Integrated Water Resources Management for the Sistan Closed Inland Delta, Iran

Main Report

Netherlands contribution funded by: Partners for Water

Version 1.3
April 2006
Integrated Water Resources Management
for the Sistan Closed Inland Delta, Iran

Main Report

Main authors: Eelco van Beek
Karen Meijer

with contributions from:

Jaap Kwadijk
Ferdinand Diermanse
Henk Ozink
Aline te Linde
Marcel Ververs
Wil van der Krogt
Ellis Penning
Juzer Dhondia
Zoltan Vekerdy

Jalal Attari
Babak Bozorgy
Shervin Faghihi Rad
Maryam Navabian
Kaveh Panaghi
Hamidreza Najafi Kouhestan
Khashayar Khazaei
Adel Ebrahimi
Maryam Emamjomeh
Shahram Khorasanizadeh

Koen Roest
Albert Beintema

and
Sara Hajiamiri
Sieger Burger

and
Behrouz Behrouzi Rad
Absaran Consulting Engineers

Netherlands contribution funded by:

Partners for Water

Version 1.3
April 2006
Preface

Within the cooperation framework between the governments of the Netherlands and of the Islamic Republic of Iran an Integrated Water Resources Management (IWRM) study for the Sistan area has been carried out. IWRM as field of cooperation between the two countries was selected as the Iranian Government intends to move towards the application of IWRM concepts in their water management and expects it can benefit from the Netherlands experience on IWRM. The Sistan area was chosen as project area because the area experiences many water related problems. It suffers from droughts and floods while upstream regulation of these droughts and floods is not possible because almost the entire catchments of the contributing rivers are located in Afghanistan. The uncertain and hard natural conditions of the area have a strong impact on the socio-economic situation. Moreover, three wetlands of international importance are located in the area, requiring water as well to sustain.

The overall aim of the project was to develop methods and tools in order to strengthen and build capacity to achieve integrated water resources management to support the development of Sistan and to sustain agriculture and ecosystems in the Sistan river basin.

The project has been carried out in close cooperation between a Netherlands consortium headed by Delft Hydraulics and the Water Research Institute of the Ministry of Energy in Tehran. The Netherlands contribution was financed by the programme Partners for Water and lasted from January 2004 till November 2005. The Iranian contribution was financed by the Sistan-Baluchestan Regional Water Authority (SBRWA) and will last till March 2007.

This Main Report provides an overview and summary of the results of the project as available at the end of the Netherlands contribution in January 2006. More detailed information is given in a series of technical Annexes. These documents are preliminary in the sense that WRI will continue the analysis activities for the project which will result in additional data and information. These will be included in the Farsi documentation of the project which is expected to become available in 2007.
Overview of Reports

Main Report - Integrated Water Resources Management for the Sistan
Closed Inland Delta, Iran

Annex A Hydrology
Annex B Forecasting the flow from Afghanistan
Annex C Sistan Water Resources System - supply and demand
Annex D Sistan Wetland Ecosystem - functioning and responses
Annex E Socio-economic valuation of allocating water to the Hamouns and to agriculture

User Manual HYMOS
User Manual RIBASIM
Content

EXECUTIVE SUMMARY ........................................................................................................... VII

1 INTRODUCTION .................................................................................................................... 1
  1.1 The project area .............................................................................................................. 1
  1.2 Integrated Water Resource Management ...................................................................... 1
  1.3 Systems analysis description ....................................................................................... 2
  1.4 Objective and approach of the project ......................................................................... 3
  1.5 Progress made in project ............................................................................................. 5
  1.6 Outline of this document ............................................................................................. 5

2 NATURAL RESOURCES SYSTEM AND ITS INFRASTRUCTURE .................................. 7
  2.1 Hirmand – the source of Sistan’s water ......................................................................... 7
  2.2 Sistan inland delta ....................................................................................................... 14
    2.2.1 Climate and general environmental conditions Sistan Delta .................................. 16
    2.2.2 Water resources for Sistan Delta ........................................................................... 16
    2.2.3 Main infrastructure and features of Sistan Delta ................................................... 17

3 THE SOCIO-ECONOMIC SYSTEM ....................................................................... 23
  3.1 Population .................................................................................................................... 23
  3.2 Employment ................................................................................................................ 25
  3.3 Agriculture .................................................................................................................. 25
  3.4 Public water supply ..................................................................................................... 27
  3.5 Conclusion on the socio-economic system .................................................................. 29

4 THE HAMOUNS - WETLANDS OF SOCIO-ECONOMIC IMPORTANCE .......... 31
  4.1 Physical and ecological aspects of the Hamoun wetlands ......................................... 31
    4.1.1 Physical aspects of the Hamoun wetlands ............................................................ 31
    4.1.2 Ecological aspects ............................................................................................... 33
    4.1.3 Management and mismanagement of the Hamouns .......................................... 37
  4.2 Socio-economic aspects of Hamoun wetlands ............................................................ 38
  4.3 Water ‘demand’ of the Hamoun wetlands ................................................................... 44
  4.4 Estimating ecosystem impacts - criteria ....................................................................... 45

5 INSTITUTIONAL SETTING AND STAKEHOLDERS ........................................... 47
  5.1 General administrative structure ................................................................................ 47
  5.2 Stakeholders in WRM and coordination ................................................................. 49
  5.3 Agreement with Afghanistan .................................................................................... 50

6 OBJECTIVES, DEVELOPMENTS AND PROBLEM STATEMENT .................. 53
  6.1 General development plans of Iran .......................................................................... 53
  6.2 Objectives IWRM in Sistan and related criteria ....................................................... 54
    6.2.1 Objectives IWRM in Sistan .............................................................................. 54
    6.2.2 Indicators ......................................................................................................... 55
  6.3 Scenarios for the future .............................................................................................. 56
    6.3.1 Socio-economic developments ........................................................................... 56
    6.3.2 Upstream developments in Afghanistan ............................................................ 58
  6.4 Problem Analysis ....................................................................................................... 60
    6.4.1 Water Balance Sistan area .............................................................................. 60
    6.4.2 Flooding ............................................................................................................. 61
6.4.3 Water quality ................................................................................................... 61
6.4.4 Future of the Hamoun Wetlands ..................................................................... 62
6.4.5 Summarizing problem statement ................................................................... 62

7 FLOW FORECAST FROM AFGHANISTAN ........................................................ 65
  7.1 Introduction ........................................................................................................... 65
  7.2 Flow Forecasting procedure ................................................................................. 67
  7.3 Modelling the flow in Afghanistan ........................................................................ 69
    7.3.1 Basin schematisation for the PCRaster-HBV model .................................... 69
    7.3.2 The hydrological model PCRaster-HBV .................................................... 70
    7.3.3 River basin modelling with RIBASIM-Hirmand ......................................... 70
  7.4 Calibration of the model ...................................................................................... 72
    7.4.1 Results ........................................................................................................ 72
    7.4.2 Possible misconceptions leading to overestimation of flow volumes ............ 75
  7.5 Conclusions and potential improvements ............................................................ 76
  7.6 Recommendations for operational use of the system ........................................... 77

8 IWRM PLANNING FOR THE SISTAN INLAND DELTA .................................. 79
  8.1 Starting conditions for analysis ........................................................................... 79
    8.1.1 Delineation of the System ........................................................................... 79
    8.1.2 Computational Framework ..................................................................... 80
    8.1.3 Analysis conditions .................................................................................. 81
    8.1.4 Scenarios (external developments) ............................................................ 82
  8.2 Overview of measures that can be taken ............................................................. 83
    8.2.1 Quantity - supply oriented measures ....................................................... 83
    8.2.2 Quantity - demand oriented measures ..................................................... 83
    8.2.3 Improving water quality ......................................................................... 85
    8.2.4 Restoring the ecological values ............................................................... 85
  8.3 Playing with some first strategies ....................................................................... 87
    8.3.1 Results for scenario 1-b ........................................................................... 87
    8.3.2 Results for scenario 2-b ........................................................................... 89
    8.3.3 Discussion ............................................................................................... 89
  8.4 Institutional aspects ............................................................................................ 90

9 PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS ....................... 93

REFERENCES ........................................................................................................... 97

ANNEX KEY INFORMATION PROJECT ................................................................. 99
Abbreviations and Glossary

asl 
above (mean) sea level

Bakhsh 
administrative level under Shahrestan level

Dehedar 
Dehestan mayor

Dehestan 
rural administrative unit under Bahksh – may include several villages

DoE 
Department of Environment

ECMWF 
European Centre for Medium range Weather Forecast

Farmandar 
governor at Shahrestan level

IRIMO 
Iran Meteorological Organization

ITC 
International Institute for Geo-Information Science and Earth Observation

IWRM 
Integrated Water Resources Management

MoE 
Ministry of Energy

MoJA 
Ministry of Jihad-e-Agriculture

MPO 
Management and Planning Organization

NOAA 
National Oceanic and Atmospheric Administration (US Dep. of Commerce)

Ostan 
administrative level under country level

Ostandar 
governor at Ostan level

Rud 
river

SBRWA 
Sistan Baluchistan Regional Water Authority

SCWM 
Supreme Council on Water Management

Shahr 
urban administrative unit under Bakhsh

Shahrestan 
administrative level under Ostan level

Shardar 
Shahr mayor

WA 
Water Authority

WRI 
Water Research Institute

WRM 
Water Resources Management

WUA 
Water Users Association

SWB 
Sistan Water Board

Naming Conventions

<table>
<thead>
<tr>
<th>Names used in present report</th>
<th>Other used names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ardaskan river</td>
<td>Harut river</td>
</tr>
<tr>
<td>Goud-e-Zereh</td>
<td>Goud-e-Zareh, Gudzareh, Gaud-e-Zireh</td>
</tr>
<tr>
<td>Hamoun</td>
<td>Hamoon, Hamun</td>
</tr>
<tr>
<td>Hirmand</td>
<td>Helmand, Hirmand</td>
</tr>
<tr>
<td>Khash river</td>
<td>Khasah Rud / river</td>
</tr>
<tr>
<td>Sistan</td>
<td>Seistan</td>
</tr>
<tr>
<td>Qala-e-bust</td>
<td>Qal-e-bist</td>
</tr>
</tbody>
</table>
Executive Summary

The Sistan Delta in Iran is located at the end of a closed basin. The entire contributing basin is about 200,000 km² and is largely located in Afghanistan. The Iranian part, the delta plain (ca. 2,500 km²) and part of the surrounding wetlands system (ca. 5,000 km²), covers less than 5% of the total basin area. The river system discharges into an inland depression which, when sufficient water is available, forms the Hamoun Lakes. These lakes are one of the main and most valuable aquatic ecosystems in Iran and are registered wetlands in the Ramsar and UNESCO Biosphere Reserve Conventions. A unique feature of the lakes is that they are fresh, despite that they are seemingly at the end of a closed basin. Actually they are not the end. During periods of very high flows the lakes spill into the Shile river and to the Goud-e-Zereh. This ‘flushing’ happens on average each 8-11 years. The Goud-e-Zereh is the real terminal lake of the basin and is very saline.

The Sistan inland delta has a population of some 400,000 people. The economy is strongly dependent on agriculture (irrigated and non-irrigated) and the goods and services provided by the wetlands. The irrigation system of about 120,000 ha has recently been rehabilitated. Three reservoirs (Chahnimeh) have been constructed for public water supply with a fourth reservoir under preparation. The inflowing rivers from Afghanistan support the irrigated agriculture in the Sistan delta but are also the source for the lake system around the delta. Unemployment in the area is high. The Iranian government tries to improve the living conditions of the people. Further development of the irrigated area will mean less water for the hamouns with resulting lower average water coverage of the lakes. This will not only endanger the ecosystem that the hamouns support but also the livelihoods of the people that depend on the goods and services that the lake provides.

To assist the Iranian government in their decision making on how to further develop and manage the area an Integrated Water Resources Management (IWRM) study has been carried out. The objective of the management of the water resources is to support the socio-economic development in the area, while at the same time protecting and restoring the natural environment.

The study started with an extensive analysis of all existing information on the river basin, in Iran as well as in Afghanistan. This included the natural resource system and its infrastructure (chapter 2 of this report), the socio-economic system (chapter 3) with particular attention to the hamouns (chapter 4) and the institutional setting (chapter 5). A detailed survey was done of the various socio-economic use-functions of the water in the area. Based on the survey a kind of water ‘demand’ of the hamoun system and the effects of a lower supply to the lakes were determined. Analyses showed that the hamoun lakes are under serious risk of loosing their ecological value and potential developments will decrease the inflow to the lakes with more than 50%. Computer models were developed to quantify the impacts of possible developments and to enable a balancing of interests.
The non-availability of data from Afghanistan requires the development of various tools and the use of remote sensing techniques to enable to make estimates for the river flow that Iran can expect from Afghanistan. The forecasting system includes a component for making forecasts on a short-range with 0-5 days lead time based on rainfall data from upstream as well as a component for making long range forecasts with 0-4 months lead time based on the analysis of snowmelt in the mountains in Afghanistan. The purpose of the system is to provide the water authorities in Sistan with information on the water supply to the Sistan Delta. The results of the long-range model are useful for taking decisions on the use and distribution of the water in the coming period. The results of the short-range model are mainly useful in case of floods. Apart from flow forecasting, the system allows for assessment of scenarios for upstream developments. In this respect the aim of the system is to answer the following questions: can we expect much/average/little water in the next months?, will there be a flood in the coming days?, if we have little water, how can we distribute the deficit?, and if upstream irrigation increases or reservoirs are built in the river basins in Afghanistan, what would be the flow to Sistan? The developed forecast model is described in chapter 7.

The collected information and developed tools were used to carry out a preliminary analysis. First an explicit objective and related indicators were defined and scenarios developed (chapter 6). Scenarios are external developments that cannot be influenced by the involved decision makers. Upstream developments in Afghanistan appear to be the most important scenario elements. Next an inventory was made on all kind of possible interventions which included supply and demand oriented measures as well as specific measures that aim to restore the ecological values of the hamouns. Chapter 8 describes this inventory and the results of a preliminary analysis of some illustrative strategies, in particular related to further development of irrigated agriculture and the use of the Chahnimeh reservoirs. Based upon this analysis some conclusions and recommendations are given in Chapter 9. Some of the main conclusions are:

- The present poor ecological conditions of the hamouns at the Iranian side appear to be the result of mis-management and not a result of years of drought in the area.
- The drinking water demand is low compared to the demand of agriculture and the ‘demand’ of the hamouns. The present capacity of the Chahnimeh reservoirs is sufficient to guarantee a reliable supply for both the Sistan area as well as the agreed upon delivery for Zahedan.
- Agriculture is a very water consuming activity in the region. The climatic conditions are far from ideal for irrigated agriculture. The expected yield does not justify major investments and the negative impacts on the ecology of the hamouns should be considered. At the other hand agriculture is of major importance for the people and a balance should be sought between using water for agriculture and the value that water has for maintaining a healthy ecosystem in the hamouns.
- The quantitative analysis shows that:
  - the use of water for irrigated agriculture in Sistan is mainly restricted by the variability of the supply and not by the total supply; the use of (the Chahnimeh) reservoirs for irrigation will improve the performance of irrigated agriculture; a further increase of the irrigated area in Sistan without being allowed to use the reservoirs for irrigation water also, is not feasible;
  - there is a direct relation between the use of water for irrigated agriculture and the environmental conditions in the area; further increase of irrigation water will decrease the average water cover in the hamouns and will have corresponding negative impacts on ecology and health;
  - developments upstream in Afghanistan can have disastrous impacts for Iran; these developments will have much more effects on the hamouns than similar developments in Iran as the Iranian developments will influence only the Hamoun-e-Hirmand.
- Developing the Sistan basin and protecting the hamouns requires an intensive cooperation between Afghanistan and Iran. This cooperation should be based on a mutual agreement on ‘sharing’ the resources and a joint development and management of the river basins. The present treaty between Iran and Afghanistan has a very limited value for Iran and mainly
guarantees a sufficient supply for drinking water purposed only. The treaty contributes hardly to sustainable irrigated agriculture in Iran or to the protection of the ecosystems in the hamouns. With the construction of the Chahnimeh reservoirs the treaty has decreased in importance even more.

The analysis carried out in the project was of a preliminary nature. This analysis should be continued by the Iranian partners involved, in particular SBRWA and WRI.
Children in a dry hamoun (courtesy dr. Behrouzi)
1 Introduction

1.1 The project area

The Sistan Inland Delta in Iran is a densely populated enclave in the scarcely populated south-eastern part of Iran. The basin is a closed inland delta at the lower end of the Hirmand river. It consists of a delta plain (ca. 2,500 km$^2$) and a wetlands system (ca. 5,000 km$^2$). This Sistan basin is part of a much larger Hirmand basin in bordering Afghanistan. The entire basin is ca. 150,000 km$^2$, and the Sistan Inland Delta at the lowest end of the system covers ca. 5% of the total basin area. The Sistan delta has a population of some 400,000 people. The economy is strongly dependent on agriculture (irrigated and non-irrigated) and the wetland natural resources. Figure 1-1 shows the location of Sistan Plain in Iran.

The Sistan river discharges into an inland depression which, when sufficient water is available, forms the Hamoun Lake(s). The Hamoun Lakes are located in the northern and western parts of Sistan Plain. The Hamoun Lakes are one of the main and most valuable aquatic ecosystems throughout Iran. The lakes are a registered wetland in Ramsar and UNESCO Biosphere Reserve Conventions.

The development and management of the Sistan River basin, both delta plain and wetlands, is confronted with irregular and extreme drought and flood conditions. The related constraints can only be addressed by an Integrated Water Resource Management (IWRM) approach within the context of the entire river basin. This approach is currently lacking.

