Appendix E: Project Planning and Analysis: Putting it All Together

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The main purpose of water resources management is to ensure the best use of available water resources. In addition to supporting life itself, water is used in the production of economic goods and services that are needed to meet national and regional development goals. Planning projects are often needed to determine how best to develop and manage these resources. This appendix describes the general approach used by WL | Delft Hydraulics to assess water resources systems and develop management strategies for them. Each water resources system is different and has different problems, and the specific application of any planning approach should address the particular issues involved. What is important in all cases is the comprehensive and systematic process of analysis, together with constant communication among planners, decision-makers and the interested and affected public.

1. Basic Concepts and Definitions

The approach taken for water resources planning involves a number of terms and concepts related to planning, management and the role of systems analysis. These terms and concepts are commonly used in water resources planning, but with varying connotations. To avoid confusion, we begin this appendix by indicating what we mean when using these terms and concepts.

1.1. The Water Resources System

A water resources system (WRS) can be considered to consist of:

- *The natural resources system* (NRS):
  - the natural sub-system of streams, rivers, lakes and their embankments and bottoms, and the groundwater aquifer
  - the infrastructure sub-system, such as canals, reservoirs, dams, weirs, sluices, wells, pumping plants and wastewater treatment plants (including the operation rules for elements of this sub-system)
  - the water itself, including its physical, chemical and biological components in and above the soil, often referred to as the 'ABC' components: abiotic or physical, biological, and chemical.
- *The socio-economic system* (SES):
  - water-using and water-related human activities.
- *The administrative and institutional system* (AIS):
  - the system of administration, legislation and regulation, including the authorities responsible for managing and implementing laws and regulations.

This definition of a WRS covers the aspects that are essential for natural resources management: supply, demand and means to manage the resources. The NRS incorporates the supply side of the system (resource base), and the SES the demand side. The management of both the supply and the demand sides is provided by the AIS.

The external natural boundaries of an NRS usually consist of the water divides of the catchment area, boundaries of the groundwater aquifer(s) belonging to it, and the point where the river or canal discharges into the sea. Beyond the latter point, one usually speaks of coastal waters. There is a (brackish) transition zone between the two systems. When discharges are large, the brackish water zone moves seaward. The extent to which the brackish water zone is explicitly included in the NRS depends upon the interests involved, the problems encountered and the management objectives to be attained.

The geographical boundaries of the SES and the AIS vary depending on what part of the socio-economic system is considered essential for managing and assessing the impacts of the NRS. For example, in order to analyse the relations between an NRS and a region with an open economy, one would have to examine the relationship of this region with the economy outside it so as to estimate future developments in the region.

1.2. Functions of the Water Resources System

A general framework of functions is presented in Table E.1. The classification distinguishes between the functions and uses that are tangible and those that are not. Tangible functions, such as hydropower generation or municipal water supply, may be assigned a monetary value; intangible functions are activities such as nature conservation. In between are environmental functions, some of which may be given a direct value and others valued indirectly, by using a shadow price or other valuation method (see Chapter 10). The self-purification process of a river, for example, may be assigned a shadow price by comparing this 'work done by nature' with the costs of constructing and operating a wastewater collection and treatment system. The functions in Table E.1 are explained below.

1.2.1. Subsistence Functions

Local communities depend to a large extent on ambient water resources for household uses, and for irrigating home gardens and village irrigation plots. They may also use the streams, paddy fields, ponds and lakes for fishing. These uses are often neglected in national economic accounts, as they are not marketed or otherwise assigned a monetary value. However, if the WRS becomes unable to provide these products, this may well be considered an economic loss, as the people who are dependent on these products now have to buy them. An example is the cost of providing purified drinking water where water quality has deteriorated and become undrinkable.

1.2.2. Commercial Functions

Commercial uses of water resources are reflected in national economic accounts because they are marketed or otherwise given a monetary value, e.g. the price to be paid for domestic water supplies. Catching fish for sale by individuals and commercial enterprises is an example. These uses have a commercial value and most are also consumptive in nature.

The concept of 'non-consumptive use' should be regarded with certain reservations. Non-consumptive water use may alter the performance of the WRS in way

Table E.1. Functions of the water resources system.

Function	Description	Examples
Subsistence functions	Local communities make use of water and water-based products which are not marketed	– local drinking water supply – traditional fishing – subsistence irrigation
Commercial functions	Public or private enterprises make use of water or water-based products that are marketed or otherwise given a monetary value	– urban drinking water supply – industrial water supply – irrigation – hydro-power generation – commercial fishing – transportation
Environmental functions	Regulation functions Non-consumptive use	– purification capacity – prevention of salt intrusion – recreation and tourism
Ecological values	Values of the WRS as an ecosystem	– integrity – gene pool, biodiversity – nature conservation value

that constrains or increases the cost to other users. Hydroelectric generation is an example of a partly non-consumptive use that affects the system in various ways. First, reservoirs built for hydropower increase evaporation losses, and hence reduce the amount of water available for downstream users. Second, operation of the reservoir for the production of 'peak power' may alter the flow regime downstream, and this can adversely affect downstream habitats and users. Finally, water quality problems related to reservoirs may seriously affect the ecosystems both upstream and downstream of the reservoir.

Another example of partly non-consumptive use is inland water transportation. Oil and chemical pollution caused by water transport activities can affect other users and the ecosystem that depend upon the water resources. Moreover, inland water transportation may involve a real consumptive demand for water. If water depths are to be maintained at a certain level for navigational purposes, releases from reservoirs may be required which provide no value to other water users. An example is the Lower Nile system, where water is released from Lake Nasser to enable navigation (and energy generation) during the so-called winter closure. This water could otherwise remain stored for (consumptive) use by agriculture during the growing season.

1.2.3. Environmental Functions

The drainage basin of a river fulfils a series of functions that require no human intervention, and thus have no need of regulatory systems. These environmental functions include the self-purification capacity of the water system, and recreational and tourism uses. It is sometimes difficult to assign a value to environmental functions. They may be assessed by using a shadow price, calculated as the costs of providing similar functions in other ways, e.g. the cost of additional wastewater treatment. Recreational and tourism values may be determined by assessing the economic benefits accruing from the use of tourist facilities like hotels, and/or the revenues from fishing licenses.

1.2.4. Ecological Values

Water is a substance that is essential for life. Rivers, streams and lakes not only offer an environment for aquatic species, but are often bordered by wetlands such as reed beds, floodplains and marshes. These land–water ecotones (transition areas between adjacent ecological communities) are known to harbour a rich assemblage of species, and are also important for the diversity of adjacent ecological communities. These ecological entities have a value of their own, irrespective of the actual or potential human use, an intrinsic ecological value. There are many concepts and expressions that describe this ecological value: 'heritage value', 'aesthetic value', 'nature value', 'option value', 'existence value' among others.

Environmental functions relate to the benefits of the natural environment for humans, and ecological values include the intrinsic value of nature. In view of the increasing emphasis on sustainability, this distinction is useful in water resources planning and management. It points clearly to the need for the continuous care for the natural conditions of our planet and the maintenance of an acceptable and sustainable level of environmental quality.

1.3. Policies, Strategies, Measures and Scenarios

In planning the terms *policy goal*, *strategy*, *measure* and *scenario* are frequently used. In popular use they are often treated as interchangeable, and this can be confusing. In this appendix, and indeed in this book, the following meanings are used:

- A *policy goal* has to do with identifying the needs, prioritizing issues and setting targets for sectors or regions. A policy goal does not by itself lay down specific actions; it merely sets the targets and constraints for the actions (levels, timing and budget). Policies also may specify in general terms how a certain target should be achieved: for example, by applying user-oriented demand management measures rather than relying on large-scale water supply infrastructure development. In specifying how targets should be achieved, other policies are taken into account (to do with foreign trade perhaps, or fiscal or income tax requirements, or environmental controls). Government policies are usually considered as given

Box E.1. Definitions

Policy goal: where do we want to go
Strategy: how do we want to get there
Measure: what are we going to do
Scenario: external development, affecting our strategy

for any WRS study, but the results of the study may lead to the adoption of new government policies.

  – A *strategy* is defined as a logical combination of individual measures or decisions that provides a solution to the WRS problem, for example, the construction of a reservoir plus the widening of the canal downstream and the increase of the intakes of the irrigation system. Together, these measures will reduce the risk of damage to the agriculture sector in a drought-stricken area. An alternative strategy might be to implement a cropping pattern that uses less water.

- A *measure* is an individual management action or decision. A distinction can be made between:
  – *Technical (or structural) measures:* modifications of elements of the water resources infrastructure such as canals, pumping stations, reservoirs, and fish stairs or ladders. Technical measures often include managerial measures as described below.
  – *Managerial measures* to improve the (daily) operation of the system, such as better ways of using the infrastructure (reservoirs, gates, weirs, sluices, etc.).
  – *Ecological (non-structural) measures* to improve the functioning of the ecosystem, for example by introducing fry in spawning areas, or large herbivores.
  – *Economic incentives* to induce water consumers to use the water resources in a socially desired manner by changing the price of the resource use (through charges, taxes or subsidies).
  – *Regulation measures* to restrict uncontrolled use of the water resources (through land-use zoning, permits, pollution control and other forms of restrictive legislation).
  – *Institutional arrangements* specifying which governmental agencies are responsible for which functions of the WRS, and specifying the necessary interactions between public and private sectors involved.
- A *scenario* is defined as a development exogenous to the water system under consideration: in other words, developments that cannot be controlled by the decision-makers involved in the system. Examples of scenario variables are climate, climate change, demographical trends and changes, and economic growth. What should be treated as a scenario and what as a (potential) measure may depend on the system boundaries that have been set. In 'real' integrated water resources management studies (see Chapter 1, Section 5.1.3), restrictions on demographic and economic developments could be treated as potential actions. In that case they are not scenario variables anymore but should be treated as measures.

1.4. Systems Analysis

In relation to the systems approach to planning, the literature often emphasizes the mathematical techniques at the core of this approach. The use of mathematical tools, however, does not of itself constitute a systems approach. The approach, designed especially for complex systems of many interdependent components, involves:

- building predictive models to explain system behaviour
- devising courses of action (strategies) that combine observations with the use of models and informed judgments
- comparing the alternative courses of action available to decision-makers
- communicating the results to the decision-makers in meaningful ways
- recommending and making decisions based on the information provided
- monitoring and evaluating the results of the strategies implemented.

Systems analysis and policy analysis are often considered to be one and the same. If a distinction should be made, one might define systems analysis as an activity that does not apply only to policy problems. It can be applied to any system one wants to analyse for whatever reason.

System diagrams or conceptual models are important tools in systems analysis. A system diagram represents cause–effect relations between elements or sub-systems of the overall system. An example of the use of system diagrams in analysing water resources problems is presented in Figure E.1.

As the figure shows, water-using activities may cause two problems. First, the quantity demanded is greater than the supply; second, they affect the natural system (e.g. generate pollution or alter the water level) with undesired effects. The perception of these problems can be a trigger for analysis and planning activities, which in turn can result in management actions. The figure shows that the problem can be addressed in two ways: either by implementing demand-oriented measures (addressing the water use, i.e. SES), or by developing the water resources (i.e. NRS). Demand-oriented measures aim to reduce water use and effluent discharge per unit of output. Supply-oriented measures on the other hand

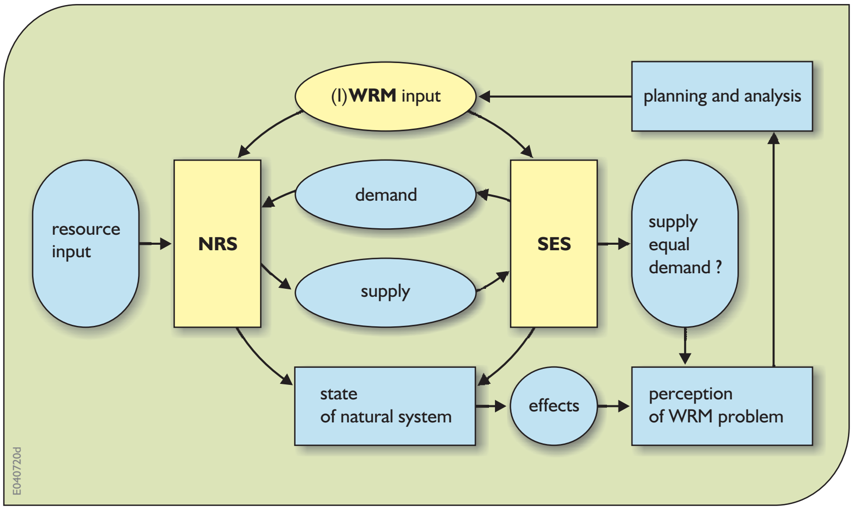

Figure E.1. Identification of a water resources management (WRM) problem.

are aimed at increasing the water supply so that shortages are reduced or at increasing the assimilative capacity of the receiving water bodies. Which measure or combination of measures is most effective depends on the criteria used by the implementing authority.

