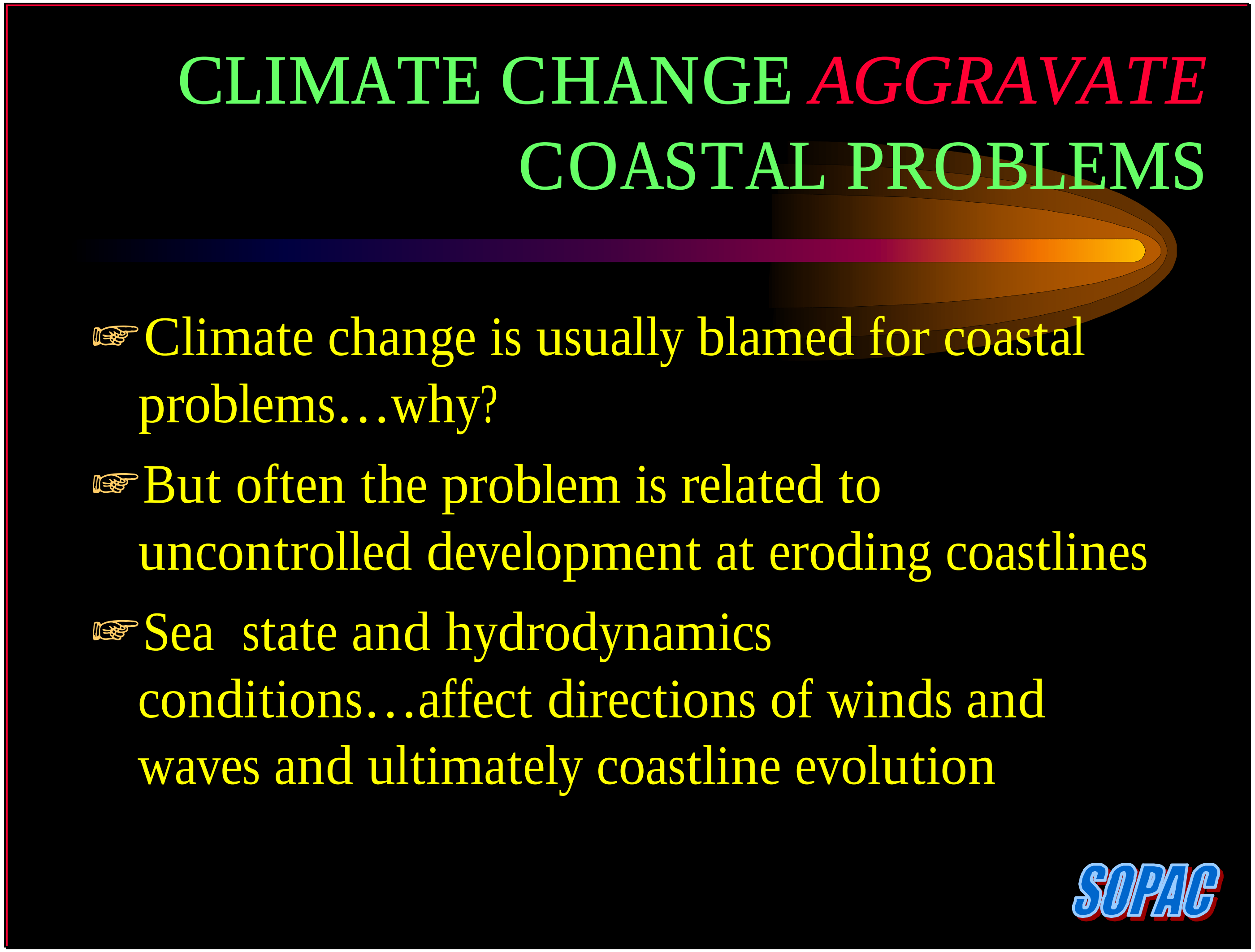
CLIMATE CHANGE *AGGRAVATE* COASTAL PROBLEMS
☞Climate change is usually blamed for coastal problems…why?
☞But often the problem is related to uncontrolled development at eroding coastlines
☞Sea state and hydrodynamics conditions…affect directions of winds and waves and ultimately coastline evolution
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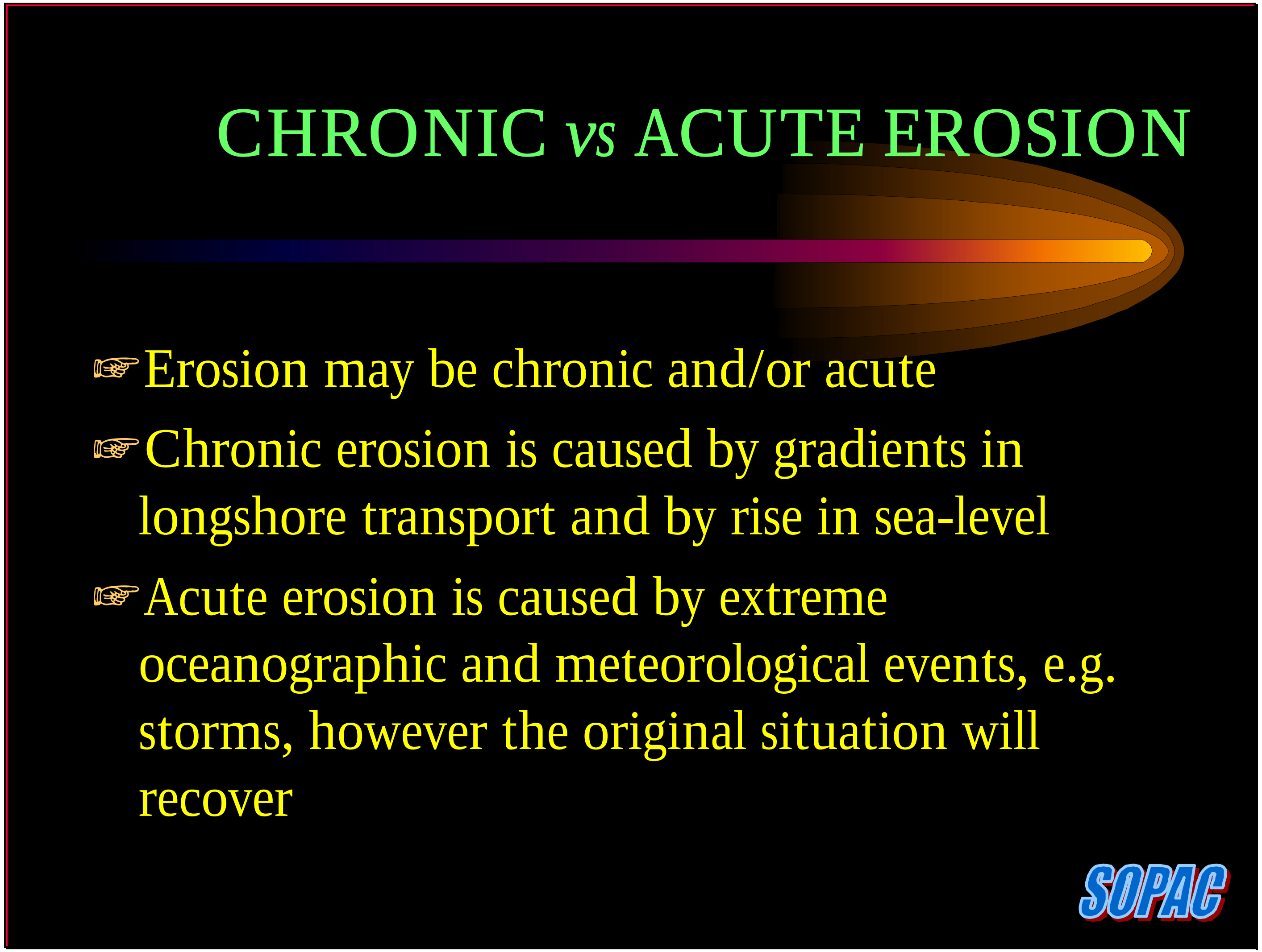