1.2 Integrated Water Resource Management

The concept of Integrated Water Resources Management (IWRM) has been developing since the beginning of the nineties. IWRM is the response to the growing pressure on our water resources systems as a result of growing population and socio-economic developments. Water shortages and deteriorating water quality have forced many countries in the world, in developed and developing countries alike, to reconsider their options with respect to the management of their water resources. As a result water resources management (WRM) has undergone a drastic change world-wide, moving from a mainly supply-oriented, engineering biased approach towards a demand-oriented, multi-sectoral approach, often labelled Integrated Water Resources Management. In the international fora opinions are converging to a consensus about the implications of IWRM. This is best reflected in the Dublin Principles of 1992 (see GWP, 2000). Not all countries endorse all these principles; in particular the fourth principle on economic
valuing is much debated. Although nearly all countries agree with the economic value of water, given the important social function of water, many developing countries do not recognize water as an economic good that can be left to the economic market of demand and supply. Notwithstanding this difference in perception on this fourth principle, the concept of IWRM let us move away from ‘water master planning’, which focuses on water availability and development, towards ‘comprehensive water policy planning’ which addresses the interaction between different sub-sectors, seeks to establish priorities, considers institutional requirements, and deals with the building of capacity.

A key-aspect of IWRM is that the management and development of the resources should take place in interaction with the users (the socio-economic system), the environment and the institutions involved. IWRM applied in this way considers the use of the resources in relation to the social and economic activities and functions. These also determine the need for laws and regulations for the sustainable use of the water resources. Infrastructure, in relation to regulatory measures and mechanisms, will allow for effective use of the resource, taking due account of the environmental carrying capacity.

IWRM practices depend on the context of the specific application. This means that IWRM as applied in Iran and Sistan will have to take into account the particular situation of the area with respect to the geographic and hydro-meteorological conditions as well as the social and cultural values of the country. IWRM should not be seen as a ‘model’ that has to be enforced upon a country or certain region. IWRM is much more a process as indicated in the definition in the text box.

<table>
<thead>
<tr>
<th>Dublin principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water is a finite, vulnerable and essential resource, essential to sustain life, development and the environment.</td>
</tr>
<tr>
<td>2. Water resources development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.</td>
</tr>
<tr>
<td>3. Women play a central role in the provision, management and safeguarding of water.</td>
</tr>
<tr>
<td>4. Water has an economic value in all its competing uses and should be recognized as an economic (and social) good</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Definition of IWRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.</td>
</tr>
<tr>
<td>GWP, 2000</td>
</tr>
</tbody>
</table>

1.3 Systems analysis description

The holistic approach of Integrated Water Resources Management as described above requires water managers to look beyond the physical aspects of the water system and to take into account also the users and uses of the water and the institutions involved. In fact, they have to consider these users and institutions as part of their Water Resources System. The Water Resources System can be defined as consisting of three components:

1. The Natural Resources System (NRS), being the system of rivers, lakes, groundwater aquifers and its related infrastructure; it includes both quantity and quality aspects of the water.
2. The *Socio Economic System* (SES), the water using and water related human activities.

3. The *Administrative and Institutional System* (AIS), the system of administration, legislation and regulation including the authorities responsible for the management of the WRS and the implementation of laws and regulations.

The Natural Resources System (NRS) stands for the supply side of the system (resource base). The demand side of the system is made up of the Socio-Economic system (SES). The Administrative and Institutional System (AIS) controls both the supply as well as the demand of the resources as illustrated in Figure 1-2.

### 1.4 Objective and approach of the project

The overall aim of the Sistan project is to develop methods and tools in order to strengthen and build capacity to achieve integrated water resources management to support the development of Sistan and to sustain agriculture and ecosystems in the Sistan river basin. The project is set up in 5 modules: Water Resources (the supply), Water Demand, Flow Forecasting and Operation Rules, IWRM and Cross-cutting activities. The activities for these 5 modules are strongly related and oriented at developing two specific deliverables: a Flow Forecasting System (FFS) and an IWRM plan.

The analysis approach that was followed in the project includes (see Figure 1-3) an initial phase, a development phase (developing analysis tools and strategies) and a selection phase (in which recommendations are made upon the best course of action).

In the *Initial Phase* (often called the inception phase) a detailed analysis was carried out on the problems and conditions involved. Based on that analysis the objectives and criteria for the required developments were specified and the approach for the remainder of the project was determined. The main purpose of this initial analysis was to ensure that the analyst had the same perception of what needs to be done in the area as the decision makers and stakeholders. A common perception is needed before the actual analysis of problems and strategies to deal with these problems under different scenarios could be carried out.

The next phase was the *Development Phase*. During this phase additional data was collected on the Natural Resource System, the Socio-economic System and the Administrative and Institutional System. Where appropriate computer tools were developed and applied to quantify the aspects involved. These tools were used to carry out the following preliminary analysis activities:

- base case analysis: the analysis of the present situation, quantifying the problems;
- bottleneck or reference case analysis: the analysis of the future situation (the time horizon of the project) under autonomous developments and no specific measures will be taken;
• screening of measures: inventory and rough analysis of possible measures to solve the problems, leading to a set of promising measures that will be analysed in more detail in the next phase.

Figure 1-3  Analysis Approach

The last phase was the Selection Phase in which the promising measures were combined in alternative WRM strategies. These strategies were analysed in detail. The models were used to determine the impacts of these strategies in terms of the indicators or criteria as defined in the Initial Phase. Once decisions are taken on a preferred strategy the resulting approach will be translated into operational rules for the (daily) management of the water resources in Sistan.

In carrying out the analysis two important elements with respect to IWRM in Sistan should be kept in mind:
1. The relation with Afghanistan. The water management in the Sistan area depends heavily on the availability of water from Afghanistan. The required flow amounts and regime to achieve the desired socio-economic and ecological situation in the Sistan area will be the starting point for the discussion with Afghanistan about the management of the Hirmand river.
2. Operational rules on how to deal with the amount of water available. The catchment knows drought and high precipitation periods. Even with a treaty with Afghanistan the inflow into the area is uncertain. Therefore it is necessary to consider what the best way is to allocate the water that enters Sistan.
1.5 Progress made in project

This report was written at the end of the Netherlands contribution in December 2005. The Iranian partner in the project, WRI, will continue the activities until the beginning of 2007. The focus of the Netherlands contribution has been on transferring methodology and computer programs, training, the set-up of first versions of the models and to do some first analyses with these models. With this as base WRI will further develop and calibrate the models and to carry out the actual analysis. At the time of writing this report the following achievements were made with respect to the content of the project (data, models and analyses):

- FFS-Sistan (Flow Forecasting System): working version available; needed: further calibration (hydrology, water management in Afghanistan), improvements (snow update module) and the development of an operational link with IRIMO.
- IWRM-Sistan model (RIBASIM): good working version available; needed: further calibration (hydrological boundary conditions, description hamoun system, schematization losses).
- IWRM analysis: first analysis done at reconnaissance level; it is needed to continue this analysis, in interaction with SBRWA and other local stakeholders, and to develop an operational plan (what to do under which circumstances with respect to the flow from Afghanistan).

Above means that the information given in this Main Report is not final. Additional information will be developed in the coming period. This will be included in the final documentation that WRI make at the end of their project in 2007.

1.6 Outline of this document

The set-up of this Main Report is as follows. First a description of the natural resource system and related infrastructure in the project area is given in Chapter 2. This is followed in Chapter 3 by a similar description of the socio-economic system. The hamouns are described in Chapter 4 in which both the natural system as well as the importance of the hamouns for the socio-economic development of the area is given. The description of the system will be completed in Chapter 5 in which an overview is given of the institutional setting and the stakeholders involved.

In Chapter 6 the analysis will start with an overview of the development goals and policies in the area out of which the resulting IWRM objectives for the Sistan area will be defined. Comparing the present situation in the area with these IWRM objectives will result in a quantified problem description. Chapter 7 describes the approach to forecast the flow from Afghanistan. Finally, in Chapter 8 the actual IWRM analysis will be described. The last chapter (Chapter 9) includes some first conclusions and recommendations on how to proceed with the analysis.
Sistan River during dry period
2 Natural Resources System and its infrastructure

2.1 Hirmand – the source of Sistan’s water

The Hirmand supplies nearly all water of Sistan. About 95% of the basin is located in Afghanistan as illustrated in the physiographic map of the Hirmand basin (see Figure 2-1). The Hirmand river rises in the Kuh-e-Baba Range, 40 km west of Kabul. It is joined by its major tributary Arghandab river, near Qale Bist, leaving the mountains to enter the plain. At Hirmand Fork, just at the border with Iran, the river bifurcates into the Sistan and Common Parian rivers. The total length of the Hirmand river is 1050 km; from Qale Bist to Hirmand Fork it runs over a distance of some 400 km. At Hirmand Fork the total basin area measures about 138,000 km². The Hirmand has no outlet to the sea, and millennia of evaporation have produced many salt flats in the Sistan Basin. Seasonal increments of snowmelt keep the rivers of the Hamoun-e-Hirmand fresh and when the lakes overflow salts are spread to other parts of the depression. The ultimate sink of the salt is the Goud-e-Zireh lake, being the deepest depression in the basin.

A more schematic presentation of the Hirmand and other rivers draining into Sistan is given in Figure 2-2. The main river systems involved are:

- **The Hirmand.** Several tributaries join the Hirmand upstream of Kajaki dam in the Hazarajat mountains, where the river flows through narrow valleys with gorge-like cliffs. Apart from the Hirmand proper the main contributors are the Kaj and Tirin rivers. Downstream of Kajaki dam the Rud-e-Musa Qala drains and several intermittent streams south of Girishk. Water is diverted from the river in this reach by the Saraj and Boghra

Figure 2-1 Physiographic Map of Hirmand Basin (source background: Tom Rabenhorst (UMBC) and Ray Sterner (JHUAPL))

For a more detailed description of the Hirmand basin reference is made to Annex B
barrages (near Girisk) for irrigation. The Boghra diversion supplies water through a right bank canal to the Marja, Nad-e-Ali and Shamalan irrigation areas.

- **The Arghandab.** The headwaters of the Arghandab squat in the granitic masses of the eastern Hazarajat 560 km away from its mouth. Since 1952 the flows of 13,170 km$^2$ of the Arghandab basin are controlled by the Arghandab or Dahla dam. Less than 80 kilometers north of Kandahar, the Arghandab flows into open country. A low line of hills separates the river from Kandahar and the Patao canal-system, which supplies the city with water. The Arghandab eventually reaches the Hirmand at Qale Bist, considerably drained off by intensive irrigation along the way. The river can even dry up into a series of unconnected pools in unusually dry years. In the Arghandab basin the following rivers are found:
  - Two intermittent streams, the Koshhk-e-Nakhud and the Garm Ab west of Kandahar, feed into the Arghandab from the north.
  - The Arghastan river, which is about 280 km long and drains an area of 20,219 km$^2$, flows east of and parallel to the Arghandab. Joined, by the Lora no. 1 and Kushk-e-Rud, the Arghastan meets the Dori river southeast of Kandahar, and the Dori then flows on to join the Arghandab west of Panjwai.
  - The Dori, about 320 km long, is called the Lora near its source in Pakistan. Its name changes to Kadanai as it enters Afghanistan, and the name Dori applies east of Spin Baldak. Irrigation largely dissipates both the Dori and Arghastan flows before they unite.
  - The Tarnak, which is about 320 km long and a drainage area of 9,076 km$^2$ is sandwiched between the Arghandab and Arghastan rivers and drains the Kalat-e-Ghilzai region. Most of the Tarnak has been diverted for irrigation before it joins the Dori.
  - The Ghazni Rud, about 240 km long, mainly waters the Ghazni area, and its principal tributary, the Jilga, flows out of Paktya. A brackish lake, Ab-e-Istadeh, (27 by 8 km), receives the runoff from the Ghazni Rud. The Ab-e-Istada, the source of Lora no. 1, freezes over in winter.

- **The Khash** is 480 km long and drains an area of 21,840 km$^2$. The river is intermittent, active only during the melt-water season. It flows from its source in the western Hazarajat to Chakansur during the flood season.

- **The Khaspus** is a small and narrow river basin between the Khash and the Farah. The river is about 250 km long and drains 9,428 km$^2$.

- **The Farah Rud.** Farther north and west, the Farah Rud (320 km long and drainage area 32,809 km$^2$), which has its watershed in the Paropamisus Mountains, flows through the desert to the Hamoun-e-Puzak and Hamoun-e-Saberi. The Rud-e-Ghor joins the Farah Rud near Kumrak before it debouches into the stony desert of the Dasht-e-Narmung. Near 32°50N and 63°15E, the Malmun River joins the Farah Rud.

- **The Harut Rud or Adraskan river.** Originating in the mountains southeast of Herat, the Harut Rud or Adraskan river flows past Shindand and in spate reaches the Hamoun-e-Saberi. The Rud-e-Gaz joins the Adraskan at Shindand, and the Khoshk-e-Rud, an intermittent stream, dribbles into the Adraskan during the flood season (December-March). Intensive irrigation by farmers considerably reduces the Adraskan flow into the Hamoun and its meager tributaries.
The main hydraulic infrastructures in the Hirmand Basin are the Kajaki reservoir in the Hirmand and the Arghandab reservoir in the Arghandab. Only limited and often outdated data are available on these reservoirs. What is known is the following:

- **Kajaki reservoir** (1953). Gross capacity 2,720 MCM; live storage 1,844 MCM (see Figure 2-3). Through three barrages below the dam (Saraj, Boghra and Darweshan) about 71,000 ha irrigation area is served. The live storage of the Kajaki reservoir is about 31% of the average annual flow which means that the dam has some power to control the Hirmand water.

- **Arghandab reservoir** (1972). Live storage of 435 MCM, supplying large areas of land in the Arghandab valley through two barrages (Zahirshahi and Arghandab).

**Irrigation in Afghanistan**

Irrigation in the Hirmand Basin takes place through project canals that take their water at diversion works and through non-project canals that take their water direct from the river without any intake, often aided by temporary structures. Data from 1975 indicated that at that moment some 132,000 ha was irrigated from the Hirmand and another 265,000 ha was identified as irrigable. This makes the total potentially irrigable area from the Hirmand to add up to almost 400,000 ha. This still excludes the irrigated and irrigable area from the Arghandab river about which no information is available.
Precipitation and evaporation

The annual precipitation in the upper reaches of the Hirmand basin amounts on average to about 350 mm, which reduces gradually to 125 mm near Qale Bist and 50 mm in the lower part, with over 90% of it occurring between December and May. The monthly precipitation pattern for selected stations in and around the river basin are shown in Figure 2-4.

In Figure 2-5 the reference crop evaporation in the Arghandab, Farah and Sistan basins is presented. It is observed that for the three Afghan stations the evaporation is considerably lower than for Zabol. In the period of the growing season of the summer crop from May to September the potential evapotranspiration in Sistan is about 700 mm higher than in the lower Arghandab, middle Hirmand and Farah region as can be observed from the figure. The strong winds in this period in Sistan cause a considerable increase of evaporation. The strong winds are not observed from the records of the Afghan stations. Such high evaporation values do have serious consequences for the crop water requirement.
River flows

The Hirmand, Arghandab, Farah and Khash rivers are the most important contributors to the inflow to Sistan. The time series of monthly flows as computed for Kajaki and Char Burjak on Hirmand are displayed in Figure 2-6. The flows at Char Burjak are affected by the operation of Kajaki dam since 1953 (dam inaugurated in April 1953). It may be observed that prior to 1953 in the lean season already irrigation abstractions took place. It is also seen that in 1953 the filling of the Kajaki reservoir started. The effect of the reservoir operation on the flows at Char Burjak is clearly visible:

- the regularity of the flow regime diminished after 1952,
- the low flows have significantly increased since the operation of the dam
- the peaks significantly reduced in the average and low flow years.

The average monthly flow values are presented in Figure 2-7 and Table 2-1. Some care is to be taken into account for an inter-comparison as the periods of the record are not equally long (Hirmand records 1947-1971, Arghandab record 1948-1965, Farah record 1953-1965, Khash...
record 1953-1964). In the last rows of Table 2-1 flow values for comparable number of years have been presented for inter-comparison. From the Figure it is observed that the highest monthly flows are generally experienced in April, except for Char Burjak. Highest precipitation occurs prior to April, hence most of the runoff is due to snowmelt.

Figure 2-7  Average monthly flows of Hirman, Arghandab, Farah and Khask rivers

Generally, the coefficients of variation are high, which indicates a large variability in the flows for a particular month from one year to another.

Table 2-1  Average monthly and annual discharges in Hirmand, Arghandab, Khash and Farah rivers (in MCM)

<table>
<thead>
<tr>
<th>Station</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Annual</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hirmand at Kajaki</td>
<td>185</td>
<td>221</td>
<td>292</td>
<td>252</td>
<td>287</td>
<td>818</td>
<td>1509</td>
<td>1335</td>
<td>546</td>
<td>257</td>
<td>156</td>
<td>150</td>
<td>1947-71</td>
<td></td>
</tr>
<tr>
<td>Arghandab at Qala-i-Bust</td>
<td>7</td>
<td>13</td>
<td>48</td>
<td>98</td>
<td>145</td>
<td>286</td>
<td>162</td>
<td>39</td>
<td>56</td>
<td>10</td>
<td>6</td>
<td>924</td>
<td>1948-65</td>
<td></td>
</tr>
<tr>
<td>Hirmand at Char Burjak</td>
<td>165</td>
<td>174</td>
<td>258</td>
<td>311</td>
<td>409</td>
<td>604</td>
<td>1187</td>
<td>1348</td>
<td>570</td>
<td>290</td>
<td>207</td>
<td>169</td>
<td>5692</td>
<td>1947-71</td>
</tr>
<tr>
<td>Farah at Farah</td>
<td>2</td>
<td>3</td>
<td>18</td>
<td>67</td>
<td>237</td>
<td>426</td>
<td>519</td>
<td>173</td>
<td>54</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>1519</td>
<td>1953-65</td>
</tr>
<tr>
<td>Khash at Dilram</td>
<td>1</td>
<td>7</td>
<td>12</td>
<td>18</td>
<td>44</td>
<td>144</td>
<td>157</td>
<td>49</td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>451</td>
<td>1953-65</td>
</tr>
<tr>
<td>Hirmand at Kajaki</td>
<td>188</td>
<td>226</td>
<td>250</td>
<td>271</td>
<td>297</td>
<td>894</td>
<td>1648</td>
<td>1439</td>
<td>587</td>
<td>291</td>
<td>175</td>
<td>163</td>
<td>6429</td>
<td>1953-65</td>
</tr>
<tr>
<td>Arghandab at Qala-i-Bust</td>
<td>10</td>
<td>18</td>
<td>67</td>
<td>115</td>
<td>142</td>
<td>314</td>
<td>184</td>
<td>49</td>
<td>77</td>
<td>14</td>
<td>8</td>
<td>1065</td>
<td>1953-65</td>
<td></td>
</tr>
<tr>
<td>Hirmand at Char Burjak</td>
<td>217</td>
<td>229</td>
<td>354</td>
<td>380</td>
<td>479</td>
<td>562</td>
<td>1216</td>
<td>1408</td>
<td>656</td>
<td>377</td>
<td>286</td>
<td>229</td>
<td>6393</td>
<td>1953-65</td>
</tr>
</tbody>
</table>

The coefficients of variation for the Hirmand flows are fairly constant throughout the year, in contrast with the Arghandab, Farah and Khash rivers. For the latter rivers the coefficients of variation are as expected high for the low flow period. For the flood season all variation coefficients appear to be of the same order of relatively high magnitude.