The relations between the elements of the systems can be expressed quantitatively. The system diagram is an outline of the computational framework to be used to analyse the performance of the system.

2. Analytical Description of WRS

Water resources management aims to match the usage of the WRS (the socio-economic system or SES) with the natural resources system (the NRS). This matching is based upon a common notion that scarce resources should be used for society in an 'optimal' way. Just what is optimum is determined by those who make decisions. The interaction between the use and availability of resources is controlled by the administrative and institutional system (the AIS) through which this management is implemented. These three 'entities' are depicted in Figure E.2.

The AIS 'manages' the other two entities, using information about the present or expected future state of each system. The management actions of this system are depicted by the single arrows leading towards the two interacting systems: by supply-oriented measures (infrastructure related) for the NRS and demand-oriented measures for the SES. The single arrow is not meant to imply there is no feedback from the NRS and the SES to the AIS; there must be feedback in the form of information

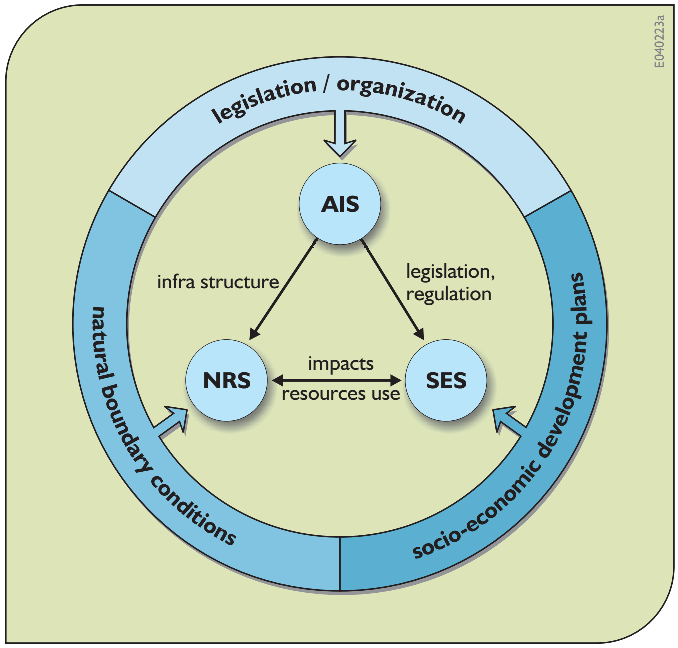

Figure E.2. Context for water resources planning.

on the state/performance of the two systems, otherwise effective management would be impossible. The arrows in Figure E.2 represent only the actions, not the information flows. The interaction between the user system (SES) and the resources system (NRS) is a physical one, depicted by the double arrow between the two systems. Resources provided by the NRS are used to support the SES, and the SES has physical effects on the NRS.

Each of the three systems is embedded within its own environment. The NRS is bounded by climate and (geo)physical conditions; the SES is formed by the demographic, social and economic conditions of the surrounding economies; and the AIS is formed and bounded by the constitutional, legal and political system. It is important to analyse these boundary conditions. Boundary conditions are usually considered fixed, but may not be as rigid as sometimes thought. For example, climatic conditions are mostly taken as fixed, and the analysis is based on historical information about precipitation, temperature and so on. These conditions may be considered to be subject to change, due to global warming. Whether to consider this possibility or not should be decided at the start of any analysis of a water management problem.

Economic growth is another example of a boundary condition that is often treated as fixed. If the resources system cannot sustain these foreseen developments (or only at very high costs), it may be appropriate to reconsider this fixed condition. By showing the consequences of unrestricted growth, the planning agencies can question the desirability of such development at a higher (usually national) planning level. This is represented in Figure E.2 by the border frame 'socio-economic development plans'. In fact, the arrow pointing inwards to the socio-economic system is reversed in such a case: the analysis provides information to a higher planning level that determines the (original) boundary conditions.

2.1. System Characteristics of the Natural Resources System

The natural resources system (NRS) is defined by its boundaries, its processes and its control measures.

2.1.1. System Boundaries

The study area will often coincide with an administrative unit (region, district, province, etc.), because the administrative system usually requires an analysis of the functioning of the water resources within its administrative boundaries. The system boundaries of the NRS, however, depend on its physical characteristics. The NRS must include the administrative area, but may extend over a larger area, depending upon the physical boundaries.

In many studies it may be useful to subdivide the NRS into smaller units with suitable boundaries. Examples are subdivisions into a groundwater and a surface water system, subdivision of a surface water system into catchments and sub-catchments, and subdivision of a groundwater system into different aquifers or aquifer components. The definition of (sub)systems and their boundaries should be done in such a way that the transport of water across the boundaries can be determined properly.

2.1.2. Physical, Chemical and Biological Characteristics

The *physical processes* in a NRS are transport and storage within (sub)systems and transport between them. For the surface water system, a distinction is made between the infrastructure of rivers, canals, reservoirs and regulating structures (the open channel network) and the catchments draining to the open channel network.

The *chemical characteristics* define the composition of groundwater and surface water and the processes that may influence this composition, such as transport, degradation and adsorption. The level of detail to which chemical characteristics are considered has to be in line with the requirements and threats of water-using and water-related activities, the problems and possible measures to be considered, and the institutional setting.

A useful concept for describing the *biological characteristics* is the ecosystem. An ecosystem is a combination of abiotic and biotic elements that influence each other. It includes all the organisms in a given area and their interaction with the physical environment, so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles within the system. The prime driving force for the flow of energy and matter within the system is ultimately the energy from the sun. Through an often complex series of steps, the solar energy is used for production and reproduction, consumption and decomposition, succession and recolonization. Ecosystems are not static or 'mechanistic'. Rather, they are dynamic networks of interrelated parts, which – to a certain extent – are capable of auto-repair when some parts are lost. This dynamic character of nature has proven to be essential in evolutionary terms, as it provides enormous resilience in coping with physical disturbances such as volcanic eruptions and global climate change. With respect to the sustainable development of water resources, the dynamic character of ecosystems guarantees that human activities can achieve equilibrium with the environment, albeit at the expense of the quality of the ecosystem in terms of species diversity and the like.

In ecosystems, a distinction can be made between the aquatic, terrestrial and land–water sub-systems:

- The aquatic sub-system may be defined as all permanent water bodies: lakes, rivers, streams, reservoirs, ponds and so on. A characteristic ecological parameter is, for example, the flow velocity.
- The terrestrial sub-system may be defined as the area that is predominantly dry and receives water only from rainfall and groundwater. Soil characteristics, altitude, slope and climate are major parameters for its living conditions.
- The land–water sub-system (wetland) is the interface between the aquatic and terrestrial subsystems. It is characterized by a highly dynamic environment, caused by the frequent (often seasonal, but also day-to-day and annual) changes in the water level. Examples are the floodplains along rivers, reed belts fringing lakes and streams, intertidal areas (mangroves) and salt marshes.

In addition to this broad classification into three sub-systems, it is often appropriate to distinguish different landscape or vegetation units, such as habitats. As a first approximation, different habitat types can be identified on the basis of homogenous vegetation structure. Once the study area has been divided into a series of sub-systems, habitats or other ecosystem classes, it is important to assess the degree of spatial relationships between these subsystems. Ecosystems are rarely completely isolated from one another, but are linked by physical transport processes (e.g. water and soil transport), nutrient pathways and migration patterns, as discussed in Appendix A.

2.1.3. Control Variables: Possible Measures

Some of the system parameters described above can be used to control the system. By adding or changing system parameters, water resources managers can change the state of the NRS in ways they desire. An example is the rule curve describing the operation of a reservoir (when to release how much water for what purpose). Another example is the dimension of feeder canals. Increasing the dimension of these canals permits greater allocations of water to farmers. Control or decision variables can include those relating to the condition, design and operation of the WRS. An example of non-physical control that changes the state of the biotic system is the release of predator fish in reservoirs to reach a desired balance of species in the ecosystem.

2.2. System Characteristics of the Socio-Economic System

Like the NRS, the socio-economic system (SES) has its boundaries, processes, and control measures.

2.2.1. System Boundaries

The economic system generally does not have a physical boundary like that of the natural system. Activities in a river basin, for example, are connected to the surrounding economies through the exchange of goods and services. Also, from a social point of view, the boundaries of the natural and economic systems rarely coincide.

The factors that determine the socio-economic activities in a study area now and in the future should be analysed in the context of the problems being considered. They could relate to larger systems, such as the national or even the international economy, e.g. when prices on the international market are important for local agricultural activities. The boundary conditions for the socio-economic system are those factors that are beyond the control of the decision-makers. Examples of such boundary conditions are the state of the world economy, the value of the US dollar or the price of oil.

2.2.2. System Elements and System Parameters

The socio-economic part of the WRS can be defined by identifying the main water-using and water-related activities, the expected developments in the study area, and the parameters that determine these developments. Examples of activities or economic sectors that may be relevant and of the type of information that has to be obtained to be able to describe the socio-economic system are:

- Agriculture and fisheries: present practice, location and area of irrigated agriculture, desired and potential developments, water use efficiency and so on.
- Power production: existing and planned reservoirs and power stations, operation and capacity, future demand for electric energy.
- Public water supply: location of centres of population and industrial activities, expected growth, alternative resources.
- Recreation: nature and location, expected and desired development, water quality conditions.
- Navigation: conditions of the water depth in relevant parts of the open channel system.

- Nature conservation: location of valuable and vulnerable areas and their dependence on water quality and quantity.

Some examples of important system parameters of the SES are: population dynamics (life expectancy, birth rates, death rates, etc.), labour force and wage rates, price levels in relation to national and international markets, subsidies, efficiency of production and water use, and income distribution.

When identifying and analysing activities in the study area, it is important to consider possible discrepancies between the opinions of individual actors and their representatives. For example, individual farmers may have different interests than suggested by the official agricultural organizations.

2.2.3. Control Variables: Possible Measures

The functioning of the SES can be influenced by legislative and regulatory measures, and the price of water may be a particularly important factor in deciding how much is demanded. This price can be influenced by the water resources managers and used as a control variable. When the cost of water use represents only a small portion of the total cost of an activity, however, an increase in its price may have little if any impact on water use. In some cases water use is a necessity of life no matter how high the costs, and in such cases, the price of water (or taxation for waste water discharges) is not a proper control variable.

2.3. System Characteristics of the Administrative and Institutional System

The administrative and institutional system (AIS), like the NRS and SES, has its elements that define its boundaries (its authority or limits) and its processes including its ways of reorganizing for improved performance.

2.3.1. System Elements

To characterize the administrative and institutional setting, the responsible institutes at the national, regional and local levels have to be identified. In most countries, the following elements in the institutional framework can be distinguished:

- the central government, divided into sectors such as public works, irrigation, agriculture, forestry, environment, housing, industry, mining and transport
- a coordinating body, for example a national water board, to coordinate actions by various sectors of the national government
- regional bodies, based upon the normal subdivisions of government, for example provinces, districts, cities and villages.
- regional bodies, based on a division according to the physical characteristics of the area, such as river basin authorities
- water-user organizations, representing the interests of directly involved stakeholders, for example in irrigation systems.

The following information needs to be made available:

- which ministries and coordinating bodies have authority and responsibilities related to water resources management
- which agencies are involved in the preparation of water resources development plans
- which national and regional water resources development plans are available
- which authorities are responsible for implementing these plans (regulation, construction and operation of infrastructural works)
- what is the existing legislation (laws and regulations) concerning water rights, allocation of water resources, water quality control and the financial aspects of water resources management.

Other sources of information about the administrative and legal setting include the policy documents and plans of other water-related sectors such as environment, agriculture, economy, transportation, physical planning and energy.

2.3.2. Control Variables: Possible Measures

From a systems point of view, the decision or control variables in the AIS are less clear than in the case of the NRS and SES. But in the case of the AIS too, measures can be taken to improve the functioning of the system, for example by establishing coordinating bodies when these are not present, shifting responsibilities towards lower levels of government, privatization and other measures.

3. Analytical Framework: Phases of Analysis

A water resources planning study generally comprises several phases. Although we do not suggest the use of a rigid framework, some distinct phases and activities can be recognized and used to structure the analysis as a logical sequence of steps. The description of these phases, the activities in them and the interactions between activities is referred to as the *analytical* (*or conceptual*) framework. A coherent set of models is used for the quantitative analysis of the water resources system, measures and strategies. This set of models and related databases will be referred to as the *computational framework*.