CHRONIC *vs* ACUTE EROSION
☞Erosion may be chronic and/or acute
☞Chronic erosion is caused by gradients in longshore transport and by rise in sea-level
☞Acute erosion is caused by extreme oceanographic and meteorological events, e.g. storms, however the original situation will recover
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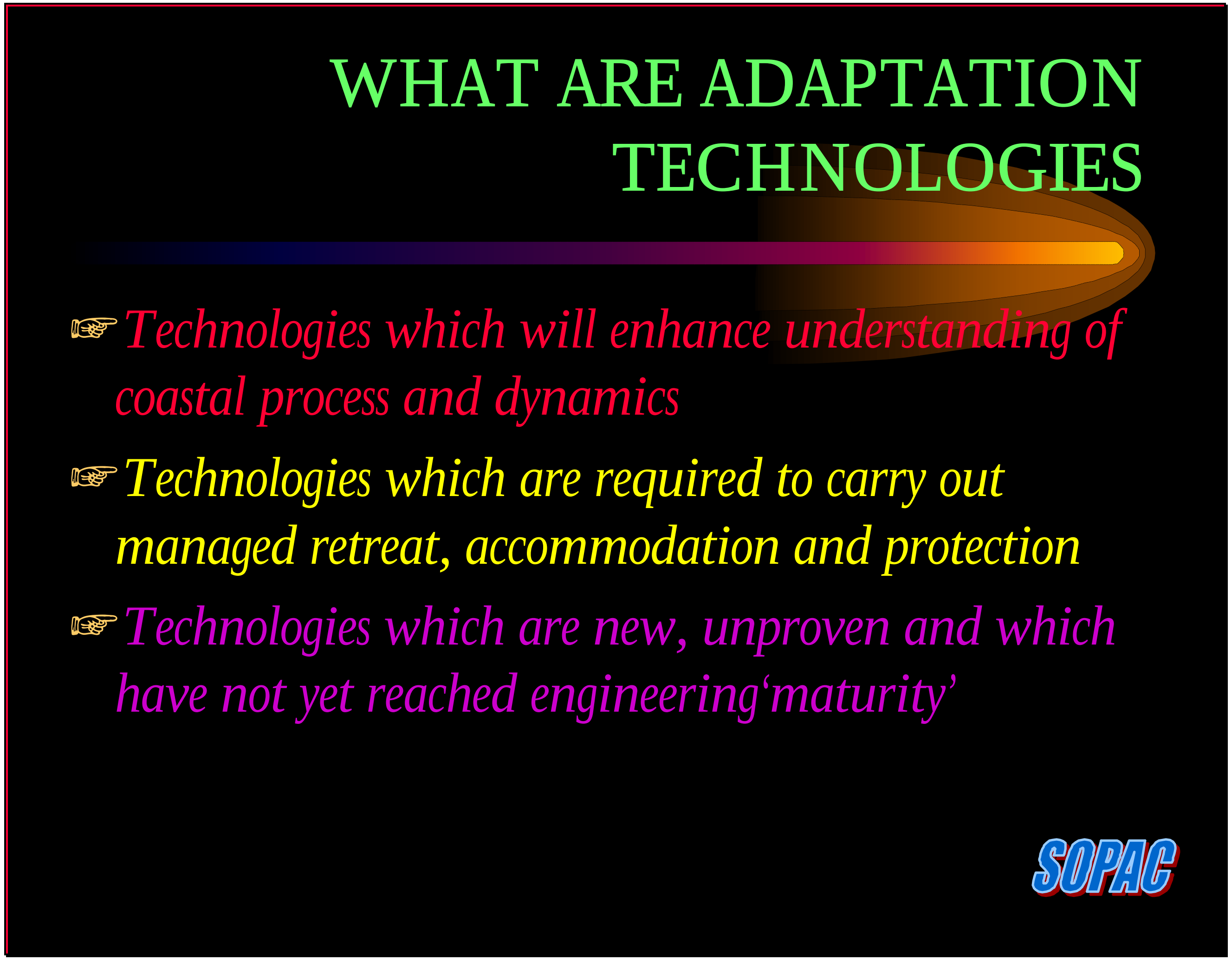
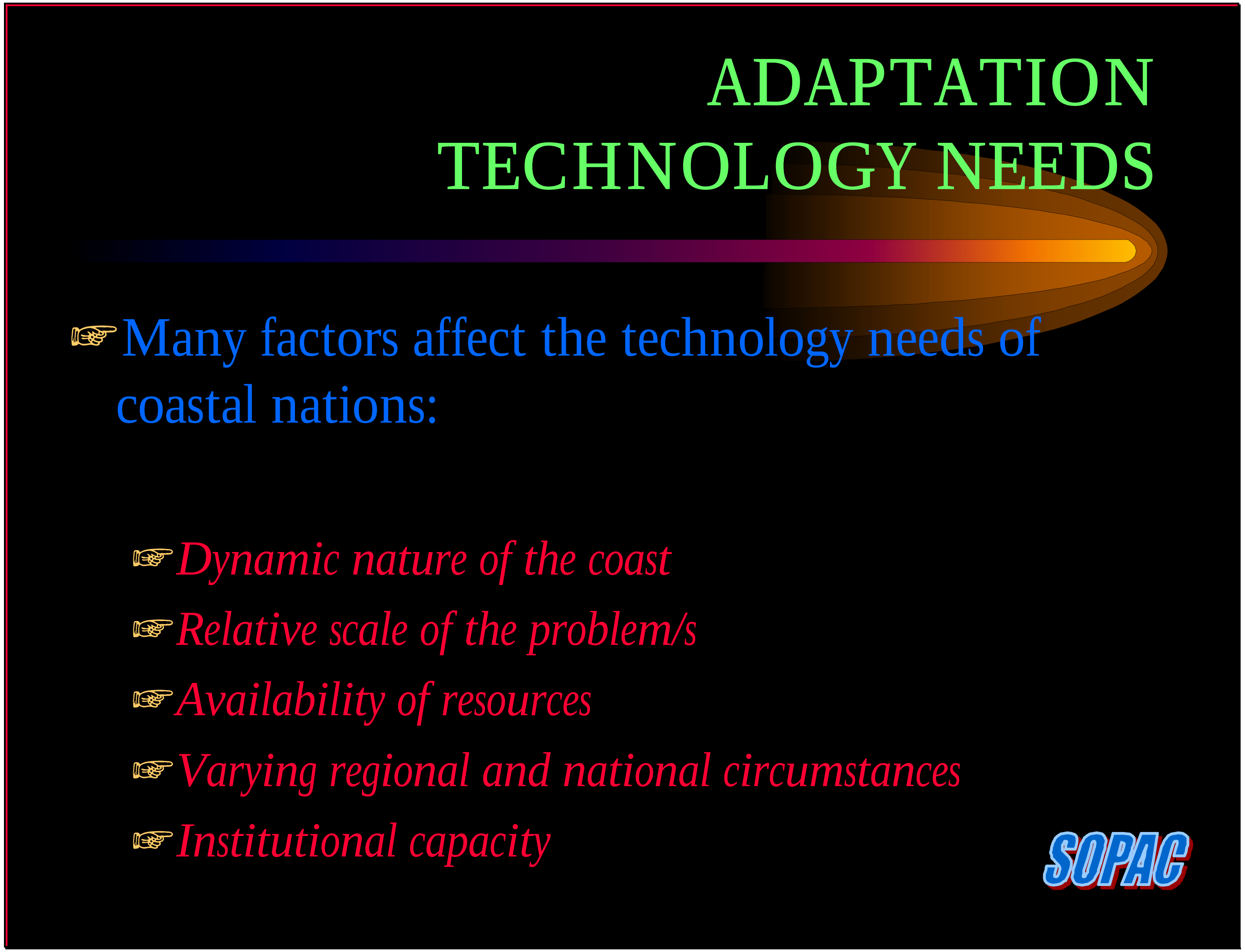
Slide 9


