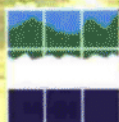




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*Conceptual Framework and
Planning Guidelines for*
**INTEGRATED COASTAL
AREA AND RIVER
BASIN MANAGEMENT**

Note:

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List of Acronyms

ICARM	Integrated Coastal Area and River Basin Management
GIS	Geographic Information Systems
DSS	Decision Support System
EIA	Environmental Impact Assessment
SEA	Strategic Environmental Assessment
CCA	Carrying Capacity Assessment
EEZ	Exclusive Economic Zone
UNEP	United Nations Environment Programme
ICZM	Integrated Coastal Zone Management
ICAM	Integrated Coastal Area Management
MAP	Mediterranean Action Plan
UNCLOS	United Nations Conference on the Law of the Sea
UNCED	United Nations Conference on Environment and Development
PAP	Priority Actions Programme
OECD	Organisation of Economic Co-operation and Development
NGO	Non Governmental Organisation
METAP	Mediterranean Environmental Technical Assistance Programme

Foreword

The world's coastlines are sagging under an onslaught of humanity. Already nearly two-thirds of the world's population – some 3.6 billion people – live along a coast-line. Within three decades, 75 per cent will reside in coastal areas. This is nearly a billion more people than the current global population.

These pressures have triggered widespread resource degradation. In much of Asia, Africa and parts of Latin America, coastal fisheries are chronically over-exploited. Critical coastal resources, such as mangroves and coral reefs – among the most productive and biologically diverse ecosystems on earth are being plundered in the name of development. Clear-cutting for timber, fuel wood and wood chips, conversion to fish and shellfish ponds, and expansion of urban areas and agricultural lands has claimed millions of hectares globally.

There is also a close connection between measures to control pollution in the marine environment and their effect on the environmental integrity of the freshwater drainage basins. It has been established that pollution from land-based activities affects the people living in fresh water drainage basins even more dramatically than they do the people living in coastal areas. This is because it is the rivers that carry much of the pollution from the land surface to the coastal waters. Thus any activity that exposes soil to erosion – logging, cutting roads into steep hillsides, construction or agriculture without proper terracing – increases runoff of sediments from the land into streams and rivers and then into the sea. Marine eco-systems are harmed by careless land practices hundreds or even thousands of kilometres upstream.

Modification of river drainage basins by human activity has led to dramatic changes in the flow of water and nutrients they bring to the sea. In the southern part of the former USSR, dam construction blocked between 30 and 97 per cent of the fresh water flow to the great estuaries and nursery grounds of the Azov, Black, Caspian and Aral Seas. In other areas depleted oxygen supplies in coastal areas have eliminated brackish water ecosystems.

In nations worldwide, the interests that determine the amount of fresh water flow into the sea are seldom the ones that deal with the health of the marine environment. Therefore, it is imperative that we develop effective mechanisms to coordinate institutions that deal with fresh waters and the marine environment if we are to maintain the vital ecological linkages between rivers and the sea.

Halting the destruction of the coastal areas is paramount if even a fraction of these genetically valuable resources are to be preserved. Nothing less than integrated coastal zone management strategies are needed – strategies that take account of population growth and distribution, urbanization trends, consumption patterns, generation of wastes and the use of available resources.

The Integrated Coastal Area Management (ICAM) is an appropriate tool for attaining this objective. Under the Integrated Coastal Area Management, coastal managers realize that freshwater input to the coastal areas has strong impacts on the coastal environment and welfare of the population living in those areas. The physical and socio-economic relationship between the river basins and their corresponding coastal areas is also the basis for such an integrated approach to sustainable development. This new approach is known as Integrated Coastal Area and River Basin Management (ICARM). The priority issues in this management approach are: capacity building, coastal land-use planning,

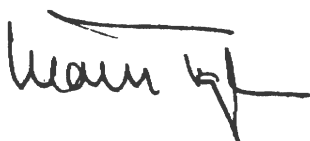
river basin development and resource management, legislation, enforcement, coastal and river banks protection and conservation.

The United Nations Environment Programme (UNEP) and the Priority Actions Programme Regional Activity Centre (PAP/RAC) of the Mediterranean Action Plan (MAP) have decided to further develop the ICARM concept and to demonstrate practically how the ICARM concept can be applied to specific management issues for river-coast systems. The first Expert Working Group Meeting on the Concept and Development of practical Guidelines for Integrated Coastal Area and River Basin Management was held in Nairobi in 1996. It decided that ICARM concept could be further developed as a tool for policy-makers and other stakeholders to achieve sustainable development of the river basins and coastal areas.

To this end, the first step was the preparation of guidelines which would serve as a concrete basis for further action. As a result of three additional meetings of the Expert Working Group, it has been possible to finalize the "Conceptual Framework and Planning Guidelines for Integrated Coastal Area and River Basin Management".

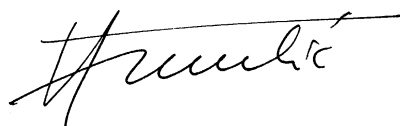
The first part of this document presents a conceptual framework for Integrated Coastal Area and River Basin Management based on the hydrological, geochemical, ecological and socio-economic linkages between the river basins and coastal areas. The second part of this document presents practical procedures for achieving the ICARM goals. These planning guidelines will serve as benchmarks for the decision makers and environment and resource planners, as well as other stakeholders involved in natural resource management.

We hope that this document will contribute to the achievement of the objectives and goals set at the Rio Summit. We also wish that the methodologies suggested in the document will be replicated not only in the Mediterranean, but also with appropriate modifications, in other regions of the world.



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Executive Summary

Links Between Coasts and River Basins

Coasts and river basins contain important natural environments but they are also used intensively by mankind. Both systems support a variety of socio-economic functions: they provide space, produce resources and absorb unwanted products. Given an increase in the scale of human activities, functional linkages between coastal and riverine areas are ever more apparent. Economic activities in downstream areas benefit from upland resources, such as water, aggregates and wood. On the other hand, coastal areas provide space for settlement, industrial activity and tourist developments that have a positive benefit for the wider river basin area.

The coastal area is an essential component of the river basin. The two areas are linked through a number of natural and socio-economic processes:

- The cycle of water which determines fresh water quality and quantity, and ultimately sea water quality, affecting coastal ecosystems and human activities on the coastal zone (fishing/aquaculture and tourism/recreation opportunities).
- Sediment transport which affects river channel and coastal zone dynamics ultimately having an impact on coastal ecosystems and human activities in the coastal zone (fishing/aquaculture, urban development, tourism, etc.).
- Human activities in the river basin can affect coastal ecosystems and human activities in the coastal zone in a positive way, providing food, water and energy; and in a negative way through water retention for irrigation and other uses, and sewage discharge.

The Need for Integrated Management of Coastal Areas and River Basins

Both river basin and coastal problems require a multi-sectoral approach although the emphasis may change:

- River basin management is essentially multi-sectoral co-ordination with some elements of rural land-use regulation.
- Coastal zone management is essentially physical planning and resource management with a strong emphasis on land-use regulation and physical interventions.

Traditionally, river basin management has been seen only in terms of water supply. Many other functions of a river basin must be recognised, including tourism, nature conservation and cultural heritage. It is now evident that river basins should be managed in an integrated way.

The coastal zone is invariably an area of intense human activity. Unlike river basins, coastal management has long combined two facets: marine resource management and land-use planning. Because coasts are so heavily used, many conflicts arise. As in river basins, it is now widely recognised that integrated management of the coastal zone is required to lay the foundation for sustainable development.

As rivers and coasts are physical and ecological entities, changing patterns of land and resource use in upstream areas will have an impact on downstream areas.

Conflicting demands on natural resources and land uses has brought the need for a comprehensive approach, involving multiple objectives and the need to account for a wider scale of interest in both space and time. Given this contemporary perspective, an integrated approach to the management of coastal zones and river basins is sensible and timely.

The Approach

Integrated Coastal Area and River Basin Management (ICARM) requires the adoption of goals, objectives and policies and the establishment of governance mechanisms which recognise the interrelationships between the two systems with a view to environmental protection and socio-economic development.

The *goals* of integrated coastal area and river basin management fall within the framework of sustainable development according to which environmental conservation is of equal importance to economic efficiency and social equity, all sought in a long-term perspective on the basis of intergenerational equity.

The basic *principles* of integrated coastal area and river basin management in the context of sustainable development must:

- Respect the integrity of the river basin or coastal ecosystem and accept limits on the use of resources;
- Ensure the strategic importance of renewable resources for socio-economic development;
- Allow for the multiple use of resources integrating complementary activities and regulating conflicting ones;
- Ensure multi-sectoral and multi-level integration in decision making linking broad scale management to local level intervention; and
- Allow for participation of all actors particularly local population in the planning process to assure effective management.

In establishing an integrated management system for river basins and coastal zones it is necessary to adopt a pro-active approach. In this context planning acquires a special role in establishing a process of governance and a strategic framework of goals, policies and actions.

Strategy formulation within the context of ICARM depends on the case study particularities and on broader regional and national conditions. The formulation of a strategy often needs to address issues which have an impact on the management of the river basin or the coast but which fall outside of the authority of the people participating in the process.

Because of its complex nature, ICARM requires a high level of integration within and between institutional structures. A high level of horizontal co-operation is required particularly among sectoral institutions at the planning stage and a high level of vertical linkage is necessary within institutions at the implementation stage.

As issues often transcend administrative boundaries, ICARM must function at different levels: national, sub-national, and local.

- At the national level policy issues related both to formulation and implementation of ICARM must be defined. A strategy needs to be elaborated providing the necessary guidelines for local and regional initiatives. An agency which can be responsible for coastal and river basin management at a national level must be

identified since environmental and conservation standards will be set at this level. A committee which will work on the sectoral concerns, allowing the participation of all interested ministries, may be formed as well.

- At the sub-national level more detailed plans may be developed on the basis of the national guidelines for ICARM. Co-ordination of local plans for integrated river basin and coastal zone management will be pursued together with the resolution of conflicts with national goals.
- Detailed plans are developed at the local level.

There are two prerequisites for implementation of the plans formulated on the basis of the strategy:

- The plans need to have a legal status that will assure successful implementation.
- The plan must be realistic. This means sensible policies and actions which are commensurate with the scale of the problem, the capability of local government, the human and financial resources required, and the necessary technology support.

A variety of tools and methods can be employed in Integrated Coastal Area and River Basin Management at the stages of information management, plan development and implementation. These include: data-bases, Geographic Information Systems (GIS), Decision Support Systems (DSS), Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), economic evaluation of costs and benefits, environment-development scenarios, Carrying Capacity Analysis (CCA), regulation and control or financial mechanisms, awareness, capacity building and education, and conflict resolution.

Scope

Some small sections of coastline may not be influenced by river inputs, but as longer sections of coastline are considered, the impact of rivers inevitably becomes greater. By the same token, small river basins are unlikely to affect the coastal zone significantly, except in a few cases. However, as the size of basin increases, the likelihood of outputs from the basin having some effect on the coastal zone increases. Moreover, because of the intimate linkage between river and coast, changes in a river system can be felt far away.

Not all of the management activities within the ICARM domain will require a fully integrated approach. The scale of the management issue and the impact of the management actions largely determine whether or not ICARM should be applied. In some cases, management in one sector may be independent of the others, but as the scale of the task increases, the need for an integrated approach will invariably become greater. The present guidelines provide a conceptual framework for evaluating each case and implementing an efficient and effective ICARM procedure.

Expected Outcome

Integrated river basin and coastal zone management provides the opportunity to consider explicitly certain aspects of these systems that have previously been seen as outside the scope of planning interest. An integrated approach leads to better co-ordination of policy making and action across sectors (water, forestry, agriculture, urban development, environmental protection, etc.) and geographically, ultimately leading to a more rational use of resources and more effective environmental protection.

The expected outcome of an integrated management approach would be optimisation of policy interventions in space and time to reduce potential conflicts, bridge potential gaps and streamline potential overlaps among policies. This can be achieved through recognition of key linkages between coastal areas and river basin systems (both natural processes and human activities), and identification of key locations, both geographical and sectoral, for policy intervention. In this regard, it should be recognised that there are substantial differences in terms of time frame and geographical scale among the various processes operating in coastal areas and river basins, and this must be borne in mind in the decision-making process.

Reader's Guide

The *Conceptual Framework* and *Planning Guidelines* are intended to:

- sensitise all those engaged in coastal zone management to river basin management issues;
- sensitise all those involved in river basin management to coastal zone management issues; and
- provide a framework of reference for Integrated Coastal Area and River Basin Management (ICARM).

The *Conceptual Framework* and *Planning Guidelines* should be seen as general reference tools while detailed descriptions of natural processes, human activities and their interactions can be found in the specialised scientific literature. Detailed accounts of environmental management and planning methods and techniques, as well as information on specific tools, can also be found in specialised sources.

Part I provides the basic *Conceptual Framework* for linking the management of coastal areas to river basins and *vice versa*.

- The first chapter sets the basic context for integrated management in river basins and coastal areas and outlines the rationale for a joint treatment of their management.
- The second chapter describes the basic physical characteristics and processes in river basins and coastal areas especially the water cycle and sediment transfer which are the structuring processes for the relationship between river basins and coastal areas.
- The third chapter treats the issue of human uses in both river basins and coastal areas focusing on population pressures, economic sector and resource development activities, urbanisation and infrastructure development and land-use patterns. The intention is to demonstrate that there are effects on environmental systems (habitat loss, pollution, erosion, etc.) which may also affect human activities.
- The fourth chapter sets the basic framework (principles, goals and objectives) for taking joint action in river basin and coastal area management, including alternative strategies for achieving success.

Part II presents the *Planning Guidelines* for Integrated Coastal Area and River Basin Management.

- Chapter five presents the basic steps in setting up an integrated management plan for coastal areas and river basins.
- Finally, chapter six provides an overview of some key policy instruments for implementing integrated management. Their basic features and potential use as demonstrated with emphasis on state-of-the-art tools.

The *Guidelines* provide a conceptual framework for initiating plans and can be used also on a selective basis for specific aspects of integrated coastal area and river basin management.

Part I: CONCEPTUAL FRAMEWORK

Chapter 1. Introducing Integrated Coastal Area and River Basin Management

1.1. Why Integrated Coastal Area and River Basin Management?

Coasts and river basins contain important natural environments that are used intensively by people. The scale of human activity has tended to increase over time, so that functional linkages between coastal and riverine areas are ever more apparent. Economic activities in downstream areas benefit from upland resources, such as water, aggregates and wood. On the other hand, coastal areas often provide space for settlement and industrial developments that have a positive benefit for the wider basin area. In earlier centuries, human impact on river and coastal systems tended to be small and localised. Today, the pressures of human activity on the landscape are large and multifarious, with clear implications for the level of linkage between river systems and the coastal area.

In order to guide and control these socio-economic developments existing administrative boundaries and governance structures are no longer sufficient. There is a need to develop new management structures and instruments that can take into account the intimate functional linkage between the coast and the river basin proper.

Both coastal and riverine ecosystems support a variety of socio-economic functions. For example:

- they provide space for human settlement and industrial development;
- they produce living and non-living resources, such as fish, agricultural products, aggregates, water, oil and gas; and
- they absorb unwanted products, such as domestic sewage and industrial waste.

Most, if not all of these functions are affected by socio-economic development. Uncontrolled developments inland may affect the coast, and *vice versa*, and may ultimately result in loss of vital resources. A few examples include:

- soil erosion and loss of fertile land due to deforestation;
- pollution of surface and groundwater due to agriculture and industrial activities;
- loss of productive land due to coastal erosion and dam construction; and
- degradation of coastal wetlands due to changes in hydrological conditions upstream.

Integrated Coastal Area and River Basin Management (ICARM) provides the key to the integrated development of natural, economic and cultural environments within river basins and coastal areas.

In order to guide and control this wide variety of physical, biological and ecological processes, current management objectives are no longer sufficient. There is a need to develop a new environmental management approach that takes into account the intimate functional linkage between the coast and the river basin proper.

1.2. Setting the scene for ICARM

1.2.1. Linkage between rivers and the coastal zone

Active management of coasts and river basins started earlier this century in order to solve conflicts in allocation of space and use of resources created by a rapid population growth. Due to the different nature of these conflicts in river basins and coastal areas, the management issues, the approaches adopted and the instruments applied differed substantially and operated independently. This is illustrated in Figure 1 which shows schematically the main spatial components of the ICARM domain:

- The river;
- The coast; and
- The nearshore marine waters.

Human civilisation has always flourished beside the sea and in nearby river basins. The coastal zone has at all times been a favourable location, providing a variety of resources and easy access. River basins too have long supported human activity, the availability of fresh water being crucial. Very often, there has been intimate linkage between river basin and coast. River valleys have always been the avenues through which traffic of people, goods and ideas move from the coast deep into the continent, and *vice versa*. The river itself provides an important supply of water, sediment and nutrient to the coastal zone: where river meets sea, particularly rich environments have been created – deltas and estuaries – providing abundant natural resources and diverse natural habitats. As the interface between land and sea, the coastal zone is an especially important and fragile environment from an ecological perspective and requires very careful management.

1.2.2. Managing the coast and the river

Initially, the coast and the river basin were treated as separate management units as shown in Figure 1.a. Management included only a limited number of issues and encompassed only a limited area:

- Traditionally, *river management* has just been seen in terms of water supply. River water and groundwater are used for a wide variety of purposes, including domestic supply, agriculture, forestry, fishing, energy production, industrial processing and effluent disposal; the aquatic environment is also an important habitat in its own right. River management, therefore, focused on water resource management only. This often encompassed relatively small subcatchments or sections of river channel.
- The coastal zone is invariably an area of intense human activity. Unlike river basins, *coastal management* has long combined two facets: marine resource management and land-use planning. Problems relate mostly to the availability of land (for urbanisation, tourism, industrial and port development) and the quality of marine resources (e.g. for fishing/aquaculture, tourism, and effluent disposal). On low-lying coasts, safety from flooding is of paramount concern; efforts to prevent beach erosion at one location can have important repercussions elsewhere along the coast. Initially, coastal managers only addressed the issue of shoreline management and erosion control within the narrow boundaries of the coastal strip.
- In nearshore waters, management of both living and non-living resources within the Exclusive Economic Zone (EEZ) has been the key issue.

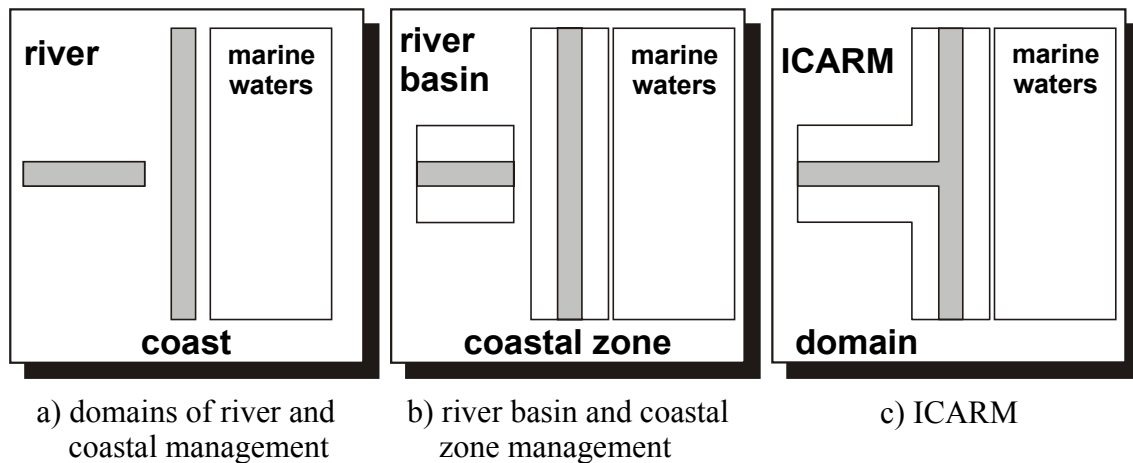


Figure 1: Main spatial components of the ICARM domain

Given these diverse issues and the limited spatial horizon of each group of managers, there was little or no overlap in management activities.

1.2.3. Expanding the management domain

Gradually, however, the need for multi-sectoral activity has become apparent, requiring a revision of the management domain. This is shown in Figure 1.b.