The purpose of a water resources planning analysis is to inform and support decisions. A decision process is not a simple linear sequence of steps, but involves feedbacks to earlier steps. Part of the process is thus iterative. A distinction is made between comprehension loops and feedback loops. A comprehension loop improves the understanding of a complex problem by cycling within or between steps. Feedback loops imply a return to previous phases of the process. They are needed when:

- solutions fail to meet criteria
- new insights change the perception of the problem and its solutions
- essential system components and links have been overlooked
- situations change (political, international, developments in society).

The general analytical framework for water resources management studies is depicted in Figure E.3. The three main phases of the framework are: *inception, development and selection*. Communication and interaction with the decision-makers are essential throughout the process. Regular reporting (inception and interim reports etc.) helps in effective communication, but a continuous dialogue is necessary at all stages of the analysis.

The first phase of the process is the *inception phase*. Here, the subject of the analysis (what is analysed under what conditions), the objectives (the desired results of the analysis) and constraints (its limitations) are specified. On the basis of this initial analysis, during which intensive communication with the decision-makers is essential, the approach for the

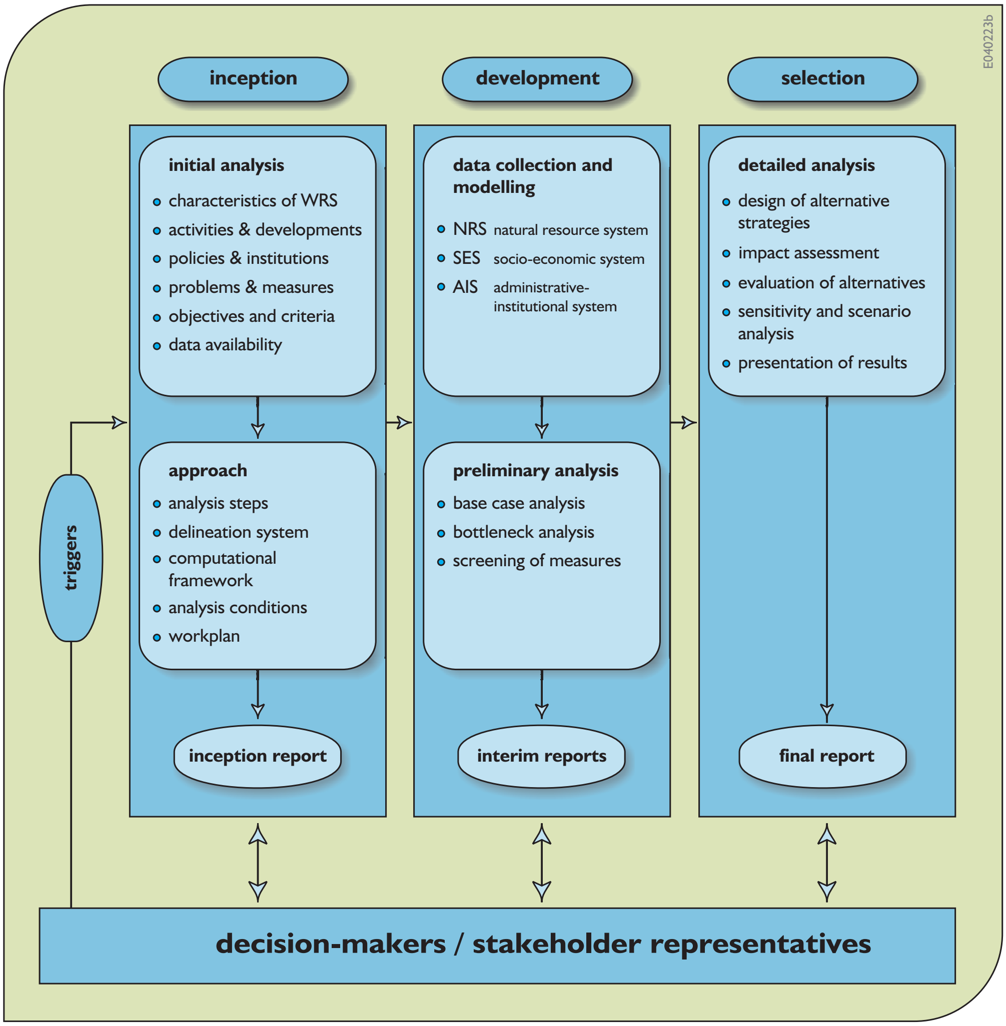

Figure E.3. Analytical framework for water resources planning studies.

remainder of the analysis is specified. The results of the inception phase are presented in the inception report, which includes the work plan for the other phases of the analysis.

In the *development phase*, the tools for the analysis and (elements of) solutions to the water resources problems are developed. Major activities are data collection and modelling. A preliminary analysis will ensure that the developed tools are suited to the generation and assessment of measures to solve water resources problems. Individual measures will be developed and screened in this phase. A gradual improvement of the understanding of various characteristics of the WRS is obtained, going from limited data sets and simple tools to more detailed data and the full set of models. Interaction with the decision-makers will be greatly enhanced if they are involved in the preliminary analysis as part of the analysis team. The formal interaction is structured through the presentation of results in interim reports.

The purpose of the *selection phase* is to generate a limited number of promising strategies that, after detailed assessment of their effects in terms of the evaluation criteria, will be presented to the decision-makers who – with inputs from the public – will decide on their preferred line of action. Important activities in this phase are strategy design, impact assessment, evaluation of strategies, sensitivity and scenario analysis, and presentation. The results of this phase are included in the final report, together with a summary of the results of the development phase. Continuous interaction with the decision-makers is essential in the phase. They or their representatives should be part of the team that carries out the analysis. During this phase, public consultations will also be needed to inform and involve stakeholders and get their reactions and inputs.

Reference is made above to the 'decision-makers'. Although it is clear that the analysis will eventually support decisions, it is not always clear who (or which unit) will make the final decisions. If an outside consultant performs the analysis, careful selection of the coordinating agency is essential for the successful implementation of the project. Interaction with the decision-making arena usually takes place through steering committees (which can act as an interdepartmental forum), technical advisory committees and public participation processes.

The inception phase is a very important component of this analytical framework. It determines to a large extent what will be done in the analysis. This inception phase should therefore get ample attention. Many commercial contract terms of reference (ToRs) for planning studies include an obligation for the 'consultant' to submit an inception report a few weeks after the starting date of the assignment. An inception report is simply an update of the proposal, covering the time between the submission of the proposal and the starting date, and addresses only the changes that need to be taken into account. Depending on the complexity of the system and required interaction with decision-makers and stakeholders, an estimate of the percentage of the total project resources (money and time) that should be devoted to the inception phase can amount to 30 or even 40%.

4. Inception Phase

Water resources planning studies are often *triggered* (left oval in Figure E.3) by specific management problems such as the need to increase power production, the occurrence of droughts or floods, or the threat of water quality deterioration. The need for water resources planning in relation to other sector planning efforts may also be a trigger. Which parts of the WRS are studied and under what conditions follows primarily from the objectives of the study (and from the available budget, information and time). The initiators of the study generally have more or less concrete ideas about the objectives and subject of the analysis. They react to triggers as mentioned above and, being aware of problems or issues, have taken the initiative for a planning analysis.

The client's ideas about the problems and issues to be addressed will usually be described in a Project Formulation Document (PFD) or ToR (terms of reference). The very first activity of the project is to review and discuss these documents. If the subject (what) and objectives (what for) of the analysis are adequately described in the ToR, the first step of the study is to specify the approach (how). In many situations however, the first task of the analysts is to assist the decision-makers in further specifying the objectives and subject of the analysis. For this activity, intensive communication is required with authorities involved in water resources planning and the stakeholders. They can provide information on the requirements of various interest groups related to water and on expected problems. It is not uncommon to have the stated objectives of a study differ from the actual (often unstated) objectives of the client. Furthermore, objectives change over time. As emphasized in Chapter 2, constant and effective communication between analysts and their clients is absolutely essential.

The inception phase starts with an *initial analysis*, to clarify the subject and the problems and objectives involved. Building on the understanding that developed from this initial analysis, a more or less formal description can be given of the *approach* that the planning study will follow, including a description of the analysis steps that will be taken, the computational framework that will be used and the assumptions and conditions under which the planning study will be undertaken.

4.1. Initial Analysis

The purpose of the initial analysis is to better understand the system (NRS, SES and AIS), its problems, management objectives and possible measures that can be taken to improve it (see Figure E.4). The analyst has to structure the activities and indicate the consequences of considering or neglecting various aspects. Brainstorming sessions with various specialists and stakeholders should help to identify and balance the different aspects of the study. The aim of these activities is to ensure that the analyst has the same perception of what needs to be done as the decision-maker and stakeholders.

4.1.1. Inventory of Characteristics, Developments and Policies

The initial analysis starts with an inventory of the *characteristics* of the WRS. This is not an easy task because it requires the reduction of a complex reality into a comprehensible description of system components. Choices have to be made about what (the detail that) should be included and what can be ignored. Such choices require engineering and economic skills in combination with a good understanding of the problems and possible measures.

The next step will be an inventory of the *activities and ongoing developments* that will determine how the system will function in the future and what kind of additional activities can be expected. This can include autonomous developments (such as population and urbanization growth) as well as policy decisions that have been or may be taken that will influence the WRS and/or its performance. An inventory of *policies and institutions* is needed to identify who is involved in the management and development of the system (and hence who should be involved in the analyses) and what their plans are.

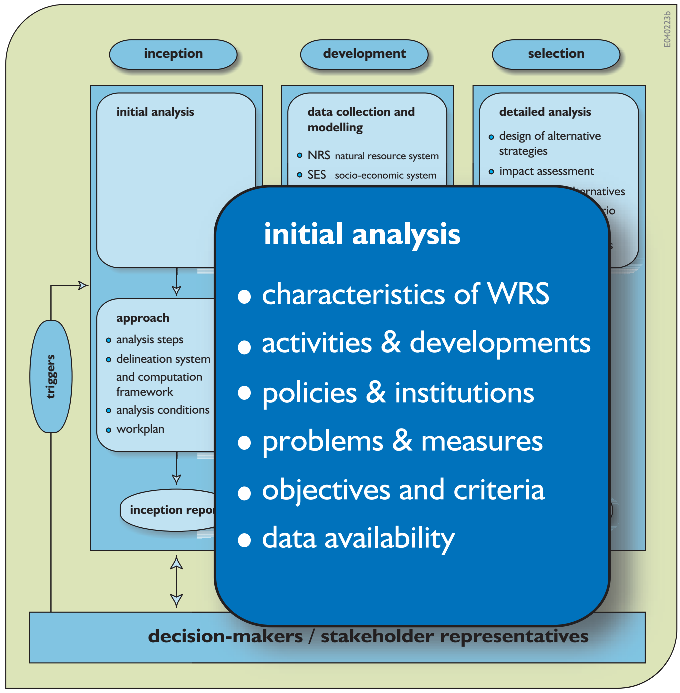

Figure E.4. Components of initial analysis.

This will contribute to the development of scenarios for the analyses. Scenarios are defined as developments exogenous to the water system under consideration (see Section 1.3).

4.1.2. Problem Analysis

Based upon the previous steps a problem analysis can be carried out. This should be done based on the facts and what the stakeholders and decision-makers perceive as a problem. A simple example of a problem analysis is presented below in Box E.2.

A problem analysis should be expressed as far as possible in terms of the socio-economic and environmental or ecosystem impacts that have meaning to the decision-makers. Not all stakeholders may be able to relate to predicted changes in flows, water levels or pollutant concentrations. Some may want to know how much money is involved (e.g. crop production, repair costs), the rate of shore line erosion, the relative change in fish population, or the number of people affected by flooding. Expressing outcomes in terms of socio-economic impacts makes it easier to relate the problems to the (socio-economic) development objectives that decision-makers have formulated for the particular region or system under consideration.

Box E.2. Example of Problem Analysis

A reservoir is in operation for power production and water supply to an agricultural area in a coastal zone. Farmers in the area are complaining that the water supply is inadequate. As the general objective for water resources planning is to develop the availability of water resources to obtain maximal economic benefits, an analysis is required.

A first analysis of the available information shows that the water demand for irrigation in August cannot be satisfied because the farmers have shifted to crops with a higher water consumption and the irrigated area has been extended. The constraint (bottleneck) is the capacity of the feeder canal to the area. If the capacity of the feeder canal is increased, the reservoir may become empty in dry years, unless the operation of the reservoir is modified. The use of groundwater could be considered as an alternative to surface water irrigation. Possible measures are:

- increasing the capacity of the feeder canal
- improving the operation of the reservoir
- increasing the withdrawal of groundwater from the coastal aquifer
- reducing the agricultural water demand in August.

A practical criterion to compare the effectiveness of the measures is their net benefit. Other factors, like the effect of groundwater withdrawal on saltwater intrusion or the loss of operational flexibility of the reservoir, may also have to be considered in the assessment of alternative solutions.