WHAT ARE ADAPTATION TECHNOLOGIES
Technologies which will enhance understanding of coastal process and dynamics
Technologies which are required to carry out managed retreat, accommodation and protection
Technologies which are new, unproven and which have not yet reached engineering'maturity'
SOPAC

Slide 10


ADAPTATION
TECHNOLOGY NEEDS
Many factors affect the technology needs of coastal nations:
Dynamic nature of the coast
Relative scale of the problem/s
Availability of resources
Varying regional and national circumstances
Institutional capacity
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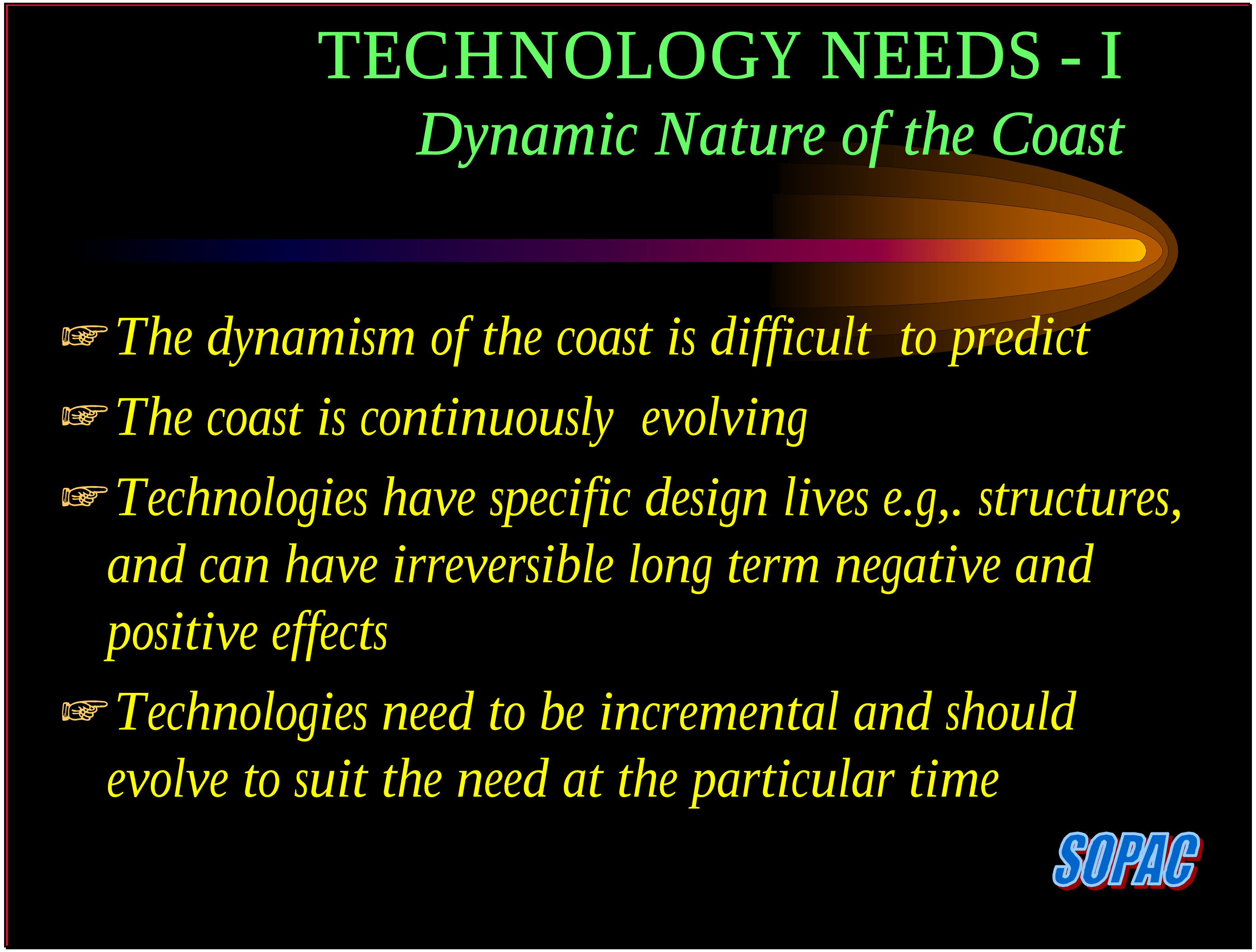
Slide 11