- The growing awareness of an intimate connection between the river and its catchment area led to a more integrated approach to *river basin management*, including consideration of water quality, as well as quantity. In both the developed and the developing world, the impact of agriculture on water resources has been particularly significant: abstraction of irrigation water, soil erosion, nutrient and pesticide export to rivers, and so on. However, management extends beyond the narrow conflict between certain land uses (e.g. farming, forestry, and human settlement) and water resources (amount and quality). Many other functions of a river basin can be recognised, including tourism, nature conservation and cultural heritage. Thus, a river basin is now regarded as a “land of many uses” and exploitation of water resources must be balanced against other desires. Given such a large number of land uses, often underpinned by complex land ownership, the difficulties of integrated river basin management can be readily understood. River management now encompasses the basin as a whole. UNEP initiatives to develop guidelines for integrated management of river basins and wetlands are good examples of this approach.
- Because coasts are so heavily used, many conflicts have arisen. Examples include incompatible uses which cannot co-exist (e.g. industry and tourism), private ownership (which prevents public use or access), and provision of environmental protection in parallel with economic development (e.g. sewage treatment for new hotel complexes). In the longer term, goals for nature conservation may inhibit immediate economic interests, and measures to combat sea level rise may also confound efforts to conserve natural ecosystems. As in river basins, it is now widely recognised that *integrated management of the coastal zone* is required to lay the foundation for sustainable development. Coastal managers, therefore, have expanded their domain in both landward and seaward directions, calling this new approach Integrated Coastal Zone Management (ICZM) or Integrated Coastal Area Management (ICAM). Again, UNEP/MAP has responded to this development by publishing appropriate Guidelines.

- *Management of marine resources* remains largely restricted to coastal waters within the EEZ. UNCLOS, The United Nations Convention on The Law of the Sea, has provided a legal framework for controlled development of resources within this zone.

Although there is a spatial overlap between these zones, river basins and coastal zones could still be managed individually as long as functional linkages between these units were of little importance so that the effects of management interventions were limited to individual areas.

1.2.4. The need for an integrated approach

Since the UNCED conference in Rio, it has become accepted that river basins and coastal sectors are intimately linked through their physical and ecological structure and related physical and biological processes. This is shown schematically in Figure 1.c. The transport of water, sediment and pollutants is of central importance. Both urban and rural land-use practices affect the quantity and quality of water arriving at the mouth of the river; this can be significant for coastal sediment budgets and for the conservation of important habitats, such as wetlands, deltas and estuaries. The movement of water, sediment and pollution along the coast is also crucial. A comprehensive approach to shoreline management must incorporate upstream areas of both coast and river basin, since management practices in either system can impact further down the coast.

Changing land-use patterns and resource use in upstream areas will affect downstream areas. Changes in land use in the catchment area, such as urbanisation and deforestation, will change runoff and sediment supply, ultimately affecting the coastal zone, and often resulting in erosion and coastline retreat. Similar effects are produced by hydro-electric power plants and river regulation: even if the average annual discharge is not changed, reduction in flood peaks and flow regulation will affect sediment transport which often results in erosion of downstream river sections and coastal areas.

There are equally important interdependencies when the effect of wastewater emission is considered. Wastewater emissions at sea may affect the quality of the water in the lower river basin due to tidal effects associated with salt water intrusion and diffusion of pollutants. Pollutants discharged in the upper part of the river will ultimately affect the quality of both the water and the sediments in the lower reaches of the river. These changes have a direct impact on the integrity of the aquatic ecosystem, its flora and fauna. In those areas where such linkages are important, Integrated Coastal Area and River Basin Management (ICARM) will be required. Integrated management has become increasingly diverse, covering a wide range of economic and social goals. Conflicting demands on natural resources has brought the need for a comprehensive approach, involving multiple objectives and the need for a wider scale of interest in both space and time. Given this contemporary perspective, an integrated approach to the management of coastal zones and river basins is sensible and timely.

1.3. How does ICARM work?

Although the spatial extent of ICARM is still under debate, we assume in the present guidelines that it encompasses the catchment, the coastal zone and the nearshore coastal waters. Management of marine resources, such as oil, gas and fish stocks, is not currently included in ICARM. In principle, ICARM aims at a sectoral integration at all levels of governance as a basis for a multi-disciplinary management of the larger catchment area, including the coast. Not all of the management activities within the ICARM domain will require a fully integrated approach, however. The scale of the

management issue and the impact of the management actions largely determine whether or not ICARM should be applied. In some cases, management in one area may be effectively independent of the others, but as the scale of the task increases, the need for an integrated approach will invariably increase.

Some small sections of coastline may not be influenced by river inputs, but as the size of basin increases, the likelihood of outputs from a river basin having some effect on the coastal zone increases. Moreover, because of the intimate linkage between river and coast, changes in a river system can be felt far away. A classic example is the erosion of the Nile delta as a result of the construction of the Aswan dam. By the same token, small river basins are unlikely to be significantly affected by developments in the coastal zone, except in a few cases. In general, as the spatial scale of interest gets larger, the relevant time scale of interest increases, too. Thus, major changes in the sediment transport rate of a large river will have long-lasting effects on the coastal zone, as in the case of the Nile.

The present guidelines introduce the concept of ICARM, provide a conceptual framework to evaluate the need for ICARM case by case and a flow chart to implement an efficient and effective ICARM procedure.

1.4. What are the benefits of ICARM?

1.4.1. Objectives

ICARM provides the context to consider explicitly aspects of natural and socio-economic systems that have previously been seen as outside the scope of interest of policy makers and planners, concerned only with the sectoral development of river basins or coasts proper. For example, there is direct linkage between soil erosion control in headwater basins and reduced sedimentation in salt marshes. Recognition of this leads to better co-ordination of policy making and action across sectors (water, forestry, agriculture, urban development, environmental protection, etc.) and geographically, ultimately leading to a more rational use of resources and more effective environmental protection.

1.4.2. Goals

The goals of ICARM fall within the framework of sustainable development, as outlined in Rio, according to which environmental conservation is of equal importance to economic efficiency and social equity, all sought in a long-term perspective on the basis of intergenerational equity.

1.4.3. Output

An integrated management approach will optimise policy interventions in space and time to reduce potential conflicts, bridge potential gaps and streamline potential overlaps between policies. This will be achieved through recognition of key linkages between coastal area and river basin systems (both natural processes and human activities), and identification of key locations, both geographical and sectoral, for policy intervention. In this regard, it should be recognised that there are substantial differences in terms of time frame and geographical scale among the various processes operating in coastal areas and river basins, and this must be borne in mind in the decision-making process.

Chapter 2. Natural Systems in River Basins and Coastal Areas

2.1. Linking rivers and coasts: the concept of systems

2.1.1. Introduction

There is a clear need for integrated management of coastal areas and river basins. As coastal and riverine environments are complex ecosystems there is a need to develop a simple analogy which scientists and managers can use to describe the essential features of these ecosystems and their interaction with human usage. The systems theory provides a way to develop such a simplified approach. The basics of systems analysis are explained in the box below.

In this chapter, we use the concept of systems as an expedient to describe the river basin at various spatial scales, encompassing the basin as a whole, as well as its individual marine, coastal and fluvial habitats. The systems analogy used in this guideline is essentially the bimodal system first used in the early 1970s by Meadows and others (The “Club of Rome”) to simulate the Earth’s population and resources.

This systems analogy has two main components: the natural system and the human system. Both components interact: nature provides resources for the people and they discharge waste back into the natural system. The terms *resource* and *waste* are used here in a wide context and cover a large number of interactions between people and nature. Managers control these interactions in two ways: through administrative rules and regulations and by means of technical intervention.

In this chapter, the natural system and its functions are described. In the next chapter, a similar approach is used to describe the human system and system controls.

2.1.2. The ICARM systems analogy

Before describing a system we have to define the boundaries of the object we want to include in the systems analysis. For ICARM we will consider issue-related boundaries, which means that the relevant management issue determines the boundaries. By contrast the system for local problems in the coastal zone, which have no impact on the river basin as a whole will include a small area of the coast only. For example, managing the effects of acid rain on the ecology of the river basin will require the analogy of systems that incorporates the entire basin.

As a first step, we characterise the system as a so-called “black box” or input/output system. The black box description focuses on the function of the system without specifying how this function is performed. Functions provide outputs for appropriate input conditions. Functions of natural systems are to provide space, to produce resources and to regulate physical and biological processes. These outputs can only be realised for suitable input conditions, such as climate and substrate.

In the next two steps, we try to unravel the contents of the black box in terms of its structure (the components and their interdependence) and the processes (the dynamic interaction between these components). Typical components are the abiotic and biotic elements of the ecosystem; important processes are the flow of water and substances and the flow of energy. These various steps are described in greater detail in Appendix 3.

Box 1

An approach to systems theory

The term *system* is loosely defined in the literature and is used by managers and politicians to describe many aspects of the coastal zone and river basin without defining precisely what a system is. Scientifically speaking, a system is a model of a part of the real world. It is composed of a number of elements and interactions and simulates the structure and dynamics of the corresponding part of the real world. The system is a convenient tool to describe complex real-world situations and to analyse complex problems. Moreover, the systems analogy is a helpful expedient:

- to visualise the structure of the real world as a first step to a GIS representation;
- to schematise the processes within the real world as a basis for system's simulation by means of models; and
- to study the dynamic interaction between people and nature.

Systems theory is based upon the idea that the real world can be described by a set of *elements* and the *interactions* between these elements. In general, the system only includes a small part of the universe, i.e. the part encompassed within the system's *boundary*. The area outside this boundary is called the system's *environment*.

Some authors have proposed a hierarchy of systems, based upon the complexity of the system being studied. Simple mechanical systems, which can be described by the laws of physics, are the lowest level. Such systems are easy to understand and easy to model. At the other end of the scale we find socio-economic systems, representing organisations and communities. Such systems can only be described verbally or in terms of empirical relations based upon fieldwork and interviews. Coastal and riverine systems are somewhere between. The natural component of such systems and their governing processes can often be modelled adequately. No "mechanical" models exist, however, for the human components and the inherent socio-economic processes.

The first step in any analysis of a system is the selection of its boundaries and the *decomposition* of the area within these boundaries into a set of elements and interactions. Elements used in the analysis of environmental systems are geographical units, often subdivided into their abiotic, biotic and human components. Interactions include a variety of abiotic, biotic, chemical and socio-economic linkages between these elements.

For a more qualitative description of the system, representative *aspects* of the system are defined and *parameters* are selected to characterise such aspects. Each element is now characterised in terms of these aspects and related parameters. The value of any parameter at a given point in time is called the *state variable*. For a physical description of a system, only abiotic aspects and parameters will be used. An example of such an aspect is the composition of the substrate, and a typical parameter would be the grain size of the substrate. When an ecosystem is defined, biotic aspects are equally important. The biomass within an element, the biodiversity and the presence of endangered species are then important parameters for the description of the system. When human aspects have to be included other parameters become important, such as population density, per capita income, etc.

In general, systems are dynamic which means that they respond to changes in their environment, or to changes within the system itself. Changing boundary conditions or inputs will affect the value of parameters and these in turn will affect the system's output, and the interaction with its environment. Values will change due to dynamic interactions between elements known as *processes*. We identify abiotic, biotic, chemical and socio-economic processes. If all processes can be adequately described a transparent description of the system is possible, often characterised by the term *white box*. In those cases where internal processes are poorly understood, empirical relations between input and output are used to describe the response to changing conditions. Such a system is called a *black box*. As stated above, only a limited number of processes can be described theoretically and simple empirical relations are used to complement the process descriptions. Most environmental systems fall into this category, and are called the *grey box* systems.

In many instances, the state values of a system's parameters should stay within prescribed limits. In self-regulating systems, feedback mechanisms exist which dampen fluctuations in state values. If no such feedback mechanisms exist, such parameters should be monitored and appropriate system controls should be used to correct inadmissible fluctuations. Typical examples of such controls are the regulation of river flow by means of sluice gates and barriers.

In this section, the systems analogy for the ICARM domain and its constituent elements, the coast, the estuary and the river will be described. The following aspects of a system will be discussed first:

- The boundaries;
- The structure; and
- The processes.

2.1.3. The boundaries

In practice, the *boundaries* of the system have to be defined first. Often these boundaries are set by law and comprise administrative units. For environmental management it is more useful, however, to choose geographical or geophysical units. For that reason, in these guidelines the watershed (or drainage divide) is the landward boundary of the system. The seaward boundary is much more flexible and is defined case by case for the relevant management issue.

In nature, a variety of coastal formations exist, ranging from steep rocky headlands to gently sloping mudflats. Appendix 2 gives a typological classification of coastal landforms. Although the guidelines are universally applicable, reference is mainly made to sandy coasts.

2.1.4. The structure

As shown above, natural systems have three interacting abiotic components:

- The atmosphere;
- The hydrosphere; and
- The lithosphere.

These spheres together form the abiotic geosphere which creates the living conditions for the biota, plants and animals, known as the biosphere.

The geosphere and biosphere can be described by a large number of parameters as shown in Table 1.

In general, this macroscale system is too crude to be used for ICARM; a further decomposition of the system is required. A mesoscale model is proposed, incorporating three geographical components: the river, the estuary and the coastal zone. These components are linked through appropriate cross-boundary fluxes at the interface between these elements. In each element we find air, water and substrate as the principal abiotic components which accommodate the marine and fluvial ecosystems.

Figure 2 shows the geophysical components of the atmosphere, the hydrosphere and the lithosphere and the links between them. Also shown are the geographical subsystems relevant to ICARM: the river, the estuary and the coastal zone with the principal interactions between the subsystems. The ICARM subsystems therefore comprise both geographical elements and geophysical components. Boxes are arranged vertically, in accordance with the geophysical structure of the Earth, with atmospheric elements at the top and the substrate at the bottom of the diagram. The horizontal arrangement of the boxes is dictated by the flow of fresh water from the headwaters of the basin to the sea.

The processes

The arrows in Figure 2 indicate a variety of macro- and meso-scale interactions between the system's components.

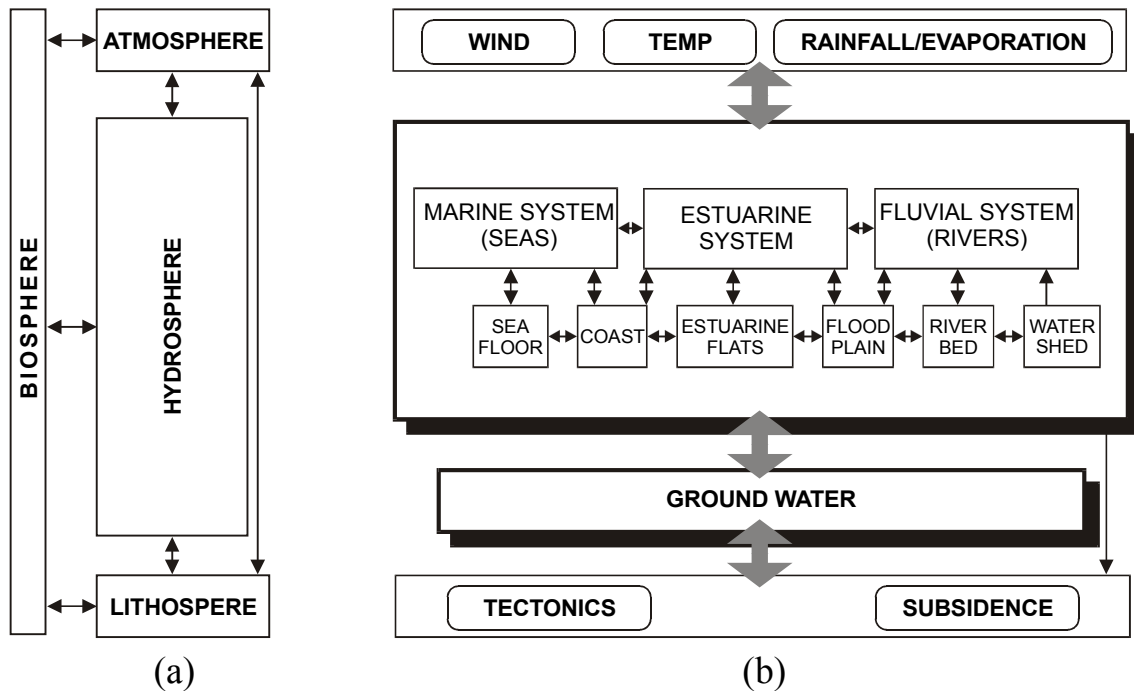
Vertical arrows between the geophysical components indicate macro-scale interactions between the atmosphere, hydrosphere and the lithosphere. Typical examples of such interactions are climatic processes like precipitation, evaporation and wind, and geological phenomena, such as subsidence.

Vertical arrows within the central box represent mesoscale interactions between these spheres. Processes at the interface between water, air and substrate govern these interactions. Typical examples are wind-generated waves and water level fluctuations, sediment transport and catchment erosion.

Horizontal arrows between the river, the estuary and the coastal area represent the flow of water and sediment, and transport of pollutants.

<p>1. Atmosphere</p> <ul style="list-style-type: none"> • Chemical composition, pollution • Concentration of dust particles • Humidity • Precipitation/evaporation • Clouds • Solar radiation input • Temperature • Frequency and strength of wind <p>2. Hydrosphere</p> <ul style="list-style-type: none"> • Volume of available surface and ground water • Water quality • Run-off and river discharge • Hydropower potential • Tidal characteristics • Wave statistics <p>3. Lithosphere</p> <p><i>Geomorphological aspects</i></p> <ul style="list-style-type: none"> • Topography • Rock type and structure • Albedo • Landforms of weathering and erosion • Sedimentary deposits • Landform types <p><i>Geophysical aspects</i></p> <ul style="list-style-type: none"> • Soil depth • Soil texture and structure • Mineral composition • Biological components • Chemical composition • Organic matter, humus content and litter • Moisture content <p><i>Geological aspects</i></p> <ul style="list-style-type: none"> • Bedrock properties • Geotectonic and geophysical features • Seismicity • Distinct geological features 	<p>4. Biosphere</p> <p><i>Vegetation</i></p> <ul style="list-style-type: none"> • Height, density, structure and roughness • Succession stage • Standing biomass, chlorophyll • Surface cover, leaf area index • Evapotranspiration and efficiency of water use • Litter production • Root system and nutrient cycling <p><i>Flora and fauna</i></p> <ul style="list-style-type: none"> • Species composition and diversity • Population size • Population viability/vulnerability • Population dynamics • Dispersal and migration • Special functional properties, such as nutritional value, biochemical properties, medicinal value, role as bio-indicator, etc. <p><i>Life communities</i></p> <ul style="list-style-type: none"> • Biomass production, photosynthesis • Consumption and respiration • Decomposition • Food chain interactions • Recycling of carbon and nutrients • Bioturbation <p>5. Ecosystem parameters</p> <ul style="list-style-type: none"> • Naturalness, integrity, heritage value • Uniqueness, distinctiveness • Diversity, richness • Ecosystem size with respect to minimum critical value • Carrying capacity, fragility • Renewability, replaceability • Information value, regarding Nature, Landscape and Culture
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Table 1. Environmental parameters to characterise natural functions



**Figure 2: a) Generalised system diagram of the natural components of the system
b) Elements of the abiotic component**

The systems analogy can be used as the basis for a microscale description of the structure and the processes within each component: the river, the estuary and the coastal area.

2.2. The coastal system

2.2.1. The boundaries

Four interacting zones are taken into consideration:

- coastal waters;
- the coastal strip;
- estuary; and
- the coastal plain.

As most coastal states have now legislative boundaries that define the extent of the various zones, no attempt has been made to delineate these zones in detail.

In these guidelines, a geophysical delineation has been implicitly used as it is assumed that the boundaries relate to the governing processes. So, for morphodynamic problems, coastal waters extend up to a depth of about 20 m below which the waves no longer affect coastal processes. In other instances, however, when dispersion of pollutants is the main issue, seaward boundaries have to be selected much further offshore.

The coastal strip is defined as a narrow transition zone between the land and the sea, where the effects of tides and waves still can be felt. In practice, this will be the zone between the mean high and mean low spring tide levels. The area further landward is considered to form part of the coastal plain. The landward boundary of the coastal plain is dictated by the need to reproduce correctly the relevant physical processes in the area.

2.2.2. Coastal waters

The structure

Air, water and the seabed are the main components of the coastal zone. These components can be described by their geometry and their physical, chemical and biological properties. Typical parameters are air and water quality, salinity, temperature and seabed characteristics, such as properties of sediments and sediment quality.

The geometry and structure of the coastal waters determines its ability to accommodate navigation and various offshore activities and to produce non-renewable resources, such as aggregates, oil and gas. The inherent natural and scenic values of the coastal waters are of great scientific and aesthetic importance for present and future generations.

The processes

Solar radiation, wind, rainfall and evaporation are driving forces in the atmosphere. In water, wind generates waves, wind-induced water level variations and currents. Tides and tidal currents are other important processes in the coastal water induced by gravitational forces. Together these processes induce transport of pollutants and sediments, processes that regulate the water quality in the coastal waters and the evolution of the seabed and coast. Moreover, the flow of nutrients and related biomass production are vital for the marine ecosystems and habitats which are to a large extent responsible for the production of renewable resources, such as fish and shrimps. Moreover, these processes create the conditions for survival of rare species. Unfortunately, millions of hectares of valuable ecosystems have been lost as a result of uncontrolled development or have been degraded as a result of pollution.