A good problem analysis will also indicate the measures that can be taken to eliminate, reduce or alleviate the identified problems. The problem analysis in Box E.2 includes such measures. The identification of measures does not only help to clarify the problems and possible solutions; such early identification is also needed for the design of the computational framework and the data collection activities (see Section 5.1). These activities should be designed in such a way that the measures can be evaluated in the analysis phases of the study.

4.1.3. Objectives and Criteria

An essential activity in the inception phase is the translation of general objectives, as described in policy documents, into operational objectives that can be

Box E.3. Examples of Objectives and Criteria

- General objectives:
  - to develop the potential of the water resources in such a way that the expected value of the (net) benefits to the national and regional economy will be maximized, while minimizing negative impacts on public health, welfare and the environment
  - to provide good drinking water to the population.
- Operational objectives:
  - to meet the given demands for public water supply (for population and industry) in a certain year
  - to realize a certain level of agricultural production in a given time
  - to meet certain predetermined water quality standards.
- Criteria:
  - cost-benefit ratio
  - amount (or value) of agricultural production
  - amount of energy production
  - area of aquifer lost to saltwater intrusion
  - changes in groundwater levels
  - environmental standards (BOD, DO, etc.).

assessed in a quantitative way. Some examples of objectives and criteria are listed in the Box E.3. The objectives and criteria used in a water resources management study in West Java, Indonesia are presented as an illustration at the end of this appendix.

To incorporate sustainability as an objective in the study, attention should be given to all aspects of sustainable development. The decision-makers and analysts must be aware of how sustainable development aspects can be incorporated in the water resources planning study. Criteria should be laid down to assess the sustainability of developments and measures that may contribute to sustainable development should be identified.

4.1.4. Data Availability

The last activity in the initial analysis is to investigate the availability of data and other information required for the study, in particular for the description of the NRS (quantity and quality) and the SES. The availability of data determines the level of detail and accuracy that can be achieved in the analysis. If few data are available, a more qualitative analysis may have to be performed.

The required level of detail will primarily be determined by what is needed to analyse the problems, objectives and measures involved. Data availability might be a constraint, but if abundant data are available they need not be all used (by applying very detailed computer models, for example). The relevant problems and measures might very well be addressed by a less detailed approach or even a qualitative analysis.

On completion of the initial analysis, the analyst should have a clear idea about what will be studied, for what purpose and under what conditions. The information related to those questions will be documented in the second part of the inception phase, the phase that defines the scope of the study.

4.2. Specification of the Approach

Once it is clear 'what' will be analysed and 'why', it is the task of the analysts to specify 'how' this will be done. Figure E.5 highlights the elements involved. The specification starts with the steps that will be followed in the analysis, enabling the stakeholders to follow the process. Next the system will be described, laying out what will be analysed and what will not. To assess the effects of measures or combinations of measures, a computational framework is required. The analysis conditions specify the assumptions and conditions under which the analysis will be performed. All required activities will be combined in a work plan. Some important elements in the specification of the approach are discussed below.

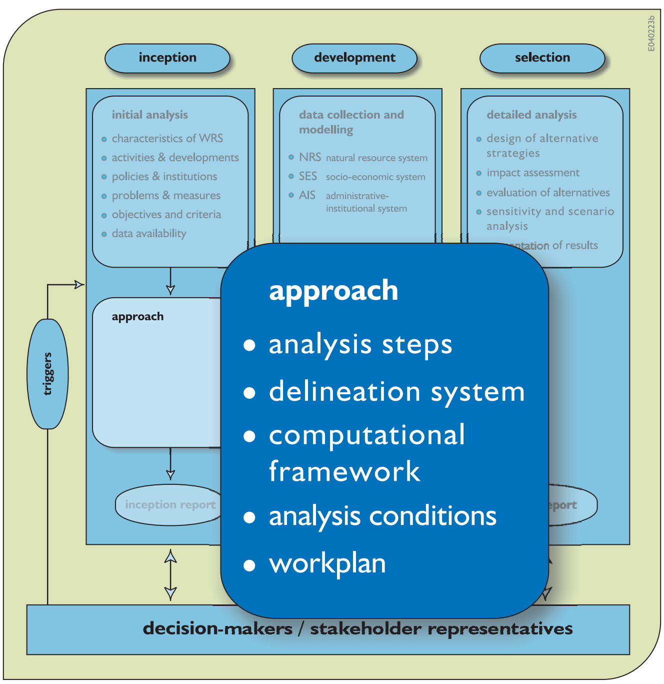

Figure E.5. Components of the inception approach.

4.2.1. Analysis Steps

The specification of the analysis steps has both an internal (to the project) and an external function. The *internal function* is that it will tell the various (often interdisciplinary) team members what the position of their contribution is in the overall analysis approach. This is necessary to schedule activities of all the members and to ensure (or at least enhance the probability) that they will provide the right kind of information to each other at the right times. The external function relates to the interaction with the decision-makers and stakeholders; it specifies when and how they will be involved in the analysis.

The specification of the analysis steps can be based on Figure E.3. This generic figure should be made more specific by addressing the particular aspects of the system and problems under consideration.

4.2.2. Delineation of System

The next step is to determine the components that will be taken into account in the analysis. The boundaries of the (sub)systems need to be determined on the basis of their natural boundaries, physical in case of the NRS, administrative in case of AIS, etc.

Required Level of Detail

An often difficult aspect to address in the inception phase is the level of detail that should be chosen for the components and subsystems of the system under study. To comply with the overall purpose of the study – the preparation of a plan that addresses the problem and provides 'the best use' of goods and services provided by the WRS – one does not have to know the use of every square metre of land in the study area or the water use of each leather tannery in the area. One has to use values averaged over areas and groups of users with just enough detail to provide the information required to support decision-making. The information is used to discriminate between alternative courses of actions and has to be relevant for the evaluation process. It should thus be expressed in terms of the selected evaluation criteria.

One of the main tasks of a project leader is to manage the experts from various disciplines in their 'enthusiasm' to find the answers to all possible questions. Not staying focused on the appropriate level of detail is one of the most common causes for project failure. If the needed level of detail is underestimated at the start of the project, the study has to go into more detail to be able to solve the problem. Sometimes the right level of detail is chosen, but team members spend too much time addressing more detailed questions and fail to come up with answers within the available time. Changing the level of detail is one of the main reasons for feedback loops in the analysis process.

The level of detail has to be specified for the following aspects:

- *Spatial disaggregation of the study area: type and size of units*. The spatial disaggregation usually depends on the types of water demand, the system of rivers and canals, and the characteristics of groundwater aquifers.
- *Sectoral disaggregation of water users*. The ISIC classification (International Standard Industrial Classification) distinguishes economic activities in various sectors. At the two-digit level for example, agriculture is treated as one sector. At more detailed levels the agricultural sector is broken down in smaller subsectors such as aquaculture, dairy farming and cotton growing.
- *Time steps for the analysis of processes*. It is important to select the most appropriate time scale. One generally has to consider various time steps. In a system with reservoirs with over-year storage, one should run a sequence of years to study the performance of the reservoir. For the analysis of the agricultural sector one often has to account for seasonal variability.
- *Quality of the environment*. Not all species can be used as indicator species. A choice has to be made to show the impacts of measures on the quality of the environment and the ecological integrity.

4.2.3. Computational Framework

The results of the preliminary analysis will define the computational framework that is needed for the analysis. This framework comprises mathematical models, databases, GIS and the like. These must describe the system (NRS, SES) and evaluate possible measures and strategies under different scenarios. (The different kinds of models and approaches that can be used are described in the main text of this book.) In general, a combination of simulation and optimization models will be useful.

For the development of the computational framework, the study area may be subdivided into smaller units considered to be homogeneous with respect to their characteristic parameters. Each unit is represented in the mathematical model(s) by a computation element. The number of elements required for the analysis depends on the issues being addressed, the complexity of the study area, the kind of measures to be studied and the availability of data. It generally is wise to start with a preliminary schematization with the minimum number of elements. If more spatial detail is required in a later stage, elements can be subdivided.

Use/Adaptation/Development of Computer Programs

Computer programs may be used to analyse various aspects of the WRS. A decision should be made about whether to use existing programs or to adapt or develop new ones. As development of computer programs is a very time consuming activity, existing ones should be used whenever they meet the requirements of the study.

Hydrometeorological Boundary Conditions

Boundary conditions for models of the NRS comprise precipitation, evapotranspiration and flow across the model boundaries. Parts of the NRS that are not influenced by water management (natural catchments) are usually not included in the computational framework. The discharges of these (sub)catchments are derived from historical streamflow data. If the availability of streamflow data is insufficient, rainfall–runoff models may be used to generate streamflow records from precipitation data.

Three approaches may be used to account for the stochastic character of the hydrometeorological conditions for which water resources strategies have to be evaluated:

a. Simulation of a strategy for a complete set of hydrometeorological data, e.g. forty consecutive years, including dry and wet periods.
b. Simulation for a selected sample of the available data, each one representative for a certain situation, such as an average year, a 10% dry year or a 2% dry year.
c Simulation of just one representative year, such as an average year.

Which approach is preferred will depend on the specific problem situation, variability of the hydrometeorological conditions, availability of data and the specific analysis that is required. It is clear that in cases where substantial over-year storage in reservoirs (surface water and groundwater) is involved, approaches b) and c) are not viable. Approach c) is only applicable in situations with very little variability over the years. Approach b) is often a good compromise. Figure E.6 illustrates the approach. The simulations are performed for three representative years: an average year (D_{50}), a moderate dry year (D_{10}) and an extreme dry year (D_5). The expected damage in this example is approximated with the following formula:

$$\text{Expected damage} = 0.125 * D_5 + (0.350 - 0.125) * D_{20} + (0.650 - 0.350) * D_{50}$$

In the development phase, when many alternative measures (solutions) have to be screened, simulations will be made for selected conditions only. For screening (see Section 5.2.3), the system is generally studied under stress conditions, for example a 10% dry year. The minimum time interval taken to represent a certain situation depends on the memory of the system. In a system comprising reservoirs with considerable over-year storage, representative periods should be more than a single year. In the selection phase, simulations will be made for promising strategies only, so that the complete set of historical data can be applied to them.

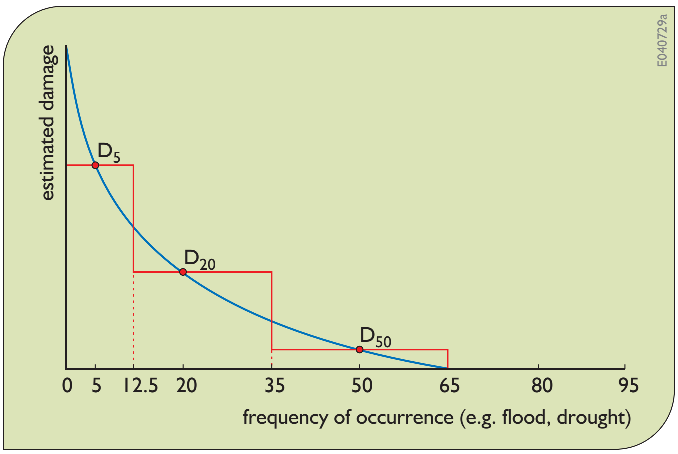

Figure E.6. Expected damage calculation based on three representative years.

Requirements for Data Collection

The analytical approach described above is usually formulated in an iterative way, taking into account data requirements, data availability and available resources (budget, manpower, models and analytical techniques). When the approach has to be modified in view of constraints (usually budgetary), the data requirements are reassessed. Once the analytical approach is specified, the exact requirements for data collection can be formulated: which data need to be collected, when, and by whom. Opportunities to collect additional data from field observations will generally be limited by the available budget and time.

4.2.4. Analysis Conditions

The assumptions and conditions under which the analysis is undertaken have to be specified in close cooperation with the decision-makers. These assumptions and conditions include:

- (Sub)systems boundaries. Definition of the WRS and a possible subdivision in sub-systems are based on physical (NRS) and/or administrative boundaries (AIS, see also Section 4.2.2).
- Base year. The analysis will be made for the present condition and one or more points in time. The present situation may be defined by the situation in the most recent year for which a reasonably complete set of data is available (the base year).
- Time horizons. These will be selected on the basis of existing planning horizons – usually ten and twenty-five years – or be related to the characteristic time scales of subsystems.

- Scenario assumptions concerning factors external to the WRS, such as the growth of population, food consumption and of water-related economic sectors and prices (energy or crop prices, for example). In many cases an analysis of socio-economic data will be required to obtain reasonable ranges for scenario variables (see Section 5.1.2).
- System assumptions. These concern factors internal to the WRS, such as the response of crop production to improved cultivation practices, or the effectiveness of price incentives on per capita water consumption. These system assumptions can be subject of additional (sensitivity) analysis in the selection phase (see Section 6.3).
- Time and budget constraints. The study has to be executed within constraints of available time and budget.
- Data availability. The study must be based on the data that can be made available within the time and budget available.