TECHNOLOGY NEEDS - I
Dynamic Nature of the Coast
The dynamism of the coast is difficult to predict
The coast is continuously evolving
Technologies have specific design lives e.g,. structures, and can have irreversible long term negative and positive effects
Technologies need to be incremental and should evolve to suit the need at the particular time
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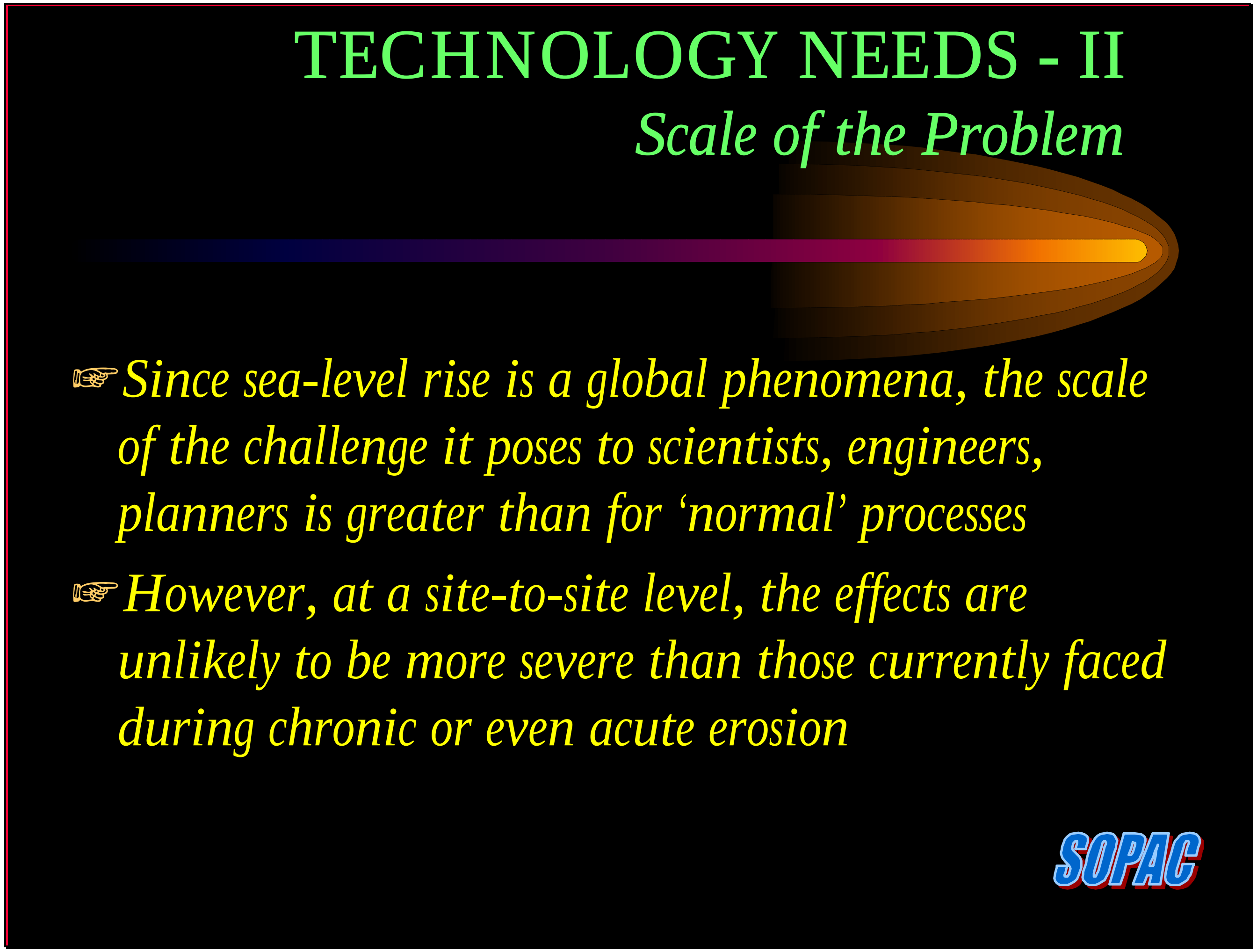
Slide 12