The processes operating within the coastal waters determine to a large extent the production of renewable resources and regulate vital processes, such as water quality and coastline dynamics. Sustainable yield and carrying capacity are indicators which should be observed in order to avoid over-fishing and pollution of coastal waters.

2.2.3. The coastal strip

The structure

Water and substrate are the main components of the coastal strip. The plan shape of beaches and the cross-shore profile, together with the characteristics of the beach material (shape, specific gravity and grain size distribution) are the most important element of the seabed. Though less important in many respects than the coastal waters, the various beach formations accommodate a variety of ecosystems and habitats, some of which are vital to combat erosion.

The geometry and structure of the coastal strip determines its ability to accommodate economic and social activities, and dictates its potential for tourism development. The coastal strip protects the hinterland against waves and acts as a barrier for storm surges.

The processes

Waves and tides create coastal currents responsible for sediment transport in longshore and cross-shore direction. As a result the sediment budget is constantly changing, which is reflected in accretion and erosion of the beach. Often these processes are aggravated by overwash during high tides and storm surges and by transport due to wind. These hydrodynamic and morphodynamic processes determine to a large extent the ability of the coast to cope with short- and long-term variations in shoreline evolution.

Biogeomorphological processes, the interaction between physical and biological processes, greatly enhance the potential of the coast to cope with these natural hazards.

Extreme winds and waves generate storm surges that may imperil the coast and its hinterland. In addition, extreme storm events can cause erosion of beaches and cliffs that may also threaten human habitation. Though less important than coastal waters, the intertidal zone is an important element of the food chain since it accommodates a large number of resident and migrating birds which feed there.

Together these processes determine whether or not people can settle safely in this zone. Beach erosion and devastating floods are, however, constant threats to coastal communities. Though less important as a producer of resources, intertidal areas are important feeding areas for water birds.

2.2.4. Estuary

The structure

Estuaries are important gateways to the hinterland and provide shelter during adverse weather conditions. Often shallow tidal flats and coastal plains are present, providing space for human settlement and development.

Fresh and salt water and suspended sediments are the main constituent elements of estuaries. The intricate interaction between these components defines the unique structure of estuaries resulting in its morphological features and ecological potential.

Estuaries are complex environments which provide great opportunities for human development due to their favourable location and geographical features. Estuaries are, however, equally important for the production of living and non-living resources, functions which exist by virtue of their intricate hydrological and ecological structure.

The processes

The unique structure of estuaries cannot be understood without a proper understanding of the processes acting in the estuary. The tidal flow, river discharge and sediment characteristics define the shape and cross section of the estuary; changes in these governing processes or in the equilibrium configuration of the estuary will have long-lasting effects.

In estuaries, fresh and saline waters mix. Mixing is a complex process where density differences and turbulence play an important role. In areas with low turbulence sharp density gradients are maintained resulting in an easily identifiable stratification, known as the “salt wedge”. In more turbulent areas estuaries are well mixed and density gradients are less pronounced.

Density differences and stratification have a significant impact on sedimentation. Due to electro-chemical processes, silt particles tend to flocculate when salinity increases, resulting in accelerated sedimentation in areas with sharp density gradients. Human interventions, such as dredging, which affect the propagation of the salt wedge, may have significant effects on these sedimentation patterns. As silt is often polluted by heavy metals and other chemicals, sedimentation inevitably results in high local concentrations of polluted sediments which in turn can affect the quality of the water. Density differences are also one of the key parameters which define the characteristics of estuarine ecosystems and habitats. Changes in runoff may have a significant effect on mangrove vegetation which in turn will affect shoreline erosion and breeding conditions for fish and other marine species.

Hydrological and biological processes in estuaries are complex; their interactions are diverse and not easily understood. Human interventions may easily disrupt this delicate environmental equilibrium resulting in changes in the environment with far reaching and long-lasting consequences.

2.2.5. The coastal plain

The structure

Substrate is the main structuring element in the hinterland. Topography, soil composition and geotechnical properties are the most important aspects that define the suitability of the coastal plain for human settlement. Liability to flooding is one of the most important topographical aspects to be considered, suitability for agricultural production another. Geotechnical conditions define the suitability for human settlements. Being an alluvial deposit, foundation conditions are often poor and subsidence problems are to be expected when large-scale urban developments are located there.

The ability to provide space for human settlements and related economic and social activities, and the potential to produce renewable resources through agricultural development are the main functions of this area.

The processes

In general, solar radiation and rainfall are processes that are highly beneficial to people, as they provide energy and water. In some coastal areas, however, hurricanes and tropical storms represent natural hazards that are detrimental to nature and people. In other areas acid rain and other atmospheric depositions endanger the quality of life in the coastal plains.

Water flows as surface and groundwater. Surface flow produces fresh water but may also cause soil erosion and material transport when the coastal plain is not properly drained. Groundwater flow is also of importance for maintenance of aquifer integrity and fresh water supply. High rates of abstraction from aquifers may result in saline intrusion and hence a deterioration of groundwater quality. Thus it has a negative impact on the production of fresh water, and on the quality and quantity of agricultural products.

Even more devastating are inundations due to storm surges and river flows. In the future these phenomena may be of paramount importance if predictions of accelerated sea level rise become reality.

Geological processes and groundwater flow determine the geotechnical behaviour of the area. Consolidation of loose alluvial deposits leads to ground subsidence, often enhanced by extraction of groundwater. This reduces the ability of the coastal plain to accommodate human settlement as it increases the risk of flooding and inundation from both the river and the sea.

Some coastal areas contain nature reserves to protect rare species or to safeguard especially important landforms. Most of these specially protected areas reveal an intricate web of interrelated abiotic and biotic processes that are still poorly understood. The importance of these areas for science is one of the principal reasons for their existence.

As in the coastal strip, natural processes define to a large extent whether people can settle safely in the coastal zone, and whether natural resources can be produced safely and economically through groundwater extraction and agriculture. In some areas, the particular ecological setting merits the status of a specially protected area to safeguard its information value for future generations.

2.3. River basins

2.3.1. Structure of the river basin

The river basin system comprises the river channel network together with its land-surface area (the “catchment” or, in the USA, “watershed”). The river basin forms the logical spatial unit for hydrological studies: apart from any groundwater leakage, the catchment system forms a clearly defined unit. A systems diagram for a drainage basin identifies the various storage components and the transfer processes within the system (see below). Within this framework a water balance can be drawn up, enabling people to manage their water resources in an efficient and sustainable manner. There is in addition, as noted above, an intimate connection between flow of water through the catchment system and the transport of sediment and nutrients.

River basins exist in a hierarchy of sizes:

- Small headwater basins are **the supply zone** for the river system. There is strong coupling between the catchment area and the channel. Vegetation cover and land management practices closely control the export of water, sediment and dissolved load into the stream channel. There is also close coupling between aquifers and the river.
- Further down the drainage network, in the **transfer zone**, extensive floodplains separate hillslopes from the channel, and there is a less direct link between catchment and the river. The dominant process in this part of the catchment is one of transfer of material through the channel network, but there may be significant temporary storage of water and sediment *en route*. The channel acts as a conveyor belt for sediments moving intermittently seawards during flood events, with material stored temporarily within the floodplain deposits. Movement of fine-grained sediment (which can include much sewage waste) and dissolved load downstream is less irregular; in-channel biochemical processes may significantly transform these fractions of the river load, especially through in-stream cycling of nutrients and organic matter.

- In the lower reaches of the river system, the **depositional zone**, the main interaction with the coastal sediment system occurs. Fine sediments (often rich in organic matter) can accumulate in salt marshes and other estuarine wetlands, while coarser material can form deltas or become incorporated into beach sediments.

In very large basins, it may take a very long time for changes in sediment or nutrient supply in headwater basins to cause any impact at the mouth of the river. In smaller, steeper basins, there will be much closer linkage between sediment and nutrient delivery from hillslopes and processes in the coastal zone.

2.3.2. Processes within the river basin

The vast majority of rainfall and snowmelt must pass over the land surface, or drain through soil and bedrock, to reach the river. In so doing, the water will interact to some extent with the land cover (usually vegetation) and with soil and bedrock materials. This can affect the quantity of water reaching the channel and its quality (sediment and dissolved load).

The catchment hydrological cycle can be viewed as a simple system. There are inputs of precipitation (**P**) which move through a number of stores by a series of transfer processes, leading to outputs of river discharge (**Q**), evaporation (**E**) and deep seepage of groundwater. It is usually assumed that there is minimal groundwater leakage and that the catchment is watertight; however, this may not be the case where there are aquifers. The catchment water balance may thus be simplified as:

$$\text{Precipitation} - \text{Discharge} - \text{Evaporation} - \text{Changes in storage} = \text{zero}$$

or

$$P - Q - E - \Delta(I, D, S, G, C) = 0$$

In the following account, *stores of water* are given in italics and transfer processes are underlined. Water lying on the vegetation canopy is called *interception storage* (**I**); this either evaporates or falls to the ground as stemflow or throughfall. Water may pond on the ground surface (*depression storage*, **D**) from where it may evaporate, run off over the surface to reach the adjacent stream channel as overland flow, or infiltrate the soil. Water stored in soil (*soil moisture*, **S**) may be evaporated, taken up by plants and transpired, or flow through the soil to the nearby stream (throughflow). Soil water that percolates down into bedrock forms *groundwater storage* (**G**); groundwater discharge maintains streamflow during dry periods. The amount of water stored within the stream channel (*channel storage*, **C**) is usually small, except at times of flood, or where there are lakes and reservoirs. Because of the effect of channel storage in large basins, the discharge regime at the basin outlet may look very different from the pattern of water delivery from the land surface.

Not all the water entering a given storage zone is released over a short time period and water balance calculations must take into account changes in water storage. For this reason, water balances are usually prepared for relatively long time periods (at least one month). Assuming that initial and final conditions are similar, an annual water balance will ignore changes in storage, so that precipitation (input) then equals discharge plus evaporation (outputs).

Through this series of transfers and stores, incoming precipitation will generate river flow, evaporation and changes in storage. The transfer of water within a river basin is closely related to land surface properties such as vegetation or soil type. Changes in these variables, especially as a result of human activity, can significantly alter the hydrological response.

Chapter 3. River Basins, Coastal Areas and Human Usage

3.1. Linking the coast and the river: an analogy for the human system

3.1.1. Introduction

As shown in the previous chapter, complex coastal and riverine environments may be described in terms of systems that describe the functions, the main structural features and the important processes within these environments. A similar analogy can also be developed for the human system, although in this case the structure and processes are more complex and less amenable to a mathematical description. System modelling is, therefore, difficult in this case.

In this chapter, the same procedure will be followed using a stepwise approach to develop the systems analogy. Firstly, a black box representation is discussed, and thereafter the structure and processes. Finally, the analogy of ICARM systems is developed, which can be used to describe the basin as a whole as well as the individual components: the coast, the estuary and the river. Details of this approach are described in Appendix 2.

3.1.2. The ICARM systems analogy

The systems analogy shown in Figure 2 can also be used as the basis for an integrated systems analogy for the whole basin. Figure 4 shows the same geographical decomposition of the basin as used in the previous section for the description of the natural components. Here, the human component in the three areas, the coast, the estuary and the river, is added. System controls are not shown but are an indispensable part of systems analogy. This analogy can be used to show how the structure and processes of the human and natural systems are coupled.

The elements of the human system are coupled through their social, demographic and administrative structure. This coupling is strong for small geographical units, such as municipalities, but decreases with increasing spatial dimensions of the area concerned. Obviously, a strong controlling mechanism is required in the latter case to ensure a controlled functioning of the system. As shown by the horizontal arrows, the various components are also coupled through dynamic processes, such as:

- Movement of people;
- Fluxes of goods and products; and
- Flow of money.

The elements of the natural system are also strongly coupled through their structure. The atmosphere, hydrosphere and the lithosphere are linked through their geological, hydrological and ecological structure. More important, however, are the linkages created by the key natural processes as described in Chapter 2., section 2.1. The important processes are:

- Flow of water;
- Transport of sediments, conservative and non-conservative matter; and
- Transfer of energy and nutrients.

Finally, components of the human system are coupled indirectly through the natural system since resource use, waste disposal and engineering interventions in one component have impacts on other parts of the natural system. This in turn will affect the functioning of the human system in these areas. Deepening of a river mouth will increase saline intrusion, for example, which may adversely affect the potential for irrigation and water supply further upstream. Release of polluted water in upstream areas may ultimately affect lower stretches of the river and even coastal areas, causing degradation of ecosystems and loss of essential production and regulation function.

The following activities may have an effect far away from the actual location:

- Changes in land use in the basin, such as urban development, deforestation and agricultural changes;
- Construction of physical infrastructure, in particular dams and reservoirs, and channel dredging; and
- Emission of waste and pollutants.

The systems analogy can be used to illustrate why integrated management is needed and how it should be accomplished. A rigorous, quantitative description of the system is indispensable. This requires, firstly, a detailed description of its structure using GIS supported by databases. Secondly, the underlying processes must be described and modelled. In this respect processes within the human system are difficult to simulate and more empirical approaches have to be used. Processes within the natural system are more tangible and a variety of models are available to describe these systems. In all cases, however, field data are needed to calibrate the models and to complement simulated results with observations.

3.2. The coastal use system

3.2.1. The boundaries

The same delineation of the coastal area will be followed as used for the description of the natural system:

- coastal waters;
- the coastal strip;
- estuary; and
- the coastal plain.

Figure 3 shows an artist's impression of the various uses of the coast. The following list provides an overview, not necessarily complete, of the characteristic functions and supporting infrastructure for each area. Obviously the list has to be expanded and adapted for practical use in specific conditions.

3.2.2. Coastal waters

Coastal waters accommodate a large number of functions, such as:

- maritime transport and navigation;
- fisheries and aquaculture;
- fresh water supply through desalinisation;
- oil and gas exploitation;
- sand and gravel mining;
- tourism and recreation;
- waste disposal and sewage treatment;

- cooling water; and
- nature conservation.

Some activities require a massive marine infrastructure; these include:

- ports and navigation channels;
- fish ponds;
- oil and gas platforms and pipelines;
- marinas;
- sewage lines and diffusers; and
- cooling water intake and outlet structures.

3.2.3. The coastal strip

Though limited in size, the coastal strip is a vital part of the coast as it accommodates a number of essential functions, such as:

- storm surge protection;
- human settlements for fishery communities; and
- recreation and tourism.

The supporting coastal infrastructure includes *inter alia*:

- dikes, coastal protection works;
- residential areas for fishery communities; and
- tourist complexes and recreational beaches.

3.2.4. Estuary

The estuary accommodates a large variety of functions, such as:

- navigation;
- fisheries and aquaculture;
- mining of aggregates;
- sewage and waste disposal; and
- fuel wood production (mangrove).

Often functions are supported by infrastructure, such as:

- Ports and ferry terminals;
- Shrimp farms and fish ponds; and
- Cooling water inlets and outlets, and pipelines.



**Figure 3: An artist's impression of the various uses of the coast
(Joliffe, I.P. and C.R. Patman, 1985)**

Legend for Figure 3:

1. Upstream dam or barrage
2. Power line
3. Lacustrine reclamation
4. Natural park or countryside conservation
5. Effluent discharge
6. Deforestation
7. Flood-prone area
8. Coastal industry or power plant
9. Estuarine urbanisation
10. Drainage and irrigation
11. Transport links
12. Redundant dock
13. Coastal airport
14. Wetland conservation or nature reserve
15. Estuarine reclamation
16. Fish farm
17. Fishing harbour
18. Caravan park
19. Coastal settlement
20. Eroding cliff
21. Marina
22. Dune conservation area
23. Inland water body
24. Hover port
25. Dredged approach channel
26. Sand banks
27. Multiple waterspace use
28. Scientific interest
29. Buoys, water skiing
30. Artificial reef fishing
31. Marine breakwater
32. Artificial beach
33. Hotel/apartment development
34. Groynes
35. Tanker terminal
36. Beach mining
37. Buoys
38. Coastal trade
39. Sea outfall
40. Aggregate mining
41. Artificial island
42. Lighthouse
43. Ferry
44. Floating or submerged storage tanks
45. Shipwreck
46. Spoil dumping
47. Navigation
48. Offshore oil and gas rigs and pipelines
49. International sea trade
50. Dumping of (toxic) waste
51. Military activities

3.2.5. The coastal plain

In general, this is the most important area as it accommodates most of the economic, public and social functions. The following is an overview of some of the activities located in this area:

- human settlement for rural and urban communities;
- industrial development;
- land, water and air transport;
- fresh water extraction;
- mining of aggregates;
- agriculture;
- irrigation and drainage;
- tourism and recreation; and
- nature conservation.

Most activities in the coastal plain are supported by a massive physical infrastructure that includes:

- urbanised areas;
- industrial complexes;
- ports, airports, roads and associated facilities;
- wells and aquifers for fresh water supply;
- quarries;
- irrigation schemes;
- tourist complexes and recreational facilities; and
- natural parks and specially protected areas.

3.3. The river basin use system

Many human activities impact upon the natural environment and, in so doing, affect the quantity and quality of water resources. This section therefore considers both the direct uses made of water resources and the human activities taking place within a drainage basin which may affect water resources. Of course, many of these operations may potentially conflict with one another, so that water management is complicated by the need to balance various demands.

Multipurpose use of water resources

Maintaining a sustainable water resource system is complicated owing to the large number of potential uses. Water resource management requires an integrated approach which balances these various uses, strengthening complementary functions and enabling critical examination of conflicts. Such an approach requires trade-offs between conflicting uses in order to arrive at an acceptable solution which not only takes economic benefit into account but also recognises other benefits which cannot be directly measured from an economic point of view.

Water “use” includes:

Withdrawal of water for various productive uses:

- domestic;
- agricultural; and
- industrial.

This is the traditional sense in which water is “used”. One of the most serious problems facing water managers is the effective allocation of an essentially fixed supply of water resources among rapidly growing and competing demand. Therefore it follows that some of the principal objectives of water supply management are:

- reducing demand;
- reducing water losses;
- controlling user wastage; and
- modifying water use types and systems.

Judicious distribution of water resources should balance competing demands without threatening other activities.

In-stream uses which require no abstraction:

- navigation
- hydro-electric power generation
- aquaculture
- waste disposal
- recreation
- tourism and landscape
- nature conservation and wildlife habitat management

Note that some of these activities make use of the river or lake directly whilst others employ the water environment in a more passive way.

Flood hazard mitigation:

Protection of life and property from flooding has long been a major concern to those dwelling in river valleys. Management of excess water is not water “use” in the strictest sense but this is nevertheless an important way in which people seek to manage water resources. Response to the flood hazard takes three main forms:

Adjustment (action on flood-prone land):

- emergency action, including evacuation
- floodproofing of specific properties
- land use regulation
- financial measures

Abatement (action in the catchment)

- afforestation
- agricultural practices to combat runoff
- retention ponds in urban areas
- management of snow accumulation and melt

Protection (action along the channel)

- dams to contain flood water
- channel modification to increase flood velocities
- confinement of floods within the channel through levee construction
- diversion schemes

Flood protection measures may lead to undesirable effects at various locations within the river system, including: loss of ecological value and biodiversity in engineered channels, inundation of land by reservoirs, nutrient and sediment retention within reservoirs, channel erosion below reservoirs.

Drought management

Shortage of water is a characteristic of many regions; drought management must integrate all facets of water resource management including water supply, water quality, irrigation and farm drainage, energy generation, fisheries management, recreation and landscape aesthetics. Response to the drought hazard takes three main forms:

Supply augmentation

- existing (e.g. inter-basin transfers)
- new (e.g. desalinisation, reservoirs)
- mixed (e.g. conjunctive groundwater storage schemes)

Demand reduction

- proactive (e.g. economic incentives, land use policies, legal measures)
- reactive (e.g. water-saving devices, legal measures, recycling, metering)
- technological adjustments (agricultural changes, urban adjustments)

Impact minimisation

- anticipatory strategies (e.g. forecasting, conflict management)
- loss absorption, acceptance and sharing (e.g. insurance, compensation, relief aid)
- loss reduction and change (e.g. affect cause, damage recovery, change water uses)

Drought management plans have tended to emphasise a series of interlocking actions revolving around six phases: preparation and planning; forecasting; mitigation; relief; recovery; post-drought measures. Effective management of the drought hazard should involve both local conservation plans and regional management of total water resources on an integrated basis.