The choice of the time horizon is often given insufficient attention. Official planning horizons (e.g. ten and twenty-five years) are often used as time horizons for all elements of the analysis. As well as the planning horizon of the traditional government planning framework, however, one should also consider the time scales of the system and the processes within it. System components will have characteristic time scales. For example:

- User functions (economic activities) have life cycles that are determined by the amortization period of the investments. The time horizon of the planning process is based on these conditions.
- Social institutions have time horizons that depend on the pace of legal/institutional and political decision-making.
- Physical–chemical systems have time scales that depend on the response or restoration times of the systems. Restoration of polluted rivers, for example, may be achieved within a few months, while the restoration of a polluted groundwater aquifer may take decades.
- Ecosystems may have a time scale of a few weeks algae blooms) or tens of years (degradation of mangrove forests), depending on the type of process or intervention.

To study the sustainability and ecological integrity of the resource system, time horizons should be tuned to the response times of the system rather than to a planning horizon only. Although more attention is now paid to sustainability, no operational procedure has been developed to give long-term effects their proper place in the evaluation process. Decision-makers tend to take short-range decisions, involving possible risks in the long term, because their political jobs are often limited to (or renewable in) short terms and hence they prefer short-term political gains.

4.2.5. Work Plan

The results of the inception phase are documented in an inception report (Figure E.3), which will be used as a reference during the execution of the study. An essential part of the report is the work plan, in which time, budget and human resource allocations to various activities are specified. This work plan typically includes bar charts for activities and staffing, time schedules for deliverables, milestones, reporting procedures and similar features. It should include a communication plan that describes the interaction between the decision-makers and stakeholders and the analysis team.

4.3. Inception Report

The inception report has to contain all the results of the inception phase. It should make clear what will be studied, why and how. In many cases it will also specify what will not be studied and why. The content of the inception report follows the subjects mentioned above under the initial analysis and approach:

- Description of the water resources system
  - NRS: components
  - SES: activities and developments
  - AIS: institutions involved, legal aspects including a delineation of the components that will be studied.
- Problem analysis and problem statement.
- Objectives and criteria.
- Analytical approach (steps, models and databases).
- Analysis conditions (time horizon, scenarios, assumptions and so on).
- Work plan.

4.4. Communication with Decision-Makers and Stakeholders

The inception report is a specific and concrete result of the inception phase. It is an important product because it contains all that has been learned in this first phase and that has been agreed upon between the analyst and the 'client' (the decision-makers and the stakeholders). A possibly even more important result of the inception phase, however, is the interaction that should take place during this phase between the analyst and the client. The client's views about problems, objectives and other aspects should develop alongside the view of the analyst. The analyst must understand the client's concerns, problems and objectives and not just his or her own. Clients should feel they 'own' the results of the inception phase and view the inception report as their own product, not merely a report of the analysts or consultants.

To achieve such ownership, frequent interaction must take place among the analysts, the decision-makers and stakeholders, to a much greater extent than is indicated in Figure E.3. This can be done in specific workshops, such as those devoted to the problem statement or to the specification of objectives and criteria, public consultation meetings.

5. Development Phase

The development phase includes simultaneous model development and data collection followed by a preliminary analysis to identify possible solutions for the problems being addressed.

5.1. Model Development and Data Collection

In the development phase, a coherent set of computational tools is developed for the analysis of the WRS and SES, as specified in the inception phase. Possible solutions for the water resources problems are also identified in this phase. The result of the data collection and modelling activity is a computational framework that represents the characteristics of the WRS at an adequate level of detail. The framework is designed to quantify the effects of individual measures or combinations of measures, expressed in values for the evaluation criteria that correspond to the objectives of water resources management. For the schematization of the study area, experience from previous applications may be helpful. However, each study is different and the schematization should always be tailored to its specific requirements.

If computer programs have to be developed from scratch, or if existing computer programs have to be adapted in a significant way, a considerable effort may be required and the activity may consume a large part of the available budget and time. Careful selection of the phenomena to be represented by the models, tuned to the needs of the analysis, can result in considerable savings. In the course of the modelling activity, more information on the study area and the type of measures to be considered may become available. Sometimes this may lead to a simplification of the modelling activity. The models should therefore be flexible and adaptable to new information. Activities related to data collection andmodelling will comprise all three components of the WRS (see Figure E.7). The emphasis is generally on the NRS, and to analyse this, a distinction can be made between physical, chemical and biotic components.

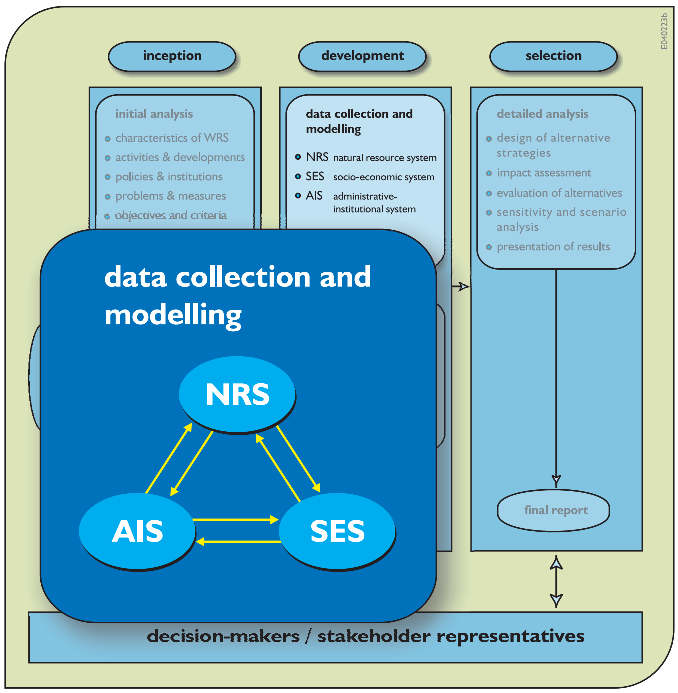

Figure E.7. Components of data collection and analysis.

5.1.1. Analysis of the Natural Resources System (NRS)

Physical Components

The NRS comprises the natural and human-made infrastructure, including the hydrometeorological boundary conditions. Models can be used to simulate the processes of water distribution through the infrastructure, taking into account the storage of water and withdrawal from the network to satisfy the demands of the water-using activities. (Chapter 11 provides an overview of possible models involved.)

The main water allocation related functions of the surface water system are storage of water in reservoirs and diversion of water from the rivers and main canals to branch canals. Typical time steps in planning studies are periods of a week, ten days, fifteen days or a month. In most river basin simulation models (e.g. RIBASIM, WEAP, MIKEBASIN), the surface water system is represented by a network of nodes and branches. At the nodes, natural runoff can be supplied to the system or water can be abstracted to satisfy specified water demands. Storage is represented by reservoir nodes, where reservoirs are operated according to user-specified rule curves. Facilities are available to account for power generation, diversion of water to branch canals, return flow from irrigated agriculture, drainage from districts, minimum flow requirements and so on. The allocation of water to the demand nodes is in upstream–downstream sequence, accounting for user-specified priorities. Most river basin models contain algorithms to include simple flow routing in the analysis. If necessary, more detailed hydrodynamic models such as MIKE-11 or SOBEK can be used.

Hydrometeorological data are analysed to provide time series of inflows to the surface water system. Typical elements of the analysis are: historical streamflow data, rainfall data and rainfall–runoff relations. The reliability and availability of historical streamflow data are often insufficient for the purpose of the study. Streamflow data may then have to be supplemented with synthetic data derived from observed precipitation and rainfall–runoff relations. A typical period for which data would be required is twenty-five years. Chapters 7, 11, and 13 introduce tools for an analysis of hydrometeorological data and rainfall–runoff simulations.

A main parameter characterizing the groundwater system is the groundwater level or head. In coastal zones, where seawater intrusion may occur, the salinity of the groundwater has to be considered as well. The time scale for effects of withdrawals on the groundwater head is in the order of ten to fifty years; saltwater intrusion is even slower and effects may have a time scale of a century or more. For such computations, steady flow conditions are often assumed and a comparison is made of the effects of different abstraction alternatives. Important aspects in the analysis of the groundwater system are the identification of the system of aquifers and aquitards and the determination of the recharge to the aquifers. Groundwater models can be used to test the consistency of collected data. Use of models to quantify the effects of future groundwater abstraction is only suggested in cases where there is sufficient information to calibrate the models for reproduction of the existing situation. Many general groundwater programs (e.g. MODFLOW) are available to compute the groundwater heads in a system of aquifers.

Chemical Components

The analysis of chemical components in the water system is used to study the influence they have on the user functions or the biological system. The components and processes that are to be considered in the analysis will have been selected in the inception phase. Their concentrations are computed in discrete segments of the surface or groundwater system, and this will require data on the influx of substances across segment boundaries and on the chemical processes in the segments. (Chapter 12 gives more detailed descriptions of available modelling approaches.)

The results of the water quantity modelling may be the inputs for water quality models, and are used to determine the water balance for each segment. To assess the mass balance of the chemical components, data on concentrations in the inflows to the segments are required. In addition to the inflow terms in the water balance, some extra terms have to be specified. For example, the discharge of sewage water may be negligible for the overall water balance but have a significant impact on the water quality of a river segment.

Biotic Components

The analysis of the biological system aims to determine the response of the ecosystems to water resources management. Because there is too little exact information on the biotic components in most cases, and because ecosystems largely depend on habitat parameters, the analysis may have to be limited to the essential relationships between ecosystems and physical and chemical parameters. The selection of key factors for ecosystem performance depends on the type of ecosystem, the kind of analysis for which they will be used and the type(s) of activities or human interventions involved.

For example, consider the impacts of dam construction on downstream ecosystems. Key parameters include:

- hydrodynamic regime (discharge characteristics and flooding pattern, such as duration, depth and frequency)
- water quality (e.g. sediment load, temperature, oxygen, salinity).

It is likely that these parameters will change due to the dam's construction, which may thus affect the downstream ecosystems. A combination of information on the present ecosystems and physical conditions and the direction and order of magnitude of change in the parameters mentioned above often enables one to make an expert judgment on the significance and direction of change of the ecosystems.

However, if one wants to make a more accurate and detailed prediction of ecosystem changes, for example by using mathematical modelling, much more information on the conditions determining fluvial ecosystems is needed. For example, a vegetation development model of the downstream areas liable to flooding needs – in addition to the key parameters mentioned above – information about:

- local topography (relief, dikes and culverts, channels, oxbows etc.)
- local geomorphology or soil types
- vegetation patterns.

Using known relationships between vegetation and physical factors such as the inundation frequency and soil/geomorphology, a preliminary model can be made that predicts changes in the vegetation pattern caused by changes in river flooding behaviour. Such an approach can be greatly enhanced by the use of geographically oriented data, in the form of digitized maps of the topography of the area, the soils, inundation and vegetation.

For aquatic habitat types, the approach may be quite different. Aquatic flora and fauna in rivers and lakes are affected by such factors as flow velocity, shear stress, water depth, bottom type and water quality. The use of one-dimensional hydraulic and water quality models is therefore often indispensable, but needs a concerted effort between ecologic and hydraulic modelling experts. It is especially important to identify data requirements as early as possible. In most cases, special physical or chemical modelling calculations are needed to supply the required data for habitat prediction. For example, hydraulic modelling often concentrates on high and low water levels, whereas floodplain ecosystems also depend on intermediate levels and duration curves. Time steps may differ and additional detail may be required in the model.

In most cases, predictions of ecosystem changes have a relatively large margin of uncertainty. Causes of this uncertainty include the often limited availability of data and the gaps in our fundamental knowledge of how ecosystems really work and of their complexity and dynamic behaviour. Creating detailed descriptions of species composition remains very difficult, especially when new species may appear. These factors also make it very difficult to assess the significance of the changes. The evaluation of ecosystems generally requires information on species diversity and the occurrence of rare or endangered species, and this is often lacking.

The significance of the effects of water management on ecosystems is increasingly acknowledged. Specific tools for predicting these effects are being developed, mostly on a regional basis. For example, models can be used for the prediction of vegetation development in relation to inundation characteristics, soil type and nature management practice in floodplains, or in relation to groundwater management. For biological water quality, models are widely available, including models for algal composition and algal bloom (Chapter 12).

Scenario Development

Depending on the scenarios defined in the inception phase, it might be necessary to develop scenarios for the natural resource system. In nearly all cases, these willcertainly be needed to take into account possible climate change that may affect the physical components (rainfall, flow, etc.), and very probably also the chemical and biotic components.

Scenarios for the natural system are also needed when the system boundaries, as defined for the analysis, do not cover the full river basin and, for example, developments upstream might influence the inflow into the system. This is typically the case in national studies where the system boundary has been set at the national border.