TECHNOLOGY NEEDS - II
Scale of the Problem
☞Since sea-level rise is a global phenomena, the scale of the challenge it poses to scientists, engineers, planners is greater than for 'normal' processes
☞However, at a site-to-site level, the effects are unlikely to be more severe than those currently faced during chronic or even acute erosion
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TECHNOLOGY NEEDS - III
Availability of Resources
When not constrained by funding, material availability and work force, construction of all conceivable protection can be done in short time frames
However, the prospects for significant changes in hard technologies used in coastal engineering are not great, largely because they are not scalable
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TECHNOLOGY NEEDS - IV
Varying Regional & National Circumstances
Needs vary from site to site, country to country and region to region
Regional problems may be common, but site-specific solutions are different
Solutions to local and regional problems cannot be found by searching the literature or reviewing state-of-practice in other parts of the world
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TECHNOLOGY NEEDS - IV
Varying Regional & National Circumstances
For SIDS, with sensitive ecosystems, small land areas and vulnerable coastal communities, adaptation technologies must be carefully selected to reflect actual site ecology, geomorphology, geology and hydrodynamic conditions.
They must also consider the human element
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TECHNOLOGY NEEDS - IV
Varying Regional & National Circumstances
☞In addition, managed retreat in response to SLR/ASLR is rarely an option for many SIDS, as are some types of shore protection structures: due to cost, ecological and environmental risks
☞Accommodation and protection may be viable, only for the short term
☞In other extreme cases, retreat may be the only viable option in the medium to long term
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TECHNOLOGY NEEDS - V
Institutional Capacity
The effective implementation of adaptation technologies requires local scientific and technical expertise, expert judgement and intitution
The lack of or availability of institutional capacity can dictate technologies for various countries and region
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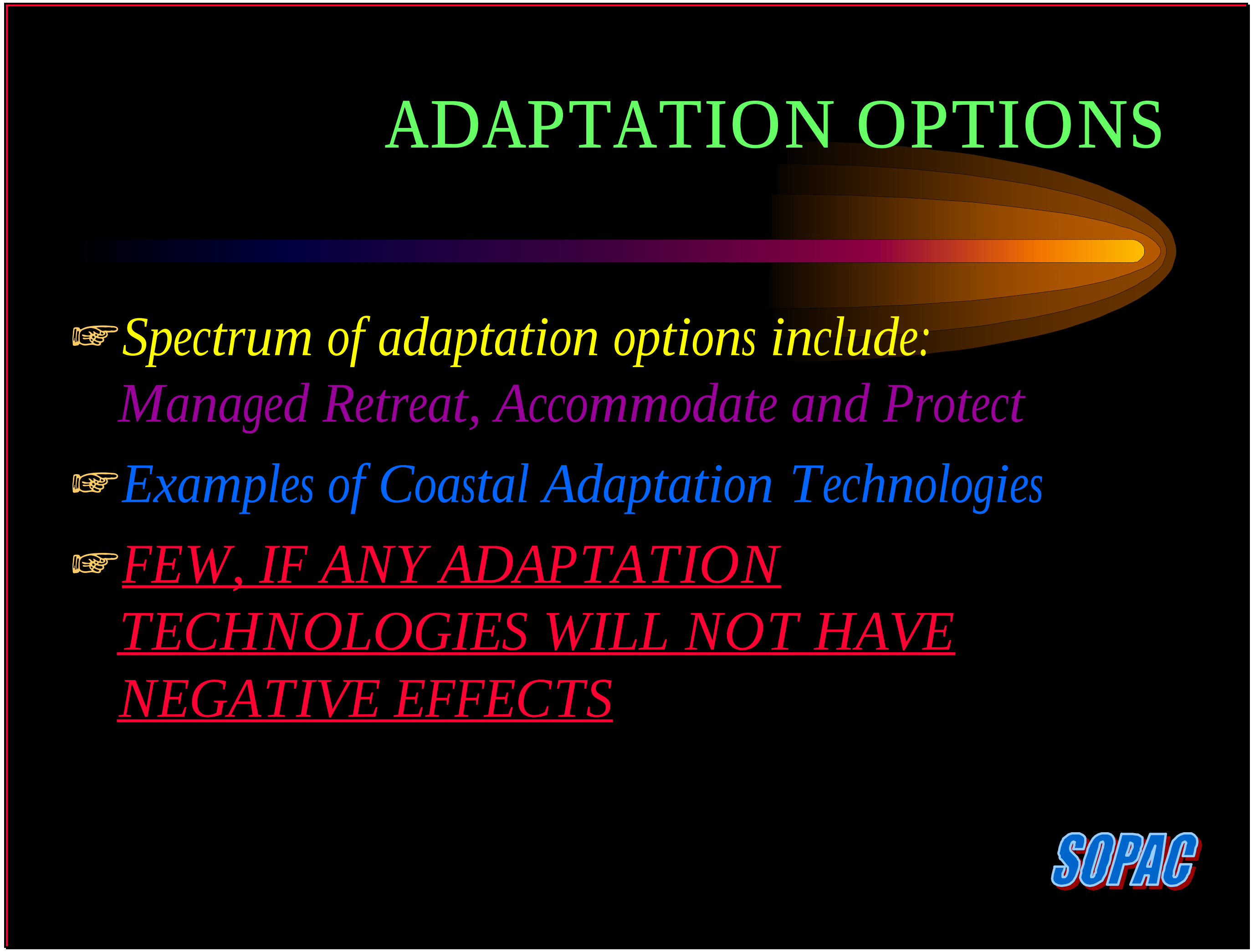
ADAPTATION OPTIONS
Spectrum of adaptation options include:
Managed Retreat, Accommodate and Protect
Examples of Coastal Adaptation Technologies
FEW, IF ANY ADAPTATION TECHNOLOGIES WILL NOT HAVE NEGATIVE EFFECTS
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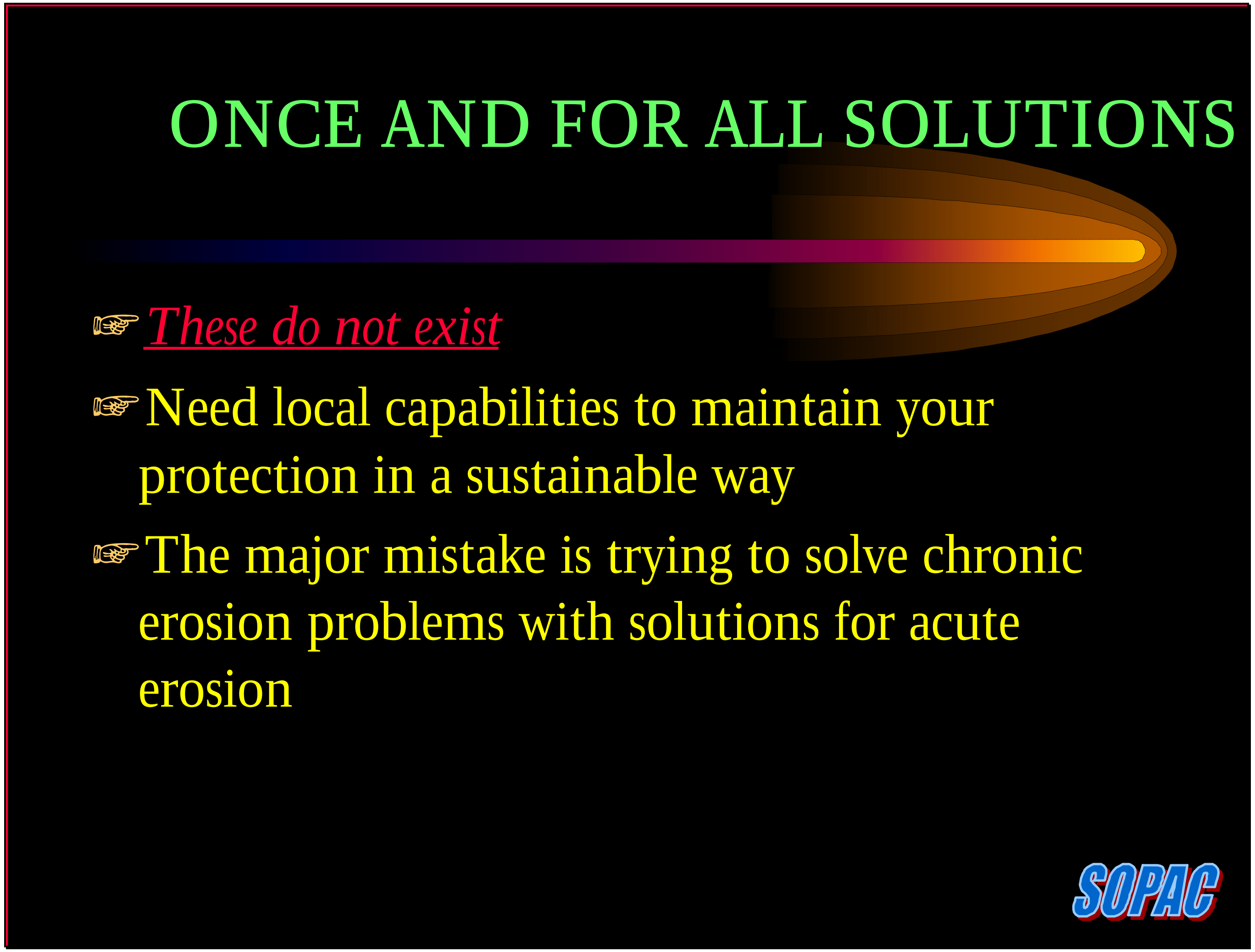
Slide 19