The relative importance of the various rivers to the flow to Sistan and the Hamouns can be observed from the last rows of Table 2-1 and the annual flow time series, which are presented in Figure 2-8.

The Figure shows that the Hirmand river gives the largest contribution. If the flow at Kajaki is put at 100% then the Arghandab flow is 17% of it, the Farah 24% and the Khash is 7% of the flow at Kajaki. It is also observed that the Hirmand flow variation from year to year is considerable, as can also be observed from the frequency distribution of the flow at Char Burjak, see Figure 2-9.
From a water balance analysis of the Hirmand flows at the Hirmand-Arghandab confluence (= Hirmand at Kajaki + Musa Qala at Musa Qala + Arghandab at Qale Bist) and the discharge at Char Burjak it is estimated that on average some 19% of the undisturbed flow at Char Burjak is diverted upstream. This is exclusive of the irrigation withdrawals upstream of Qale Bist in the Arghandab basin.

From a spectral analysis of annual flows of Sistan river it is concluded that the Hirmand flow behaves cyclic with a period of 12-14 years (see Annex A). This implies that prolonged dry and wet spells prevail of on average 6-7 years duration.

From Figure 2-8 it is observed that the flows of Farah and Khash rivers together are larger than the outflow from the Arghandab basin. It is also observed that the flows of Farah and Khash are sometimes of the same order of magnitude as of Hirmand. It implies that the contributions of these rivers should be incorporated in the Sistan and Hamoun-model. The contribution of Farah is on average 3 times the amount from the Khash river. The relatively low outflow from the
Arghandab basin can be explained by the large use of water for irrigation as mentioned in above.

2.2 Sistan inland delta

The Sistan inland delta starts at the Hirmand Fork where the Hirmand river bifurcates into the Sistan River and the Common Parian. The main features of the inland delta is given in Figure 2-10.

Figure 2-10 Overview map of Sistan Inland Delta
The delta (excluding the hamouns) is about 250,000 ha. The surrounding lakes and wetlands, which are partly located in Iran and partly in Afghanistan, cover during wet conditions an area of up to 500,000 ha. The Sistan inland delta is fully located within the Zabol shahrestan (see section 5.1). The land use of this shahrestan is given in Table 2-2. The LANDSAT image given in Figure 2-11 shows that during wet conditions substantial areas are flooded (the hamouns) or cultivated.

<table>
<thead>
<tr>
<th>Type of land</th>
<th>ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm land</td>
<td>139 734</td>
</tr>
<tr>
<td>Forest</td>
<td>61 000</td>
</tr>
<tr>
<td>Pasture</td>
<td>474 595</td>
</tr>
<tr>
<td>Residential land</td>
<td>1 940</td>
</tr>
<tr>
<td>Other</td>
<td>377 340</td>
</tr>
<tr>
<td>Total</td>
<td>1 054 609</td>
</tr>
</tbody>
</table>

Straight after the Hirmand Fork water flows from the Sistan River through a feeder canal to the Chahnimeh reservoirs which are mainly used for drinking water purposes. In the Sistan Plain three irrigation command areas can be distinguished: two using water from the Sistan River and one getting its water from the Common Parian.

The Sistan Plain has three wetlands of international importance: the Hamoun Puzak, Hamoun Saberi and Hamoun Hirmand. Being indicated as Ramsar sites, these should be protected, but are frequently without water. When water levels are high the three wetlands are linked. The Common Parian flows into Hamoun Puzak which is linked to Hamoun Saberi and then to Hamoun Hirmand. Also the Sistan River flows into this last wetland.
2.2.1 Climate and general environmental conditions Sistan Delta

The Sistan Delta has a very hot and dry climate. In autumn, the weather is moderate and it is cold in winter. But, it exceeds 50 °C in summer. The average of absolute maximum annual temperature in Zabol meteorological station is about 46.4 °C. The average temperature in Zabol in the hottest month (July) is 34.5 °C. The yearly average temperature is about 21.8 °C. According to Koppen classification, Sistan is classified as a very hot and dry region.

Strong winds is one of the main factors affecting weather condition in Sistan. The winds blow alternatively in winter and continuously in spring and summer. The wind is mostly blowing from north and north-west. It blows more strongly during winter and spring than summer and autumn. There are most winds in winter and least winds in autumn. Low pressure which is exerted on Lut Desert in summer, is the main reason for the strong winds in this area. In the summer, a phenomenon occurs that is called the ‘120 days wind’ with prevailing wind speeds of nearly 20 knots.

The region has a strong temperature fluctuation during a day and the difference between the lowest and highest temperatures can be about 33 °C. Zabol is more humid than Zahedan. Relative humidity during the last months of autumn and winter is more than the other seasons in Zahedan and Zabol.

The average annual rate of rainfall in Zabol, Nahbandan, Zahak Dam and Mount Khajeh stations are 60, 90, 60 and 65 mm, respectively. Although Zabol is not too far from Zahedan, the rainfall in Zabol is less than a half of the rainfall in Zahedan. About 80% of total rate of annual rainfall occurs in autumn and winter and both regions have little rainfall during summer.

2.2.2 Water resources for Sistan Delta

Surface water resources

The Hirmand is the main source of water for the Sistan Delta. The water availability from the Hirmand was at average between 5,000 and 6,000 MCM per year (see Section 2.1). This availability seems to have decreased in the last 20 years, most probably due to use of Hirmand water upstream in Afghanistan for irrigation purposes. The treaty with Afghanistan guarantees a yearly amount of 820 MCM (see Section 5.3).

Rainfall is limited and seasonal as indicated above. An average annual rate of rainfall of 70 mm produces at the land area of the Sistan Delta of 250,000 ha only about 18 MCM per year.

Groundwater resources

A distinction is made between deep (aquifer) groundwater and sub-surface (shallow) groundwater. Various explorations have confirmed that there is no deep groundwater in the area, even not under the hamouns.

The availability of shallow (phreatic) groundwater is somewhat unclear. The general opinion is that there is no groundwater available in the region. It appears that with ‘groundwater’ only the deep groundwater is meant and not the sub-surface water. Information from the Agricultural Bureau in Zabol mentions the existence of 5600 shallow wells (out of which 4700 have been issued certificates) with an average discharge of 1.4 l/s. In the dry year 2003 about 101 MCM was exploited by these wells. No information about safe yields is available. It is assumed that withdrawals above 101 MCM per year includes mining and will result in decreasing phreatic levels.
2.2.3 Main infrastructure and features of Sistan Delta

To explain the main features of water resources system of the Sistan Delta a distinction can be made in the sub-systems: the Sistan River, the Common Parian, the Hamouns and Shileh Emissary, the Chahnimeh reservoirs and the groundwater system.

Sistan River

The Sistan River constitutes the core of the water resources system of the region. The river is about 60 km long from Hirmand Fork till Hirmand Lake. From upstream to downstream the following structures are encountered (see also Figure 2-12):

- **Hirmand bifurcation.** The diversion ratio between the Common Parian and Sistan River will strongly depend on the flow and the amount of sediment. Under high flow conditions about 40% seems to be diverted to the Sistan river. The amount diverted during low flow conditions can be influenced by dredging.

- **Intake Feeder Canal for Chahnimeh reservoirs.** This intake is located about 100 m downstream of Hirmand Fork. Hydraulic model simulations showed that the capacity of the intake is about 480 m$^3$/s, well below the design capacity of 1,000 m$^3$/s (Delft Hydraulics - WRC, 2003).

- **Kohak barrage with former off-take.** This barrage was constructed in 1955 to divert water into the Azar canal but is no longer in operation. At this moment the Kohak barrage has no specific function anymore except that it influences the amount of water diverted to the Sistan river and forms an obstacle that raises the peak flood water level during high flows.

- **Niatak floodway.** The Niatak weir has been constructed to divert water from the Sistan during high flows. The design capacity is 600 m$^3$/s. The Niatak Floodway is about 12 km till it reaches the Niatak River.

- **Zahak barrage with off-takes.** This barrage forms a constriction to the flow of the Sistan River and there is a considerable difference in water level across the barrage. The barrage

---

2 For a more detailed description of the hydraulic infrastructure of Sistan reference is made to Annex C.
heads up the water for the irrigation canals Shahr and Taheri (older, but still functioning irrigation systems).

- **Headrace canal of Chahnimeh reservoirs.** The function of this Exit Canal of Chahnimeh reservoirs is to provide supplementary water for the irrigation systems along the Sistan in case the river itself contains too little water.

- **Sistan barrage with off-take canals.** This barrage is the main structure for providing water to the irrigation system around the Sistan river. The off-takes are upstream of the barrage and comprise at the right bank the Posht-ab Main Canal and at the left bank the Shib-ab Main Canal.

- **Posht-ab and Shib-ab irrigation systems.** This irrigation system has been constructed in 1983. It includes a drainage system which discharges in two closed reservoirs in the Hamoun-e-Hirmand.

- **Sistan bifurcation at Sistan Fork.** Finally, at Sistan Fork the river bifurcates into the Adimi River to the North and the Afzalabad River to the South. The diversion over these two branches is influenced by morphological developments.

**Common Parian**

The first part (about 30 km) of the Common Parian river forms the border between Iran and Afghanistan. After that the river bifurcates in a kind of delta system with many branches, ultimately ending in the Hamoun-e-Puzak. At the Iranian side there are 3 structures that control the off-takes and inflow to Iran. In addition to these structural off-takes there are a number of pumping stations that withdraw water from the Common Parian.

![Figure 2-13 Schematic lay-out of rivers and canals branching off from Common Parian](image)

Figure 2-13 provides a schematic overview of the rivers and canals branching off from the Common Parian:

- **The Shirdel river/canal** is mainly used for irrigation. It bifurcates downstream into the Niatak and Maleki rivers. The Niatak River receives during high flows additional water from the Sistan River through the Niatak floodway and then serves also the function to divert flood water. The Niatak and Maleki rivers ultimately drain to Hamoun-e-Saberi.
- The **Main canal 1** intake serves the irrigation area in the Northern part of the Sistan plain. It continues as Main Canal 2. At the head of the irrigation system the canal bifurcates in Canal 3, the Rendeh Canal and the Golzar Canal. The drainage water of this irrigation area is flowing into Hamoun-e-Saberi.

- The **Golmir Canal** is again mainly used to discharge flood waters. The Golmir river joins the Maleki River about 20 km downstream of the intake after which it drains into the Hamoun-e-Saberi.

### Hamouns and Shileh Emissary

The Hamoun system around Sistan consists of several lakes that during high water periods form an extensive wetland of about 5,000 km$^2$. During low flows the lake splits into several parts, separated by low strips of land as indicated in Figure 2-14. In extreme dry periods the lakes disappear altogether as was the case during most of the period 1997 till 2000. All three lakes have their own receiving rivers. During periods of high flows water of the Hamoun-e-Puzak will flow into the Hamoun-e-Saberi while the Hamoun-e-Saberi will release its high waters to the Hamoun-e-Hirmand. The outflow of the Hamoun-e-Hirmand is the Shileh Emissary, which is a (mostly dry) river that drains the water to the deepest depression in the area, the salt lake Goud-e-Zereh. The main features of the system are:

![Figure 2-14  Overview Hamouns and river system](image-url)
• The **Hamoun-e-Puzak**. This Hamoun is for a large part located in Afghanistan. The main rivers debouching into this Hamoun are the Common Parian (the Northern branch of the Hirmand, including the flow of the Podat and Khash rivers), the Khaspas river and part of the Farah River, all from Afghanistan.

• The **Baringak and Chonge Sorkh** areas, which form the link between the Hamoun-e-Puzak and Hamoun-e-Saberi. This part of the overall wetland is in particular important for ecology from a biodiversity point of view.

• The **Hamoun-e-Saberi**. The Hamoun-e-Saberi is located in Afghanistan and Iran. This Hamoun is fed by the flow of the Farah river (part) and the Harut or Adraskan river and, in case of overflow (at about 474.5 m above sea level, the drainage level under the road crossing the Hamouns from Zabol to Nehbadan), by the Hamoun-e-Puzak. The Sistan delta is protected from flooding from the Hamoun-e-Saberi by a dike.

• The **Hamoun-e-Hirmand** is the most important lake for the Sistan area. It is fed by the Sistan river (the Southern branch of the Hirmand) from Afghanistan, the Bandan and Shur rivers from Iran, and, in case of overflow (at about 474.5 above sea level) by the Hamoun-e-Saberi. The Sistan delta is protected from flooding by a dike.

• The **Shileh spillway** at the downstream part of the Hamoun-e-Hirmand. This spillway has been constructed to prevent drainage of the lake during low water levels and to prevent erosion of the Shileh Emissary. The spillway level is at level 475.46 above sea level.

• The **Shileh Emissary** is a natural connecting channel between the Hamoun-e-Hirmand and the Goud-e-Zereh in Afghanistan.

• The **Goud-e-Zereh** is the lowest depression in the area and, hence, ultimately accumulates all the salt of the system. The Goud-e-Zereh is a deep lake which nearly always contains water, even if the Hamouns have dried up. The Goud-e-Zereh collects also water from the basins located to its south. The water level of Goud-e-Zereh varies around 455 and 460 above sea level.

More detailed information on the hamouns is given in Chapter 4.

**Chahnimeh Reservoirs**

In 1981 three reservoirs were constructed at the site of natural depressions for storage of water. The intake for the reservoirs is at the Sistan river. The total capacity of these three reservoirs is 628 MCM, with a live storage of 350 MCM (SBRWA, 2002). An overview of the Chahnimeh reservoirs is given in Figure 2-15.

- Chahnimeh 1: 226 MCM (area 21 km$^2$)
- Chahnimeh 2: 87 MCM (area 9 km$^2$)
- Chahnimeh 3: 315 MCM (area 17 km$^2$)

Figure 2-16 shows the level-area-volumes curves for the combined Chahnimeh 1,2 and 3 reservoirs. Currently, a fourth reservoir with a total capacity of 820 MCM and live storage 600 MCM is being constructed which will be in operation in 2008.

The Chahnimeh reservoirs were specifically developed to safeguard the drinking and industrial water supply for both Zabol and surrounding areas as well as for Zahedan (0.90 m$^3$/s). The reservoirs are rather deep and they provide little opportunities for wildlife which prefer shallow water or wetlands. During dry years some water can be released to supply the irrigation areas Posht-ab and Shib-ab.

The intake of the Chahnimeh reservoirs is from the Sistan River through the Feeder or Entrance Canal, just downstream of Hirmand Fork while the reservoirs have an outlet back to the Sistan River through the Head Race or Exit Channel about 4 km downstream of the Zahak Barrage.
Another potential reservoir that is talked about is the Khatam reservoir (Godal Khatam). The location of this potential reservoir is shown on Figure 2-10. Further information on Chahnimeh 4 and the Khatam reservoir is given in Annex C.
Shile weir at the end of Hamoun-e-Hirmand
3 The Socio-Economic System

The Sistan plain is completely located in the administrative unit of Zabol shahrestan. In this shahrestan about 400,000 people live currently. The economy of the region and the income of a large part of the population largely depend on water: through both irrigated agriculture and products provided by the Hamoun wetland. Besides for the economy, the supply of water to Sistan plain is important for domestic water. A good functioning of the wetland is important for maintaining acceptable living conditions in the area. This chapter describes the population, and the use and importance of water for the people of Sistan Plain.

3.1 Population

The population of Zabol Shahrestan has seen large fluctuations in the past, resulting from drought. Table 3-1 shows the increase of the rural population since 1965. Without the Chahnimeh reservoirs to provide drinking water, people were forced to move to other areas in years with low availability of water in rivers and wetland. This explains the relatively low increase in population numbers compared to regions of similar development level.

Table 3-1 Population and population increase since 1965

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Posht-Ab</td>
<td>48,075</td>
<td>45,281</td>
<td>54,900</td>
<td>36,965</td>
</tr>
<tr>
<td>Markazi</td>
<td>3,595</td>
<td>5,607</td>
<td>6,838</td>
<td>31,515</td>
</tr>
<tr>
<td>Shib-Ab</td>
<td>35,101</td>
<td>31,340</td>
<td>37,139</td>
<td>41,871</td>
</tr>
<tr>
<td>Shahraki and Narooee</td>
<td>33,467</td>
<td>33,644</td>
<td>45,674</td>
<td>53,452</td>
</tr>
<tr>
<td>Miankangi</td>
<td>21,796</td>
<td>26,089</td>
<td>48,001</td>
<td>59,213</td>
</tr>
<tr>
<td>Total</td>
<td>142,034</td>
<td>141,961</td>
<td>192,552</td>
<td>223,016</td>
</tr>
</tbody>
</table>

Growth rate (%) -0.005 3 1.5

Source: Statistical Yearbook Sistan-Baluchestan Ostan (in Delft Hydraulics, 2001)

It is assumed that the numbers presented in Table 3-1 comprise the rural population only. The statistical yearbook of the Sistan-Baluchestan Province (2002) mentions a rural population of 230,000, and in addition an urban population of 150,000 people. This comes to a total population of 380,000 people for Zabol Shahrestan in 2002. Table 3-2 shows the data with a separate urban population for 1996 and 2002. These data are used to make an estimation of the population in 2005.

Table 3-2 Population numbers for urban and rural areas of Zabol shahrestan 1996 & 2002 (Source: Statistical yearbook of Sistan-Baluchestan Province, 2002).