5.1.2. Analysis of the Socio-Economic System (SES)

Developments in the SES determine the way demands on the NRS will develop. Conversely, the development of economic activities within the study area may depend on the availability of water. For example, good supplies of relatively cheap surface water may stimulate the development of irrigated agriculture, or attract industrial activities that require large quantities of water for their production processes. Another example is the development of water-based recreation around a reservoir. These socio-economic system developments in turn increase the water demands.

It is the task of the economist or planner to estimate the future levels of the activities that require water resources for their development, as well as the resulting water demands (and discharges). The estimate is made for the time horizon of the study, within the geographical boundaries of the area. The main activities are:

- assessment of the present economic situation
- activity analysis
- scenario specification.

Assessment of the Present Economic Situation

The starting point for an analysis of the SES is an assessment of the present economic situation with respect to the water-related activities and the factors that determine these activities. Past trends should be analysed to provide information on factors that have been decisive in bringing about the present situation and that may give clues about future developments. The analysis should focus on present and future major water use categories, which are identified at an early stage in the analysis, rather than trying to estimate water demands and discharges for all possible water use categories.

One's attention, then, should be on the most important factors that determine relevant water-related activities rather than on an analysis of the total economy. The difficulty in forecasting economic developments is, however, that one does not know *a priori* which factors will be decisive for these developments. As population dynamics are explanatory factors for many economic developments, demographic analysis (population growth, where and at what rate) is generally one of the first activities in this phase. Other important parameters for the development of water-related activities are:

- sectoral distribution (primary, secondary and tertiary sectors)
- industrialization
- labour force and wage development
- the price of oil and other commodities
- the balance of trade (imports and exports)
- the stability of local currency.

In the analysis of the present economic situation, attention should be given to the possible effects of changes in the WRS on the regional or national economy. To determine how effects related to water users may influence major economic indicators such as gross national product, balance of trade or equity considerations, a macro-economic analysis of the relation between the water-related sectors and the rest of the economy and its surroundings (e.g. foreign trade) is often required.

An example of a macro-economic model that could be used for such an analysis is an input–output model. Such a model shows the relationships between various sectors of the economy. Using an input–output model, one can analyse how effects generated in one sector influence other sectors of the economy, not only in terms of value added, but also in terms of labour requirements. Such economic models have been extended to include environmental and resource-use aspects (national resource accounting models). Inclusion of these aspects, however, requires a rather large effort (in terms both of data and of manpower) and should therefore only be considered when major effects on the national economy are expected.

Activity Analysis

The activity analysis focuses on the relation between the economic activities and their water use. It focuses on the relations that determine the type and amount of water used by various activities. An activity analysis must answer the following questions with respect to each identified activity:

- What are the amounts of water (quantity and quality) demanded during which periods of the year and at which locations?

- What are the amounts of water discharged and the pollution loads during which periods of the year and at which locations?
- What are the benefits to the user if these amounts are made available?
- What is the damage to the user if these amounts cannot be made available?
- Which costs can be recovered by having the user pay for the water?
- Will cost recovery influence the water use pattern of the water user (both at the intake and the discharge side of his activity)?

Estimates of future water demands and wastewater discharges are generally based on the determination of unit water use and wastewater discharge per unit of activity. Looking at combined trends in unit water demands and economic developments can provide insight in possible future water demands. The final result of the activity analysis should be water demand functions, relating water demand to exogenous parameters.

As well as the level of activities and the resulting water demands, the geographical location of water-using activities (the pattern of activities) must also be known or estimated. If the pattern of activities is not expected to change, the analysis can be focused on the present situation in the study area. If new activities are expected to develop within the study area, it may be necessary to analyse the water-use characteristics of similar activities in other regions.

The resulting water demands should not be considered as 'given'. Water-use coefficients can be changed through measures such as water pricing that aim at reaching a socially preferred use pattern. Technological developments may result in less water use and pollution load per unit of product. If supplies and demands are matched before the effects of such incentives are analysed then one may end up with an overcapacity, because the 'given' demands may be lower if water users are confronted with the costs of the use of the water resources. This type of feedback needs to be considered in the study.

Estimating benefits and costs related to water use provides information to evaluate water resources management strategies. One of the criteria in this evaluation is the net economic benefit of the measures for various water users. One needs to know what benefits water users derive from the use of the water resources, and what costs they have to pay in order to obtain these benefits. The activity analysis should produce therefore benefit and cost functions related to various water uses. These functions can be used to evaluate the proposed strategies.

Scenario Specification

Because of the multitude of factors that determine water demand, perfect forecasting of economic development and resulting water demands is a utopian dream. Future water demands are often dependent on future scenarios. A water demand scenario is a logical combination of basic parameters of the economy, their effects on water-related activities, and the resulting water demands. An understanding of the functioning of the socio-economic system developed through the assessment of past and present trends should be used to formulate a limited number of consistent scenarios.

For analytical purposes, it is useful to define an autonomous development scenario (i.e. the development of the socio-economic system) and its water demands, as it would develop independently from changes in the WRS. An autonomous development scenario does not consider possible constraints in the supply of water, and is thus very useful for analysing bottlenecks in the water resources system.

In a regional water resources management analysis, national economic growth and technological development are usually taken as exogenous parameters for the autonomous development of the region. Regional measures can however influence water use and may divert economic activities away from the area of study, or even influence the growth of the national economy, which was originally seen as an exogenous parameter.

Since many uncertain factors influence the development of water demands, the future cannot be projected by using a single autonomous development scenario. Rather than constructing many alternative scenarios through permutation of the uncertain parameter values, one may have to consider only two or three different development paths.

Scenario building is not a straightforward activity; it is partly an art that depends largely on the views of the analysts and local experts about which trends are likely to prevail in the future. The developed scenarios have to be internally consistent with respect to the magnitude and direction of the developments. Exogenous variables (population growth, economic growth) and water-related

Box E.4. Example

The development of water demand in agriculture is autonomous only to a limited extent, as it depends largely on the availability of land and water resources. The demand for agricultural products, however, will develop in an autonomous way. If the availability of water resources in a region is limited, the autonomous development of agriculture will be limited as well, and one would predict a small increase in agricultural water demand. If the demand for agricultural products increases considerably and self-sufficiency in food production is an objective, then the desired agricultural development to meet this objective may be considerable. The water demand corresponding to this desired agricultural development will show the need for further development of the water resources in the region.

variables (for example per capita water consumption) are combined into logical, coherent water-demand scenarios. An increase in per capita income could cause an increase in per capita water consumption. A scenario which presumes high economic growth should therefore also presume high per capita water-use coefficients.

Scenarios are often made top-down: that is, first one projects the basic parameters of an economy (population, gross national product, imports and exports, etc.) for the whole country or large parts of it. The economic developments projected at the national level are then broken down for regions, usually using past trends in regional economic growth related to the national average growth trend. These regional projections should be in line with population projections, because economic development also depends on population growth. One should use information available at the local level to check the assumptions made in disaggregating national projections.

5.1.3. Analysis of the Administrative and Institutional System (AIS)

An analysis of the AIS is required for three reasons:

- The information required for the study has to be obtained from the agencies involved.
- The legal framework may impose certain constraints on the development of water-using activities.
- The implementation of measures may be constrained by institutional bottlenecks.

In the inception phase, a preliminary analysis is made of the institutional setting of water resources management. The responsible authorities and institutes in the water resources sector and water-related sectors are identified at the national, regional and local level. In the analysis phase, the responsibilities and instruments of the authorities are reviewed. Attention must be given to the interaction between various authorities involved in water resources management and to the effectiveness of the AIS.

The responsibilities and authorities of various agencies are generally described in national legislation. An analysis of the legal framework should identify the various agencies responsible for (aspects of) water resources managment, their authority, their instruments and their coordination with other agencies. Arrangements made in the past concerning the use of water (water rights) should be carefully studied, since these may significantly constrain the options for water resources development.

Water resources management studies are often limited to the preparation of policies for a certain agency. In this situation, the analysis of the AIS will mainly serve to identify measures that can be implemented effectively by that agency. The responsible agency should be aware of the possible solutions and the role they may have in solving the managementproblem. Sometimes, the analysis of the AIS may result in recommendations for institutional and legal changes.

5.1.4. Integration into a Computational Framework

The various models and components developed for the NRS and SES describe parts of the total system. Some models may produce output that is needed as input for another model. Some may run interactively. This means that all models will have to be linked in a computational framework. Depending on the models and the problem situation, such linkage can be very strict and formalized in a kind of decision support system. In other cases, a clear description of information flow from one model to the other may be sufficient. In optimization models the linkage of the various components is taken care of by the structure of the model.

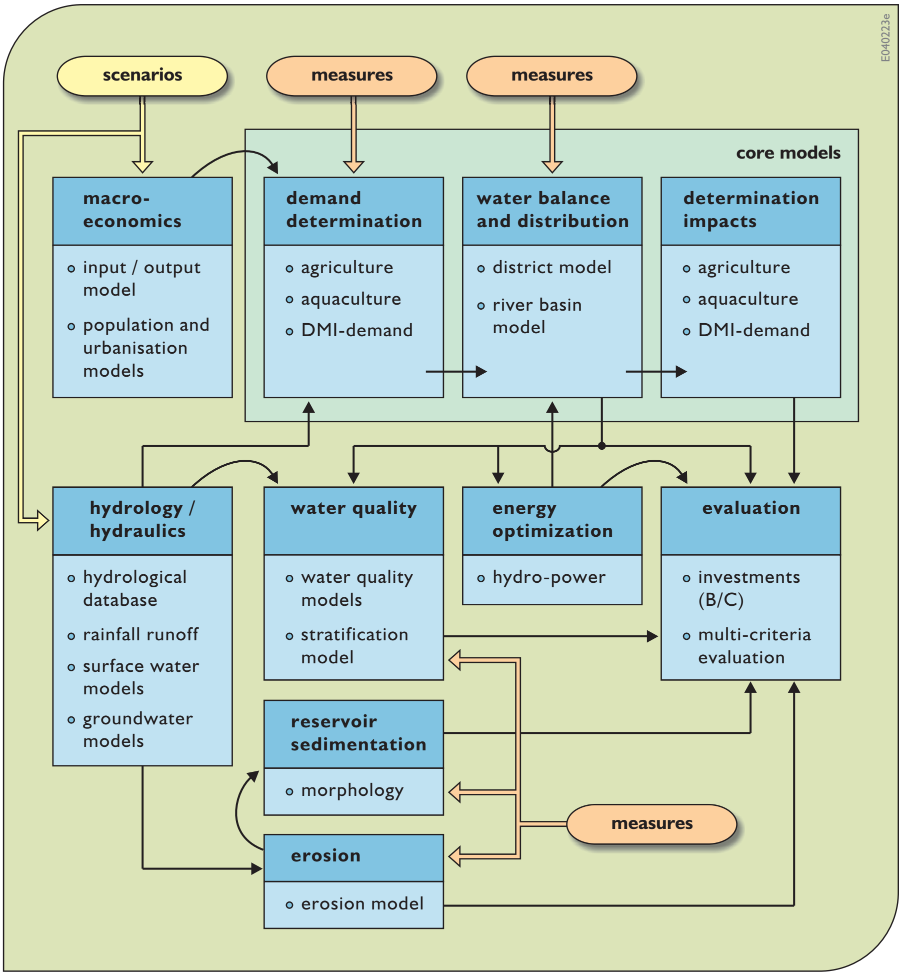

Figure E.8. Typical computational framework of simulation models.

Figure E.8 gives an example of a computational framework in which various simulation models are combined to analyse a river basin under drought conditions. The reservoirs in the system require special attention for the quality of the water they contain, sedimentation and the optimization of hydropower generation. The core of this computational framework is formed by the 'core models' block in the upper right corner of Figure E.8. In this block the demand for water is determined, followed by a balancing of supply and demand and the determination of the implications of the water allocation for the use functions. The models and modules in this core will typically be combined into one unit with automated linkages between the models and modules. The other models are linked through file transfer. This applies to the required input on macro-economic and hydrometeorological conditions (generated by scenarios) as well as the side analysis with respect to the modelling of the sedimentation and water quality in the reservoirs. The last parts of the computational framework are the modules that determine the financial and economic aspects (investments, operation and maintenance, benefit–cost, etc.) and support the overall multi-criteria analysis. At various places in this computational framework, measures can be included by changing input parameters. Scenarios can be analysed by changing the macro-economic and hydrometeorological conditions.

Figure E.8 is just an example. Other problem situations may require different computational frameworks. Computer modellers and analysts have a tendency to make these computational frameworks rather complicated and fancy. Sometimes this complexity is necessary, but in most cases a simple computational framework will be sufficient and preferable. The basic approach is to start as simple as possible and only add details when they prove necessary to carry out a proper analysis.