ONCE AND FOR ALL SOLUTIONS
These do not exist
Need local capabilities to maintain your protection in a sustainable way
The major mistake is trying to solve chronic erosion problems with solutions for acute erosion
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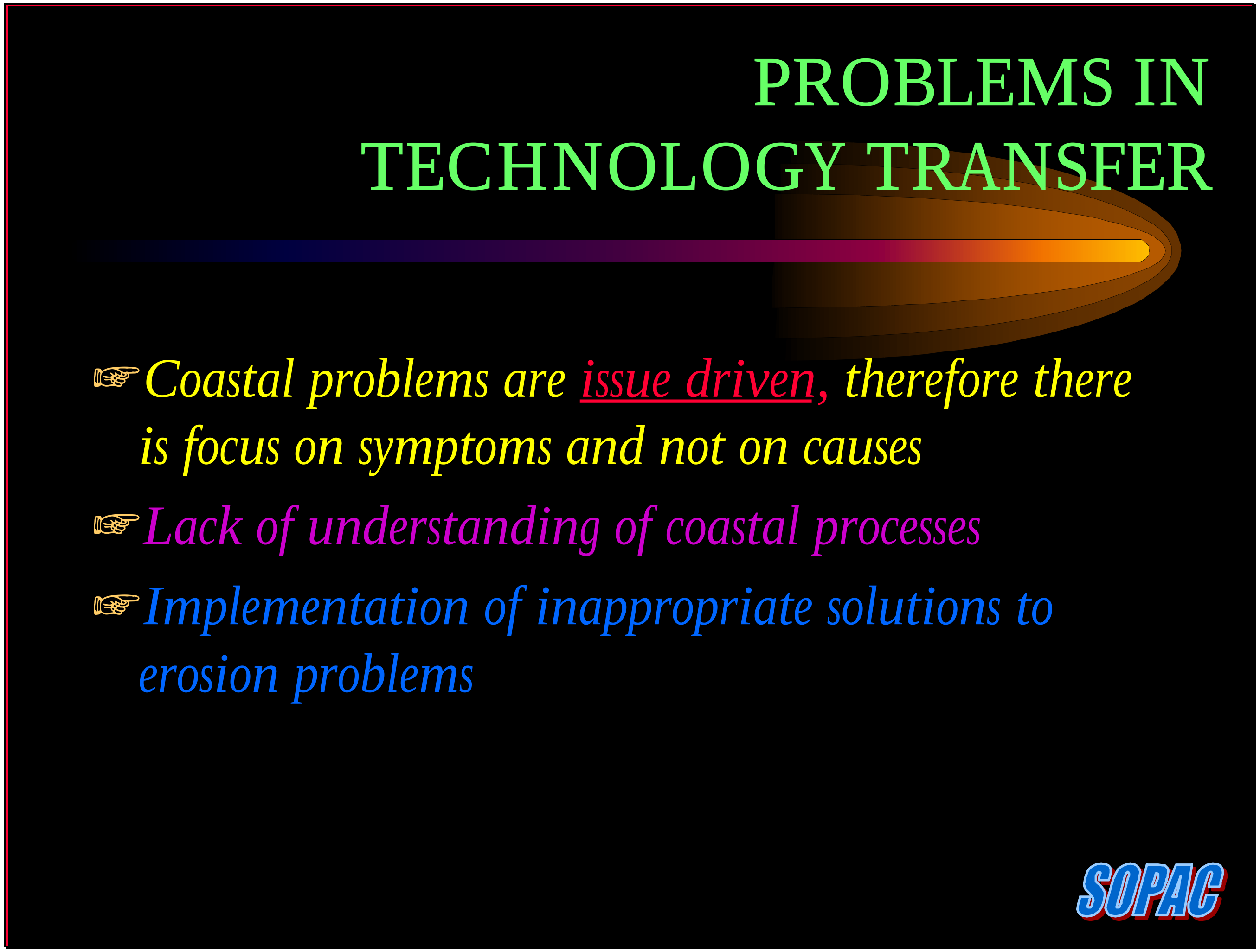
Slide 20