Pollution reduction management

Water pollution control is one of the most important elements in an integrated water resource management scheme, especially where water shortages are commonplace. It is important to take into account both the point (mainly urban) and diffuse (mainly rural) sources of pollution within the catchment. Pollution management plans must take into consideration the following:

- measures to reduce the generation of pollutants at source (e.g. changes in industrial processes; pricing policies; recycling; good farming practice)
- measures to reduce waste after generation and collection (e.g. recycling; tertiary treatment of sewage effluent; buffer zones)
- measures to increase the assimilative potential of water resources (e.g. dilution, mixing, re-aeration)

Human Intervention in the Catchment System

The impact of land use and land management practices on the catchment runoff system takes many forms, affecting not just volume and timing of runoff but also the sediment and pollution load carried by the river. Deliberate modification of the runoff regime is achieved through regulation of the main channel system, especially in relation to dam construction. Inadvertent modification of catchment hydrology can result in many ways; some of the more important are discussed here.

Forestry

- Tree planting can increase the volume and speed of storm runoff if land drainage is required before planting.

- Mature forests reduce runoff, mainly because of canopy interception losses; there are reductions in both storm runoff volumes and baseflow.
- Runoff increases after harvesting/clear-cutting until vegetation cover is re-established; in regions with high rainfall intensities, there may be high volumes of runoff on less permeable soils, with much associated soil erosion, possibly decreasing dry season baseflow as a result.

Urbanisation

- Increase in speed and volume of runoff as more surface runoff and less infiltration; runoff may be even more rapid where storm drainage systems are installed.
- Decreased groundwater recharge.
- Water quality deterioration from domestic sewage, industrial effluent, power generation (heat), salts and hydrocarbons from roads.
- Ecological damage to river channels as a result of channel engineering and embankment construction.
- Loss of floodplain functions because of urban encroachment, particularly buffer zone processes (e.g. sediment trapping, denitrification) and floodwater storage.

Mining

- Suspended solids from coal mines and quarrying.
- Heavy metals from mine disposal sites.
- Leakage of organics and xenobiotics from landfill sites.
- Pollution of groundwater.
- Little impact on runoff regime.

Agriculture

- Irrigation diverts water, much of which is then lost via evaporation, which would otherwise have flowed downstream.
- Drainage and reclamation for farmland leads to the loss of important wetland functions including storage of flood waters, amelioration of water quality, fisheries, forest products, biodiversity and wildlife, recreation and ecotourism.
- Drainage of floodplain land to allow more intensive farming may lead to loss of buffer zone functions and higher nutrient export to surface waters.
- Intensive arable cropping and high densities of livestock can lead to increased nutrient export and high rates of soil erosion.

River regulation

- Direct supply reservoirs reduce downstream runoff volumes and delay flood peaks by storage.
- River regulating reservoirs reduce or increase runoff volumes according to the operating conditions; hydro-electric dams may affect the runoff regime at timescales from diurnal to seasonal.
- Evaporation losses from lakes are significant in warmer climates.
- Silt trapping leads to loss of storage capacity.
- Alteration of downstream nutrient loads and water temperature; clear-water erosion of channels.

3.4. User conflicts, constraints and opportunities

Introduction

The coast is an area with a rich natural potential for development. Present and future generations will benefit from this potential if a sustainable development policy is implemented. This should aim at a steady economic growth without losing the potential value of the ecosystem.

The potential value of the ecosystem can be expressed in non-monetary or monetary units, with reference to natural functions. It is common to make a distinction between use and non-use values. The latter represent values of the information function that should be preserved for future generations. No methods exist to measure the non-use value directly. Therefore, indirect methods, such as willingness to pay and travel cost are used to quantify the value of such assets. Non-use values determine to a large extent the so-called conservation value of the ecosystem.

Use values include direct and indirect use values. Direct use values relate to the carrier and production function. Their value can be assessed by normal economic indices. The carrier function may be expressed as price per acre; the production function can be related to market values of goods produced. More difficult to assess is the indirect use value, which is primarily related to the regulation function. Often the replacement value is used, the cost of restoring the function once it is destroyed. Use values determine the potential for economic use and development.

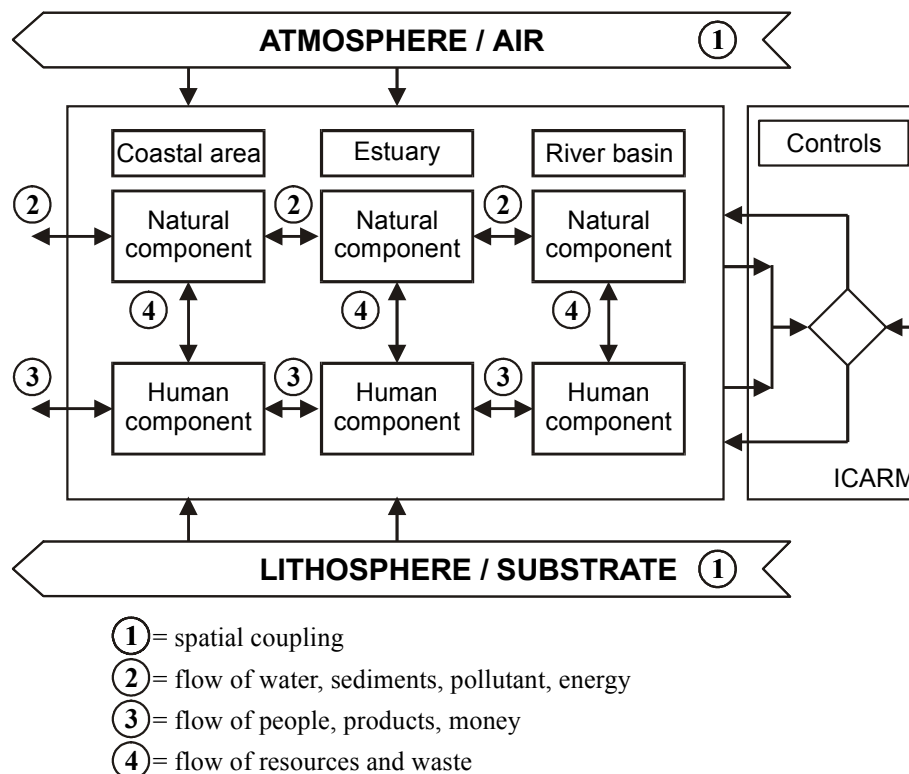


Figure 4: ICARM system analogy

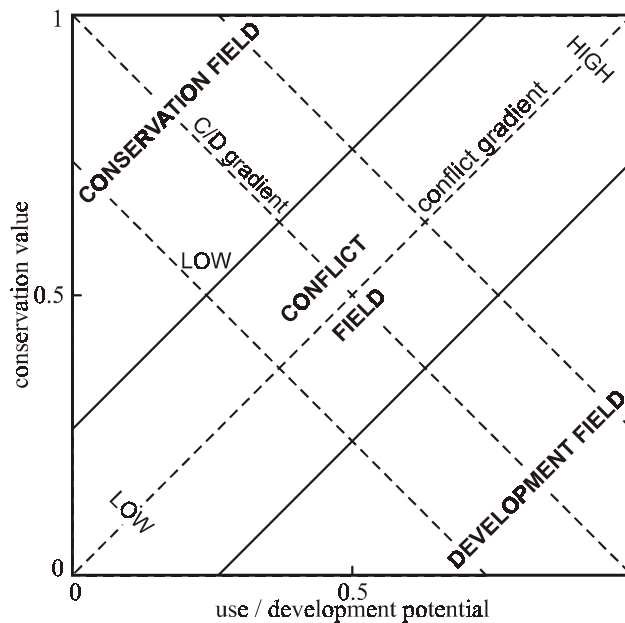


Figure 5: Conservation-development diagram (Cendrero *et al.*, 1997)

Sustainable development aims at exploiting the current use or development potential without jeopardising the conservation value. Cendrero, *et al.* (1997) have developed a method to determine values for the use or development value and the conservation value as a basis for the selection of development strategies. Both the conservation value and the use or development potential are expressed in dimensionless values using an ordinal scale, with values ranging between 0 (no value) to 1 (maximum value possible). Maximum values are defined by a number of experts, using the Delphi method to handle uncertainties. Values are plotted in a diagram with the two parameters as principal axes. Such a diagram is shown schematically in Figure 5.

Figure 5 can be used to select the most promising development strategies for specific coastal areas. Areas with a low conservation value but a high use potential should be developed first (the development field in the diagram). These areas offer strong opportunities for development, therefore. In these areas EIA procedures should be strictly followed to demonstrate that negative effects on the conservation value are within acceptable limits. Alternatively, areas with a high conservation value like wetlands, with low potential for development, should be safeguarded (the conservation field in the diagram). Developments in these areas should be resisted. In the remaining fields, both values are of the same order, causing conflicts between conservation and development (conflict field). Conflicts are more severe in high-value areas and less in low-value areas. Further in-depth analysis of these conflicts is required before a development strategy can be formulated. A first step in this analysis is the use of conflict matrices, as described in the next section.

User conflicts: the conflict matrix

The natural system is a multi-resource system, which provides goods and services to a multi-user system. Moreover, users discharge their unwanted products back into the natural system as waste. It is the objective of ICARM to manage the interaction between the two systems in such a way that the interests of both systems are safeguarded, and that conflicts between conservation and development are resolved.

<div> <div>User function</div> <div>Function of nature</div> </div>	Urbanisation	Subsistence	Economic activities	Public activities	Social activities
Carrier function	↓ →	↓ →	↓ →	↓ →	↓ →
Production function	↓ →	↓ →	↓ →	↓ →	↓ →
Regulation function	↓ →	↓ →	↓ →	↓ →	↓ →
Information function	↓ →	↓ →	↓ →	↓ →	↓ →

Figure 6: Impact matrix

The guidelines for coastal zone management, produced by UNEP/PAP advocate the use of conflict matrixes to visualise these conflicts. A slightly modified matrix is proposed here, as shown in Figure 6. The vertical columns represent various uses or user groups on the demand side. The horizontal rows represent the various functions of nature that can supply the required resources. The cells indicate how users interact with these functions of nature. A vertical arrow shows that the user has an impact on the corresponding function of nature, through land use, resource use or waste emission. The impact matrix can be used for various spatial scales, ranging from the shoreline to the full river basin. Obviously, due to the linkages between the various components of the river basin complicated cause-effect relations have to be used to assess the impact of local activities on the whole basin. These cause-effect relations can be visualised and quantified through the coupled ICARM systems analogy as described in the previous section.

In general, primary impacts on the natural system include:

- Impacts on the use of the territory (conflicts with the carrier function);
- Impacts on the quantity and quality of the natural resources (conflicts with the production function);
- Impacts on the structure and function of the ecosystem (conflicts with the regulation function); and
- Impact on the natural and man-made landscape (conflicts with the information function).

The horizontal arrows show that a function of nature is of great importance for the corresponding user group. The vertical arrow shows that such users will be adversely affected if the function is lost. The matrix can be used for an initial qualitative assessment of potential conflict areas. The analysis does not provide any quantitative information on the severity of the conflicts, however. In the next section, a more quantitative evaluation method will be described, known as the pressure-state-response diagram, which can be used as a tool to select most promising development strategies.

User conflicts: pressure-state-effect-response diagram

The pressures

In order to quantify the interactions between the various users and the functions of nature, a sequential cause-effect analysis can be made with the help of the systems analogy. In this guideline we apply the method advocated by the OECD called the pressure-state-response approach. The approach is shown schematically in the P-S-E-R diagram in Figure 7. The various parts of the diagram are explained below.

The upper box is used to define the *pressures* of the user system on the natural system. Land use, resource use and discharge of waste products cause pressures on the natural system. These pressures are computed for various users and aggregated for user groups or economic sectors. In this way pressures due to changes in land use, resource use and waste emissions are established for the various sectors.

Typical pressures generated by human activities are shown in Table 2.

The state of the environment

Pressures cause changes in the natural system. Natural functions are affected and degradation of the natural system may be the result. The corresponding changes in state variables can be predicted by means of the systems analogy and will result in new state variables for the system. The second box is used to define this impact on the receiving medium. Vertical columns represent various components of nature: the air, land or water component of the sea, estuaries and rivers. The rows indicate the different functions of nature for each component. The impacts are expressed as changes in state of the environment indicators, selected system parameters which are related to the more important functions of nature.

Effect indicators

As shown in Figure 7, changing environmental parameters may adversely affect the user functions. The above impact matrix may be used to define which user functions are affected by the changes in state indicators. For most user functions threshold values for environmental state parameters have been defined which should not be exceeded. In the third box these aspects are further elaborated for selected user functions, and results are expressed in terms of effect indicators, selected system parameters which are often related to human health and well being.

Response and controlling actions

In the P-S-E-R diagram this is further elaborated in the fourth box, which shows response actions by individuals, public, and private bodies.

The systems analogy can now be used to assess the effect of these interventions on the various functions of nature and hence on the users.

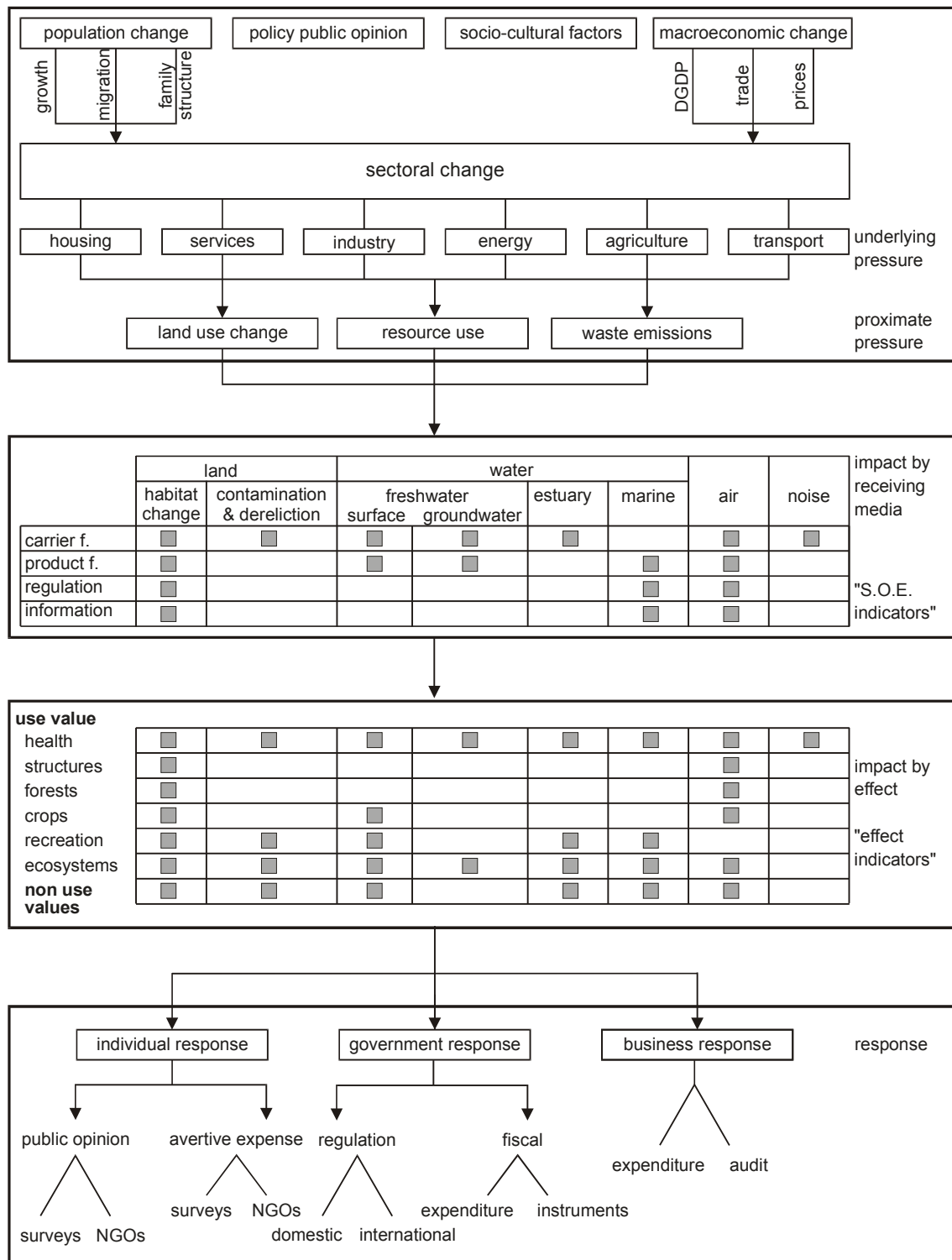


Figure 7: General pressure-state-effect-response (P-S-E-R) framework (based on OECD environmental indicators format)

Human activity	Impact on water related processes	Impact on transport of sediment	Impact on transport of other substances
Urbanisation, Tourism	Changes in runoff. Use of surface and ground water for water supply.	Changes in sediment yield.	Pollution due to sewage and solid waste.
Agriculture	Use of surface and groundwater for irrigation. Lowering of water table, saline intrusion increases risk of flooding due to subsidence.	Catchment erosion due to changed land use. Changes in sediment transport due to subsidence.	Pollution due to pesticides and herbicides. Eutrophication due to nutrients.
Deforestation	Changes in runoff.	Catchment erosion.	Increased nutrient export
Industry	Use of surface and groundwater as process and cooling water.		Thermal pollution Pollution of surface- and groundwater due to waste disposal and storage.
Hydropower	Changes in river regime.	Changes in sediment transport sedimentation	
Thermal and nuclear power stations	Use of surface water as cooling water.		Thermal pollution.
Oil and gas exploitation	Increased risk of flooding due to subsidence.	Changes in sediment transport due to subsidence.	Pollution of surface- and groundwater due to waste disposal and storage.
Large physical infrastructure	Changes in runoff	Changes in sediment transport.	Pollution during construction and operation.
Yachting, navigation		Changes in sediment transport due to dredging.	Pollution, human waste and oil spills.
Fisheries and aquaculture			Eutrophication due to nutrients
Atmospheric inputs	Changing rainfall patterns and sea level rise due to climate change.	Changing sediment transport due to climate change.	Pollution due to acid rain.
Land-based inputs	Interbasin water supply, river diversion	Changes in sediment transport due to changes in neighbouring areas.	Landfill.

Table 2: Pressures on the natural system due to human activities

Chapter 4. Towards a Strategy for Integrated Coastal Area and River Basin Management

4.1. Approaches to management of river basins and coastal zones

River basin management and coastal zone management come from two different traditions. River basin management stems from a water resource management perspective. From early consideration of the river as a hazard for flooding, the water flowing to the sea as wasteful and shallow channels as an obstruction to navigation, there followed the recognition of ecological and landscape values and the need to protect water quality and the environment. This has brought a “holistic” approach to river management placing emphasis on the management of water quantity and quality and sediment transport.

River basin management focuses on a single resource (water) with multiple uses placing emphasis on environmental management through multi-sectoral co-ordination with some elements of land-use regulation.

Coastal management stems from two perspectives: marine resource management and physical planning. The former relates to fisheries management (in the broadest sense). To the extent that fisheries may be threatened by land-based activities and waste, the interest of the management scheme extends to the landward side. The latter is strongly based on the tradition of planning, focusing on the rational allocation of land use (including sea use) to human activities (tourism, industry, urban development, etc.) but also on the need to protect the coastline. To the extent that such activities affect the narrow coastal strip, planning may include use of the sea as well. The approach is based on the perception of coasts and coastal zones as common property which is, therefore, in need of protection and regulation. The recent strong impetus for environmental protection has accelerated the need for an integrated approach to coastal management merging of all the above concerns but also extending the interests of coastal management to broader issues, such as pollution from land-based sources, etc.

Coastal zone management focuses on multiple resource and multiple use management based on physical planning and resource management with a strong emphasis on land-use regulation and physical interventions.

The basic difference between river basin management and coastal management lies in the environmental conditions and factors, the natural processes, the human activity characteristics and pressures, the various stakeholders and their needs, and the institutional context, but also the interventions (policy tools) employed. It is evident that river basin management and coastal zone management do not always share the same concerns. However, because they often share space and resources, they also share issues and problems. To the extent that one influences the other, river basin management and coastal management can be directly linked:

- a) On a *local* scale by focusing on:
 - controlling key processes especially the flow of water and sediment;
 - managing critical issues;

- controlling waste and pollution;
 - assuring that the quantity and quality of water arriving downstream is adequate for coastal sediment budgets and for the conservation of habitats;
 - protecting areas of high ecological value of mutual interest such as wetlands, river deltas and estuaries; and
 - siting of projects and structures.
- b) At a *national* level by focusing on:
- establishing a mechanism for co-ordinating goals and decisions of all stakeholders;
 - integrating socio-economic considerations with environmental issues;
 - identifying and evaluating human pressures; and
 - linking broader issues with river basin and coastal systems.
- c) On an *international* scale by focusing on:
- establishing resource monitoring schemes; and
 - establishing large ecosystem management schemes.

It should be noted that the hinterland may not be linked with the coast just through water-related issues. Sediment transport, natural ecosystems and particularly human use patterns provide interlocking mechanisms which impose an integrated approach to the management of river basins and coastal zones.