<table>
<thead>
<tr>
<th></th>
<th>1996</th>
<th>2002</th>
<th>Growth rate (%)</th>
<th>2005 (estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>108,900</td>
<td>152,500</td>
<td>5.8</td>
<td>180,500</td>
</tr>
<tr>
<td>Rural</td>
<td>225,600</td>
<td>227,500</td>
<td>0.1</td>
<td>228,500</td>
</tr>
<tr>
<td>Total</td>
<td>334,500</td>
<td>380,000</td>
<td>2.1</td>
<td>405,000</td>
</tr>
</tbody>
</table>

Table 3-3 shows that the household size in both rural and urban areas is 5.7 persons. Using this household size leads to an estimation of the number of households in Zabol Shahrestan for 2005 of 32,000 urban and 40,000 rural households.
Table 3-3 Household size households Zabol Shahrestan 1996 and estimate 2005

<table>
<thead>
<tr>
<th></th>
<th>Total households</th>
<th>Persons per household</th>
<th>Estimate households 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>19,200</td>
<td>5.67</td>
<td>32,000</td>
</tr>
<tr>
<td>Rural</td>
<td>39,500</td>
<td>5.68</td>
<td>40,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>59,500</strong></td>
<td><strong>5.68</strong></td>
<td><strong>72,000</strong></td>
</tr>
</tbody>
</table>

**Composition of the population with respect to age and gender.**

In Zabol shahrestan the gender ratio is about 1.0, meaning there are as many men as women. The composition of the number of people in the different age groups is shown in Figure 3-1. There are relatively many young people, characteristic for developing regions. This is clearly shown in the cumulative chart (Figure 3-2): 50% of the population is below 20 years, and 75% below 30 years of age.

![Figure 3-1 Division (%) of the population of Zabol Shahrestan over different age groups](image1)

![Figure 3-2 Cumulative presentation of population in various age groups](image2)

**Opportunities: literacy & education**

The total literacy rate in Zabol Shahrestan was 61% in 1996, but according to the Shahrestan’s office this has increased to 72%. There are differences between gender and between urban and
rural areas: in 1996 the literacy rate was highest for urban male (83%). For urban female the ratio was 72%. In rural areas the literacy rate is lower, for male 60% and for female only 47%. In 1996 56% of the persons between 6 and 24 years old were following education.

3.2 Employment

Table 3-4 shows how the employment of Zabol Shahrestan’s population is divided over the various sectors. Agriculture and fisheries (all mentioned water-related sectors) together comprise 38%, while services make up 54% and a small contribution come from industries (6%).

<table>
<thead>
<tr>
<th>Sector</th>
<th>Number of people employed (1997)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, hunting and forestry</td>
<td>23,371</td>
<td>37.0</td>
</tr>
<tr>
<td>Fishing</td>
<td>354</td>
<td>0.6</td>
</tr>
<tr>
<td>Mining</td>
<td>38</td>
<td>0.1</td>
</tr>
<tr>
<td>Industry</td>
<td>3,852</td>
<td>6.0</td>
</tr>
<tr>
<td>Services</td>
<td>33,957</td>
<td>54.0</td>
</tr>
<tr>
<td>Other</td>
<td>879</td>
<td>1.4</td>
</tr>
<tr>
<td>Total</td>
<td>62,451</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: Statistical yearbook (2002)

It should be noted that in 1997 the drought was starting. Possibly before the drought the water-related sectors may have had a larger contribution. However, these data were not available at the time of writing of this report.

In Iran the labour force is defined to consist of all people of 10 years old and older. This means 70% of the population which comes to a total of about 280,000 persons in 2005. On the other hand, in a household not all members over 10 years will be formally employed. If it is assumed that per household 2 persons generate income, only about 120,000 jobs should be provided.

If indeed 70% of the population should be counted as labour force, the total labour force in 1996 was about 230,000. This would have meant an unemployment rate of about 75%. However, in 1996 only about 6000 people were registered to be unemployed (Statistical yearbook of Sistan-Baluchestan, 2002). This would mean that the actual labour force in 1996 was around 70,000; about 30% of the population. With this ratio, the demand for jobs in 2005 is around 120,000.

3.3 Agriculture

Types of agriculture
Various types of agriculture are practised on the Sistan plain. Originally these were field cultivation, horticulture and animal husbandry. Nowadays also greenhouses and fish ponds can be found. Table 3-5 shows that especially field cultivation has suffered from the drought, but also horticulture and animal husbandry have seen large losses.
Table 3-5 Economic benefit of different agricultural activities before and during drought (source: Leaflet Agricultural Bureau Zabol)

<table>
<thead>
<tr>
<th>Type of activity</th>
<th>Economic benefit before drought (MEuro/year) (about 1997)</th>
<th>Economic benefit during drought (MEuro/year) (about 2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field cultivation</td>
<td>60.80</td>
<td>6.8</td>
</tr>
<tr>
<td>Horticulture</td>
<td>3.45</td>
<td>0.8</td>
</tr>
<tr>
<td>Animal husbandry</td>
<td>33.80</td>
<td>23.6</td>
</tr>
</tbody>
</table>

**Cultivated area**

The total command area of the irrigation scheme is currently around 120,000 ha. The Ministry of Jihad of Agriculture plans to extend this area to a total of 250,000 ha. The main crop during non-drought conditions is wheat (60,000 ha) followed by barley (20,000 ha) and watermelon (20,000 ha). Horticulture covers about 3,000 ha (leaflet Agricultural Bureau).

**Response to drought**

As a result of the drought the cultivated area has decreased. As an alternative, the Agricultural Bureau has introduced greenhouses and fish ponds. For both types of cultivation shallow groundwater is pumped. Shallow groundwater is also used for field cultivation in drought periods. The land-use map given in Figure 3-3 gives an indication of the areas where groundwater wells are used at present.

Figure 3-3  Groundwater land-use map (Source: Agricultural Bureau Zabol - January 2005)

In this map yellow indicates the area which is severely affected by the sand problems (approx. 300 villages) predominantly around the lake boarders. There are groundwater wells in the yellow part, but these are too saline for use. **Light green** indicates that no agriculture is practised intensively, only cattle grazing occurs, so the problems are less intense than in the yellow area. **Darker Green:** agriculture is being practised in this area and around 6,000 shallow depth wells (up to 12 m. depth) are being used for irrigation in case of drought. This area is around 15,000 ha.

**Livestock numbers**

Large numbers of livestock were available in the area at the start of the drought (1997) (Table 3-6). The table shows that poultry numbers have increased, while the numbers of the larger animals have decreased with 45-70%. Cows, sheep, goats, and camels will have made use of the grasslands surrounding the Hamouns, although part may have also been kept at the farms and been fed with cultivated fodder crops. It is therefore not clear what part of the benefits of animal...
husbandry should be attributed to the supply of irrigation water and what part to the supply of water to the Hamoun wetlands.

Table 3-6 Livestock numbers in the pre-drought situation (leaflet Agricultural Bureau Zabol)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>135,000</td>
<td>61,750</td>
</tr>
<tr>
<td>Sheep</td>
<td>1,021,000</td>
<td>496,000</td>
</tr>
<tr>
<td>Goat</td>
<td>242,000</td>
<td>124,000</td>
</tr>
<tr>
<td>Camel</td>
<td>8,350</td>
<td>5,700</td>
</tr>
<tr>
<td>Domestic Poultry</td>
<td>342,000</td>
<td>416,660</td>
</tr>
<tr>
<td>Industrial Poultry</td>
<td>1,743,000</td>
<td>2,975,000</td>
</tr>
</tbody>
</table>

Number of people employed
Information on the number of people depending for income on agriculture is very unclear and not consistent with the information on employment mentioned above. The leaflet of the Agricultural Bureau in Zabol mentions that before the drought agriculture (including possibly some Hamoun use) provided 119,000 jobs. Comparing this number with the employment as given in Section 3.2 it is assumed that this includes also informal jobs by e.g. family members. What is clear is that agriculture is an important income-generating sector for the population of Zabol Shahrestan. Farmers have greatly suffered from the drought.

3.4 Public water supply

Public water supply and waste water treatment can be divided in three systems:
- Rural water supply and waste water treatment Zabol Shahrestan
- Urban water supply and waste water treatment Zabol Shahrestan
- Urban water supply for Zahedan City

Rural water supply and waste water treatment
The rural water supply system is new; the construction started about 7 years ago with connections to 30 villages and steadily extended to full coverage. Full coverage was reached 3 years ago. The provision of domestic water to the rural population has prevented people to move away from the Sistan plain, which did happen during the drought of 1970-1971.

Figure 3-4 shows the layout of the rural water supply network. Besides the 934 villages of Zabol Shahrestan, the rural water supply network supplies water for a few cities, which are not included in the urban network. These are Dust-Mohammad, Adimi, Zahak and Mohammad-Abad, with a total of about 5,000 connections. Also the Afghan city Shahr-e-No, a city of approximately 10,000 inhabitants, receives water through the rural distribution system. The total population connected to the rural system is around 220,000.

Although the design for the rural system was a supply of 100 l/cap/day, the current use is 156 l/cap/d. According to people from the Rural Water and Waste Water Authority, this is due to the use of piped water for irrigation and industries. Water for the rural distribution network is treated at Zahak through infiltration and chlorination. The capacity of the treatment plant is 1200 l/s, which is currently not fully used.

Waste water from rural areas is currently not treated. The water is collected in infiltration pits from where it enters the groundwater. Since the groundwater table is low, this is not considered a problem.
Urban water supply and waste water treatment
The urban water supply system covers the Shahr’s Zabol and Bonjor. The coverage is 90%. The total population connected to the urban system is around 150,000. Per capita use in urban areas is 115 l/day.

Waste water from urban areas is collected and treated at the Zabol Waste Water Treatment Plant. This plant has a capacity of 39,000 m³. After treatment the water is reused in agriculture (It is not clear where and for which purposes).

Zahedan water supply
The city of Zahedan also takes part of its drinking water from the Chahnimeh reservoirs. For this purpose a pipeline of more than 200 km is constructed from the reservoir to Zahedan. The capacity of this pipeline is about 0,9 m³/s. The water supply from Zabol to Zahedan was put in operation early 2003. Through this pipeline a volume of 27 million m³ is transferred to Zahedan annually.

The total amount of water allocated to public water supply amounts to 50 MCM/year. All water for each of these three supply systems is taken from the Chahnimeh reservoirs. For rural and urban distribution networks of Zabol Shahrestan the water is taken from reservoir 1, while the water for Zahedan is taken from Chahnimeh 3. Currently, the intake level for the Zabol rural network is a limiting factor. Also, Chahnimeh 3 is the deepest reservoir, and at low water levels, reservoir 1 and 3 are not connected. Canals are being constructed to ensure the connection at low levels.
Industrial water use
Some small industries or enterprises use water from the public water supply system. The total abstraction from the rural supply system for industries is estimated at 50 l/s. Zahak slaughterhouse is a somewhat larger user with a demand of 11 l/s. These industrial demands are included in the per capita use of the water.

Zabol Sharestan counts 4 mines. The sector is not big, not from an economic perspective nor from an employment perspective. It is not clear how much water the mines withdraw and from where they withdraw this water.

3.5 Conclusion on the socio-economic system

Three main water demand sectors can be identified: public water supply, agriculture and the Hamoun wetland. Public water supply has the highest priority. Although the amounts involved in public water supply are small compared to what the other two sectors demand, the uncertainty in supply from Hirmand results in the need for storage of large volumes of water in the Chahnimeh reservoirs. The socio-economic importance of the hamouns will be described in the next chapter.

When additional water is available, it has to be divided over the two sectors of agriculture and the Hamoun wetland. Both sectors provide income for many people and both contribute to the regional economy. Careful analysis should point out what the best way is to allocate the available water, in which the additional functions of the Hamoun wetland in regulating the living conditions and providing an area for recreation and traditions should not be ignored. This analysis will be described in Chapter 8.
Reed harvesting in hamouns (courtesy dr. Behrouzi)
4 The hamouns - wetlands of socio-economic importance

The hamouns of Sistan are part of the Natural Resource System (described in Chapter 2) but their socio-economic features make them also part of the Socio-Economic System, described in Chapter 3. This chapter specifically addresses the hamouns, providing detailed information on both aspects (the natural and socio-economic). The Hamoun Wetlands have always been a unique feature of the Sistan area with important ecological and socio-economic values. They provide overwintering habitat for birds and products which are used for economic purposes by the population such as livestock grazing, reed-cutting and fishing.

4.1 Physical and ecological aspects of the Hamoun wetlands

4.1.1 Physical aspects of the Hamoun wetlands

What makes the Hamoun lake system ecologically unique, is that it is essentially a freshwater ecosystem at the end (or seemingly at the end) of a river in an endorheic (inland) basin in an otherwise extremely arid area. Usually, rivers in such endorheic basins in arid areas end in saline, or even hyper-saline depressions. In fact, the case of the Hirmand River is not different, as the Hamoun lakes do not really form the end depression. In most years, the lakes seem to be the end of the river system, but occasionally, with exceptional floods, the lakes are flushed and flow over into an even lower depression which forms the true end of the system. On average, this happens every 8-11 years. The true end lake, the Goud-e-Zereh in Afghanistan, is saline (see Figure 2-14).

Figure 4-1 gives a longitudinal profile of the river and hamoun system from Hirmand Fork to the Goud-e-Zereh. This profile is based on the Digital Elevation Model (DEM) as developed for this area (for further information on how this DEM was developed reference is made to Annex C). The profile follows the Hirman along the Common Parian, through the Hamoun-e-Puzak, overflowing into the Hamoun-e-Saberi and next into the Hamoun-e-Hirmand after which
it flows through the Shileh to Goud-e-Zereh. Included in the figure is the schematic profile through the Hamouns as developed by Absaran. The schematization of Absaran indicates the deepest areas in the Hamouns compared to the ‘average’ level of the flow channel as indicated in the profile from the DEM. The level-area-storage curves of the three Hamouns are given in Table 4-1 and Figure 4-3.

<table>
<thead>
<tr>
<th>Table 4-1</th>
<th>Level - area - volume relations for Puzak, Saberi and Hirmand hamouns</th>
</tr>
</thead>
<tbody>
<tr>
<td>level (m)</td>
<td>Puzak</td>
</tr>
<tr>
<td>in m.</td>
<td>area in km²</td>
</tr>
<tr>
<td>470.0</td>
<td>2.5</td>
</tr>
<tr>
<td>470.5</td>
<td>3.0</td>
</tr>
<tr>
<td>471.0</td>
<td>3.8</td>
</tr>
<tr>
<td>471.5</td>
<td>97.5</td>
</tr>
<tr>
<td>472.0</td>
<td>99.6</td>
</tr>
<tr>
<td>472.5</td>
<td>105.8</td>
</tr>
<tr>
<td>473.0</td>
<td>119.0</td>
</tr>
<tr>
<td>473.5</td>
<td>151.2</td>
</tr>
<tr>
<td>474.0</td>
<td>200.5</td>
</tr>
<tr>
<td>474.5</td>
<td>311.8</td>
</tr>
<tr>
<td>475.0</td>
<td>451.5</td>
</tr>
<tr>
<td>475.5</td>
<td>666.2</td>
</tr>
</tbody>
</table>

**Water volume in the Hamouns**

An estimate was made of the water volume in the Hamouns over the years 1985-2005, based on depth estimates (interviews with local experts) and satellite image analysis (Figure 4-2).

Based on the temporal pattern of stored volumes, four periods can be identified in the last twenty years:

1. A low-water period in 1985-1988. Almost each year the Hamouns dried out or shrunk to a very small size, but there was some inflow in each year.
2. A high-water period in 1989-1993. For five years, there was a considerable inflow and the Hamouns shrunk to a smaller size then the maximum of the previous period only for a very short time.
4. A very dry period in 2000-2004. The inflow ceased and a catastrophic drought occurred. The end of this phase is marked with a flood in 2005, comparable to the maximum flood of the dry period.

4.1.2 Ecological aspects

The Hamoun lake complex forms a unique freshwater wetland ecosystem of outstanding local, national and international importance. In particular the ornithological value of the Hamoun wetlands is well documented. The Hamouns have since long been known as a wintering area of international importance for migratory waterbirds. This importance for waterbirds has been the main reason to designate in 1975 a major part of the Hamoun lakes as a wetland site of international importance under the Ramsar Convention. Figure 4-4 gives an overview of the two Ramsar sites in Iran. Afghanistan is not a member of the Ramsar Convention and, hence, has not assigned specific Ramsar sites in their part of the Hamouns.
Besides assigning the area as a Ramsar site, the Iranian government has also assigned in 1967 part of the wetland as protected area. The present boundaries of this protected area are also given in Figure 4-4.

The 2000-2004 drought has transferred the Hamoun lakes from an important wetland into a desert. People lost their livelihoods and the increasing desertification and resulting sandstorms make the Zabol area more and more difficult to live in. In 1990 the site was placed on the Montreux Record, a list of Ramsar sites under direct and serious threat of irreversible damage. The year 1990 indicates that the deterioration of the wetlands started before the present drought and has been the result of over-exploitation of the natural resources and mismanagement of the lakes.

Drought has always been part of the history of Sistan. The lakes have fallen dry on numerous occasions. No hard data is available on this. People in the area recall a drought in 1916 when the lakes remained dry for more than half a year. The lake also fell dry for about half a year in 1947 and in 1971. In all those cases the ecology recovered, in particular the more sensitive reed beds. Drought stroke again at the end of 1985 and 1987, leaving the lakes dry for several months. Recovery after these droughts differed from all previous ones, as the reed beds failed to recover, in spite of subsequent good wet years. This has been attributed to the devastating effect of herbivorous fish, the grasscarp, which has been introduced into the Hamouns in the seventies.

So far, there is no hard evidence of drought periods prior to 1990’s which exceeded the duration of a whole year. Under normal conditions rhizomes of reeds and other standing aquatic
vegetation can easily survive such periods. Recent years have been very dry. In the course of 2000 the lakes fell dry and remained dry until January 2002, for the first time for more than a year. The year 2001 was the first year without any water. Since then, the lakes have fallen completely dry every year, but it is not true that they have remained dry all the time since 2001. In 2002 there has been a little water from January to April, in 2003 there has been quite a bit of water from January to July, and in 2004 there has been water from February to April, but only in the Hamoun-e-Saberi (i.e. not from the Hirmand but from the Farah-Rud). As of January 2005, Hamoun-e-Puzak and Hamoun-e-Hirmand were dry since 2003 until 2005 when water reappeared in the Hamouns.