PROBLEMS IN
TECHNOLOGY TRANSFER
Coastal problems are issue driven, therefore there is focus on symptoms and not on causes
Lack of understanding of coastal processes
Implementation of inappropriate solutions to erosion problems
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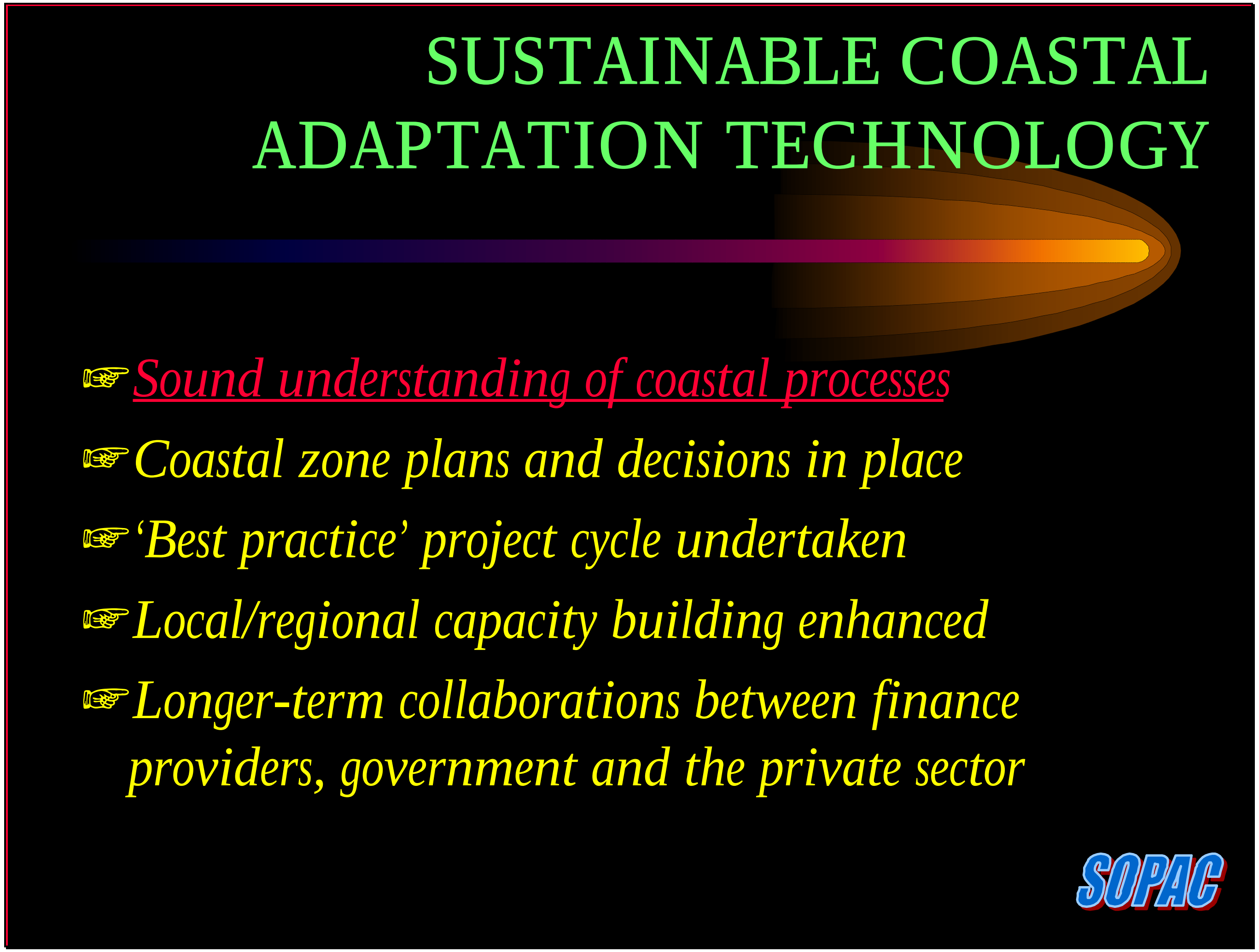
Slide 21