5.2. Preliminary Analysis

The 'preliminary analysis' includes the application of the knowledge obtained from data collection and modelling (Figure E.9) to identify possible solutions for the water resources management problem. At the start of the development phase, the analysis is focused on problems in the present situation (base case analysis) and the future situation (reference or bottleneck analysis). Knowing the problems that are to be expected under certain conditions, measures to solve them can be defined.

Water resources development should be guided by the principle of sustainable development. It should lead to a sustainable economy, in which natural renewable resources are used without being depleted (in either their carrying capacity or environmental utilization space). Sustainable economic development can also be supported by the development and adaptation of knowledge and improvement of organizational and technical efficiency.

Many alternative measures can be identified in general, each making a contribution to the (partial) solution of a particular problem. To avoid spending time on less effective measures, the effects of individual measures should be compared and promising measures selected for further analysis. Preliminary versions of the computational framework can be used to get a first idea of the effects of different measures. During the development phase, when it becomes clear which types of measure are promising and which elements in the computational framework are critical for the assessment of their effects, the computational framework can be modified.

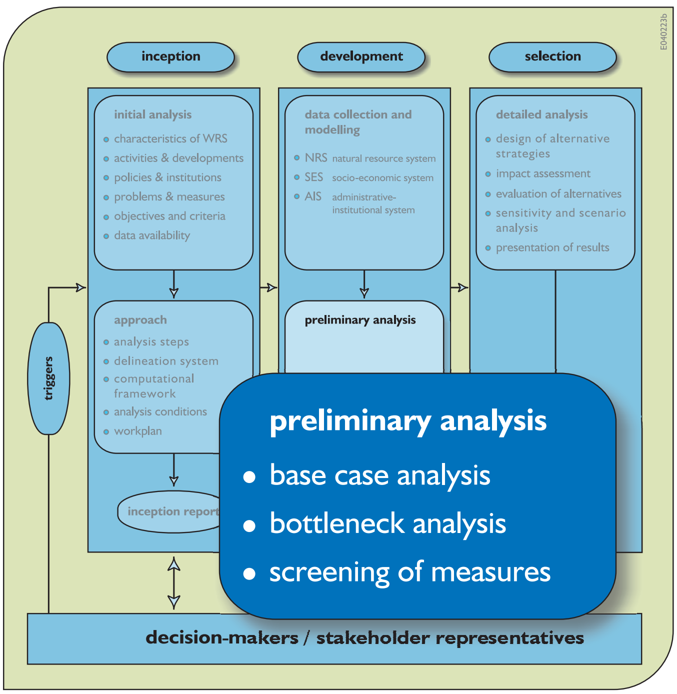

Figure E.9. Overview of activities in the preliminary analysis.

Box E.5. Definitions

- Base year: present situation.
- Time horizon: future situation.
- Base case: performance of WRS in present situation.
- Reference case: performance of WRS in future situation if no additional measures are taken.

5.2.1. Base Case Analysis

In the inception phase, a provisional problem statement is formulated on the basis of the results of the initial analysis. In the development phase, computational tools are used to further elaborate the problem statement. This is done by specifying two cases: the base case and the reference case.

In the base case analysis, the performance of the WRS is studied for the infrastructure and water demands in the base year, which is the most recent year for which a complete set of data can be collected. The base case describes the performance of the WRS in the present situation. A comparison of this base case with targets as specified in the management objectives produces a quantified problem statement.

From a modelling point of view the base case analysis also functions as a kind of calibration of the models. The results can be compared with measured information and, when necessary, parameters can be adjusted to better reflect the reality. Sufficient attention should be given to proper calibration and validation procedures.

5.2.2. Bottleneck (Reference Case) Analysis

An essential activity is an analysis of the WRS's performance if present policies are continued ('no change alternative'). This is called the bottleneck or reference case analysis. The latter term is used here because, in a later stage of the analysis, the effects of measures and strategies will be determined by comparing the results of that strategy with the reference case situation. The performance of the measure or strategy is assessed by using evaluation criteria related to the management objectives.

For the future (the planning horizons), the reference case comprises the present infrastructure, to which measures are added that have already been executed or decided, together with projected demands.The effects of autonomous developments in the SES are accounted for in these projected demands.

5.2.3. Identification and Screening of Measures

Once the base case and reference case have been defined, and problems and bottlenecks identified, measures are developed to alleviate the problems. In the identification of measures, a distinction is made between various categories of measure, as listed in Section 1.3.

An inventory of all possible kinds of action that can be taken will in general result in hundreds of measures. In most cases it will not be possible to analyse all of them in detail. A screening process is needed to select the most promising ones. This can be done in several ways. As mentioned in various chapters of this book, separate optimization models can be used to limit the solution space. It can also be done by using the computational framework developed for the project but limiting the analysis to a few criteria, such as benefit and costs. The measures with the highest benefit–cost ratio will be labelled as the most promising ones. A third kind of screening analysis is to apply a qualitative judgment, for example in terms of criteria effectiveness, efficiency, legitimacy and sustainability. Box E.6 explains these criteria.

The aim of the screening process is to get some feeling of how likely the measures are to alleviate the present and expected problems. No final judgment is given and no measures will be discarded in the process.

The screening of measures is a cyclic process. Assessing the measures will contribute to a better understanding of their effectiveness and new ones may be identified (comprehension loop). Combinations of measures may be considered for specific parts of the WRS, for instance for solving the water quality problems in a sub-basin. The result of the screening process is a set of promising measures that can be used for strategy design. The whole process of base case and reference case analysis and screening is depicted in Figure E.10.

Box E.6. Criteria

Effectiveness. Meaning that the measures to be taken are those which solve the most serious problems and have the highest impact on the objectives. Measures to prevent the problem will be preferred to those that solve it. Similarly, measures that solve the problem are preferred to those that only control it.

Efficiency. The measures to be taken should not meet the explicit objectives at the expense of other implicit objectives. The cost-benefit analysis (at the national level) is one indicator of efficiency. An example is to issue a law that forces industrial firms to incur the full cost of end-of-pipe treatment. In Egypt, this would improve the Nile-system water quality, and thus improve health and avoid environmental damage, but on the other hand it might impose high costs to the firms, possibly resulting in loss of employment. An efficient decision may be to opt only for cost sharing rather than full cost recovery.

Legitimacy. Measures to be included in the strategy should not rely on uncertain legal/institutional changes. Measures should also be as fair as possible, thus reducing public opposition so that they will be favoured by as many stakeholders as possible. For instance, reducing drainage water pollution through subsidizing non-chemical pesticides will be more legitimate than applying penalties on excessive use of chemical pesticides.

Sustainability. The measures to be taken are those that improve (or at least maintain) the present environmental and socio-economic conditions for future generations.

5.2.4. Finalization of the Computational Framework

During the screening of measures, adjustments in the computational framework may be necessary. Some components may need to be defined in more detail than was realized in the inception phase, while for others a simpler approach may be justified. Additional evaluation criteria may also be introduced to better discriminate the effects of different measures.

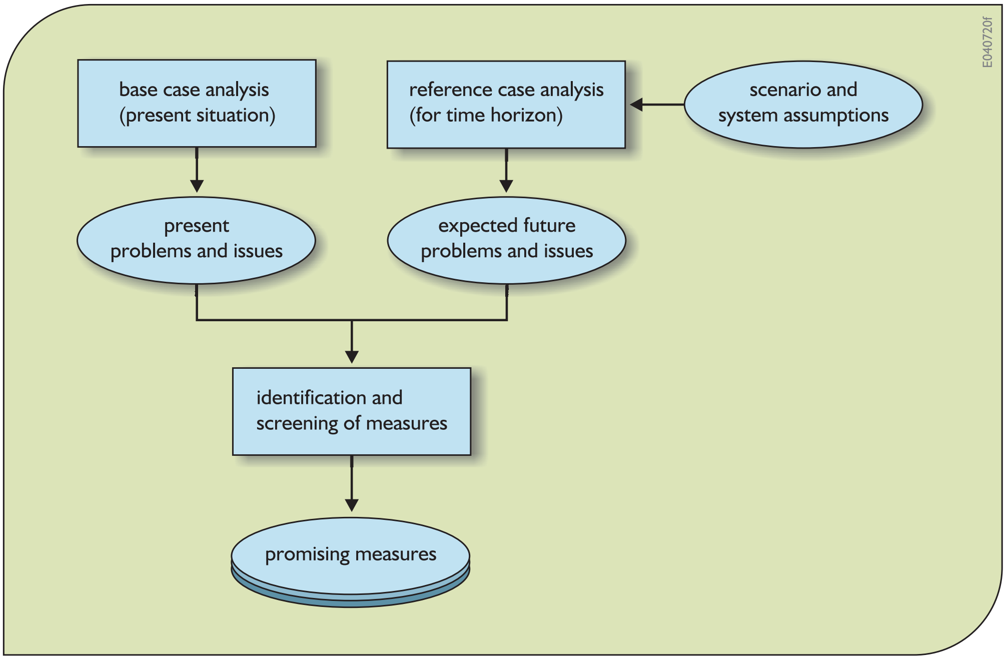

Figure E.10. Elements of the preliminary analysis.

6. Selection Phase

In the selection phase, promising measures are combined into strategies. The effects of various strategies are assessed and a limited set of promising ones is defined. For these promising strategies, the effects are assessed in more detail. The sensitivity of these effects to (uncertain) assumptions in the analysis is then assessed, and finally the results of the selected strategies are presented to the decision-makers. Figure E.11 highlights these steps, and the selection process is depicted in Figure E.12.

6.1. Strategy Design and Impact Assessment

Strategy design is the development of coherent combinations of promising measures to satisfy the management objectives as far as possible. As there are generally many criteria related to these objectives, and probably many expressed in different units, the strategy design is not a simple process. Relations among combinations of measures and their scores on the evaluation criteria are usually non-linear. As there are no general methods to compensate a lower score on one criterion with a higher score on another, the optimum itself is not uniquely defined. Sustainability should be considered in the assessment of measures and strategies.

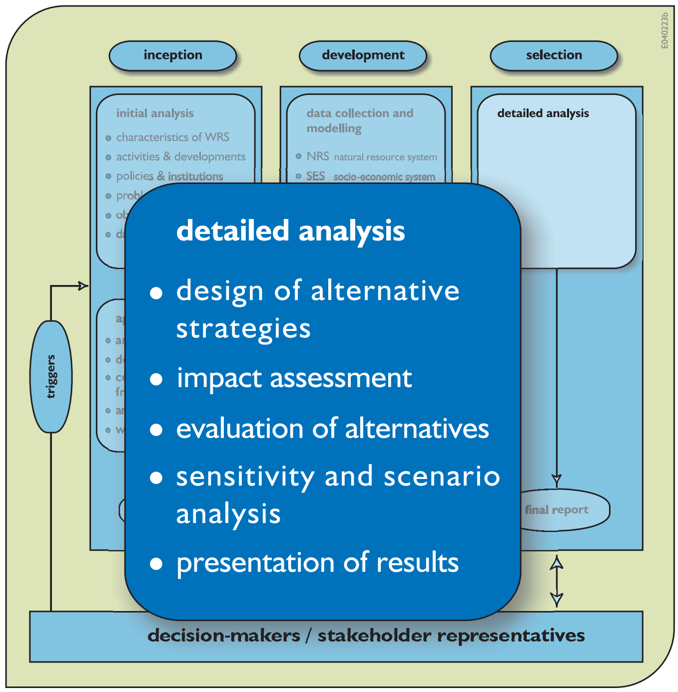

Figure E.11. Components of the selection phase.

The design of strategies is an iterative process. One could start by developing strategies on the basis of a single objective like, for example, food production or maximum net economic benefit. These strategies define

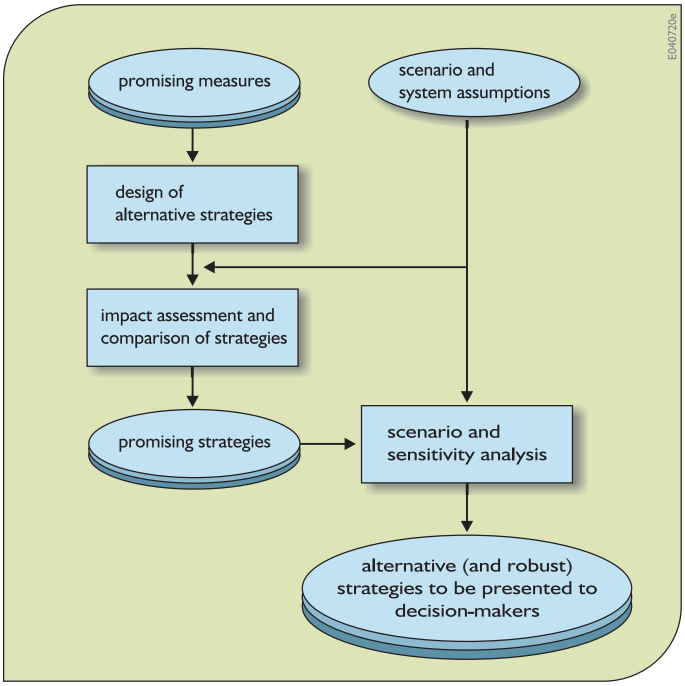

Figure E.12. Activities in the selection phase.

the boundaries of the solution space. Comparison of the impacts of these strategies can lead to the construction of compromise strategies by changing elements in the strategy. A resulting loss with respect to one criterion is then compared with gains to another.