The Hamouns play an important role in how the ‘120-day wind’ is experienced in the Sistan area (and beyond). In the past, when the Hamouns were filled with water and reedbeds, the 120-day wind blew over the lakes before hitting the Zabol area. It would pick up some moisture from the lake and in the process cool down a little, and the reedbeds would filter some of the sand and dust the winds might carry. Thus, the Hamoun lakes acted as a natural airconditioner for the people of Zabol. The typical local house, built of clay-bricks, has a dome-shaped roof (the dome shape seems best suited to fend off heat from solar radiation), with a ‘chimney’ on top, with an opening on the side. The opening is directed into the wind. Thus, the ‘treated’ air from the 120-day wind would optimally circulate through the house, to climatise it.

During drought periods, it has always been a problem that the 120-day wind may turn into a dust- or sandstorm. When blowing over the lakes, instead of picking up moisture, it would pick up dust and sand from the dry lake beds, and blow it straight into Zabol. This is very well illustrated in the satellite image (quicklook) of 24 September 1987 (Figure 4-5), when the Hamoun-e-Puzak was still filled with water, but the Hamoun-e-Saberi and Hamoun-e-Hirmand were completely dry. Vague dust clouds can be seen coming from the Hamoun-e-Hirmand, but a spectacular dust ‘jetstream’ is coming from the lakebed of Hamoun-e-Saberi, blowing right through the centre of Zabol and across the Chahnimeh reservoirs.
The sand and dust cause big problems for the people of the Zabol area. Many villages along the borders of the former lakes have now been abandoned, not only because the sources for living (fishing, grazing, etc.) have disappeared, but also because of the sand. Some of the villages still inhabited, have been engulfed by moving sand dunes, and houses have to be freed with bulldozers.

The problem of dust storms may be aggravated by people digging in the lakebeds, for instance to collect clay for making mud bricks, or for use as fertilizer on agricultural fields. Figure 4-5 clearly shows how the major dust stream originates from a very small source in the Hamoun bed. Accumulating sand is not only a nuisance, as it covers agricultural land, and blocks canals and irrigation structures, but dust and sand also form a serious health problem. Eye problems and lung diseases (silicosis) are quite common in the area, nowadays.

**Change of vegetation cover in the Hamouns**

Based on different types of satellite images and quick looks using processing methods of different types a mapping was carried out on the vegetation cover in the hamouns (see Annex D for details). The NOAA AVHRR images represent the most complete time series and form the backbone of the analysis (1985-2005). Nevertheless, the one-kilometre resolution does not allow a detailed mapping of the vegetation cover.

For producing the vegetation cover time series, a *supervised classification* was carried out on some images, to obtain masks of characteristic inundation patterns. When a series of masks of different characteristic vegetation percentages were produced, visual comparison of the masks with the satellite image was used to estimate the vegetation cover (*visual estimate*). This method is slightly less accurate but considerably faster than standard image classification.

On Landsat quick look images either this visual estimate was carried out, or a quick ‘supervised classification’ supported the estimate (*digital estimate*). It is important to emphasize that this latter method is not a real image classification, since it was carried out on the RGB bands of a quick look picture and not the original image. Information distortion occurs also since this picture is distributed as a JPEG image, i.e. compressed with a lossy compression.

![Vegetation cover changes in the Hamouns 1985-2005](image)

**Figure 4-6 Vegetation cover changes in the Hamouns 1985-2005**

The applied visual and digital estimates of vegetation cover are only approximations, with an estimated error of ±10%, so it is risky to compare the individual images, but the long-time trend is well represented by them (Figure 4-6).
The vegetation cover does not reflect the four major periods identified in the water cover pattern until the end of 1999. Then, the drought damaged practically the entire wetland vegetation in the Hamouns. The total vegetation cover shows an annual dynamics, although inaccuracies in the individual estimates distort the picture to some extent. The most alarming observation from the chart is that a clear overall declining trend is present in the total vegetation cover until the end of 1999. This is indicated with the trend line in Figure 4-6. Rapid vegetation collapse started in 2000, after which very little vegetation remained, mainly in pockets where rivers bring some effluent waters from the irrigation schemes. The floods in 2005 triggered a recovery of the vegetation, as reported from field observations. It is not possible to judge at this moment whether the long term decline will be continued or with abundance of water the vegetation cover will grow in the future.

A full overview of the time series of the vegetation over maps is given in Annex D. The decline of the vegetation cover over the last twenty years is the most evident in the western Hamouns (Saberi and Hirmand). Detailed analysis of the individual Hamouns is given in Vekerdy and Dost (2005).

4.1.3 Management and mismanagement of the Hamouns

The Hamoun lake ecosystem is a highly dynamic ecosystem. The system depends on the discharge of the Hirmand River and a few smaller rivers, but the flow differs greatly between years. Both excessive floods and prolonged severe droughts occur at irregular intervals. Floods and droughts are a problem for the human population, but are essential for maintaining the characteristics of the dynamic ecosystem. High floods are necessary to prevent the lakes from gradually becoming saline, by intermittent flushing the contents into the terminal saline depression of the Goud-e-Zereh. Periodical droughts are needed to ‘reset’ the system, and maintain the dominance of early succession stages of marsh vegetation. Vast reed beds are characteristic for this stage. Reed beds are of great economic value for the local population.

Over the last decades drought seem to have occurred more frequently than before, and the vegetation cover has dramatically decreased. The degradation of the ecosystem is of great concern to the authorities and the local people, who see their livelihood threatened (see Section 4.2). With the decline of the vegetation, also the migratory birds have vanished. Between 2001 and 2005 the lakes have been completely dry most of the time. People lost their income from fisheries, reed harvest, grazing, and bird harvesting, and agriculture suffered from severe shortage of water. Reasons for the degradation may be increased occurrence of droughts, decreased discharge of the Hirmand River due to increased water use in Afghanistan, over-exploitation of natural resources by the growing local population, and the introduction of exotic herbivorous fish which may have prevented regrowth of reeds after the droughts of the mid-1980’s.

Analysis of discharge figures and estimates of water and vegetation cover from satellite images show that there is no clear declining trend in water supply, but that vegetation cover suddenly disappears in the late 1980’s, following a short period of drought. In earlier years, vegetation cover followed the fluctuations in water coverage, in later years it doesn’t. This suggests that the effect of climate and water use in Afghanistan may have been over-estimated, while the effect of local over-exploitation, mismanagement, and local irrigation has been under-estimated.

Although there is no clear downward trend in the long term water supply, the drought between 2001 and 2005 has been unusual, in that the lake beds have not been completely dry for such a long time ever before (as far as memories go). This drought has caused many families (notably fishermen) to leave, and also resulted in a drastic reduction of the number of cattle in the area. With the strong NW winds prevailing in summer (the 120 day wind), the dry lake beds fed
dramatic dust storms, hitting Zabol, and causing physical and mental health problems. The occurrence of reed beds, fish and water-birds has been reduced to zero.

In January 2005 mission the situation in the dry Hamouns looked very bleak, and restoration of the ecosystem looked very improbable. However in April 2005, after a good flood had occurred, the situation looked quite different. Young reeds were seen emerging from the water, locally even starting to form reed beds, flies, mosquitoes, midgets and dragonflies (all depending on water for their reproduction) were numerous, and flocks of water-birds were present, albeit in very small numbers yet. Fishermen were catching fish, both exotic and native species, and the endemic *Schizocypris altidorsalis* were already ready for spawning, starting to swim upriver again. In April 2005, the Hamoun-e-Puzak and Hamoun-e-Saberi were well filled, but Hamoun-e-Hirmand remained dry, for the greater part. This is probably because virtually all the water from the Sistan River was diverted into irrigation canals.

Observations show that the Hamouns have a potential to recover if there is sufficient water supply, but this can only happen if people can refrain from over-using the natural resources again. With respect to ‘sufficient water supply’, the future does not look bright. It can be expected that not only the amount of water held back in Afghanistan will increase, but also the amount of water taken for storage, irrigation and domestic use in the Zabol area. Only in years with high discharges there will be enough water left to fill (part of the) Hamouns, and the incidence of dry years in the lakes will certainly increase.

It seems that there will not be enough water to develop irrigated agriculture in Sistan, and restore the Hamouns at the same time. Choices have to be made. If priority is given to restoration of the ecosystem, changes in agriculture are necessary, such as improving the efficiency of irrigation, changing to crops that are less water demanding, reducing the area of agricultural land, etcetera. If priority is given to agriculture, further degradation of the lakes has to be accepted, including loss of grazing and fishing, and a more frequent occurrence of dust storms.

In order to save wetland values on a more local scale, artificial reduction of the size of the Hamouns has been suggested as a solution. This is only possible in Hamoun-e-Hirmand, because only this lake lies entirely within Iran. A reduced Hamoun-e-Hirmand must be fed through the Sistan River. An increased flow through the Sistan River may result in less water for Hamoun-e-Puzak. This would be unfavourable, because the Puzak lake complex has the highest ecological value at present, and the highest potential for recovery. Plans for the establishment of a reduced Hamoun-e-Hirmand must be judged on their ecological impact on the surroundings regardless of international borders.

### 4.2 Socio-economic aspects of Hamoun wetlands

The Hamoun wetlands play an important role for the people of the Sistan plain: the wetlands provide various products, prevent sandstorms and offer possibilities for recreation. This section discusses the functions of the wetland and for whom they are important. Annex E provides additional information on this topic.

**Wetland functions**

Various authors have classified the various functions of the wetland. It should be noted that classifying the functions is not an aim in itself: the main purpose is to prevent functions from being overlooked as well as from being double counted. The classification used in this report is the one by De Groot (1992). De Groot identifies the following seven categories of functions:
• **Carrying functions** are characterised by the environment providing nothing more than space, substrate or backdrop for human activities.

• **Joint production functions** are defined by the types of relationships in which human decisions and inputs remain a dominant factor, but in which the environment is also actively involved, providing, for instance, soil fertility and the will-to-develop inherent in plants and animals.

• **Natural production functions** are characterised by the fact that the environment now produces (or has produced in history) largely on its own; human beings are only the harvesters. Harvesting, in this function category, is confined to physical entities (oil, wildlife etc.).

• **Signification functions** are defined by the fact that the environment again largely ‘produces’ on its own and human beings are only the ‘harvesters’, but ‘harvesting’ now lies in the cognitive and spiritual realms, e.g. those of science, cultural orientation and spiritual participation. The term ‘signification’ has been chosen as a reference to both the relatively superficial concept of ‘to signal’ and the deeper concept of ‘to signify’.

• **Habitat functions** are those of which not humans, but the other intrinsically valuable inhabitants of the earth are the prime beneficiaries; habitat function is the provision of their ecological home.

• **Processing functions** are characterised by all the relationships in which people benefit from the capacity of the environment to undo the harm or risk inherent in human actions. In many of these functions (e.g. dilution, sequestration), the environment is relatively passive. In others (e.g. chemical transformation or the processing of organic waste), the environment plays a more active role.

• **Regulation functions** refer to the capacity of components of the environment to dampen harmful influences from other components. Often, this takes the form of a shield against too high levels of something, e.g. cosmic radiation or floods. In other instances, it is the dampening of processes that tend to go too fast or fluctuate too widely, e.g. soil erosion, the development of pests or river flow fluctuations.

Because the wetland is currently in a degraded state, to get a good impression of the goods and services the wetland provided in a healthy state, a reference situation should be considered. As reference situation the 1970’s are chosen. For this period it is known that the wetlands were healthy. In the 1970’s the wetlands were surrounded and partly covered with reed beds. Satellite images show a vegetation cover of 160,000 ha (in 1977). Large groups of migratory birds frequent the area in winter, and there are large groups of residential birds as well. Mansoori (1994) mentioned the presence of 190 species of birds, with total numbers up to 700,000 in 1977. The Hamoun wetlands were an important source of fish. Numbers of fish are not known. The Fisheries Bureau in Zabol mentions annual catches of 12,000 ton fish (pers. comm. March 2005). The area harbours rare and threatened endemic fish species and birds. Some reptiles and mammals were also found. Because of this important function of the wetland in preserving biodiversity, it has been designated as wetland of international importance under the Ramsar Convention by the Iranian Government in 1975.

In 1975 the rural population counted approximately 30,000 households, with a total of 142,000 people when including the urban areas. After the 1970’s various changes have taken place: the population more then doubled between 1975 (142,000 people) and 2005 (404,000 people), the Chahnimeh reservoirs were constructed (1981) and the agricultural area was extended and modernised (construction of Shib-Ab and Posht-Ab irrigation areas around 1983). Also in Afghanistan developments may have taken place, although it is possible that due to the political problems many projects have not been carried out as planned. Pressures on the Hamoun wetland strongly increased.

The analysis of functions of the Hamoun wetland is done by applying the functions classification by De Groot (1992) on the situation in the 1970s.
Carrying functions
When the Hamouns are filled with water, fishermen travel by boat to other villages to buy wheat and other products. This function can contribute to various values: income (market), food (market), independence & social structure (own transportation and contacts with others).

Natural production function
The Hamoun wetlands have a very important natural production function. The main products which are harvested are fish, birds, and reed. Various people obtain their food and income through catching of harvesting these products. The products are also important at the local market; they provide fresh, varied and affordable food for the entire population of the Sistan plain.

Joint production function
The pastures surrounding the Hamoun lakes, which require regular flooding of the area are important for livestock breeding activities. There are nomads in the area, who travel around with their herds, but also settled farmers who let their cattle graze on these pastures. There is no large scale recession agriculture, but the former pastoralists mention that they grew fruits and vegetables on the land that had been inundated. Due to the fertile soil these crops were easily grown. Like the natural production functions, the joint production function provides income for the livestock herding people, but also ensures the availability of meat and dairy products at the local market, benefiting the entire population of Sistan plain.

Signification functions
For the people living close to the Hamoun wetlands, the wetlands were the scene for wedding, parties, and perhaps other traditional or cultural events. People further away visit the area for recreation, to enjoy. The ancient buildings on the Kuh-e-Khajeh, an old volcano, are the aim of their trip, but the beauty of this site lies in the surrounding of the mountain with reeds and water.

The wetland has not only a local function, but also a global function. Being on the north-south route of migrating birds, it plays a role in sustaining global biodiversity. This intrinsic value is appreciated by nature lovers throughout the globe. The importance of the site is reflected in the designation as ‘Ramsar’-site, although the recent degradation has put the wetland on the Montreux-list, the list indicating threatened wetlands.

Processing functions
It is not clear to what extent this function plays a role in case of the Hamoun wetland. Waste water from irrigation is collected in isolated parts of the wetland, to prevent harming the wetland. Waste water from households is infiltrated in the soil (rural areas) or treated (urban areas) and reused. If the wetlands would play a role in waste processing, the people benefiting most from this would be the people in the direct proximity or downstream of the wetland. During the drought waste accumulation has not turned out to be a problem.

Regulation functions
A very important regulation function of the Hamoun wetland is the regulation of the local climate and the prevention of sandstorms. The notorious 120 days wind blows around the months of May, June and July at a windforce of 4-6 Beaufort. During these months the temperature may reach above 40°C. Whereas in the situation with a wet Hamoun wetland, these winds would spread small water droplets over the area, relieving the heat a bit, when the lakes are dry these winds bring nothing but sand and dust. This is done in such a way that complete houses have been covered with sand. Also numerous people suffer from skin, lung and eye complaints as a result of the dust. Women suffer even more because of the continuous cleaning.
Economic importance of wetland functions

The products provided by the Hamoun wetlands contribute to the economy of the region. Also, fisheries, reed cutting, and bird catching employ large numbers of people (see next section). Unfortunately, data on magnitude of production, such as fish catches, were not available. At the other hand, a leaflet of the Agricultural Bureau of Zabol provides some information on the extent of fisheries and reed harvesting (Table 4-2).

Table 4-2 Economic benefit of Hamoun products (source: Leaflet Agricultural Bureau Zabol)

<table>
<thead>
<tr>
<th>Product</th>
<th>Before drought (MEuro/year)</th>
<th>During drought (MEuro/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>9.3</td>
<td>0</td>
</tr>
<tr>
<td>Reed</td>
<td>3.1</td>
<td>0</td>
</tr>
</tbody>
</table>

The total area of pastures is estimated at 470,000 ha, with another 20,000 ha of reed beds. Fish catches are estimated from 9,000 ton/year (Leaflet Agricultural Bureau Zabol) to 12,000 ton/year (Fisheries Bureau, pers. communication, March 2005).

Users of the Hamoun wetland

Hamoun wetland users groups can be distinguished based on different relationships between goods and services of the Hamoun wetland and human well-being values. Assumed is that for the groups of people who use the Hamouns for income, the Hamoun will be of high importance. Probably, those people use the Hamouns for other well-being components as well. The people who do not use the Hamouns for income, may still find the Hamouns important because of contribution to health and possibilities for recreation. A distinction is made between people who depend for income on other water related activities (agriculture) and people who don’t. Assumed is that since the Hamouns compete with agriculture, farmers may appreciate the Hamoun services less than the city dwellers may do. Beneficiaries of the Hamoun wetlands are not all located in Iran; the Hamoun wetlands extend into Afghanistan, where there will be Hamoun users for income as well. The regulation of sandstorms will be beneficial to people in Afghanistan and Pakistan, while the sustenance of global biodiversity may be appreciated worldwide. Because the focus of the study has been on how water resources management in Iran can improve the situation for the local people, those foreign stakeholders are not further considered. To be able to investigate the differences between groups, and thus social equity, the groups of Hamoun users for income and of not Hamoun users, but water users for income, have been further separate in bird catchers, fishermen, reed harvesters, pastoralists and field cultivators (near Hamouns), and in animal husbanders on farm and field cultivators (far from Hamouns). Table 4-3 summarises the derivation of stakeholder groups.