SUSTAINABLE COASTAL ADAPTATION TECHNOLOGY
☞Sound understanding of coastal processes
☞Coastal zone plans and decisions in place
☞'Best practice' project cycle undertaken
☞Local/regional capacity building enhanced
☞Longer-term collaborations between finance providers, government and the private sector
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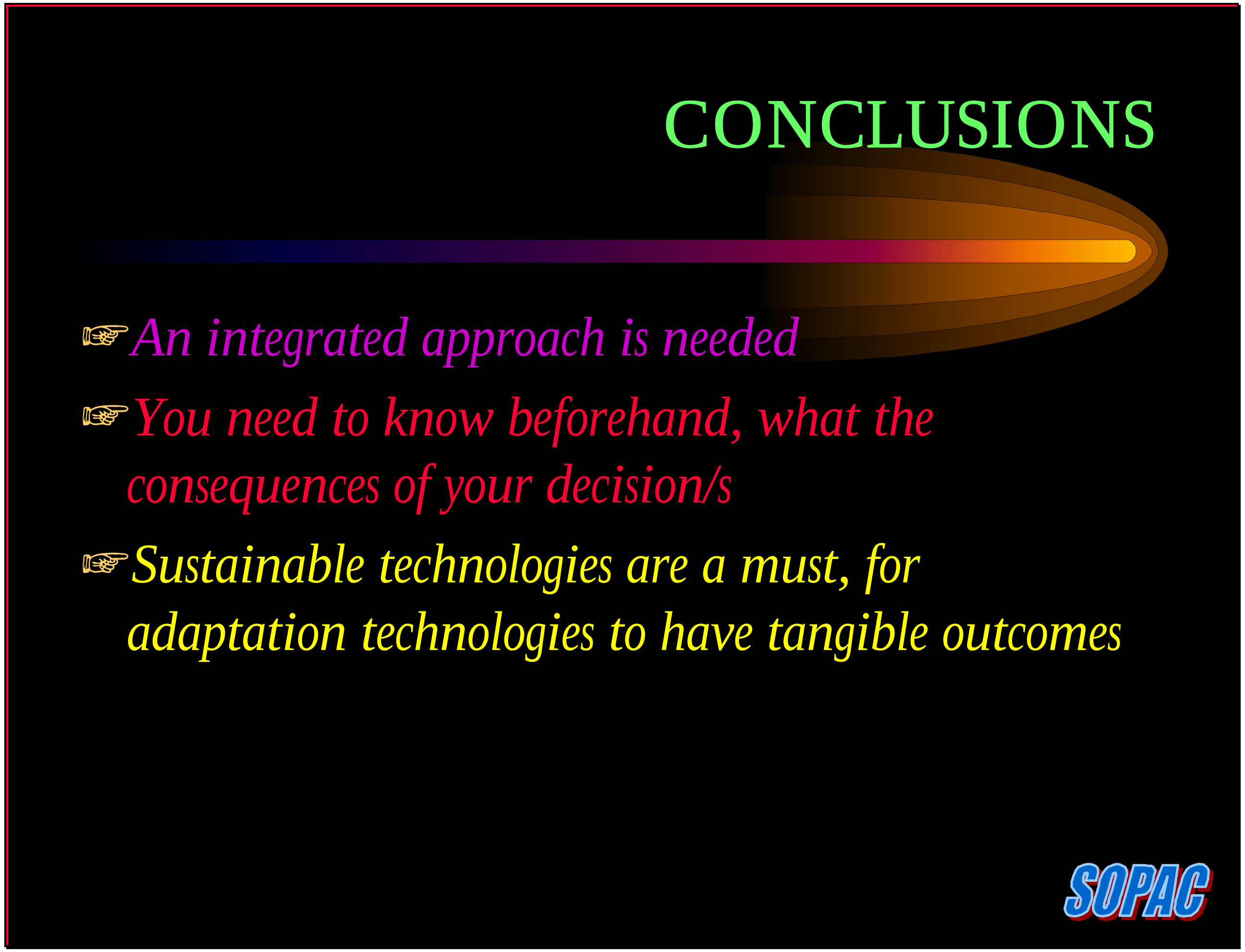
CONCLUSIONS
An integrated approach is needed
You need to know beforehand, what the consequences of your decision/s
Sustainable technologies are a must, for adaptation technologies to have tangible outcomes
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Coastal adaptation technologies include technologies to gather information about coastal characteristics and processes, (e.g. gauges, monitoring technologies), decision tools (models, software) and technologies included in the design, construction and maintenance of projects designed to retreat, accommodate or protect a particular part of the coastal strip.

The suitability of a particular adaptation technology is highly sensitive to local conditions, priorities and social choices, economy and finance (GDP/GNP). In turn, as this paper stresses, coastal zone planning and decision-making require adequate institutional and technical capacity. Nevertheless, the development and transfer of appropriate coastal adaptation technologies (appropriate technology) can potentially help to lower the cost and expand the scope of options available to adapt to possible sea-level rise and associated effects.

It was emphasised during the lecture that the technologies themselves are sub-components of the wider framework of coastal zone management (CZM/ICZM), rather than traditional coastal engineering. In addition, the following were highlighted:

- coastal adaptation technologies should be developed based on local expertise and knowledge;
- local data collection, instrumentation and monitoring are essential to project implementation;
- coastal projects pursued should be pursued from a more regional approach, inter-disciplinary and holistic;
- transfer of technology should be based on local and site-specific conditions;
- post project monitoring and evaluation is necessary, as well as failure analysis/forensic engineering of coastal development projects, which will facilitate optimum project appraisal and refine project execution in the future and
- training (institutional strengthening and capacity building) of technical people in practical aspects of CZM/ICZM and engineering needs to be pursued.

In addition, it was also emphasised that South Pacific SIDS need to consider the following for the successful implementation of adaptation technologies:

- Local and regional governments need to make firm commitments to retaining trained professionals in the profession,
- Local and regional governments should have specialised agencies or departments/units to address the various problems in the coastal zone,
- The cost of technologies should be based on local economy/finance and local GND/GDP,
- Funding agencies, in particular, bi-lateral and multi-lateral aid agencies should examine the possibilities of longer-term funding of coastal projects, as opposed to the shorter 2-3 or 3-5 year cycles,
- Longer-tern funding facilitates longer-term coastal monitoring, optimum data collection and more informed decision making (key to sustainable economic development),

Indeed most, if not all, technical responses to sea-level rise and associated effects have social, economic and/or environmental drawbacks. It was pointed out that applying technologies which are not properly understood or have been simply copied and applied to a new location without due attention usually results in an exaggeration of such drawbacks. In many cases, experience has demonstrated that taking action can be worse than doing nothing.

Nevertheless, in specific situations where coastal processes are understood and clear political decisions have been taken in the context of an integrated coastal plan, technologies are available to attenuate or avoid particular coastal impacts.

The coastal project cycle was presented as a practical framework within which to understand and describe the development and in particular the transfer, of coastal adaptation technologies

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APPENDIX 1
MONITORING AND EVALUATION IN SOPAC SIDS
ALL MEMBER COUNTRIES

Task: RT 99.040 *SOPAC Unit: Coastal* *Work Program:1999*

Proposed: 09-Jul-99	Started:	Cancelled:
Approved:	Deferred:	Completed:

Objectives:Prepare technical guidelines for the assessment of beach erosion and dynamics, to assist in the sustainable use and management of the coastal zone in SOPAC small island developing states (SIDS).

Proposed: SOPAC Technical Reports and in-country presentations detailing the achieved objectives.

Background:Coastal erosion and shoreline management continues to be a chronic problem for many SOPAC SIDS. While this silent natural hazard has plagued the region for years, technical information to evaluate various apsects of erosion and management of coastlines are unavailable at the local level. Where information is available, it issometimes too technical and complex or even over-simplified.

The objective of this task is to prepare technical guidelines which can be used for the evaluation of beach and shoreline change in these Pacific SIDS. The guidelines will discuss the various aspects of coastal erosion, how to identify and characterise erosion, what data should be collected, how to collect, process and manage data and how to utilise the data sets for coastal management.

In addition, practical aspects of erosion and beach monitoring will be presented, which are feasible for Pacific Island countries.

Equipment Needs: Desktop computing resources.

Work Plan:
1. Review coastal problems in SOPAC SIDS.
2. Review existing technical guidelines and manuals.
3. Prepare appropriate guidelines and draft report.
4. Publish report.
5. Present and distribute to member countries.

Information: N/A

Clients: All SOPAC SIDS

SOPAC: Russell J. Maharaj

Report: SOPAC Technical Reports.