Integrated Coastal Area and River Basin Management (ICARM) is the adoption of goals, objectives and policies and the establishment of governance mechanisms which recognise the interrelationships between the two systems with a view to environmental protection and socio-economic development.

The following constitute the key characteristics of ICARM:

- The objective of ICARM is to develop the sustainable production of goods and services required by society and to resolve conflicts in resource allocation for the production of these goods.
- ICARM encompasses the catchment area and the adjacent coastal zone and takes into account ecological, economic, social and cultural aspects of this area at various levels of governance.
- ICARM is based upon a coherent set of strategic, tactical and operational activities and uses technical and managerial instruments to realise its objectives.
- ICARM is action-oriented in nature, continuous and adaptive in time and participatory *vis a vis* public and private stakeholders.

The basic *principles* of ICARM in the context of sustainable development include:

- Respect the integrity of the river basin or coastal ecosystem accepting limits on the use of resources;
- Ensure the strategic importance of renewable resources for socio-economic development;
- Allow for the multiple use of resources integrating complementary activities and regulating/separating conflicting ones;
- Ensure multi-sectoral and multi-level integration in decision making, linking broad-scale management to local-level interventions; and
- Allow for participation of all stakeholders, particularly the local population, in the planning process to assure effective management.

Box 2

About goals of ICARM

The Schema Directeur d'Amenagement et de Gestion des Eaux (SDAGE) for the Rhone-Mediterranean-Corsica Basin is a river basin management plan. The area under study extends from the Mediterranean coastline far into the continent, encompassing the whole basin of the biggest river in France. Although SDAGE is a medium-term water resources management plan, it also aims to promote socially and economically sustainable development of the area. In particular, it aims to integrate the management of a large and complex catchment area and to fulfil the collective needs of the entire population, giving priority to public health. In particular, the plan aims to manage water resources including water pollution, guaranteeing the high quality of water, giving priority to good management before making investments, and respecting natural systems and their preservation.

Source: World Bank. (1997). "Assessment of Integrated Coastal Area Management Initiatives in the Mediterranean: Experiences from METAP and MAP (1988-1996). The World Bank: Washington.

The goals of river basin management and coastal zone management fall within the scope of sustainable development where economic efficiency and social equity goals are linked to environmental conservation goals. In this context the goal of integrated coastal and river basin management is the promotion of sustainable development including the maintenance of all essential ecological processes, life-support systems and biological diversity, while providing local communities with a basic healthy quality of life and reducing their vulnerability to hazards.

In order to realise these objectives, ICARM will focus on efficient use of space and resources, effective reduction of waste emissions, and preservation of valuable ecosystems. To that end, ICARM will apply modern management techniques to ensure multi-sectoral and multi-level integration and will foster participation of all stakeholders involved in the decision-making process.

The *general objectives* of ICARM stem from the need to express such goals in terms of long-range considerations and medium- or short-range needs, allocating resources to various users and maintaining at the same time the proper function of natural ecosystems. In particular ICARM seeks to:

- develop human resources and strengthen institutional capacities;
- ensure participation of all different stakeholders from both the private and the public sector, in both the upstream and downstream areas;
- protect traditional uses, when proving to be beneficial for both local socio-economic development and environmental protection, and rights and equitable access to coastal resources;
- encourage complementary rather than competitive activities;
- identify where resources can be harnessed without causing degradation or depletion;
- renew or rehabilitate damaged resources for traditional or new uses;
- guide the level of use or intervention so as not to exceed the carrying capacity of the resource base;
- ensure the integrity of coastal and river basin ecosystems;
- ensure that the rate of loss of renewable resources does not exceed the rate of replenishment;

Box 3

About specific objectives of ICARM

Specific objectives for freshwater might include:

- Improve efficiency of water use;
- Reduce water treatment costs through improvement of the quality of water before treatment (preventive approach);
- Improve sustainability of water supply through pricing;
- Increase amenity values of surface water;
- Protect habitats and species both in water bodies, wetlands and surrounding areas.

Specific objectives for natural ecosystems i.e. wetlands might include:

- Maintain water quality;
- Reduce erosion;
- Protect from floods;
- Provide habitats for species.

- ensure that benefits from the exploitation of non-renewable resources are used for sustainable development;
- reduce risks to vulnerable resources; and
- respect natural processes, encouraging beneficial ones and preventing adverse interferences.

Furthermore, the translation of broader goals (i.e., economic efficiency, social equity and environmental conservation) into objectives must not be done in a linear, independent way. Instead economic issues need to be integrated with social and environmental ones. The definition of objectives must take into account the particular circumstances, both environmental and socio-economic issues of each case. The objectives need also to be linked to the particular *spatial/geographical* context of the area. The objective and corresponding strategies should reflect the nature of the complex issues encountered in the river basin and coastal areas, which are multidimensional, multiobjective and multispatial.

4.2. Policy Priorities

Defining priorities for integrated coastal area and river basin management is essential in spite of an apparent shift from integration and a holistic, long-term point of view. Often, the identification of priorities may be influenced by “fashion, the availability of data, the offer of external funding, sectoral needs, or political imperatives”. In the context of rational management, priorities should be set on the basis of objectives and available resources only then taking advantage of local resident, official and political support, in the hope that successful intervention will create opportunities for more generalised action.

It is possible to identify in which specific *areas* of both the river basin and coastal areas the *issues* and *needs* identified seem to be most pressing. Therefore, priorities can be defined in spatial terms. Within this context, areas and resources of high development potential, urgent needs, fragile ecosystems and vulnerable populations may be identified as suitable for the adoption of integrated management measures. Priorities may also be defined in terms of uses taking into account the long-term availability of resources.

Setting priorities may help the stakeholders involved to structure a simpler, clearer picture of what the goals and expectations of ICARM are. The complexity and the need to address other issues as well will become evident during the planning process, although it requires a lot of effort so as to avoid scaling down the initial ideas in favour of practicability and short-term efficiency.

4.3. Strategies

Integrated Coastal Area and River Basin Management (ICARM) draws from natural resource management, environmental management and land-use planning:

- *Natural resource management* focuses on the identification and valuation of key natural resources, putting in place rules and priorities for their development with a view to sustainable development.
- *Environmental management* deals with a range of environmental quality issues, from species to ecosystem management.
- *Land-use planning* concentrates on the allocation of uses to resources and spatial areas with a view to anticipating future developments. It is also concerned with infrastructure development.

In all three of the above the need to extend the scope of intervention towards an integrated approach to river basin and coastal area management is often evident:

- In the management of natural resources, the impact of resource use is occasionally felt outside the area where the resources are produced; this calls for an extension of the spatial coverage of the management process. Moreover, interaction with the outside world becomes more dynamic which requires insight into processes operating within the system. Management focuses on controlling the production function both in terms of the structure of the system and the driving processes. Since in many instances production is governed by slowly varying processes, a quasi-static approach is used.
- Environmental management is related to the control of large, dynamic ecosystems. The management of the regulation and information functions is now the leading issue. This often calls for an extension of the spatial coverage, as is the case in ICARM. As the regulation function is often governed by rapidly varying processes, a dynamic description of the system is required.
- In land-use planning, well defined spatial units (zones or areas) are often selected with little interaction with the outside world. The objective is to control the carrier function within these boundaries through the topological and functional structure of the system.

Strategy formulation within the context of ICARM cannot be described as a unique, reproducible process, applicable to all kinds of case studies nor there is a single solution for each case. Practice has indicated that there is a variety of strategies which can be developed:

- *On the case study particularities* - an area which is polluted will need a completely different strategy compared to a natural area where the emphasis may be on preventing, reducing or eliminating pollution. This is done by giving priority to interventions at source and ensuring prudent management of natural resources in compliance with the “Polluter-Pays-Principle” and the principle of pollution prevention.

- *On a broader regional or national scale*, the existence of a national institutional framework, and the economic opportunities/constraints arising from the broader region, will determine the need for specific solutions.

It is quite often the case that a strategy needs to address issues which have an impact on the management of the water or the coast but which fall outside of the authority of the people participating in the process since either:

- the source of the problem lies outside the River Basin District, or
- the issue can only be dealt with the measures or legislation available at a national or supra-national level, or
- the issues relate to policy areas over which the people involved have no control.

In such cases, external factors have to be introduced as driving forces together with internal factors and developments.

Strategy formulation will vary depending on the framework provided by existing institutional contexts (laws, regulations, authority, responsibility, decision-making structures, etc. or established practices) and problem structure. It might be necessary, for example, in cases of intense conflicts over the use of land (usually associated with intensive urbanisation pressures or agricultural development) to rely on “strict” regulations controlling development in the form of land-use planning. In another case, it might be enough either to rely on institutional arrangements (e.g. special committees, standards, etc.), or it might be wiser to attempt to integrate socio-economic development concerns and objectives to environmental conservation in the form of better sectoral policy co-ordination regarding resource usage. In a more rural context, for example, it might be enough to rely on environmental management alone, setting conditions for the development of human activities in general terms. There is no single approach and quite often it is necessary to employ a mix of strategies.

Furthermore, strategy emphasis will change across operational or administrative levels. At a local level, it has to reflect local complexities, for example focusing on the identification of areas of soil or vegetation that need to be preserved. At this scale, land-use planning close to the coast may be the key strategy. At a sub-regional national level (a river basin), emphasis could be on resource management policies possibly encompassing land-use plans for key areas. At a national level, institutional issues and the establishment of a policy framework could be the core of a strategy providing guidelines for the development of regional and local plans.

Part II: PLANNING GUIDELINES

Chapter 5. The Process of Planning of Integrated Coastal Area and River Basin Management

In establishing an integrated management system for river basins and coastal zones, it is necessary to adopt a pro-active approach. In this context planning acquires a special role in establishing a process of governance and a strategic framework of goals, policies and actions. This takes the form of a strategic integrated management plan which can be specified in spatial terms and which requires consideration in advance of changes anticipated in the medium- and long-term. The emphasis is here on the process of establishing priorities and actions for integrated management of a coastal area and its river basins.

The process might look similar to ICAM (the process of Integrated Coastal Area Management as proposed in UNEP/PAP Guidelines) because the basic steps in decision making and planning are more or less the same. However, the focus of analysis (scale, characteristics, issues and patterns of interactions) reflects the structure and dynamics of relationships between river basins and coastal zones as described in previous sections. As a result the strategies are different since the critical issues are not always identical.

5.1. Phases of the process

Planning is a cyclical process following a sequence of basic steps from analysis to synthesis and action which for the purposes of these guidelines can be distinguished as follows (see Figure 8):

- *Initiation*
This is the basic inception task which involves organisation and mobilisation for planning.
- *Analysis of the existing situation*
This step involves essentially a reconnaissance survey of basic characteristics in terms of the structure and dynamics of natural and human ecosystems. Therefore, it deals with the critical processes and factors, their extent and spatial distribution, etc.
- *Identification of conflict and opportunities*
This step deals with the interaction between natural and human ecosystems today and in the future. It includes the analysis of needs of and the pressures on the basic stakeholders; these influence decision making in development and environmental management.
- *Identification of goals and alternative courses of action*
This step involves an analysis of critical factors and processes, conflicts and opportunities in order to identify basic management goals and objectives. These should be formulated with a long-term perspective in the context of sustainable development principles. Alternative courses of action can be then identified reflecting the different priorities which may be placed on goals and objectives.
- *Development of a strategy*
A selection is made, in the context of public policy making, from among the alternative strategies identified above in order to translate the goals and objectives

into targets and policy measures, with the aim of developing a guidance system for environmental management. The institutional setting influences such decisions as it identifies stakeholder responsibilities and legal/administrative procedures. This step involves commitment to mobilise resources and priorities in the form of a programme of action.

- *Implementation*

This phase involves the actual implementation of the programme of action and is strongly linked to the next step.

- *Monitoring and evaluation*

This provides for administrative procedures and mechanisms to review periodically progress towards the achievement of goals and objectives, through assessment, of the state of the environment and policy implementation.

The planning process is cyclical allowing for periodic review, assessment and revision of goals, strategies, priorities and measures.

Finally, remember that these steps are indicative and outline a typical process, which must be adjusted depending on the specific situation at hand.

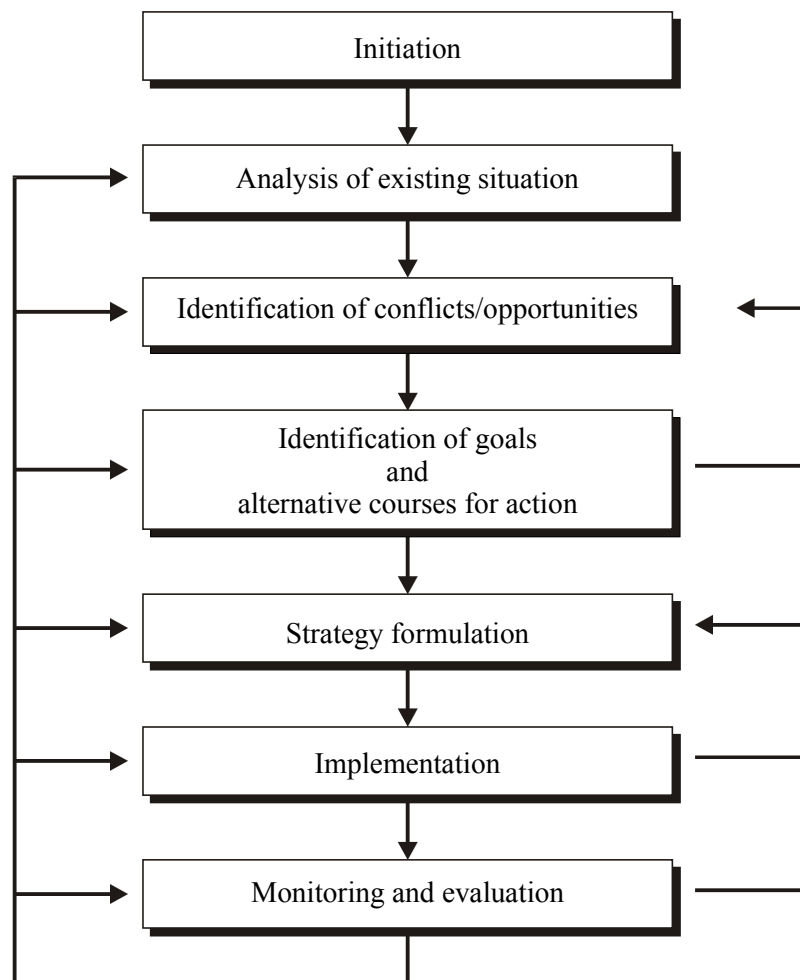


Figure 8: Planning process of ICARM

5.2. Description of the ICARM process

5.2.1. Initiation

Initiation of an integrated river basin and coastal zone management process includes identification of the key factors (sometimes called triggering factors) which may contribute significantly to the awareness of the public with respect to coastal and river conservation and management and encourage the adoption of action plans.

Factors that can trigger initiation of the ICARM process could include:

- urgent problems, e.g. the need for water, the need for economic development;
- decisions, both past and present, that have resulted in or are likely to result in severe environmental degradation, accidents, or conflicts over the use of important resources;
- broader initiatives promoting integrated management, e.g. international agreements, national development plans, water master plans;
- increased awareness from the public, arising either from the growing problems or the demand for improved environmental quality (as a key aspect of the quality of life itself).

One or a combination of the above factors may initiate the process of ICARM. Last but not least political willingness and commitment by all interested parties is fundamental for the initiation of such processes.

At this stage, a *proposal* may have to be written describing all activities of the preparatory phase. This proposal could contain the prerequisites for ICARM (such as political will, scientific knowledge, existence of a national framework for ICARM, recognition of the values of river basin and coastal areas and the benefits arising from their sustainable management, financial aid), the general goals (to be specified later), the geographical area under consideration, the people, institutions, organisations expected to participate, available finance and a workplan with a corresponding timetable.

Decisions related to the spatial scale need to be taken well in advance. This is not always an easy task. It is interesting to note that apart the similarities that exist between river basin management and coastal management, which can be attributed to the fact that these two systems share part of the same territory (a coastal zone can always be considered as part of a river basin), there are some important differences which seem to make decisions on planning issues more complex:

- A basic issue is the different types of ecosystems in coastal areas and river basins (fresh water, terrestrial or marine) although there are some in common in transitional zones, such as coastal lagoons, wetlands or estuaries.
- Another issue is the scale of the territory, which influences the scope of planning. River basins are generally much larger units than coastal areas as already discussed in Chapter 2.1. The scale of the territory determines not only the relevant processes but also the management goals and related measures. Scale is also related to the issue of boundaries as discussed below.
- An important issue for planning and management is also that of time. Processes in river basins and coastal areas may involve different forces and time frames. Changes and impacts can be seen over different time periods. In addition, there are cyclical variations (daily, seasonal, annual, etc.) in driving forces and processes which have to be considered. Some rivers are subject to periodic (seasonal) floods while coastal areas are subject to daily periodic influences (i.e.

tides). Surface water and groundwater are in principle renewable resources. However the time required for their formation and renewal is different and, as a result, planning protective measures need to be differentiated.

- The issue of boundaries may be quite difficult since river basins are clearly identifiable geographical units while coastal areas are not easily defined either in terms of the inland boundary or seawards. The issue of boundaries and delineation of management zones is discussed further in the section 5.2.3.

5.2.2. Analysis of existing conditions and forecasts

This stage is quite important as it will input into the formulation of goals and objectives and leads to the definition of management strategies for sustainable development in river basin and coastal areas. It should be stressed that the whole process at this stage is issue oriented. There are various terms used to describe this stage: profiling, environmental assessment, S.W.O.T. (Strengths-Weaknesses-Opportunities-Threats) analysis, etc. They all aim to describe the system and identify the key issues.

In this stage the following steps are undertaken:

1. Surveys of selected key issues, both socio-economic and ecological. New data will be collected if gaps have been identified and if information on these issues is fundamentally important.
2. Analysis of the natural systems present in both the coastal areas and the river basin. The main purpose of this is to report on the impact of human activities on natural resources and ecosystems. Within this context detailed information is collected on:
 - current rate of resource use according to present socio-economic activity;
 - assessment of the impacts of resource use practices on the state and stock of natural resources;
 - estimation of waste generated and of the fraction being discharged into natural systems, including calculation of the waste that is being generated in other regions but discharged to natural systems within the region under study;
 - assessment of possible effects of climate change; and
 - impacts of socio-economic activities on natural resources and ecosystems.

For this, the following data will be required:

- *basic environmental data*, biology, topography, hydrology, geology;
- *natural resources* including water, agricultural land, forest, fishery and aquatic resources, natural heritage, minerals;
- *environmental hazards* including floods, geotechnical hazards, cyclones, volcanic activity;
- *spatial (terrestrial and sea) uses* including all economic sectors, urban development, infrastructure; and
- *networks* including water supply and drainage, waste disposal and transport.

Data should also indicate seasonal changes and other temporal variations.

A fundamental need for successful coastal and river basin management is the identification and evaluation of the current state of resources:

- In the river basin system, all water resources and water-related resources including wetlands need to be identified and if possible quantified. Evaluations should include both water quantity and quality and should refer to both surface and groundwater resources and coastal waters. The interactions between different water resources need to be highlighted and evaluated. Biophysical processes and hydrological functions need to be carefully studied.
 - In the coastal system, although the whole system is the focus of management and the area is of high biological diversity, some critical areas, such as tidal flats, beaches, and coral reefs, are of high value and the pressures affecting them need to be addressed as a priority.
3. Analysis of the socio-economic context along with their spatial implications. Within this context information on the following issues needs to be generated: demography, economy, social structure, spatial patterns, and institutional issues. A link to risk issues, such as sea level rise for the coastal areas, needs to be made as well.
 4. Forecasting future developments. This can be based on projections of existing trends and forecasts of activities not currently affecting the region but expected to affect the natural systems of the river basin or of the coastal area, or both, in the future. This can be done with the help of cross-sectoral scenarios.

5.2.3. Delineation of management zones

River Basin

The delineation management zones within a river basin relates to the distribution of physical features (geomorphology, hydrology, etc.) across the entire drainage basin. In that sense it usually encompasses a large area, even though interest is often focused on a narrow strip alongside the river. The definition of such a strip is a function of natural ecosystems but also relates to land use. In general one can distinguish between:

- A *strip* extending just beyond the river banks, usually identifiable on the basis of river-related flora and fauna;
- A *riparian (buffer) zone* extending over a few hundred metres either side of the river which is delineated on the basis of either physical features or land use;
- The rest of the *drainage basin*, which influences the river in terms of water, material and energy flows.