Table 4-3 Identification of stakeholder groups

<table>
<thead>
<tr>
<th>Hamoun users for income</th>
<th>Iran</th>
<th>Bird catchers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fishermen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reed Harvesters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pastoralists</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field cultivation near Hamoun</td>
</tr>
<tr>
<td></td>
<td>Afghanistan</td>
<td>Not further considered</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Not Hamoun users for income</th>
<th>Water users for income</th>
<th>Iran</th>
<th>Animal husbanders on farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not water users for income</td>
<td></td>
<td>Afghanistan</td>
<td>Field cultivators far from Hamouns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pakistan</td>
<td>Not further considered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global environmental protection groups</td>
<td>Not further considered</td>
</tr>
</tbody>
</table>
The number of households in each group has been estimated based on population statistics for rural and urban areas, and on discussion with people at authorities and in the field. The total population in 2005 consist of approximately 404,000 people, 152,000 in urban, and 252,000 in rural areas. With households sizes of 5.67 and 5.68 for urban and rural households respectively, this means 26,800 urban and 44,400 rural households. The Agricultural Bureau of Zabol mentions about 30,000 cattle herding families, 15,000 of them on the borders of the Hamouns (referred to here as pastoralists), and 15,000 on farms (referred to as animal husbanders). Another group of pastoralists are the nomads, 3200 households are under the cover of the Nomads Bureau. According to the Fisheries Bureau, the number of 2500 fishermen’s households in 1999 has not increased since. In all group discussions the number of households depending mainly on reed harvesting is mentioned to be very small. Bird catchers mentioned during the group discussion that in and near their city 300-400 bird catching households were living, and this was similar in a few other places. A total of 1000 households is assumed. Most of the rural households involve in field cultivation. The number is calculated by abstracting above numbers from the total number of 44,400 rural households. Of the resulting 21,900 households, 3000 are assumed to live near the borders of the Hamouns, and 18,900 further away. During group discussion and interviews (see Annex E) it has become clear that most of the households involve in more than one activity. Yet, they refer to themselves as belonging to a certain group based on what they consider their main activity. The numbers, which are summarised in Table 4-4, will contain uncertainties, but are expected to give a good estimation of the relative size of each group within the community of Zabol Shahrestan.

Table 4-4 Number of household in each stakeholder group

<table>
<thead>
<tr>
<th>Group</th>
<th>Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bird catchers</td>
<td>1 000</td>
</tr>
<tr>
<td>Fishermen</td>
<td>2 500</td>
</tr>
<tr>
<td>Reed harvesters</td>
<td>500</td>
</tr>
<tr>
<td>Pastoralists</td>
<td>11 000</td>
</tr>
<tr>
<td>Animal husbanders</td>
<td>7 500</td>
</tr>
<tr>
<td>Field cultivators near Hamoun</td>
<td>3 000</td>
</tr>
<tr>
<td>Field cultivators far from Hamoun</td>
<td>18 900</td>
</tr>
<tr>
<td><strong>Total rural households</strong></td>
<td><strong>44 400</strong></td>
</tr>
<tr>
<td>City dwellers</td>
<td>26 800</td>
</tr>
<tr>
<td><strong>Total households</strong></td>
<td><strong>71 200</strong></td>
</tr>
</tbody>
</table>

Values of goods and services for stakeholder groups

The relationship between changes in goods and services and stakeholder groups depends on the value the goods and services have for people. Four groups of values can be identified:

- **Income and food**: income-generation and food production are often interchangeable: if more income is obtained less food need to be produced and the other way around. Income and food contribute to physical material well-being.
- **Health**: this category considers all contribution to physical well-being except income and food, for example clean and sufficient drinking water and the absence of disease vectors.
- **Perception & experience**: a nice environment is important for people to give them a sense of belonging to an area, to feel fine, and to have opportunities for recreation. Also cultural and religious traditions may be linked to certain environmental conditions. Perception & experience values contribute to mental well-being.
- **Independence & social structure**: this category of values has mainly to do with change. In a certain situation people will experience a certain level of independence and are part of social structures. Changes in the environment will may lead to changes in independence, for example because sources of income-generation disappear, and in social structure, when family ties are broken because migration is required. Independence and social structure values contribute to mental well-being.
The functions, values and people from above analysis are summarised in Table 4-5. Although all stakeholder groups have a relationship with the Hamoun wetlands, when we refer to ‘Hamoun users’ we mean the combined group of fishermen, bird catchers, reed harvesters and pastoralists, whose income mainly comes from the Hamouns. The table mentions a few other groups of people, who are potentially benefited: people in Afghanistan and Pakistan, as well as the entire global community. Because the focus of the study is the importance of the wetland for Sistan, these people are not further considered in the analysis.

The change in ecosystem condition will result in a change in the socio-economic situation of the Sistan plain. Linkages between the wetland ecosystem and the life of the wetland users have been assessed through group discussions and interviews. The method and results of this assessment can be found in Annex E. Only some general results are presented here.

Table 4-6 shows the importance of the Hamoun wetlands for the various human well-being values. To avoid misunderstanding about what the different components comprise, a number of sub-components were used. The components and sub-components have some overlap on purpose; for example, people may not directly link domestic water and health. Through different levels of shading (from light to dark coloured shading) the values are indicated which are perceived by less than 90%, less than 80%, less than 70% and less than 50% of the people in a certain group.

<table>
<thead>
<tr>
<th>Function</th>
<th>Values</th>
<th>Income &amp; food</th>
<th>Health</th>
<th>Perception &amp; experience</th>
<th>Independence &amp; social structures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carrying</strong></td>
<td>Hamoun users: access to market</td>
<td></td>
<td></td>
<td></td>
<td>Hamoun users: own transport and contacts with others</td>
</tr>
<tr>
<td><strong>Natural production</strong></td>
<td>Hamoun users: income &amp; food Sistan plain population: food Afghan Hamoun users: income &amp; food</td>
<td></td>
<td></td>
<td></td>
<td>Subsistence users: subsistence</td>
</tr>
<tr>
<td><strong>Joint production</strong></td>
<td>Subsistence users : income &amp; food Sistan Plain population: food Afghan subsistence users: income &amp; food</td>
<td></td>
<td></td>
<td></td>
<td>Subsistence users: subsistence</td>
</tr>
<tr>
<td><strong>Signification</strong></td>
<td></td>
<td></td>
<td></td>
<td>Sistan plain population: recreation, traditional/religious events Global community: intrinsic value</td>
<td></td>
</tr>
<tr>
<td><strong>Processing</strong></td>
<td>Subsistence users Downstream communities (if any)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regulation</strong></td>
<td>reduction of sandstorms: Sistan plain population South-west Afghan, and North-west Pakistani population</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4-6 gives a quick impression of why the Hamoun wetlands are valued by the population. Of the first four groups most of the people use the Hamoun wetlands for many components of their well-being. Naturally, people without livestock will not value the importance for livestock.

Food originating from the Hamoun wetland is important for all people of the Sistan plain, as well as the contribution to living condition and climate and to health. The Hamoun wetlands are also valued for their recreation opportunities by the entire population.

It is interesting to see that also within the groups of people living far from the Hamoun wetlands, and of the people who have not-water related activities as their main income-generation activity, many people indicate the use of the Hamoun wetlands for income-generation.

It can be concluded that although the subsistence users have the most direct relationship with the Hamoun wetland, virtually all people of the Sistan plain consider the Hamoun wetland important for some components of their well-being.

Table 4-6 Importance of different wetland values for different groups of people (in %)

<table>
<thead>
<tr>
<th>Main activity</th>
<th>Nr. participants</th>
<th>% of population</th>
<th>Income and Food</th>
<th>Health</th>
<th>P &amp; E*</th>
<th>I &amp; S*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Employment &amp; income</td>
<td>Food</td>
<td>Materials</td>
<td>Livestock</td>
</tr>
<tr>
<td>Bird catchers</td>
<td>39</td>
<td>1.4</td>
<td>100</td>
<td>100</td>
<td>92</td>
<td>59</td>
</tr>
<tr>
<td>Fishermen</td>
<td>41</td>
<td>3.5</td>
<td>100</td>
<td>100</td>
<td>98</td>
<td>73</td>
</tr>
<tr>
<td>Reed harvesters</td>
<td>28</td>
<td>0.7</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>71</td>
</tr>
<tr>
<td>Pastoralists</td>
<td>37</td>
<td>15.4</td>
<td>100</td>
<td>100</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td>Field cultivators near Hamoun</td>
<td>38</td>
<td>4.2</td>
<td>92</td>
<td>100</td>
<td>87</td>
<td>95</td>
</tr>
<tr>
<td>Animal husbanders</td>
<td>8</td>
<td>10.5</td>
<td>88</td>
<td>100</td>
<td>38</td>
<td>100</td>
</tr>
<tr>
<td>Field cultivators far from Hamoun</td>
<td>26</td>
<td>26.5</td>
<td>92</td>
<td>100</td>
<td>12</td>
<td>92</td>
</tr>
<tr>
<td>Urban people</td>
<td>31</td>
<td>37.8</td>
<td>29</td>
<td>97</td>
<td>6</td>
<td>35</td>
</tr>
</tbody>
</table>

* P & E = Perception and Experience
* I & S = Independence and Social Structure

4.3 Water ‘demand’ of the Hamoun wetlands

The water demand for the Hamoun wetlands is determined in a different way than the demand for agriculture and domestic use. Instead of assessing the demand for a fixed situation the impact of changes in the hydrological situation of the wetland is assessed. Four hydrological characteristics have been identified which are assumed to determine for a large extent the condition of the wetland. These characteristics are:

- frequency of spilling/flushing of the wetlands (to avoid salt accumulation in the lakes)
- frequency of complete (less than 5% of maximum area) drought
- volume reaching the wetlands in spring
- inundated area in fall
For each of the characteristics thresholds have been identified for which it is assumed that large ecosystem changes will occur when the thresholds are crossed. Combining all thresholds and characteristics has led to 24 possible hydrological situations. Then, for each of these situations the change in wetland condition compared to the situation in the 1970s has been assessed.

### Table 4-7 Estimated effects for combination of parameter classes

<table>
<thead>
<tr>
<th>Inter-annual</th>
<th>Intra-annual</th>
<th>Reed</th>
<th>Fish</th>
<th>Birds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spill</td>
<td>Drought</td>
<td>Flood</td>
<td>Area</td>
<td>Fall</td>
</tr>
<tr>
<td>T ≤ 15 y</td>
<td>Drought occurs ≥2000 MCM</td>
<td>Area fall</td>
<td>&gt;40%</td>
<td>100</td>
</tr>
<tr>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
<td>20-40%</td>
<td>90</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>No</td>
<td>&gt;40%</td>
<td>20-40%</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>no</td>
<td>&gt;40%</td>
<td>&lt;20%</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

* shaded areas are assumed to be impossible combinations of parameters

### 4.4 Estimating ecosystem impacts - criteria

Estimation of ecosystem impact is done by using ranges of percentages. For example, when the table states that in a certain situation the condition for reed will be 50-80%, this means that the condition/availability of reed will be 50-80% of the condition/availability in the 1970s. The situation of the 1970s is taken as the reference situation as that period is in general considered as have been good. By using percentages some of the uncertainty about actual ecosystem responses can be presented. It should be noted that the estimation of impacts has been done with a severe lack of data on the ecosystem condition. As an exercise it has served well, but the results merely show an order of change and updating of the table when additional data become available is required.

Because of the different types of wetland use, and the fact that certain groups of people have more access to not-water related resources, the different groups of people will be affected in different ways. The impact of changes in the ecosystem on the well-being of the population was assessed as mentioned through group discussion and interviews. In the analysis of the results a conceptual framework for assessing the social value is applied. This framework is presented in Figure 4-7. Important in this framework is that the context is taken into account. For example, to understand the impact of change in the wetland on income for a household, it is not only
important to know the income obtained from the wetland, but also the extent to which wetland use contributes to the total income of a household.

By applying this conceptual model, the relationships between wetland condition and a number of socio-economic criteria were assessed. Relevant criteria followed from the analysis are described in Annex E. Table 4-8 shows the identified criteria for each well-being value.

Table 4-8 Identified criteria for well-being values

<table>
<thead>
<tr>
<th>Well-being value</th>
<th>criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income &amp; food</td>
<td>Change in income/food (%) compared to reference</td>
</tr>
<tr>
<td>Health</td>
<td>Number of months with risk of sandstorms</td>
</tr>
<tr>
<td>Perception &amp; experience</td>
<td>Condition of reed (%) compared to reference</td>
</tr>
<tr>
<td>Independence &amp; social structure</td>
<td>Mainly related to change in income, no additional criterion</td>
</tr>
</tbody>
</table>

The resulting scores of possible water resources management strategies can be found in Chapter 8. So, not the actual water demand which has been assessed, but rather the ecological and socio-economic consequences of changes in the hydrological situation. What is chosen as the preferred water resources management strategy, indirectly determines the actual water demand for the Hamoun wetlands.
5 Institutional setting and stakeholders

5.1 General administrative structure

Administratively, Iran is divided in 30 Ostans, which are divided in shahrestans. The Sistan plain and Hamoun lakes are completely located within the boundaries Zabol Shahrestan, which is part of the Sistan-Baluchestan Ostan. Zabol Shahrestan is divided in five Bakhsh. The Bakhsh level contains Shahrs which are urban areas and Dehestans which are rural areas. A Dehestan can contain several villages. Zabol Shahrestan counts 6 Shahrs and 17 Dehestans (with over 900 villages). The different administrative units of Zabol Shahrestan are named in Table 5-1, and presented in Figure 5-1.

Table 5-1 Administrative units of Zabol Shahrestan

<table>
<thead>
<tr>
<th>Ostan</th>
<th>Sistan-Baluchestan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shahrestan</td>
<td>Zabol</td>
</tr>
<tr>
<td>Bakhsh</td>
<td>Posht-Ab</td>
</tr>
<tr>
<td></td>
<td>Shahraki and Narooee</td>
</tr>
<tr>
<td></td>
<td>Shib-Ab</td>
</tr>
<tr>
<td></td>
<td>Markazi</td>
</tr>
<tr>
<td></td>
<td>Miankangi</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shahr / Dehestan</th>
<th>S</th>
<th>D</th>
<th>S</th>
<th>D</th>
<th>S</th>
<th>D</th>
<th>S</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adimi</td>
<td>Adimi</td>
<td>Zahak</td>
<td>Zahak</td>
<td>Mohammad-Abad</td>
<td>Mohammad-Abad</td>
<td>Zabol</td>
<td>Dust-Mohammad</td>
</tr>
<tr>
<td></td>
<td>Bazi</td>
<td>Bazi</td>
<td>Khomak</td>
<td>Khomak</td>
<td>Kuh-e-Khajeh</td>
<td>Kuh-e-Khajeh</td>
<td>Bonjar</td>
<td>Dust-Mohammad</td>
</tr>
<tr>
<td></td>
<td>Sefid-Abad</td>
<td>Sefid-Abad</td>
<td>Jazinak</td>
<td>Jazinak</td>
<td>Teimoor-Abad</td>
<td>Teimoor-Abad</td>
<td>Morgan</td>
<td>Ghorghori</td>
</tr>
<tr>
<td></td>
<td>Ghaem-Abad</td>
<td>Ghaem-Abad</td>
<td>Khajeh</td>
<td>Khajeh</td>
<td>Lutak</td>
<td>Lutak</td>
<td>Jahan-Abad</td>
<td>Morgan</td>
</tr>
<tr>
<td></td>
<td>Adimi</td>
<td>Adimi</td>
<td>Ahmad</td>
<td>Ahmad</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Water is an important element for many socio-economic activities in the project area. Water is needed for drinking water and public health. Agriculture and industrial activities depend on the availability of sufficient water. Water in the Hamouns supports economic activities such as fisheries and reed-cutting. That same water supports also the ecological value on and around the lakes. Considering this all it is not surprising that many governmental institutes are somehow involved in the development and management of the water resources in the area.

The Ministry of Energy has a key-role in the management of the water resources in Iran. The Ministry is responsible for both the development and management of the general resource (rivers, reservoirs, groundwater, irrigation infrastructure, etc.) as well as for the provision of drinking water and sanitation facilities. The other key-players are the Ministry of Jihad-e-Agriculture (representing the biggest water user) and the Department of Environment (safe guarding that developments meet environmental criteria). Other important actors are the Management and Planning Organisation (MPO – allocating development funds) and the Department of Interior (responsible for regional development).
Figure 5-1  Administrative units project area

Ostan (province) Sistan-Baluchestan with Shahrestan Zahedan and Zabol

Bakhtsh and Shahr
1 - Miarangi
2 - Markazi
3 - Shahraki and Narooce
4 - Shib-Ab
5 - Posht-Ab

Dehedans
1 - Ghaem-Abad
2 - Bazi
3 - Ghoghorli
4 - Adimy
5 - Selid-Abad
6 - Dust-Mohammad
7 - Morgan
8 - Bonjar
9 - Jahan-Abad
10 - Zehak
11 - Toinooor-Abad
12 - Mohammad-Abad
13 - Kuh-e-Khoje
14 - Khomah
15 - Khoje Ahmadi
16 - Jazirak
17 - Lutalk
5.2 Stakeholders in WRM and coordination

All above ministries and departments have offices at the regional level. Figure 5-2 provides an overview of these offices at Ostan (province), Shahrestan, Bakhsh and Shahr/Dehestan level. From the perspective of our project the key-stakeholders are the ones that are shaded in the figure. They all are involved in water resources management (WRM) in Sistan and should be consulted. The practise of WRM in Sistan is that this is the sole prerogative of the Sistan Baluchestan Regional Water Authority (SBRWA) in Zahedan and its executive arm in Zabol the Sistan Water Board (SWB). They are responsible for the Chahnimeh reservoirs, the irrigation network and flood protection. The Sistan Water Board provides raw drinking water to the Water and Waste Water Authority. This Water and Waste Water Authority treats the water and distributes it to the customers. The same applies for irrigation water. The Sistan Water Board is responsible up to the secondary irrigation network. From there on (tertiary network and actual irrigation) the regional office of the Ministry of Jihad-e-Agriculture takes over.

The Department of Environment and its regional offices supervise the projects carried out by the other ministries and regional offices from an environmental point of view. They are also responsible for the enforcement of environmental and ecological laws and regulations in the area.

Figure 5-2 Vertical governmental structure in Sistan

Both at the Ostans and at the Shahrestan level two authorities are present for Water and Waste Water: Rural Water and Waste Water Authority and Urban Water and Waste Water Authority. They are responsible for purifying and distributing the water, and for collection of the waste water, which is in case of urban areas also treated.