The developed computational framework may be used for the assessment of selected strategies. Input data sets will be prepared for the computations, defining the modification of the water resources situation (strategy) and the assumed water demand (scenario). Such a data set will be referred to as a case. Each case is associated with a unique combination of a WRS, its demand situation (scenario) and its hydrometeorological boundary conditions.

6.2. Evaluation of Alternative Strategies

Strategies are compared on the basis of their scores on the evaluation criteria that were chosen to characterize the management objectives (see Section 4.1.3). To facilitate the comparison, the number of evaluation criteria should be limited. Criteria have to be comprehensive (sufficiently indicative of the degree to which the objective is met) and measurable, i.e. it should be possible to assign a value on a relevant measurement scale. Where possible, criteria should be aggregated; for example, some financial criteria might be processed into a single value when distribution issues are not important. It is usually impossible to express all criteria in a single measurement scale such as a monetary value. Criteria related to the quality of the environment can often be expressed only in non-monetary terms. This should however be done in such a way that a ranking is possible on the basis of the criteria.

Generally, there will not be a single strategy that is superior to all other ones with respect to all criteria used in the assessment. That means that an evaluation method is required for the ranking of alternative strategies (see Chapter 10). The evaluation can be an 'intuitive' one that gives implicit weights to various criteria and, depending on these weights, selects a preferred strategy.

In multi-criteria evaluation methods, formal decision rules are used to obtain a ranking. The weighted summation is one simple method. The best alternative is the one that gives the best weighted score.

6.3. Scenario and Sensitivity Analysis

Before drawing conclusions from the impact assessment, it is necessary to analyse the effects on the results of changes in the assumptions about the scenario variables and model parameters. The analysis of the influence of the exogenous variables is called scenario analysis; analysis of the influence of model parameter values (the system assumptions mentioned in Section 4.2.4) is called sensitivity analysis (Chapter 9).

Scenario analysis is done by repeating the impact assessment for the selected strategies under different scenario assumptions. If the selection of a different scenario would significantly change the attractiveness of the selected strategies, then additional study is required to reduce the uncertainties in the scenario assumptions. The sensitivity of the results for a change in model parameters and assumptions is done in a similar way.

6.4. Presentation of Results

Presentation of the selected promising strategies to decision-makers may be by means of briefings, presentations, summary reports or other media. The level of detail and the way results are presented have to be selected carefully. The presentation should give a good overview of the results, without an overdose of information or detail. Visual aids such as score cards and interactive computer presentations of study results are extremely helpful for a discussion of the results of the analysis.

The results of selected strategies can be presented in matrix form on 'scorecards'. The columns of the scorecard represent the alternative cases used in the analysis. The rows represent the impact of different alternatives with respect to a given criterion. An example is depicted in Figure E.13. Scorecards can contain numbers only, or the relative value of the criteria can be expressed by a colour or shading to obtain a visual picture of the relative order of the alternatives for various criteria. This can also help to detect clusters of criteria for which alternatives have a consistently better score. The presentation of the results in scorecards allows a decision-maker to give each impact the weight considered most appropriate.

Two examples of objectives and criteria are shown in the following two boxes. Box E.7 lists the objectives and criteria adopted in a water resources management study in West Java. Box E.8 is a scorecard used in Egypt for the development of the National Water Resources Plan. This example does not show alternative strategies; only the chosen strategy 'Facing the Challenge' has been given. Including the values of the base case (present situation) and reference case (future situation if no new measures are taken) provides a good overview of the new strategy's impacts.

7. Conclusions

This appendix has described the approach used by WL | Delft Hydraulics to assess water resources systems and develop plans and management strategies for them. Like many other such organizations, WL | Delft Hydraulics has been actively involved in numerous regional water resources planning and management projects throughout the world, mostly in developing countries. The approach described in this appendix illustrates how these projects are conducted, and the major factors that are considered while conducting them. The effects and impacts of some projects are only local and require consideration of only a few sectors of the economy. Other, more comprehensive projects have had national or international impacts. Clearly each water resources system is unique with respect to its management issues, problems and institutional environment.

Figure E.13. Example of a scorecard.

	promising strategies			
	agricultural strategy	**industrial strategy**	**anti pollution strategy**	**mixed strategy**
strategy components: **impacts on criteria:**	• irrigation • water storage • pumps • etc.	• water storage • groundwater use • canal improvement • etc.	• water conservation • purification • tax on water use • etc.	• water storage • purification • etc.
total investment costs m euro/yr	300	400	700	700
total benefits m euro/yr	1200	700	100	1000
increased agricultural production m ton/yr	800	150	50	600
drinking water price euro/m^3	1.40	0.90	1.20	1.10
pollution ppm	150	220	35	70
power production MW	200	1200	50	800
fisheries ton/yr	70	20	80	40
safety from flooding %	99	98	96	99

best / middle / worst

Box E.7. Example 1: Objectives and criteria adopted in West Java WRM study

OBJECTIVES	*EVALUATION CRITERIA*
SOCIO-ECONOMIC OBJECTIVES AND CRITERIA	
1. Improve employment	Increase of employment by WRM strategies: – number of permanent jobs (#) – number of temp. jobs (mn/yr)
2. Increase income of people	
– improve income position of farmers	– farmer net income (Rp/yr)
– improve equity in income distribution.	– difference in benefits of WRM strategies per capita between: kabupatens (%) urban/rural areas (%) income groups (%)
3. Increase the non-oil export production (shrimps, tea and rubber).	– export value (Rp/yr)
4. Support economic development in an economically efficient way.	– total annual. benefits (Rp/yr) – total annualized costs (Rp/yr) – B/C ratio (-) - IRR (%) – NPV (Rp/yr) – total capital required (Rp) – foreign currency required (%) – total construction costs (Rp) – total O&M costs (Rp) – sectoral value added (Rp/yr) – GRP (Rp/yr)
USER-RELATED (SECTORAL) OBJECTIVES AND CRITERIA	
1. Increase agricultural production (3% per year)	– padi (ton/yr) – palawija (ton/yr) – export value of crops (or import substitution) (Rp/yr) – unit costs water supply (Rp/m^3) – % failure meeting demand (%)
2. Increase power production	– installed capacity (MW) – power production (GWh/yr) – failure meeting firm power (%) – price of power prod. (Rp/Kwh) – energy production value (Rp)
3. Increase fish production	– fish produced (ton/yr) – fish pond area (ha) – export value (Rp/yr)
4. Support industrial development • water supply for industry (full supply) • provision of opportunity for discharge of waste water	– amount of supply (m^3/s) – cost of water supply (Rp/yr) – unit costs water supply (Rp/m^3) – level of failure to meet demand (%) – cost to maintain water quality standards (Rp/yr)
5. Enhance water-related recreation	

(Contd.)

Box E.7 Example 1: Continued

OBJECTIVES	*EVALUATION CRITERIA*
ENVIRONMENTAL AND PUBLIC HEALTH RELATED OBJECTIVES AND CRITERIA	
1. Improve public health	– supply (l/day/ capital)
• improve drinking water supply	– % of people connected (Rp/m^3)
– urban: BNA, IKK and major city programs: 60 l/cap/day, serving 70%	– price of drinking water (%) – % failure meeting demand (%)
– rural: 55%	
• improve flushing (1 litre/s/ha in urban area)	– volume of flushing water (m^3/s) – unit costs (Rp/m^3) – % failure meeting demand (%)
2. Improve/conserve natural resources and environment	– area severely eroding (ha) – erosion (mm/year)
• erosion and sedimentation control (erosion $<$ 1 mm/yr)	– sediment yield (tons/yr) – reforested area (ha)
• conservation of nature	– replanted area (ha)
• water quality	– terraced area (ha) – ratio of external wood supply to total wood demand (%)
	– concentration water quality parameters (ppm)
3. Provide flood protection (return period: depending on value of endangered area)	– return period (years) – flood alleviation benefits (reduced damage) (Rp/year) – flood control cost (Rp/year) – number of people in endangered areas (#) – flooded area (ha)
PLANNING AND IMPLEMENTATION RELATED OBJECTIVES AND CRITERIA	
1. Take care of maximum agreement with existing policies in other fields of planning (e.g. economic regional planning).	– deviations from/conflicts with existing policies
2. Maximize flexibility of proposed strategy.	– degree to which strategy can be adjusted to changes in demands, standards, technological innovations
3. Maximize reliability of proposed strategy.	– degree of certainty with which proposed strategy will meet the realization of objectives
4. Provide sufficient acceptance of proposed strategy by public, interest groups and executing authorities.	– degree of acceptance by parties involved
5. Take care of maximum agreement of proposed strategy with existing competence and responsibilities of agencies concerned.	– deviations from/conflicts with existing competence and responsibilities

Note: GRP = Gross regional product
IRR = Internal rate of return
B/C = Benefit-cost ratio
NPV = Net present value
O&M = Operation and maintenance

○ kabupaten = Indonesian administrative unit ○ padi = rice crop ○ palwija = non-rice crop ○ Rp = Rupiah

Box E.8. Example 2: Score-card for Egyptian National Water Resources Plan study

	Unit	*1997 Base*	*2017 Reference Case*	*Strategy Facing the challenge*
General (middle scenario)				
Population	Million	59.3	83.1	83.1
Urbanization	Ratio	0.44	0.48	0.48
GDP at economic growth of 6%	Billion LE	246	789	789
Economic development objectives				
Agriculture: irrigation area	M feddan	7.985	11.026	10.876
Gross production value	Billion LE	34.46	35.76	38.50
Crop intensity	Ratio	2.1	1.5	1.7
Net value production per *feddan*	LE/feddan	2,812	2,075	2,153
Net value production per unit of water	LE/m^3	0.64	0.66	0.60
Export/import value	Ratio	0.09	0.12	0.20
Industry: Costs of polluted intake water	LE/m^3	0.65–1.10	0.65–1.10	2.00
Wastewater treatment costs	LE/m^3	0.22–0.50	0.22–0.50	1.00
Fishery: production (index 100 in 1997)	index	100	86	95
Tourism: navigation bottlenecks	Index	100	114	0
Social objectives				
Create living space in desert areas	% of total pop	1.5%	23%	22%
Employment and income				
Employment in agriculture	M pers.year	5.01	6.24	7.30
Employment in industry	M pers.year	2.18	4.99	4.99
Average income of farmers	LE/yr	5,362	4,629	4,309
Drinking water supply				
Coverage	Percentage	97.3%	100%	100%
Sanitation				
Coverage	Percentage	28%	60%	60%
Equity				
Equity water distribution in agriculture	–, 0, +	0	+	+
Self sufficiency in food: cereals	Percentage	73%	53%	46%
Meeting water needs				
Water resources development				
Available Nile water	BCM	55.8	55.5	55.5
Abstraction deep groundwater	BCM	0.71	3.96	3.96
Water-use efficiency of Nile system				
Outflow to sinks from Nile system	BCM	16.3	17.6	12.5
Overall water-use efficiency of Nile system	Percentage	70%	67%	77%
Water in agriculture				
Supply-demand ratio (1997 assumed 1.0)	Ratio	1.00	0.80	0.92
Water-availability per *feddan* in Nile system	m^3/feddan/yr	4,495	3,285	3,866
Public water supply				
UFW losses	Percentage	34%	34%	25%
Supply/demand ratio	ratio	0.67	0.76	1.00
Health and environment				
Pollution and health				
E-coli standard violation (1997 = 100)	Index	100	121	110
Water quality of shallow groundwater	–, 0, +	0	–	–
Ecology and sustainability				
Sustainability: use of deep groundwater	abstr/pot	0.15	1.00	1.00
Condition of Bardawil (Ramsar site)	–, 0, +	+	–	+
Condition of Coastal Lakes	–, 0, +	0	–	0

Note: UFW = Unaccounted for water (the water that is lost in the system)

○ feddan = 0,42 ha ○ LE = Egyptian pound

Project planning and analysis approaches must adapt to these situations. Hence, each project will differ, and will no doubt need to deviate from the general approach described in this appendix. Other approaches are possible and may be equally effective. What remains important in all cases is the establishment of a comprehensive, systematic process of analysis together with constant communication among planners, decision-makers and the interested and affected public. The end result should be an improved, sustainable and equitable water resources development plan and management policy, appropriate for the region and its people.