Box 4 **Area definition in ICARM**

The coastal area inside the terrestrial part extends to the boundaries of the closest *watershed area*, while the marine area extends towards the presumed area of inference of the discharged waters (generally it is considered to be the 100m *bathymetric line*). The SDAGE had also recognised 50 homogenous zones that represent coherent *management units*. Each one of these units constitutes a homogeneous zone for an optimal integrated approach to the management of rehabilitation and conservation, as well as exploitation of the coastal area.

Source: Comité de Bassin Rhône-Méditerranée-Corse. (1995). Schéma Directeur d'Aménagement et de Gestion des Eaux (SDAGE).

Coastal Zone

The definition and spatial delimitation of coastal areas depends on physical (geomorphology, hydrology, etc.) and ecological (terrestrial and marine ecosystems) factors, human activities and land use (type and intensity of development), as well as on institutional factors (administrative and legal framework regulating development and use of space).

From a management perspective, depending on the physical and ecological features, and the human activities present, there are several zones which can be identified in coastal areas:

- a *critical zone* or a narrow band of land and sea a few hundred metres wide, adjacent to the shoreline, usually of highest ecological value and subject to intense pressures for development;
- a *dynamic zone* which may extend both inland and seaward, usually a few kilometres wide, where there is strong dependence and/or influence of human activities and natural processes on coastal features and resources; and
- a *wider zone of influence*, often many kilometres wide which influences in part, directly or indirectly, the other two zones.

These zones can be further broken down in smaller geographical units on the basis of environmental and socio-economic development/land-use criteria (i.e. valleys, enclosed bays, upland rural areas, tourist zones, etc.) which could be used for differentiating policies and actions from a management perspective.

5.2.4. Identification of conflicts/opportunities

Problem definition is considered to be a key point of the whole process of integrated coastal and river basin management as it determines the scope of management and planning. The problem must be initially defined but is often restructured, modified, or reformulated as information and understanding increases. In complex cases problem definition is a goal in itself. However, it is very important that all participants agree on what the problem is, since many different problem definitions may appear in the first place. Problem identification is related to goals definition. Because of this conflicts may be identified at the very early stages of the planning process.

Problems are identified particularly in terms of environment/development interactions. The Pressure-State-Effect-Response matrices, discussed earlier, are particularly helpful in structuring such interactions. Conflict is not the only source of input for management. Of equal importance is the identification of opportunities - for development but also for intervention or action in general. These can be identified not only with respect to the environmental quality of resources and ecosystems, but also in terms of economic and social development. Problems also need to be classified in many different ways: in terms of time (i.e. if they are urgent or not), in terms of irreversibility (reversible, non reversible), in terms of their impact on ecological values, etc.

5.2.5. Identification of goals and alternative courses for action

On the basis of the analysis of conflicts and opportunities, goal setting follows. This is an important step of the ICARM process and needs to be sustained until the goals are achieved (or revised if that proves necessary). Public participation is essential as well as that of the "corporate" stakeholders. These may represent the public sector, usually having various responsibilities over river basin resources and the coastal zone, but they may also be from the private sector, for example, the large scale industries.

Goals can be of three types: global (goals which are general and do not result from area-specific requirements) area-specific and sectoral. Goals need to be as clear as possible to provide guidance. They may be conflicting but not contradictory.

Furthermore, goals may be interpreted into a set of objectives which will help the achievement of the goals. The objectives are operational statements of purpose (policy statements) and can be short or medium-term and when possible expressed in a quantitative form. Goals are important as criteria for selecting further along among alternative courses of action.

The next step is the formulation of possible strategies which aim to achieve the goals and the objectives. A strategy consists of goals and objectives which are linked in a coherent way. They may relate to existing strategies or develop new ones. Obviously the existing situation has important constraints on potential action, and therefore conditions to a large extent strategy formulation.

Once sectoral and cross-sectoral objectives are defined, the next step is to pursue their integration. The multi-dimensional character of the problems encountered in river basin and coastal area management suggest that there could be a range of alternative objectives and policies which could be pursued. Quite often alternative strategies are generated by combining objectives and policy options. Each strategy should include criteria which will help in evaluation and implementation, since they indicate the limits within which the use of resources is permitted so as to protect them from irreversible damage.

Management strategies may be proactive or reactive. Proactive options include government initiatives for controlled development of pristine areas, integrated rural development of uplands, etc., all aiming at anticipating future development and providing guidance mechanisms for future action. Reactive approaches range from beach erosion to flood mitigation, restoration of wetlands, support of declining agricultural activity, etc., actions which are driven by urgent problems requiring corrective measures. In many instances proactive plans are preceded by reactive strategies, triggered by conflicts or opportunities. In general, one can identify some of the following conflicts/opportunities:

- among users, which are addressed by land-use plans (i.e. for forest development or tourism, etc.) or resource allocation plans (i.e. for water development or energy production, etc.);
- between users and the environment, which are addressed by pollution abatement plans and environmental management plans; and
- between the environment and users, addressed by hazard management plans (i.e. flooding, beach erosion, etc.).

Alternative strategies, meaning alternative ways to alternative future(s) need to be evaluated in order to select the best one to follow.

In this phase, a systems analogy may be used, supported by databases, GIS techniques and simulation models. GIS is used to visualise the structure of the system, whereas models are applied to describe the driving processes. System simulations are used to compare various strategies arising from the different input scenarios.

In the selection phase, the output of these simulations is used to evaluate the various alternatives. Multi-criteria techniques are applied to discriminate between the various options. Often Decision Support Systems are applied with a user friendly Graphical

User Interface and facilities to manage the analysis process. Sophisticated multi-media techniques are now available to communicate the results to the stakeholders.

The basic purpose of all these methods and tools is to study the impacts of development on the environment and, on this basis, to evaluate alternative courses of action in terms of their potential benefits and costs. The final output of this stage is the selection of strategy.

"Who selects?" and "How?" are important issues at this stage of the planning process. Answers to these questions have to be sought through the institutional setting in the area (river basin and coastal zone) since there are wide variations across the world in this respect. Legitimisation, presence/importance/influence, expression of public interest, etc. are among the criteria often used to select between the various stakeholders.

5.2.6. Development of a strategy

In the previous phase, a long-term strategy has been formulated. The task of this phase is a detailed elaboration of this strategy which should include:

- the specification of policies and measures; and
- an Action Plan which will guide the implementation of the strategy in the short and medium term.

The first of these can take the form of a "Strategic Action Plan" which should include key issues, such as future population growth, socio-economic development targets, infrastructure development, basic land-sea-river use allocations, designation of environmentally sensitive areas for conservation, legal and institutional issues and financial aspects in terms of required financing. The Plan translates goals and objectives to policy measures (regulatory, physical or economic) and puts priorities on actions.

This can be further elaborated, if necessary, in detailed area-specific Master Plans (for priority zones) which include proposals for land and sea use where sectoral policies and programmes of action related to the development and protection of the resources of the area are well integrated. Such a document can incorporate provisions for agricultural land, forestry, industrial areas, residential areas, tourism and recreational areas, sea uses, systems of urban and rural centres, protected areas, open spaces, transport corridors and areas, other infrastructure, major public works, etc.

Besides this, the Strategic Action Plan needs to define the administrative context along with the regulatory framework required for its implementation. Usually, implementation depends on the existing legal framework but there could always be suggestions for new legislation or people that need to participate in the process. The reference to regulatory context must include all necessary details, such as, for example, the instruments to be used (i.e. building permits, written regulations, etc.). Financial and technical feasibility aspects need to be addressed, as well.

Due to its complex nature ICARM requires a high level of co-operation within and between institutional structures. A high level of horizontal co-operation is required particularly among sectoral institutions at the planning stage and a high level of vertical co-operation is necessary within institutions at the implementation stage. The institutional framework should also pursue integration in managing quantity and quality issues for both surface water and groundwater.

It should be emphasised, however, that there is a strong interdependence between the river basin system and the coastal system. In terms of ecological processes, the existing institutional framework does not recognise this "internal" linkage.

ICARM depends on the participation of several stakeholders from both the public and private sector. The nature of their power is usually of three types:

- executive;
- judicial (enacting regulations, enforcing standards); and
- market.

Usually, all of the above are involved.

In addition, as issues often transcend administrative boundaries, one needs to work on three different levels: national, sub-national, and local. At each level different responsibilities are assigned:

- At the national level the policy issues related to both the formulation and implementation of the ICARM process must be defined. A strategy needs to be elaborated providing the necessary guidelines for local and regional initiatives. If necessary, an agency which will be responsible for coastal and river basin management at a national level needs to be identified as well. Environmental and conservation standards will be set at this (national) level. A committee which will work on the sectoral concerns, allowing for the participation of all interested ministries may also be formed.
- At the sub-national level detailed plans may be developed on the basis of national guidelines for ICARM. Co-ordination of local plans for integrated river basin and coastal zone management will be pursued along with the resolution of any conflicts with national goals.
- Detailed plans must be developed at the local level.

Public participation in integrated river basin and coastal area management is essential to raise awareness to long-term values and supra-local concerns. It must allow for the identification of the needs and concerns of all water users. In the past, it was believed that planners and politicians could better determine what the public wanted. In several cases, the public was involved only in the final stages of the planning processes, when goals had already been defined. It has become evident though, that unless people's aspirations are incorporated from the very early stages, management plans are unlikely to be successful, particularly if they are in conflict with public goals. In some countries public participation issues have been addressed with priority and a greater role has been provided to the public. Agenda 21 calls for the development of participatory techniques and their implementation in decision making, particularly the enhancement of the role of women in water resource planning and management. Participation of all interested groups may provide planners and decision makers with new insights with respect to unknown uses and values of resources within the basin. It is quite important that both upstream and downstream users meet and talk to each other from the very beginning of the endeavour.

In addition, participation can help achieve commitment, ownership and shared responsibility. It can also increase the awareness of the project and the issues involved. All this will contribute to greater efficiency. Within this context, of crucial importance are the mechanisms through which public participation is assured. Institutions are required which will allow the public to come up with comments and proposals for integrated river basin and coastal management. Forums for open discussion may serve this purpose. Even so, some criticism about participation remains. It is argued that most activities are already managed by statutory organisations working within the legislative framework. In addition, participation is both costly and time consuming. Effective participation usually requires the provision of adequate information before the procedure starts so as to enable people to contribute to the process in a more constructive way.

Box 5

Types of participation

1. Directed

The community is treated passively and informed as to why particular course of action has been adopted, rather than learning by being in the decision-making process.

2. Informing

Through informing, people are told what has been decided or has already happened, or may be asked for views on a single option.

3. Consultation

Consultation implies that people participate by being contacted regarding a specific proposal/document and/or are asked questions. In this situation people's opinion is listened to, there is an opportunity for discussion and decisions are considered jointly.

4. Partnership

Local people use representatives to advise or influence the power holders.

5. Interactive

Planning and decision-making responsibilities are shared between the statutory authorities and the people.

6. Community Management

"This is the bottom-up approach whereby people initiate and handle the entire job of planning, policy making and managing a programme independent of external organisations, although external organisations provide help in the form of resources, support and technical advice".

Source: Bayliss R., B. Shipman, M. Turnbull and A. Winder. (1998). Participation Techniques in Coastal Management. A case study of Dorset, Devon and Cornwall.

5.2.7. Implementation

There are two prerequisites for implementation of the plans formulated on the basis of the strategy:

- The legal status. The plans need to have a legal status that will ensure to a great extent the possibility of a successful implementation; and
- A realistic basis, meaning sensible policies and actions which are commensurate to the scale of the problems, the capacity of governance, the human and financial resources required, and the technological support which is necessary.

As soon as the appropriate level of governance for the plan is defined, a co-ordination mechanism has to be set in place, usually in the form of a special agency, committee or body which is assigned the leading role in plan implementation.

Both the strategy and the plan have a long-term framework including short, medium and long-term goals, objectives and corresponding projects. For all practical reasons it is recommended that the plans are broken down into more than one step which are in appropriate sequence. The time-frame of each step could range between 3 and 5 years and needs to include all necessary details in terms of goals, projects, financial and technical aspects, investment, administration, issues of participation, etc.

Actions are required to implement and enforce management decisions. In general, we may apply following actions:

- Actions of individuals, stimulated by community-based incentives and public awareness campaigns;
- Actions of private bodies (including financial contribution schemes), supported by incentives for new technologies and products; and

- Actions of government, through institutional arrangements, administrative regulations, capacity building and financial support mechanisms.

Implementation also includes:

- Implementation and enforcement. At this stage plans are implemented through technical, administrative, legal and financial instruments supported by public participation; and
- Management and control interventions to correct unwanted short-term developments.

5.2.8. Monitoring and evaluation

Monitoring is an important element of any planning process, and is linked directly with the assessment of the performance of the ICARM policies and the results achieved with respect to the goals and objectives that were initially defined.

As there is a wide range of natural forces and processes operating in river basins and coastal zones there is a multitude of factors and variables which should be monitored to examine the state of the systems involved. Such a task is demanding and complex, often well beyond the means and scope of any individual ICARM. For all practical purposes it is necessary to concentrate monitoring on a few key indicators which relate to the key factors and planning issues identified earlier. Often, indicators may be organised in the form of the P-S-I-R model (Pressure-State-Impact-Response) which is widely used in environmental management. These indicators can even be linked to a GIS to reflect spatial variations in the area. Monitoring should certainly include the key processes and the key uses of river basin and coastal zones with particular emphasis on the fluxes between the two systems.

In more elaborate ICARM initiatives, comprehensive monitoring systems can be employed. These may consist of several components. For example, if monitoring of surface waters is required, then ecological monitoring of the geochemical, biological and physical characteristics of the water body, as well as chemical monitoring for the polluting substances can be considered. For groundwater monitoring, the quantity of groundwater and chemical monitoring of certain substances is included.

Changes in the natural system are monitored by means of *in situ* measurements or remote sensing techniques. Slowly-varying processes can be monitored at discrete time intervals; typical examples are the morphodynamic development of coasts and changes in ecosystems. Rapidly varying processes require continuous observations. Typical examples are water-level recording, flow measurement and wave observation. Changes in the socio-economic system are monitored by assessing values for demographic, social and economic parameters. Typical examples are population density, land use, unemployment rates and GNP.

Monitoring is a continuous process, starting from the very beginning of the project, to reflect the specifics of the setting (i.e. natural features, key resources and constraints, etc.). Monitoring is also linked to the management objectives so it has to be built up gradually to reflect the key concerns.

The information generated from the implementation of the plan will be used to analyse:

- the effectiveness of ICARM decisions;
- the efficiency of the investments undertaken; and
- the distribution of benefits among various social groups in order to assess the degree of equity achieved.

Evaluation is not (unlike monitoring) a continuous process. Instead, it is performed at selected times, in particular in the middle, at the end and some time after the completion of the programme:

- *Interim (on-going) evaluations* are carried out during the implementation phase and are designed to overview progress and to anticipate likely effects.
- *Terminal evaluations* are carried out at the end of the implementation phase. They are programme and process related.
- *Impact evaluations (ex-post)* are normally undertaken several years after the final disbursement by independent authorities and aim at measuring direct and indirect impacts.

In all cases, evaluation needs to be characterised by its objectivity, credibility and representation (participation) ensuring that key local and national stakeholders are involved in the monitoring and evaluation process.

Chapter 6. Implementation Instruments and Methods for Integrated Coastal Area and River Basin Management

There is a variety of instruments and methods which can be employed depending on the scope and scale of Integrated Coastal Area and River Basin Management.

In the following paragraphs some of the more salient ones are briefly introduced, organised in three basic categories:

- Information Management;
- Plan Development; and
- Plan Implementation.

These are indicated in Table 3 as they relate to the phases of the planning process as discussed above.

	Initiation	Analysis	Conflicts/ Opportunity	Goals	Strategy	Implementation	Monitoring & Evaluation
Data acquisition	+	+					
Data utilisation		+	O				+
Database		+					O
DSS		+	+	O	+		+
Scenarios		+	+	O	+		O
CCA		+	O	O			O
Regulation					+	+	O
Zoning					+	+	O
Economic instruments					+	+	O
Awareness	O				+	+	O
EIA						+	+
SEA		+	+				+
Economic Evaluation		+	+				+
Risk analysis	O	+					+
Conflict resolution	+			+		+	+

+ most useful
O useful

Table 3: Tools of ICARM

6.1. Information management

6.1.1. Data acquisition and management

Data are the essential ingredient of any information system. Their reliability, accuracy and accessibility are essential to decision making. Recent developments in remote sensing, particularly with the aid of images acquired by orbiting satellites, are making data available even for inaccessible locations where data were previously difficult to collect. But technological advance is not going to solve all data collection problems for coastal and river basin management. Even after utilising all the data that can be obtained through remote sensing, much will be needed from field survey. The only guideline for field survey which can be offered is that it should be reduced to the minimum necessary for the defined functions of the database system.

Data management includes:

- Indication of areas or variables likely to be under pressure from future development;
- Selection of sites most appropriate for essential public services which do not cause environmental degradation;
- Identification of resources of high sensitivity to the impact of oil spills for protection policies;
- Identification of priorities for nature conservation where sensitive ecological resources are in areas subject to pollution;
- Planning tourism development in relation to the carrying capacity of natural resources;
- Selection of alternative development scenarios or projects;
- Identification of appropriate policy instruments; and
- Definition of appropriate financial mechanisms.

An important element of data management for ICARM is bringing together the data on physical/natural resources and economic information (such as social and economic benefits of the development, the costs of environmental damage caused by the development, costs of measures to avoid damage, and the benefits if damage is avoided or reduced). The integration of the physical and economic data is one of the most complex tasks in data management for ICARM.

6.1.2. Data utilisation

Data utilisation includes:

- Identification of key indicators of the existing state of the coastal environment;
- Identification of coastal resources under stress or at risk, and their level of vulnerability or risk of degradation;
- Forecasting the possible impacts of alternative development trends on sensitive resources;
- Identification of areas for development using site suitability and exclusion criteria;
- Simulation and testing alternative options;
- Monitoring and feedback; and
- Exploration of available information and alternative scenarios.

Box 6
A suggested database for ICARM

- resource management (quantity and quality of resources)
 - land area
 - built-up area
 - agricultural land
 - land set aside for conservation
 - land set aside for special purposes
 - forests
 - water resources
 - surface water
 - ground water
 - coastal waters
 - marine resources
 - wildlife resources
- economic activities
 - industry
 - mineral and construction material extraction
 - agriculture
 - tourism
 - fishing and aquaculture
 - forestry
 - transport
 - energy
- infrastructure
 - roads
 - railways
 - airports
 - water supply
 - sewage treatment
 - irrigation
- pollution discharge
 - air
 - water
 - waste
 - hazards and risks
- existing policies, plans and programmes

The model subsystem is used for analysis, predicting and decision guidance. This subsystem will include a variety of models ranging from simulation to optimisation models, which may have various levels of sophistication.

The dialogue subsystem is the component of the decision-support system which provides the essential human-machine interface. Advanced technology provides user-friendly information, including high resolution colour graphics, animation and multimedia presentations.

6.1.3. Contents and structure of the database

The types of information needed include:

- Basic environmental conditions (geology, hydrology, climate, biology and topography);
- Natural resources (water supply, agricultural land, forest and pasture land, fishery and aquatic resources, recreation and tourist resources, natural heritage resources, mineral resources);

- Environmental hazards (floods, geotechnical hazards, etc.);
- Land use (agriculture, extractive, industrial, residential and services); and
- Networks and infrastructure (water supply and drainage, waste disposal, transport, etc.).

6.1.4. Decision Support Systems (DSS)

Decision Support Systems (DSS) can become an indispensable part of decision-making process in many cases of coastal area and river basin management by highlighting complex patterns of interactions between natural and human ecosystems and interactions among management decisions.

The differentiation in both time and space of complex patterns of interaction make the use of **Geographic Information Systems (GIS)** ideal for coastal and river basin management purposes. The ability of **GIS** to store, handle and analyse spatial data (geographical and attribute) including real-time performance boosts the decision-making process. The linkage, combination, intersection, etc. of various layers of information in parallel with a built-in capability of algebraic operations makes **GIS** a necessary tool for the direct evaluation of the management process.

Decision theory focuses on finding the best solution to any problem. Conventional **DSS** use the so-called "constrained optimisation" and are usually established on a single criterion. The **ICARM** process implies conflicting interests and presents multidimensional characteristics where a single criterion is not sufficient and multiple criteria are needed. Artificial intelligence methods and techniques are powerful tools in conflict management and could be embodied in **DSS**. The main objective of expert systems is the introduction of human knowledge about problem solving within computer software. The underlying concept of building knowledge into computer systems is far more enduring and generally more applicable than a narrow focus on the traditional approaches of expert systems. The leading edge of the technology is moving towards more intelligent knowledge-based systems based on hybrid mixtures of neurocomputing, fuzzy logic, etc.

Box 7

Forth Estuary, Scotland, U.K.