At the Shahrestan level the Ministry of Jihad-e-Agriculture seems to have bureaus for several fields:
- Agricultural Bureau
- Natural Resources Bureau
- Fisheries Bureau
- Bureau of Nomads Affairs

The Sistan Water and Land Development Company is part of the Ministry of Energy. They have the responsibility for all water resources development plans in the Sistan region.

A different kind of stakeholders are the knowledge institutes and NGO’s. The University of Zabol is involved in WRM for their specific knowledge of the area but also to achieve local
knowledge dissemination. No information is available about specific NGO’s related to water. If these NGO’s exist they should be invited to participate in the planning process.

**Coordination**

At this moment there does not exist a permanent coordination committee for water resources management at the Ostan level. In case of crises (such as droughts and floods) a crises committee is formed between the Regional Water Authority, the Regional Water & Waste Water Company and the Regional Department of Environment. This committee is chaired by the Ostandar (provincial governor).

A permanent committee at the Ostan level is the Supreme Administrative Committee. This committee deals with many issues and as such is less suitable for specific water resources issues. The same applies for the technical committee which has to approve all plans that are being proposed for the province.

**Regional Water Council**

The development and management of the water resources in the Sistan area asks for a coordinated effort of all stakeholders involved. It is suggested that a Regional Water Council is formed in which all these stakeholders are represented. Two levels can be distinguished in this level. The first level contains the key-stakeholders involved as mentioned above. This level will have decision making power. The second level will contain all other stakeholders. They will have an advisory role and will be consulted on all major development with respect to the water resources in the Sistan area.

**Steering Committee for IWRM in the region**

The project described in this report aims to develop an IWRM plan for the Sistan Closed Inland Delta. This plan will address policy fields of many of above mentioned stakeholders and should be developed in close interaction with these stakeholders. Besides a good collaboration at working level it is needed that the progress and results of the project is discussed regularly at regional policy level. In case a Regional Water Council would be present it seems logical that this Council will provide the framework for these discussions and consultations of all stakeholders involved.

As a regional water council is not present yet a specific steering committee was installed for the project. That committee should be chaired by the governor (or one of his senior staff) while the technical secretariat of this committee should be with the Sistan-Baluchestan Regional Water Authority. Due to administrative constraints this Steering Committee has not functioned sufficiently yet.

**5.3 Agreement with Afghanistan**

The sharing of the resources of the Hirmand has been the subject of long disputes between Afghanistan and Iran since the separation of the two countries in 1875. Various agreements have been negotiated (1902, 1920, 1948) but all of them were either not ratified or not executed.

The last agreement between the two countries is from 1973. This treaty on the distribution of the Hirmand flows between Afghanistan and Iran guarantees Iran a minimum annual inflow of 820 MCM in normal or wet months. In dry months, Afghanistan is allowed to supply less than the agreed minimum. Rules are available to determine how much Afghanistan can reduce the flow. The definition of wet and normal months is based on the flow at Dehravud, upstream the
Kajaki reservoir. The agreements on the monthly distribution of the minimum flow at Hirmand Fork are shown in Table 5-2. On average Iran receives a discharge of 26 m$^3$/s. Afghanistan supplies 22 m$^3$/s according to the treaty and an additional 4 m$^3$/s as sign of goodwill.

Table 5-2 Treaty between Afghanistan and Iran concerning minimum discharge at Hirmand Fork

<table>
<thead>
<tr>
<th>Month</th>
<th>Normal Flow in Dehravud (MCM)</th>
<th>Iran’s Water Right in Normal and Wet Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monthly Flow (MCM)</td>
<td>Monthly Flow (m$^3$/s)</td>
</tr>
<tr>
<td>Oct,</td>
<td>189</td>
<td>13.4</td>
</tr>
<tr>
<td>Nov,</td>
<td>212</td>
<td>33.0</td>
</tr>
<tr>
<td>Dec,</td>
<td>216</td>
<td>61.7</td>
</tr>
<tr>
<td>Jan,</td>
<td>219</td>
<td>92.9</td>
</tr>
<tr>
<td>Feb,</td>
<td>256</td>
<td>189.1</td>
</tr>
<tr>
<td>Mar,</td>
<td>734</td>
<td>195.9</td>
</tr>
<tr>
<td>Apr,</td>
<td>1,424</td>
<td>80.6</td>
</tr>
<tr>
<td>May</td>
<td>1,271</td>
<td>24.2</td>
</tr>
<tr>
<td>Jun,</td>
<td>542</td>
<td>51.1</td>
</tr>
<tr>
<td>Jul,</td>
<td>260</td>
<td>36.8</td>
</tr>
<tr>
<td>Aug,</td>
<td>169</td>
<td>25.1</td>
</tr>
<tr>
<td>Sep,</td>
<td>154</td>
<td>6.0</td>
</tr>
</tbody>
</table>

ANNUAL: 5,646 809.7 26.0

* Please note that a constant discharge of 26 m$^3$/s during a year would lead to a total of 820 MCM. However, due to variations of the treaty flow over the months and the different month lengths the total is not more than 810 MCM.

The actual flow at Hirmand Fork is determined based on whether the previous month was wet or normal, or dry. If the previous month was wet or normal, Afghanistan should provide the agreed minimum flow for the actual month. If the previous month was dry two rules are available, of which it is at present not clear which is actually being applied.

1. The flow in the actual month is the multiple of the coefficient of the actual discharge at Dehravud in the previous month divided by the normal discharge at Dehravud in the previous month (as stated in the treaty) and the Hirmand flow for the actual month as stated in the treaty.

\[
Q_{HF_{actual,t}} = \left( \frac{Q_{DRV_{actual, t-1}}}{Q_{DRV_{normal, t-1}}} \right) \times Q_{HF_{treaty, t}}
\]

2. The flow in a month is the multiple of the coefficient of the sum of the actual discharges at Dehravud in the previous month (starting from March) divided by the sum of the normal discharges at Dehravud in the previous months (as stated in the treaty) and the Hirmand flow for the actual month as stated in the treaty.

\[
Q_{HF_{actual,t}} \left( \frac{\sum_{t-1}^{t-2} Q_{DRV_{actual, t}}}{\sum_{t-1}^{t-2} Q_{DRV_{treaty, t}}} \right) * Q_{HF_{treaty, t}}
\]

For the analysis the first option is considered. After running the simulation for the present and the future situation, the results will be analysed and where necessary increased according to the treaty. It should be noted that the Olumbagh reservoir is planned upstream of Dehravud, which implies that Dehravud will no longer be a suitable measurement location to assess the natural inflow in a year. In assessing the scenarios in this report the actual flow at Dehravud in the present situation has been used for all scenarios in which the treaty is being considered.

A particular situation exists at this moment as the Dehravud station has been destroyed by flood waters. It is not known how this will be solved in relation to the treaty.
The agreed upon 810 MCM per year is only a fraction of the average water availability of the Hirmand (order of magnitude 5,000 MCM at Char Burjak). The exceedance frequency of this 810 MCM is more than 95% (see Figure 2-9). The active storage capacity of the Kajaki reservoir is about 1,800 MCM. To give an indication of the order of magnitude of these numbers the following data on the drinking water demands in the region are given. The yearly drinking water demand of Zabol is about 40 MCM while the drinking water delivery to Zahedan is about 27 MCM a year.

It is noted that the agreement between Iran and Afghanistan on the Hirmand includes the use of the agreed-upon water by Afghan farmers north of Zaranj, most probably withdrawing their water from the Common Parian. This means that, according to the agreement, Iran is not allowed to use all the water at Hirmand fork to fill up the Chahnimeh reservoirs and that even in case of very low water flow some discharge into the Common Parian should be guaranteed.
6 Objectives, developments and problem statement

6.1 General development plans of Iran

The prime guidance document on development goals and policies in Iran is the national 5 year plan. The 3rd 5-year plan has just finished and is now being followed by the 4th 5-year plan that covers the period March 2005- March 2010. Due to the extreme drought in the Sistan area it was decided to revise the part that relates to this area.

The water related sectoral developments are described in the document Long-Term Development Strategies for Iran’s Water Resources. This plan is a joint document of the main stakeholders involved in water resources development and management in Iran, i.e. the Ministry of Energy, the Ministry of Jihad-e-Agriculture and the Department of Environment. Important principles and policy objectives described in the document are the following:

- The concept of IWRM (macro-management) will be applied, including an increase in the participation of people’s and local organizations and using basins as the natural units of water management.
- Groundwater utilization should not increase. Increased demands should be met by increasing the present share of surface water resources from 46% to 55% in 20 year.
- First priority will be given to drinking water and sanitation, followed by the demand for industry and services and finally to agriculture/gardening. The share of water use by agriculture should reduce from the present 92% to 87% in the coming years by doubling the water use efficiency.
- The management of the water should be based on the economic value of the water.
- The price of water for different users should take into account the basic needs of the people for drinking water and sanitation. Above that basic need on for other uses, pricing will depend on the particular situation, first covering the costs of O&M and next also the investment costs.
- Water management and use should be done in way to control pollution and gradually improve water quality.
- Transboundary water exchange should be considered, taking into account the national interests and technical, economic, environmental and social feasibilities involved.
- Development plans and projects and land use planning should take into account the sustainable use of available water resources. Inter-basin water transfer can be considered, taking into account the rights of interested parties, national interests and technical, economic, environmental and social feasibilities. Provincial development plans should consider basins as effective territories for the economic and social development of the province.
- Drought and flood management plans should be based on a risk management approach and be prepared and executed with the cooperation of all related organizations.
- In urban and rural water supply management first priority should be given to methods to reduce water consumption and control water losses.
- The High Water Council will coordinate all policies in water supply, distribution and consumption.
6.2 Objectives IWRM in Sistan and related criteria

6.2.1 Objectives IWRM in Sistan

Based on the policy documents and discussions with the stakeholders the following general objectives for Water Resources Management in Sistan were formulated.

<table>
<thead>
<tr>
<th>Objectives WRM in the Sistan Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>To support the socio-economic development of the Sistan area on the basis of sustainable resource use (surface water and groundwater), while protecting and restoring the natural environment. Specific policy objectives are:</td>
</tr>
<tr>
<td>1. to supply domestic water according national standards;</td>
</tr>
<tr>
<td>2. to support the generation of employment in the area, either in agriculture (supply of water for irrigation), hamoun use, in industry or the services sector;</td>
</tr>
<tr>
<td>3. to supply facilities to protect public health and the environment (sanitation and sewage treatment &amp; protection against / prevention of sandstorms); and</td>
</tr>
<tr>
<td>4. to sustain or restore the ecological and socio-economic value of the Hamoun wetlands</td>
</tr>
</tbody>
</table>

Ad 1. Drinking water for the population has the first priority. Currently the demands for public water supply can be met. The objective is that the requirements are still met when taking into account population growth. It should also be taken into account that when the ecological and economic situation improves people who left the area may like to return to their hometown. This would result in extra population growth. The standards for domestic water supply are described in:


For the Sistan area specific objectives apply. These have been described in Section 3.4.

Ad 2. Many people have left the area because of the bad economic situation, in general but further worsened by the drought. The objective is to provide livelihood for all people currently living in the area. The endogenous economic activity is agriculture, both field cultivation and animal husbandry. In addition fisheries and other natural resources use provide income. All of these activities require water. In the analysis the feasibility of other opportunities for economic activities (industry and services) and their water demand should be considered as well. This specific objective should be made operational by analysing the sectoral plans on agriculture and industrial developments. For industrial development specific targets can be accommodated, assuming that the industrial developments will not be very water consuming. For agriculture no specific targets are possible. An upper bound of water demand for agriculture can be determined by assuming the full development of the 240,000 ha agricultural land and present cropping patterns. In practise the analysis should try to optimise agricultural production and/or employment given a certain availability of water from the Hirmand.

Ad 3. Two issues are important with respect to public health and environmental protection. At first, the largest health problem the inhabitants of the Sistan plain are currently facing consist of respiratory, eye and skin problems resulting from the increased dust in the air and in severity
increased sandstorms. The second issue is water quality. Water quality is not a problem yet, but may form a problem when the population increases and when agriculture becomes more intensive with increased use of chemical fertilisers and pest- and herbicides. Another water quality issue is salt. Cultivated crops are more vulnerable to this than natural vegetation but with an increase also the Hamoun vegetation will suffer. WRM should prevent a degradation of the water quality below national standards, prevent a salinity increase in the Hamouns above fresh water salinity levels, and should keep the level of dust in the air and the frequency and severity of sandstorm at an acceptable (pre-drought) level.

Ad 4. The wetlands have an important ecological and socio-economic value. They provide over-wintering habitats for birds. The Hamoun lakes provide fish and reeds which are used for economic purposes by the population. When the lakes dry out they become very vulnerable to wind erosion. The resulting dust storms are reported to have reached Pakistan and countries at the other side of the Persian Gulf.

6.2.2 Indicators

To quantify the extent to which the objectives are met, indicators need to be defined. These are directly linked to the operational objectives described in previous section. Indicators can be defined at different levels, where indicators at lower levels are linked to indicators at higher level. For example, an indicator for the ecological condition is the amount of birds that overwinters in the project area. Since the amount of birds is related to the surface area of the Hamouns, this surface area could be used as an indicator as well. On the other hand bird numbers can be translated into criteria at higher levels, like economic value and job opportunities. These are not ecosystem restoration but socio-economic indicators. Indicators should always be expressed at the highest level, because that is what decision-makers are interested in and what enables them to compare the result to socio-economic development targets. In the project it is chosen to express criteria at different levels, because together they provide a picture of the situation which can be understood by a broad audience.

Objective 1: To supply domestic water according to national standards
Related criteria:
- Number of months during which supply does not meet demand

Objective 2: To support the generation of employment and income
Related criteria:
Through irrigated agriculture:
- Supply/demand ratio (average over the irrigation areas)
- Production of grains (wheat + barley)
- Production of fodder (fodder barley + fodder maize)
- Production of fruits, vegetables and spices (alfalfa + clover + grapes + sweet and water melon)

Through Hamoun wetlands
- fish (ton/year)
- birds (ton/year)
- reed products (mats) (m²/year)
- cows and camels that can be supported (numbers/year)
- sheep and goats that can be supported (numbers/year)

Changes in income of groups of people from both agriculture and Hamoun use
- fishermen
- bird catchers
- reed harvesters /processors
- pastoralists
Objective 3: To supply facilities to protect public health and the environment
Related criteria:
- Number of years with increased risk for sandstorms; risk for sandstorms is assumed to exist in situations when the inundated area of Hamoun-e-Saberi is less than 20% of the maximum area between May through August
- Number of months with increased risk for sandstorms (similar to the previous criteria)

Objective 4: To sustain or restore the ecological and socio-economic value of the wetland
Related criteria:
- Return period of complete droughts (needed to ‘reset’ the system)
- Return period of flushing of the individual Hamouns (to keep salt at acceptable levels)
- Average inundated area in fall/winter (between October and January)
- Average volume entering the Hamouns in spring (between February and June)
- Based on the result for above characteristics the average condition will be estimated of
  - Reed
  - Fish
  - Bird

Some criteria will be expressed as a percentage of the ‘reference situation’. As reference the situation of the 1970s are taken which are considered as having been good.

6.3 Scenarios for the future

The functioning of the Sistan area and the hamouns will strongly depend on external factors with respect to socio-economic developments, water availability from Afghanistan, etc. These external developments are called ‘scenarios’. From a water management point of view these scenarios should be considered as given and fixed, in contrast with ‘measures’ and ‘strategies’ that the water managers in the region can decide upon. A measure is defined as a single action while strategies are a logical combination of several measures. Measures and strategies will be addressed in Chapter 8.

In this section the following scenario elements will be described:
- socio-economic developments (population growth and related drinking water demand)
- water availability from Afghanistan

Further development of irrigated agriculture is not included in the scenarios as the decision makers involved can decide about this and this development will be an element of the strategies.

6.3.1 Socio-economic developments

Demographic developments

The demographic development of the region is highly uncertain. The drought and generally harsh situation of the Sistan Plain has caused people to migrate. It is possible that for that reason the net population growth is low, but if the situation improves, people may return to their homelands. On the other hand, because of the 100% coverage of public water supply, many people who may have otherwise migrated decided to stay in the area. The data of 1995 and 2001
show a large increase in the urban population, with a growth rate of 6%, while the growth rate for the rural population is only 0.23%; the drought has enhanced urbanisation of the area.

These growth rates were used to determine the population in 2005. It is not clear whether this urbanisation trend will continue. It is therefore chosen as one possible scenario to estimate population numbers in 2020. The other scenarios are a low scenario of 1% growth, a high scenario of 4% growth (which was the growth rate in the rural areas in the 1970’s and 80’s) and a middle scenario of 1.5%, which is normally used in Iran for the developing provinces. In these three scenarios population growth in urban and rural areas has the same growth rate. With these scenarios the population in 2020 is likely to be between 420,000 and 760,000 people as indicated in Table 6-1.

<table>
<thead>
<tr>
<th>Present (2005)</th>
<th>Low</th>
<th>Middle</th>
<th>High</th>
<th>Urbanisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban population</td>
<td>190,819</td>
<td>221,535</td>
<td>238,568</td>
<td>343,655</td>
</tr>
<tr>
<td>Rural population</td>
<td>230,917</td>
<td>268,087</td>
<td>288,699</td>
<td>415,868</td>
</tr>
<tr>
<td>Total</td>
<td>421,736</td>
<td>489,622</td>
<td>527,268</td>
<td>759,522</td>
</tr>
</tbody>
</table>

The consequence of a growing population is that it will require an increased supply of water for drinking, industry and food production.

**Developments in domestic, municipal and industrial (DMI) water demand**

The developments of the demand for the DMI sector are rather straightforward. The demand will follow the developments in population and industry. The Sistan-Baluchestan Water and Waste Water Company has made a plan how they foresee to supply the demand. This includes the upgrading of the Zahak Water Treatment Plant from 0.7 m$^3$/s to 1.2 m$^3$/s and the extension of the distribution network as indicated in Figure 3-4.

According to the Sistan-Baluchestan Water and Waste Water Company the demand per capita in rural areas is 156 l/c/d and for urban areas 110 l/c/d. The resulting demands are given in Table 6-2. The supply of raw water for the Zahak Treatment plant is taken care of by the Chahnimeh reservoirs which have sufficient capacity to guarantee a very high reliability of this supply.