A hundred kilometres long, the Forth estuary has a catchment of 4500 sq. km. It supports five bird populations of European importance for nature conservation while at the same time 1.25 million people live around its perimeter, part of which is heavily urbanised and industrialised.

To encourage partnership management that takes as much account as possible of the interests involved, a Forum (voluntary association) was established in 1993 comprising over 200 representatives of local authorities, statutory agencies, commerce, industry, NGOs, etc. This project is financed by the European Commission.

In the context of the activities of the Firth of Forth Forum, special arrangements have been set-up in terms of information management.

Managing the coast of the Forth Estuaries in an integrated manner relies upon decision makers having access to comprehensive information on the resources and uses of the region.

Geographical Information Systems (GIS) have emerged as a technology that is increasingly being used in coastal applications. These allow data in computerised format to be stored, visualised, analysed and managed in an integrated manner.

Developing an environment that would allow partners to have access to relevant and current information on the Forth raises many questions and issues including: access to information; data licensing and copyright; information exchange; data requirements; application-specific development; and on-going system maintenance.

As there is a multitude of interests and management objectives, an ICARM **GIS** should reflect these as far as possible. Although some interactions are measurable and, therefore, quantifiable a number of linkages and phenomena can only be expressed in a qualitative manner. This fact generates the need to embody a multi-objective **DSS** to the **GIS**. The variety of decision-making situations, especially where spatial information is of crucial importance, generate the so called **Spatial Decision Support Systems (SDSS)** which are an important subset of **DSS**.

6.2. Plan development

In the process of plan development a wide range of methods can be employed (reconnaissance surveys, data management, demographic analysis and forecasting, etc.). In the following paragraphs certain synthetic tools are presented which are particularly valuable at the stage of identifying conflicts and opportunities as the basis for setting goals and objectives.

6.2.1. Environment-development scenarios

Understanding the interaction between the environment and long-term development is an important prerequisite for ICARM; prospective studies exploring future options are a tool for achieving such understanding. The basis for prospective studies is a systemic approach. It provides authorities, planners and managers with the opportunity to set development strategies within a broader context that takes into account uncertainty about changes in internal and external conditions.

A development-environment scenario is usually long term (time horizon up to 30 years) and could be regarded as a link between the present and the future through a pathway built in stages of 5-10 year periods. A simplified picture of the phases of a scenario preparation lists:

- a) identifying critical factors that influence development opportunities;
- b) setting up hypotheses about changes in critical factors;
- c) developing coherent sets of hypotheses on the alternative pathways of change; and
- d) analysis of impacts on the environment including consideration of feedback effects on development opportunities.

6.2.2. Carrying Capacity Analysis (CCA)

In environmental planning the intensity of development pressure in an area is vital particularly if it is related to the existing environmental conditions in the area. This calls for a measure of the relative capacity of the local system to cope with pressures. Carrying capacity can be best defined as the maximum load of activity (or maximum number of users) which can be sustained by a natural or man-made resource or system without endangering the character of that resource. By defining the carrying capacity for a certain activity, it is possible to establish the framework for development and management of the areas under consideration. The application of CCA leads to the identification of the maximum number of users which can be absorbed at any time by the receiving area without disturbing the physical, economic and socio-cultural environment. Such analysis is often performed in relation to specific natural resources, (soil, water, beach area, etc.) considered to be constraints to development. CCA is employed to estimate the theoretical maximum level of an activity in order to establish "acceptable" (lower) levels as guidance for future development. Tourism development, agriculture, wildlife and range management are activities which can benefit from this type of analysis. CCA is best suited to relatively small sites such as beaches or valleys.

6.3. Plan implementation

6.3.1. Regulation and control

Regulatory instruments (laws, agreements, etc.) are widely used in environmental management and in other fields of governmental activity where the market mechanism is absent or ineffective. The range of instruments includes land-use planning, building regulations, construction guidelines for the coastline and the hinterland, including the river basin, conservation regulations, regulations of water use, agricultural practices, fishing quotas, marine and river transport regulations, aquaculture requirements and licensing of various other activities.

Land-use planning, zoning and building regulations, when properly implemented, define the shape and nature of coastal and river basin development. These can be organised as a form of policy statement (principles and rules) or even put in spatial terms in the wider context of a master plan to guide the intensity and extent of development in various sub-regions. These controls can be supplemented with other traditional regulatory instruments, such as emission standards. Pollution regulation helps maintain environmental quality; other regulations define activities in a way to prevent pollution or aesthetic damage and to manage and conserve resources.

- *Urban land-use and development control*: the approaches can be analysed in (i) a system in which individual development choices are decided on their own merits, on the basis of guidelines contained in planning documents and other relevant considerations; (ii) a zoning system, in which the development of certain and predefined activities is permitted. Detailed regulations as far as land and building are concerned should be part of a broader land-use strategy.
- *Building regulations* should ensure (i) environmentally-friendly building, (ii) structures resistant to environmental hazards, and (iii) enhancement or preservation of the aesthetic quality of the surrounding landscape (in the wider sense).
- *Zoning* has a particular significance in *hazardous areas*, for example floodplain zoning, shoreline exclusion or restriction zones and other critical areas. Relatively small areas, clarification of the pressures/conflicts and public support are preconditions for successful implementation. Identification of the area in which all types of development are prohibited should be combined with a detailed management plan incorporating more positive action.
- *Environmental controls* may be introduced at national, state and local levels on air and water pollution, and the disposal of solid and hazardous waste.

Regulations offer, therefore, a range of instruments of implementation but they have to be employed with two provisions in mind:

- They have to be used in the most cost-effective and environmentally most advantageous way. In cases when other criteria are equal, the most environmentally favourable should be chosen.
- Regulatory instruments need an enforcement mechanism. For this purpose, managers should be able to make use of: (i) withdrawal of permits to build, (ii) withdrawal of permits to operate, (iii) imposition of effective fines, and (iv) access to courts for imposition of penalties.

Regulatory instruments are preferable when quick action is required and rules can be made quite clear to all parties concerned.

Box 8
Ria de Aveiro, Portugal

A river and coastal area of 600 sq.km. around the Aveiro lagoon is of European importance for nature conservation. Almost 400,000 people live in the area. The main threats to the ecosystem are construction of dams, harbour extension work and tourist developments. The need for an integrated approach that can reconcile socio-economic development with the conservation of the lagoon and its functional characteristics is widely recognised. Several central and local stakeholders and authorities are collaborating with the support of the University of the Aveiro in a programme of integrated coastal zone management financed by the European Commission (Life-Environment). Among the anticipated results are better co-operation and more effective decision making, consistency of spatial plans and environmental management programmes and establishment of an integrated management structure.

6.3.2. Buffer zoning

This is one example of zoning or the delineation of specific areas for specific functions or activities. Vegetative buffers constitute valuable management practices for the protection of water quality and the preservation of the important functions of sensitive areas, such as steep slopes, flood-prone areas, wetlands, etc. Buffers are perceived as one of the most cost-effective ways to halt nitrate, phosphorus and suspended solids loading into rivers and streams.

Runoff from adjacent developed areas should never be discharged directly into an adjacent waterbody or into a buffer zone as a concentrated flow. To the extent practicable, stormwater runoff should enter buffers as sheet flow in order to maximise infiltration and allow the filtering of pollutants from runoff. If preserved and managed properly, buffers can be a valuable tool:

- protecting water quality by filtering pollutants from runoff;
- providing shade, helping the lower water temperatures and maintain dissolved oxygen concentrations;
- infiltrating and slowing runoff, reducing peak flows and downstream flooding;
- providing valuable habitat for fish and wildlife;
- stabilising stream banks, reducing sedimentation problems;
- helping preserve the aesthetic quality of riparian areas;
- increasing adjacent property values; and
- providing areas for appropriate recreational activities.

Box 9
The example of North Carolina

The value of forested and vegetative buffers has been recognised in North Carolina, USA, and they have become an important tool in the State's water quality management programme. For example, the catchment protection rules relating to water supply require that new developments maintain natural or vegetative buffers around all perennial waters with a minimum width of 30 ft (10 m) for low-density development and a minimum 100 ft (30 m) buffer for high-density development. The buffer is measured landward from the normal elevation of impounded structures and from the bank of each side of the stream or river.

6.3.3. Economic instruments

Economic instruments can function as incentives or disincentives for environmentally-sustainable use of resources. They can be:

- *impact fees* (one-time payments by developers to pay for infrastructure and environmental protection, e.g. roads and storm drainage, flood protection, environmental monitoring);
- *taxes/charges* on pollutants or potentially polluting products, e.g. effluent charges, or refundable deposits on potentially polluting production, tax incentives;
- *removal of subsidies* on environmentally unsound production;
- *revision of pricing policies* to reflect the full environmental costs of a resource, while ensuring basic needs, satisfaction and equitable access. Resources, such as water, have frequently been under-priced, but accepting that they are not free and unlimited implies a fundamental change in attitude;
- *low-interest loans and grants*, e.g. for improving buildings to withstand certain environmental threats, for production of appropriate building materials to substitute for imports (using non-polluting technology), for industries to invest in pollution control or relocate (negative taxation); and
- *flood insurance*, which may be government subsidised and provided on condition that flood protection measures are taken.

Economic instruments are used to supplement regulations in areas where economic efficiency is important, where regulations have failed and/or where funds need to be raised to implement public policy, e.g. for environmental infrastructure.

6.3.4. Public awareness, capacity building and education

Public support for environmental aspects of development policies, and for the successful enforcement of policies, especially regulatory policies, is very important. Dissemination of information about valued environmental resources and the way in which they are threatened, hazardous areas, and ways of developing and building to reduce risk and environmental degradation, is an essential element in implementation. The need for education on the environmental implications of human activity is as great within governmental agencies as it is outside.

A precondition to informed public participation is that the public recognise the economic and environmental values of integrated river basin and coastal area management. In particular, public participation is enhanced when the negative economic and environmental consequences of, for example, draining wetlands, clear-felling forests or discharging pollutants, are recognised.

Therefore, public awareness programmes targeted at the general public, non-governmental organisations (NGOs), government departments and other groups active in river basin and coastal area management should be put in place.

Various stakeholders can promote the holistic management approach for coastal and river basin areas by establishing specific organisational structures (i.e. an information office) as well as introducing financial incentives. To assist them it might be necessary to develop training programs as part of capacity building activities in order to improve their administrative capabilities.

Box 10
EIA Objectives (as set by the State of California, USA)

- Disclose to decision makers and the public the significant environmental effects of proposed activities;
- Identify ways to avoid or reduce environmental damage;
- Prevent environmental damage by requiring implementation of feasible alternatives or mitigation measures;
- Disclose to the public reasons for agency approval projects with significant environmental effects;
- Foster interagency co-ordination; and
- Enhance public participation.

Source: Wood, Ch. (1995). Environmental Impact Assessment: A Comparative Review. Essex: Longman Scientific & Technical.

6.3.5. Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) is a method of identifying (i) the impacts of human activity on natural environments, and (ii) options to reduce or mitigate negative impacts.

6.3.6. Strategic Environmental Assessment (SEA)

Environmental impact assessment should be carried out at both the policy and project levels. At the policy level, it is often referred to as Strategic Environmental Assessment (SEA) and at the project level as Environmental Impact Assessment (EIA) – Figure 9. The use of SEA provides a means of focusing attention across disciplines and organisations on strategic options enabling the identification of the strategic “best practicable option” for the river basin as a whole.

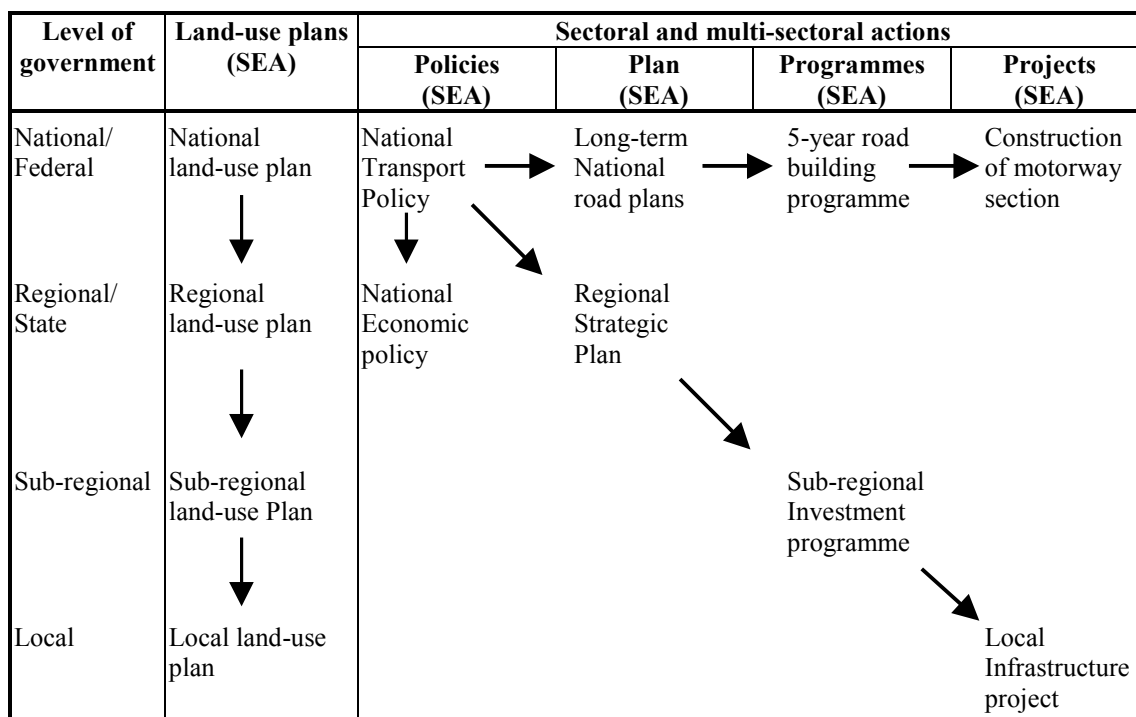


Figure 9: Stages in the EIA process (Barrow, 1997)

6.3.7. Economic evaluation of costs and benefits

Apart from physical evaluations, such as Environmental Impact Assessment and risk analysis, economic evaluations should also be carried out to ensure economic efficiency in river basin and coastal management. The combined results of economic and environmental assessments can provide useful insight into acceptable options.

Many outputs of activities taking place in the coastal area and the river basin are channelled through the market (tourist expenditure, industrial output, etc.). However, environmental benefits/damages (clean and efficient water, conservation of natural areas, etc.) are seldom traded in the market. Furthermore, even market-traded activities are evaluated only in financial and not in economic terms; and most activities and environmental protection require substantial expenditure in order to produce benefits for a long period in the future. To provide a common denominator for these various activities, expenditures, costs, and gains require a comprehensive, analytic framework such as cost/benefit analysis.

Type of projects to be evaluated

Major infrastructure projects and other governmental expenditures, taking into account their environmental benefits and costs.

Private investment projects, particularly when they are subsidised by the government. All private projects have environmental impacts which require pollution control or conservation measures, either by the entrepreneur or by the government. Subsidies in these projects often take the form of tax allowances, cheap land for tourism or cheap government loans for various types of development, governmental expenditures to minimise their environmental impacts, or straight cash subsidies.

6.3.8. Risk analysis

One of the consequences of the intensive development of coastal areas and river basins is that the probability of various risks increases, and even larger amounts of people are exposed to them. The general awareness of exposure to natural and technological risks is increasing but in many cases the relevant knowledge is incomplete and is not integrated into management policies or contingency measures.

In order to mitigate or prevent possible negative effects, and sometimes environmentally catastrophic consequences, of such hazards, risk management techniques should be part of ICARM. However, risk management can prepare only for probabilities of risks occurring and can only broadly estimate their consequences. Vulnerability analysis offers supplementary information to risk analysis by identifying acceptable levels of impacts on key resources and factors.

Three steps can be distinguished in the risk management procedure:

- Identification of major hazards;
- Assessment of the potential of individual hazards; and
- Formulation of a plan that integrates the various management approaches to risk.

6.3.9. Conflict resolution

The high social value associated with coastal areas and river basins is likely to generate numerous and severe conflicts. Some of these conflicts are of a “vertical” nature, i.e. may occur between the authorities and interests at various levels (international, national, regional, and local), while others are “horizontal” conflicts between the users and

activities at one and the same site or at adjacent sites. Especially important are the conflicts between the interests of individual users of land and water resources. A reasonable and just solution to such conflicts is one of the most important objectives of any coastal area and river basin management.

The procedures for working through conflicting interests are:

1. Formation of *ad hoc* task forces (commissions, scientific bodies) for resolving a particular problem; this can be implemented at all levels and its efficiency depends on factors such as members selected, objectives, level of authority, and funds available. In most cases such bodies propose solutions, while decisions are left to other authorities.
2. Formation of long-term or permanent bodies to monitor a particular process, direct and resolve the conflicts: interministerial councils, interagency councils, local authorities' councils. Such bodies are often entitled to take decisions and they also carry public responsibility for those decisions.
3. Generation of a policy dialogue through discussion among interested parties in potential conflict is often used by moderators or facilitators. The special value of this technique is that it can provide a relatively objective insight into the various interests of the different parties while the possible consequences of the decisions can produce additional information and provide the basis for compromise solutions.
4. Nomination by the authorities of qualified intermediaries when a dialogue is impossible or has been interrupted. Their role is much more active and responsible than that of facilitators as, in many cases, they propose their own solutions after they have heard all parties and studied all individual interests.
5. Creation of an arbitration procedure is used for cases where it is impossible to find a solution through negotiation. Legal authority or the consent of the interested parties is an essential prerequisite for its application. Decisions of the arbitrators bind all parties and, therefore, their impartiality and their ability to understand the issues are basic to the arbitration process.

Appendix 1. Developing a systems analogy for the natural system

In this Guideline we use a dynamic systems analogy, developed in three successive steps. For each step techniques and tools are discussed which can be used to provide a quantitative description. These techniques and tools are not discussed in detail, but reference is made to specialised text books.

Step 1. The natural system as a black box

The first step describes the natural system as a black box and defines input/output relations for various functions of the box. The structure and the processes within the box remain unknown. Figure 10 shows such a black-box representation of a system. The box represents the system itself, the left-hand arrow represents the input from the outside world (the system environment) and the right-hand arrow represents the output back into this environment. The downward arrow simulates the flow of resources to the users within the system (the human system). As stated above the box may represent the entire river basin or coastal system or part of it.

Inputs for the natural system are fluxes of energy and matter, such as solar energy, water and sediment.

The *black box* contains a number of essential functions of nature. The following functions are identified:

- Carrier function: the ability to provide space and substrate for human activities;
- Production function: the potential to provide living and non-living resources for subsistence and economic activities;
- Regulation function: the ability to regulate essential ecological processes and life-support systems; and
- Information function: the maintenance of unique natural values that provide opportunities for reflection, spiritual enrichment, cognitive development and aesthetic experience.

A complete list of functions is given in Table 4.

All functions together produce as *output* goods and services required by people. In subsistence economies, where outputs are used exclusively for own consumption, these goods and services are consumed by users within the system. This flux is characterised by the downward arrow. In production economies, where part of the goods and services is exported to other users outside the system, there is a flow of products out of the system. This is expressed by the right-hand arrow.

This systems analogy can be used for initial evaluation of the integrity and ecological value of natural systems.

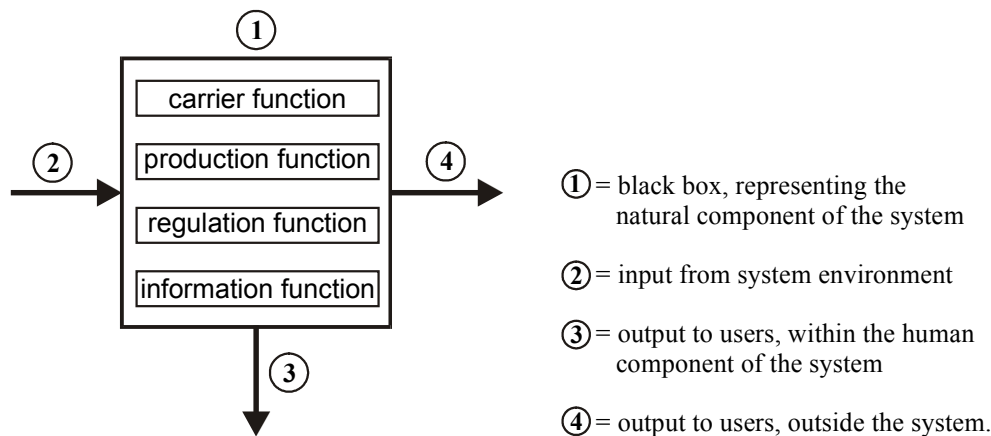


Figure 10: Black box analogy of natural component of the system

Step 2. The structure of the system

The second step defines the structure of the system in terms of the elements and the linkages between these elements. It is common to decompose the system further into a number of *interacting elements*. For the river basin, we apply a two-dimensional geographical decomposition. Elements are clustered into three main geographical units: the coast (with the coastal waters, the coastal strip and the coastal plain as main elements), the estuary and the river. In some instances, a three-dimensional analogy has to be applied, where the air, the water and the substrate are used to describe the third dimension. Note that this description is an ideal base for representation by means of GIS.

For each of the geographical elements geometrical, physical and biological properties have to be described. To that end, all elements are characterised by a number of parameters, each representing a certain *aspect* of that element. The most common properties are the geometric data of the element, its shape, size and elevation. Other convenient parameters are those describing the geophysical characteristics of the element. Finally, we can define parameters that are related to the biological and ecological properties. Relevant parameters are selected to describe these properties of the elements and state variables are introduced to quantify the value of these parameters at a given point in time. The elevation and height of an element is an example of such a parameter to characterise a geometric property. The grain size distribution of a sandy beach is an example of a parameter used to describe a physical property. Water quality parameters, such as BOD (Biological Oxygen Demand) may be used as an indicator for water quality, whereas the bio-diversity index is an example of a biological parameter. Obviously, only those parameters which are essential for the problem under study have to be used.

The following environmental parameters are especially important:

- Atmospheric parameters and related climatological processes;
- Hydrological parameters and related processes;
- Geological and geomorphological parameters and related processes;
- Soil characteristics and processes; and
- Ecosystem parameters and processes.

A complete list of environmental parameters is shown in Table 4.

Carrier Function Provides space and suitable substrate for: <ol style="list-style-type: none"> 1. Human habitation and settlement 2. Cultivation (Crop growing, animal husbandry, aquaculture) 3. Economic activities (Energy production, industry, tourism) 4. Public activities (Transport, water supply, electricity) 5. Social activities (Recreation) 6. Nature conservation and protection 	Regulation function (Indirect use value) Regulates the following processes: <ol style="list-style-type: none"> 1. Inflow of harmful cosmic influences 2. Local and global climate 3. Local and global energy balance 4. Runoff and related processes in the river basin 5. Groundwater recharge 6. Composition and fertility of topsoil 7. Catchment erosion and sediment transport 8. Coastal erosion 9. Storage of energy through biomass production 10. Storage and recycling of organic matter 11. Storage and recycling of nutrients 12. Storage and recycling of human waste 13. Biological control mechanisms within food web 14. Protection and conservation of nursery habitats 15. Preservation of biological and generic diversity 16. Chemical composition of the atmosphere 17. Chemical composition of the hydrosphere
Production Function (Direct use value) Provides renewable and non-renewable resources such as: <ol style="list-style-type: none"> 1. Oxygen 2. Water 3. Food and nutritious drinks 4. Genetic resources 5. Medicinal resources 6. Raw materials for private use 7. Aggregates and raw materials for construction and industry 8. Biochemicals 9. Fuel, gas, wood other sources of energy 10. Fodder and fertiliser 11. Ornamental resources 	Information function (Existence value) Provides information on the following non-monetary values: <ol style="list-style-type: none"> 1. Aesthetic and scenic values 2. Spiritual and religious values 3. Cultural and artistic values 4. Historic (heritage) values 5. Scientific and educational values

Table 4: Functions of Nature

The checklist can be used to make a baseline description of the system in terms of the quality of the environmental parameters and the related integrity of the natural system. All aspects can be expressed in so-called state values, indicating the value of the corresponding parameter at a given point in time. Again, using the terminology of GIS, these state values can all be represented by means of different overlays in the GIS.

Elements are not randomly positioned: the topology of the system defines the position of the elements in relation to each other (topological structure). Essentially this is the geographical map of the coastal area and its neighbouring river basins. Moreover, certain elements or aspects have specific functional relations (functional structure). Examples are the close linkage between geometric and geophysical properties and the relation between biological and geophysical aspects of the environment.

This systems analogy can be used to describe slowly varying properties of the system. The topography of the area and the volumes of non-renewable resources are typical examples of such an application. Together with a GIS this is a useful expedient to support land-use planning and resource management.

Step 3. The processes within the system

The third step uses a dynamic systems analogy that simulates both the structure and the processes within the system. As most systems are dynamic, values of the parameters, defined as state values, change with time as a result of dynamic interactions between elements, known as *processes*. In general, we identify abiotic (physical), biological and chemical processes. Examples of abiotic processes in the river basin are the flow of water, driven by gravity, especially at times of flood production, and the related transport of conservative and non-conservative substances, and energy flow and biomass production in ecosystems. Biological processes of importance are the flow of nutrients and energy through the food web. Processes can be described by empirical relations derived from historical data, or by mathematical equations, based upon the laws of physics or chemistry. In many instances mathematical processes have been solved numerically and numerical models have been developed to simulate these processes.

This systems analogy can be used to describe the dynamics of the natural system. Input-output relations can be computed and the effect of changes in the system predicted. Moreover, the analogy can be used to assess the effect of system control by means of management intervention or engineering works. As such it is the appropriate tool for environmental management. In most instances, however, the description has to be highly empirical. Only in a few cases are the governing equations for the steering processes known as an essential condition for a more rigid mathematical description.

Appendix 2. Coastal classification

Introduction

Coasts are the result of a continuous battle between the abrasive forces of wind and water and the ability of geological and geomorphological formations to resist these forces. Plate tectonics and subsequent tectonic movements have laid the foundation for the river basins. Rainfall and runoff have eroded these formations and deposition of erosion products has given the basin its present shape. Erosion products carried to the sea by the rivers have been reworked continuously by waves and tides resulting in a wide variety of coastal landforms. Climate (via the intensity of runoff) and geology (via the resistance of rocks and basin topography) determine the sediment load delivered to the coastal zone.

At the coast, wind, waves and currents rework the sediment. In practice, the power of waves exceeds by far that of wind and currents since they represent the accumulated energy of the wind in the fetch area. Along high-energy coasts with little or no sediment supply, rock will be exposed resulting in cliff coasts and gravel beaches. If sediment supply is high, waves will transport fine material to deeper water and medium to coarse sand will remain on the beaches. Depending on the local topography and the wave climate, pocket beaches, spits, deltas or coastal plains will be formed. Sediment transport is low along low-energy coasts. Consequently most sediments, even the finer silt particles are deposited in the nearshore area, resulting in the formation of coastal plains and mud flats. The latter mainly occur in areas with high rainfall where rivers discharge huge volumes of sediment to the sea.

All three parameters - geological resistance, rainfall and wind - together are responsible for coastal genesis. Over short time scales, say a period of years, these parameters will not change much and coastal formations can mainly be described by geomorphodynamic processes. For longer periods, however, ecological and biological processes are more importance resulting in dune and wetland formation, salt marshes and mangrove vegetation. In some tropical areas, biological processes like reef formation may become the controlling factor in beach formation.

In recent years, people have become an important factor in the coastal environment. As a result coastal defence works such as dikes, revetments, groynes and offshore breakwaters have modified the shape of the coast.

Based upon this analysis, the following classification of coasts is proposed:

1. Geomorphological processes dominant

- Rock coasts;
- Cliffs;
- Gravel beaches;
- Sand beaches; and
- Mud flats.

2. Geomorphological and biological processes co-dominant

- Dunes;
- Salt marshes;
- Mangroves;
- Wetlands and lagoons; and
- Sea grass fields.

3. *Biological processes dominant*

- Reef formations.

4. *Human influence dominant*

- Dikes, revetments;
- Groynes;
- Sea walls; and
- Offshore breakwaters.

All categories can be further subdivided, using specific coastal features as discriminating parameters. Typical examples are the subdivision of sandy coasts into straight beaches, barrier coasts, pocket beaches, spits, tombolas, etc.

The present guidelines are written for alluvial coasts, dominated by geomorphological processes, but the methodology is universally applicable.

Appendix 3. Developing a systems analogy for the human system

In this Guideline we use a dynamic systems analogy developed in three successive steps. For each step techniques and tools are discussed which can be used to provide a quantitative description. These techniques and tools are not discussed in detail, but reference is made to specialised text books.

Step 1. The user system as a black box

As in natural system, the user system can be represented as a black box that generates services and products by using inputs from the natural system. At the same time, unwanted products are released back into the system. Schematically, the systems analogy is shown on Figure 11. This black box contains a number of functions, essential for mankind. Broadly speaking, the following functions can be identified:

- human settlement and urbanisation;
- subsistence, the production of food and water for survival;
- economic activities, the production of services and goods to earn money;
- public activities such as transport, sewage treatment etc; and
- social activities, such as recreation.

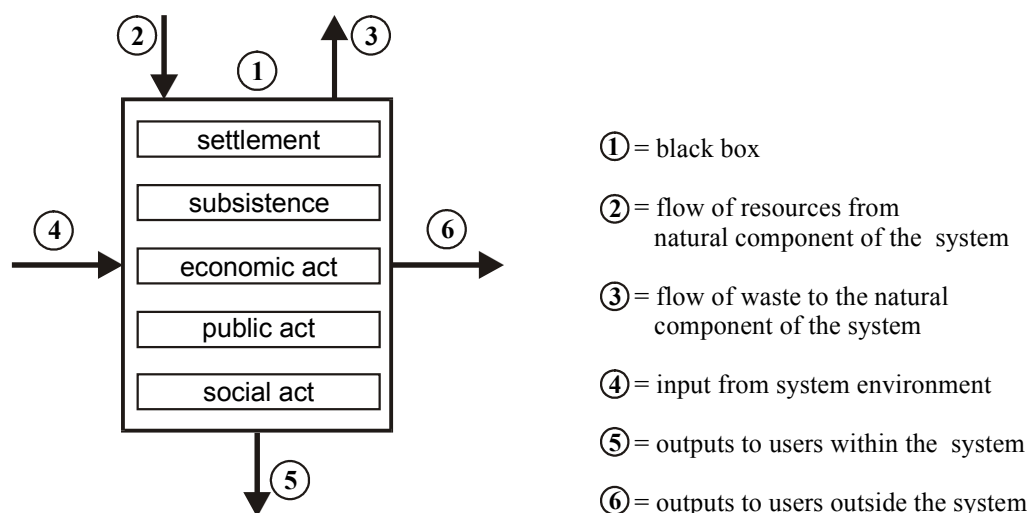


Figure 11: Black box analogy of the human component of the system

Obviously, this list is not exhaustive and should be modified and expanded for practical use.

Often economic activities are grouped according to economic sectors, which are used for an analysis of the economic structure of the region. Conventional sectors used by economists are: housing, services, industry, energy, agriculture and transport. These sectors may be subdivided into a number of more specific economic activities for practical applications.

The interaction between the resource system and the user system is strong: all users consume resources and discharge waste. Both have a strong impact on the functions of the natural component of the system. This is shown schematically in Figure 12 where the coupled system is shown. Human settlement and urbanisation draw heavily upon the carrier function and use large volumes of non-renewable resources and aggregates produced by the production function. Human subsistence consumes water, energy, renewable and non-renewable resources provided by the production function.

Agricultural products and fish constitute the main elements for subsistence in coastal communities. Economic activities use large volumes of energy, living and non-living resources whereas public activities like rail and road transport and associated infrastructure occupy again vast areas of valuable land. No wonder that in many areas little room is left for social activities, recreation or nature conservation.

So far, the natural system and the user system have been regarded as interacting in an uncontrolled way. In most instances, system control is required through regulation or technical intervention. This is shown in Figure 13 where a third box is added containing the control mechanism.

Controls are shown here at a high level of abstraction. In practice, controls include management interventions through laws and regulations, which steer and control the functioning of the human system. Moreover, technical methods may be applied to control the functioning of both the natural and human component of the system. Sewage treatment plants, coastal defence works, river regulation and training works are typical examples of such interventions.

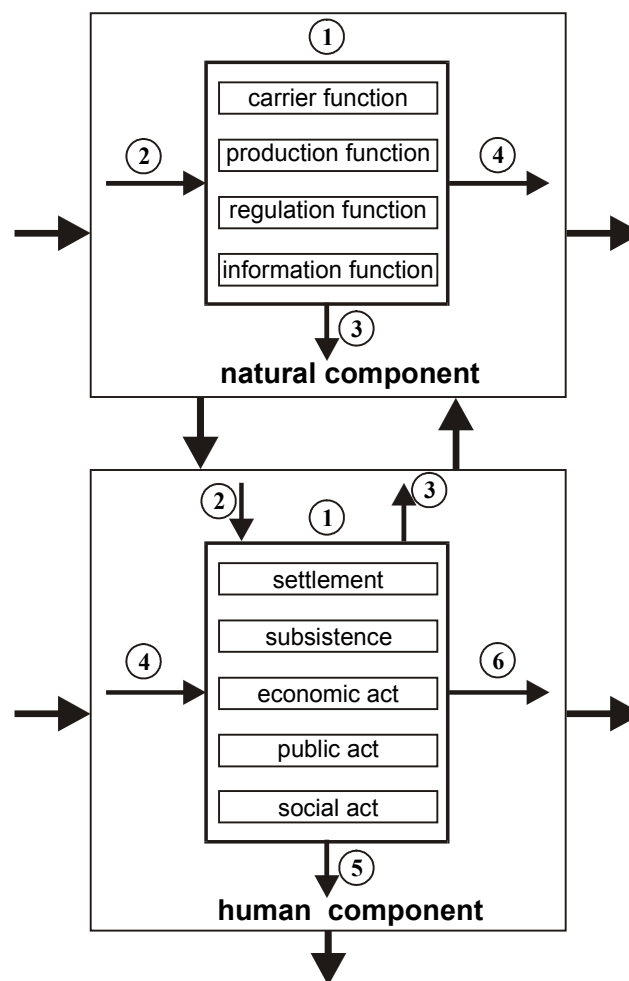


Figure 12: Coupled natural and human system components

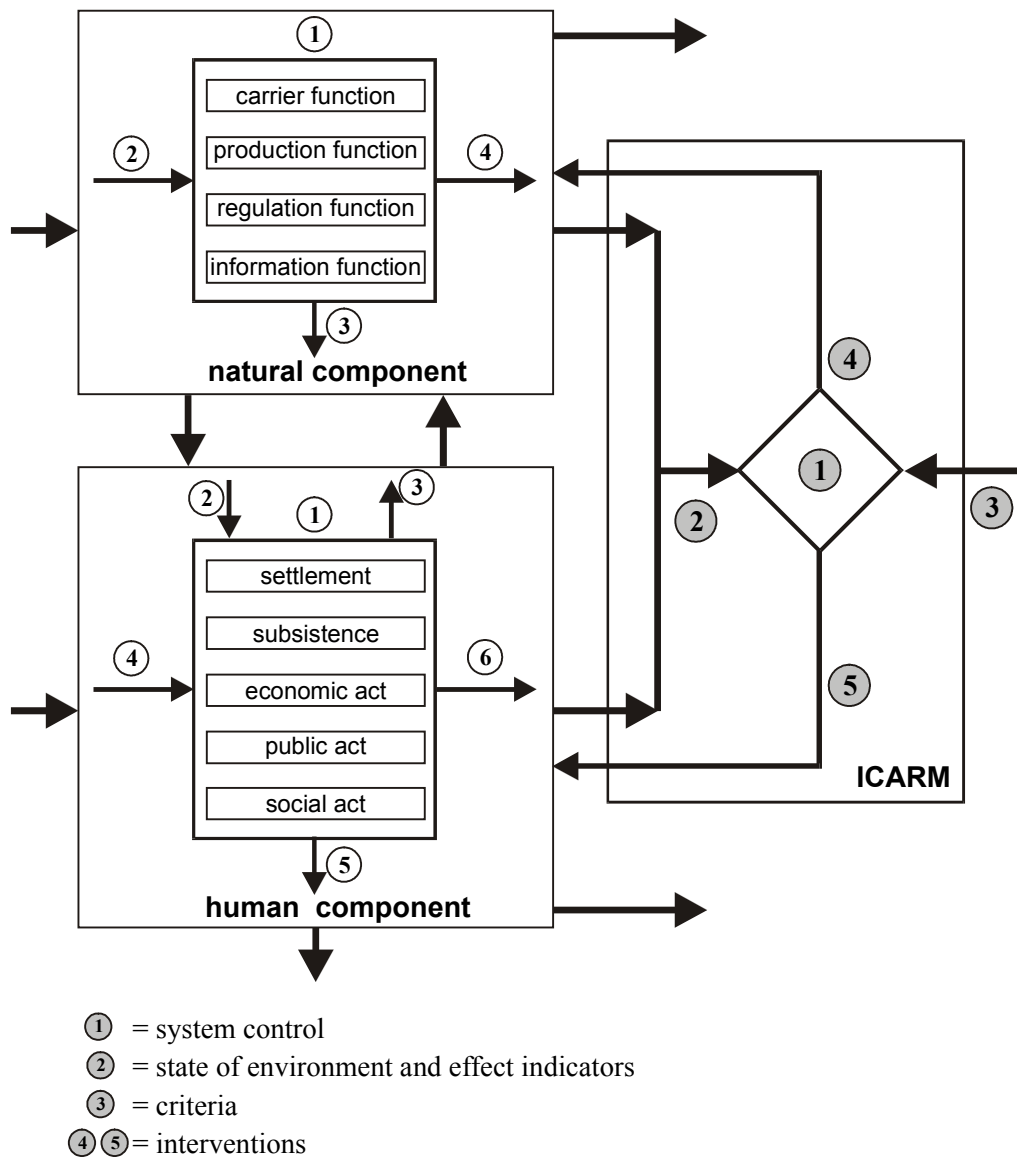


Figure 13: System and controls

In practice, controls will be applied only if state parameters of the natural system (for instance environmental indicators for water quality) or the human system (for instance health conditions) exceed critical values. Monitoring of such parameters is an essential part of the control mechanism, therefore, as it provides the input for the control function. By the same token monitoring is required to assess the efficiency of the interventions.

The present chapter only describes the functioning of the controls, from a system perspective. Practical examples of how to implement system controls are discussed elsewhere. (see references).

Step 2. The structure of the user system

Various authors have tried to develop a systems analogy for the human system that can be used as the basis for calculation of the national or regional Gross Natural Product (GNP). Basically these systems have following interacting components:

- the social capital, the labour force and its social infrastructure required for socio-economic activities; and

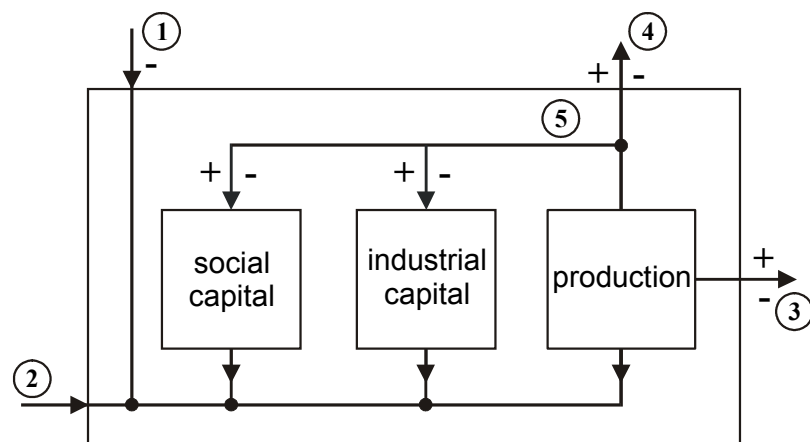
- the industrial capital, the equipment, buildings and infrastructure to support these activities.

Together with the flow of resources from the natural system component - often called the environmental capital - goods and services are produced. The various users as described above consume these goods and services. In most economic models goods and services are grouped into economic sectors, which are used as the basis for calculation of GNP. As stated above, the production system produces both wanted and unwanted products. Part of this output is released back to the natural system (see Figure 14).

Step 3. The processes

The arrows shown in the system diagrams represent the flow of resources, services and products generated by the system. Arrows within the box symbolise outputs of processes that take place inside the system: the left-hand arrows represent inflow of capital and labour from outside, the right-hand arrows indicate the flow of products and services out of the system.

This systems analogy can be used to describe qualitatively the structure of the user system and illustrates the importance of the linkage between the natural resource system and the user system. As such it has been used as a basis for a “Green Natural Product” which takes into account both economic and ecological aspects within a framework of sustainable development. More detailed data on the characteristics of the individual boxes is required, however, before a more quantitative computation of this Green Natural Product can be made.



- ① = flow of natural resources from natural system component
- ② = input (labour, capital) from system environment
- ③ = output of wanted (+) and non wanted (-) products to users outside the system
- ④ = output of wanted (+) and non wanted (-) products (waste) to natural system component
- ⑤ = output of wanted (+) and non wanted (-) products for users within the system

Figure 14: Structure of the human component of the system

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