<table>
<thead>
<tr>
<th>Present (2002)</th>
<th>Low</th>
<th>Middle</th>
<th>High</th>
<th>Urbanisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban population</td>
<td>7.7</td>
<td>8.9</td>
<td>9.8</td>
<td>13.8</td>
</tr>
<tr>
<td>Rural population</td>
<td>13.1</td>
<td>15.3</td>
<td>16.4</td>
<td>23.7</td>
</tr>
<tr>
<td>Total</td>
<td>20.8</td>
<td>24.2</td>
<td>26.0</td>
<td>37.5</td>
</tr>
</tbody>
</table>

To calculate the water demand in 2020, a per capita use of 156 l/d in rural areas and 110 l/d in urban areas is used. These numbers include the use for small enterprises. The Chahnimeh reservoirs also feed the 200 km long pipeline that supplies drinking water to Zahedan. The capacity of this pipeline is about 0.9 m$^3$/s, transferring about 27 MCM to Zahedan annually. It is assumed that this amount will not increase any further.

**Developments in (irrigated) agriculture**

The drought conditions have prevented a sufficient supply to agriculture. This has had an enormous impact on the sector being the main economic activity in the area and providing jobs and income for many habitants. Without sufficient river water, agricultural activities cannot take place and the people are deprived from income and are likely to leave the area to find jobs
elsewhere. In spite of the scarcity of water, the irrigation methods applied in many regions are highly inefficient.

Developments in agriculture will strongly depend on the availability of water. The command area of the present irrigation system is 130,000 ha. The potential cultivation area is 224,000 ha and there are plans to increase the irrigation system by another 100,000 ha to supply the additional cultivation area with irrigation water. Under the present conditions and given the uncertainty about the supply from Afghanistan such increase in command area under irrigation does not seem to be justifiable.

At the supply side the main developments might come from the water availability of the Hirmand. These will be influenced by (irrigation) developments upstream in the Hirmand in Afghanistan as well as the operation of the Kajaki dam. This will be described in Section 6.3.2.

It might be considered to use the Chahnimeh reservoirs to guarantee the water supply for high-yielding crops. The use of sub-surface water might be developed further, possibly augmented by the use of accelerated infiltration techniques.

At the demand side developments can be expected on the use of less water consuming crops, the use of modern irrigation techniques and the reduction of losses in the system by the lining of canals.

Socio-economic pressures on wetlands

Although irrigated agriculture is reportedly the main income generation activity for the people of the Sistan plain, it is not the only one. ‘Free’ products are caught and collected from the Hamoun wetlands, providing income for thousands of households. The main products used are fish, birds and reed. Allocation of water to the Hamoun wetlands will maintain the livelihood of these subsistence users.

As will be described in more detail in section 6.4.4, which describes the future of the Hamoun wetlands, various factors have contributed to the degradation of the wetlands. One of these factors is presumably the pressures exerted on the wetland by people. With a growing population these pressures will increase. A wetland has a certain carrying capacity, with a threshold. Once the pressure exceeds the thresholds the system rapidly degrades.

Since the economic and social values derived from the wetland are highly valuable for the population, it is important to maintain the wetland in a healthy condition and to define the associated carrying capacity. Based on this a maximum abstraction of resources from the wetland can be defined, which may provide livelihood for a limited number of households.

Management measures are important to prevent exceeding the pressure-threshold. Different options are available for this, which will be described later in this chapter, in the field of incentives, community management of natural resources, awareness raising, etc.

6.3.2 Upstream developments in Afghanistan

In Iran very little concrete information and data is available about the upstream developments in Afghanistan, in particular around the Hirmand river. All observations and available information indicate a strong influence of the construction of the Kajaki dam (inaugurated in 1953) and the Arghandab dam (inaugurated in 1972) and related irrigation developments along the river. UNEP (2003) state the uncontrolled, hydropower oriented releases of the dams, in combination with increased evaporation from the reservoirs, which may actually have increased the vulnerability of the Sistan basin to drought rather than the aimed improved water management
and distribution. However, the main reason for a decreased supply undoubtedly will be the development of irrigation.

A full description of available information on developments in Afghanistan is given in Annex B. The developments of water use and management in Afghanistan will consist of an increased total capacity of reservoirs, as well as increased irrigation acreage and improved irrigation facilities.

Table 6-3 lists the differences with respect to reservoir capacity and irrigated area for the present and future situation in the Hirmand basin.

**Reservoirs**

In the future situation two new reservoirs might be constructed: Bakhshabad of 570 MCM and Olumbagh, estimated at 435 MCM. The Arghandab has lost 80% of its volume in the present situation due to siltation. A new reservoir will be constructed which is assumed to restore the original volume of 435 MCM. The Kajaki reservoir will be enlarged from 1800 to 3000 MCM.

<table>
<thead>
<tr>
<th>Reservoir storage capacity (in MCM)</th>
<th>Present case</th>
<th>Future case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kajaki</td>
<td>1,800</td>
<td>3,000</td>
</tr>
<tr>
<td>Arghandab</td>
<td>87*</td>
<td>435</td>
</tr>
<tr>
<td>Bakhshabad</td>
<td>0</td>
<td>570</td>
</tr>
<tr>
<td>Olumbagh</td>
<td>0</td>
<td>435</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Irrigated areas (in ha)</th>
<th>Present case</th>
<th>Future case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kajaki to Shamlan</td>
<td>14,437</td>
<td>14,437</td>
</tr>
<tr>
<td>Seraj</td>
<td>12,624</td>
<td>24,000</td>
</tr>
<tr>
<td>Upper Boghra</td>
<td>8,171</td>
<td>8,171</td>
</tr>
<tr>
<td>NadiAli</td>
<td>16,534</td>
<td>16,534</td>
</tr>
<tr>
<td>Marja</td>
<td>21,559</td>
<td>21,559</td>
</tr>
<tr>
<td>Shamalan</td>
<td>8,742</td>
<td>16,000</td>
</tr>
<tr>
<td>North Argandab</td>
<td>15,011</td>
<td>15,011</td>
</tr>
<tr>
<td>Central Arghandab</td>
<td>22,764</td>
<td>22,764</td>
</tr>
<tr>
<td>Tarnak</td>
<td>8,729</td>
<td>8,729</td>
</tr>
<tr>
<td>Arghastan-Dori **</td>
<td>465</td>
<td>465</td>
</tr>
<tr>
<td>Darweshan Area</td>
<td>13,434</td>
<td>24,000</td>
</tr>
<tr>
<td>Khanessin Area</td>
<td>2,298</td>
<td>31,000</td>
</tr>
<tr>
<td>Toghaz Area (P)</td>
<td>planned</td>
<td>8,540</td>
</tr>
<tr>
<td>RightRudbare Area (P)</td>
<td>planned</td>
<td>48,000</td>
</tr>
<tr>
<td>LeftRudbare Area (P)</td>
<td>planned</td>
<td>83,000</td>
</tr>
<tr>
<td>Bandar Area</td>
<td>524</td>
<td>11,000</td>
</tr>
<tr>
<td>Khushk (P)</td>
<td>1,421</td>
<td>36,000</td>
</tr>
<tr>
<td>Taraku (P)</td>
<td>1,421</td>
<td>36,000</td>
</tr>
<tr>
<td>Chakhansur</td>
<td>11,767</td>
<td>93,000</td>
</tr>
<tr>
<td>SistanAfg/Qala Fateh Kuabgh</td>
<td>333</td>
<td>48,000</td>
</tr>
<tr>
<td>Sikhsar</td>
<td>1,421</td>
<td>32,000</td>
</tr>
<tr>
<td>Farah area</td>
<td>47022</td>
<td>47,022</td>
</tr>
<tr>
<td>Adraskan area</td>
<td>42,682</td>
<td>42,682</td>
</tr>
<tr>
<td>Khaspas</td>
<td>7,895</td>
<td>7,895</td>
</tr>
<tr>
<td>Middle Hirmand</td>
<td>37,895</td>
<td>37,895</td>
</tr>
<tr>
<td>Total</td>
<td>246,111</td>
<td>682,664</td>
</tr>
</tbody>
</table>

* the Arghandab reservoir is reportedly silted up. Assumed is a capacity of 20% in the present situation. In the future situation the capacity has been restored.
**Shaded areas are along branches without inflow series and therefore do not contribute to water use in the analysis described in this report.
Irrigation
The irrigated area will increase, mostly by restoring irrigation systems that have been broken down or were not maintained during the years of war in Afghanistan. Various plans for extension were available already in the 1970s, which probably have never been carried out. In the scenarios the acreage of reported potential irrigated areas is used. This means that for some of the areas no actual development plan for the new future may exist, and that the areas are possibly over-estimated. The increase in storage capacity of the reservoirs is likely to lead to an intensification of agriculture. In the future scenario the same ratio between single- and double cropped areas has been used. However, with a more secure supply from a reservoir, it is possible that relatively more land will be double-cropped. This may mean that water use is underestimated in the future scenarios, especially during the low flow season (summer). Therefore the present areas are used for all irrigation schemes, but the complete area is irrigated following a double-cropping pattern. This will increase water use during summer. Exceptions in this case are the irrigation areas which are not yet used in the present situation: Toghaz, Rudbare Left and Rudbare Right. These areas are included with the future areas and a single cropping pattern. In Table 6-3 the areas which are not considered in the scenario simulations are shaded.

An overview of the resulting scenarios is given in Section 8.1.4.

6.4 Problem Analysis

6.4.1 Water Balance Sistan area

In order to get a first impression of the order of magnitude of the water volumes involved a very rough water balance has been developed for the Sistan area. Table 6-4 presents the average annual water balance as calculated by the water allocation model (RIBASIM) that was developed for this project (see also Section 8.1.2. In this calculation a 55-year time-series is considered as described in Annex C. The table shows the large contribution of the Hirmand river to the total available amount of water in Sistan. The Farah also contributes a considerable amount (25%). By far the largest water ‘user’ is the Hamoun wetland with an evaporation of over 4,000 MCM. Compared to this amount the consumption of water by agriculture is modest and only 15% of the water used by the wetlands. Because flushing of the wetlands is required, the outflow through the Shileh of 238 MCM/year could be considered to be used by the wetlands as well.

Table 6-4 Average annual water balance

<table>
<thead>
<tr>
<th>Inflow</th>
<th>Outflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hirmand</td>
<td>Net agriculture use Iran (120,000 ha)* 593</td>
</tr>
<tr>
<td></td>
<td>Losses from irrigation 564</td>
</tr>
<tr>
<td></td>
<td>Agriculture Sikhsar (Afghanistan) 4</td>
</tr>
<tr>
<td>Farah</td>
<td>Public water supply 34</td>
</tr>
<tr>
<td>Khash</td>
<td>Hamouns evaporation 4,378</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Chahnimeh evaporation 124</td>
</tr>
<tr>
<td></td>
<td>Outflow to Shile 238</td>
</tr>
<tr>
<td>Total</td>
<td>5,935 Total 5,935</td>
</tr>
</tbody>
</table>

* actual supply; the full demand of the 120,000 ha is much higher (2,069 MCM/yr).

The balance also shows an outflow of the considerable amount of 564 MCM/year through boundaries, at the end of irrigation schemes. Assumed is that only part of the water not evaporated by crops returns to the system. An additional part may be lost to evaporation directly from the field or seepage from irrigation and drainage canals. In fact, what exactly happens to this water is not clear. If it indeed evaporates, it is lost due to inefficiencies in irrigation and should be added to the irrigation water demand. In this case irrigation water use is double.
However, in case the water infiltrates, it could turn up again through the exploitation of groundwater reservoirs. This remains as a topic for further investigations.

Whether or not this distribution of water over the main water demand sectors is acceptable depends on the contribution of the sectors to the socio-economy and environmental sustainability of the region.

### 6.4.2 Flooding

The flooding situation in the Sistan area has received ample attention in the last 20 years. Following the devastating floods in 1991 major investments have taken place in the area. In the period 2001 - 2003 a Flood Warning and Emergency Plan was developed for Sistan. Floods as such are not considered to be a part of the IWRM study reported here. It is assumed that the previous studies have covered the subject sufficiently and that adequate measures have been taken. However, reference is made to the major conclusions that were drawn in the preparation study for the Flood Warning and Emergency Plan:

- The Sistan River Flood Protection Project does not have sufficient capacity to pass a design flood with a peak of 3200 m$^3$/s in the Sistan River at Hirmand Fork;
- The Chahnimeh intake has a maximum capacity of approximately 480 m$^3$/s. This is lower than the design value of 1000 m$^3$/s stated by the Sistan-Baluchistan Regional Water Authority;
- A significant degree of overtopping of the flood defences will occur for a flood with a peak of 2500 m$^3$/s in the Sistan River at the Hirmand Fork;
- The town of Zabol is likely to be flooded under design flood conditions.
- For Sistan River the 100 year flood values range from 1800 – 2100 m$^3$/s.

As mentioned above, no specific activities are carried out in the present project in relation to above conclusions. They are just mentioned here as reference.

The contribution of this project related to flooding is the development of the Flood Forecasting System (FFS). Reference is made to the next chapter and Annex B for more information on this FFS.

### 6.4.3 Water quality

Water quality (except salt) is not a priority issue in the Sistan area. Domestic and industrial pollution is low and effects are limited to local areas only. The main water system doesn’t seem to be affected by this pollution. Agricultural pollution (nutrients, herbicides, pesticides, etc.) could be a point of concern but adequate measures have already been taken to divert the drainage water to specific reservoirs in the Saberi and Hirmand Hamouns. This is not the case yet for the northern irrigation schemes from the Common Parian. In case the pollution from this area will reach an unacceptable level a similar solution as for the other areas can be taken. Given above it is decided not to include specific water quality oriented measures.

Salt is a natural phenomenon and as such should not be considered a water quality issue. However, human interference in the system may increase the salt concentration in certain areas, making the water less suitable for certain uses. An increase in salt concentration could result from drainage water. Two receiving basins at the end of the drainage system at the Posht-ab and Shib-ab irrigation system prevent the drainage water to affect the Hamouns in this respect, at the same time taking care that pesticides, herbicides and nutrients would not pollute the Hamouns. The drainage water of the northern irrigation area (taking water from the Common Parian) still discharges into the Hamoun-e-Puzak.
A more important reason for human-induced increase in salt concentration in the Hamouns is caused by the reduction of flushing of the Hamouns to the Goud-e-Zereh. Such reduced flushing is to a minor extent the result of all withdrawals upstream but in particular as a result of the construction of the Shileh-weir that aims to keep the water in the Hamoun-e-Hirmand with the apparent aim to support the ecological value and the socio-economic activities of the Hamoun. It might well be that a possible negative effect of the weir on the salt-concentration has been overlooked in designing this system. Whether such an increase in salt concentration takes place is not certain. According to prof. Tajrishi from Sharif University (pers. comm., May 2005) the weir was built to restore the natural situation after erosion had taken place. The computational framework of the Sistan project (see Chapter 8) will be used to analyse this aspect.

6.4.4 Future of the Hamoun Wetlands

The Hamoun system is (or was previously) of significant environmental, economic and social value. During the recent decades, most of the wetlands have been greatly affected by water resources controls from upstream, which have been exacerbated by the severe drought that occurred between 1999 and 2002. As a result, they have lost many of their economic, social and environmental values. However, it is not only the lack of water which has caused the degradation of the Hamouns; unsustainable use and wrong management measures have taken part in this as well.

At the end of the 1980’s the wetlands vegetation and bird population has collapsed. Since this was before the drought, other factors have played a role in this. Two possible causes are:

1. the introduction of the grass-carp, which lead to degradation of the reed areas, and subsequently to the disappearance of birds, and
2. the increase in population which has probably led too much livestock grazing the reeds, and too many birds and fish being caught, by which a threshold was passed and the equilibrium collapsed (data on number of livestock and catches are currently being collected).

With an increasing population the pressure on the wetland will increase as well. With or without water, the wetland is unlikely to obtain a healthy equilibrium. To restore the ecological function of the wetland, and to maintain the wetlands source of food, income and other values, it requires the allocation of sufficient water in combination with management measures to prevent the pressures to increase the carrying capacity.

6.4.5 Summarizing problem statement

The main employment sectors in the Sistan delta are agriculture-fisheries (38%) and services (54%). The industrial sector is small (6%). Unemployment in the area is high. Reliable statistics on unemployment are lacking but indications point in the direction of about 50%. The very skewed population structure (about 50% of the population is below 20 years) will further deteriorate the employment situation. The Sistan Delta is a very political sensitive area bordering Afghanistan and Pakistan (Baluchestan) and the Iranian government wants to stabilize the area, among others by investing in its socio-economic development. Possibilities to increase the industrial sector are constrained by the geographical location of the area in relation to potential markets of the products. Solutions are sought in agriculture. Already 120,000 ha irrigated agriculture have been developed and there are plans for another 125,000 ha. However, agricultural development is severely constrained by the harsh climatic conditions and the variable water supply. Moreover, the withdrawal of the water for irrigation will be at the expense of the hamouns and their ecosystems. The variable river flow will require the further
development of storage reservoirs to support the irrigation. The existing Chahnimeh reservoirs are only for drinking water but could be extended to serve irrigation as well.

The first issue is the available water supply to support these developments. The total available water is 5,935 MCM/year. The demand for the present 120,000 ha irrigated agriculture is 2,069 MCM/year. Due the variability of river flow and presently non-existent storage capacity for irrigation the actual supply is only 1,169 MCM. If the irrigation area is increased this has to be done in combination with the development of surface water storage schemes. Groundwater storage is not possible because of the geo-hydrological situation.

The second issue is what the effects of this additional agricultural development will have on the hamouns. From a water quality point of view measures are taken that take care that the pollution (fertilizers, pesticides) resulting from agriculture will not reach the lakes. A major part of the drainage water is collected in special basins from where the water evaporates. Hence, the main impact of further agricultural development will be a reduction in the evaporation of the lakes and a reduction of the outflow to the Shile. The hamouns are at present by far the largest ‘water user’ of the system, evaporating 4,378 MCM/year. Reducing the evaporation of the hamouns is synonymous with reducing the average water cover area of the lakes and with that their potential to support the ecology depending on that water. In principle the relation between agricultural development and water cover is quite simple. An open water evaporation of 3,000 mm/year means that each 100 MCM/year additional withdrawal for irrigation will reduce the average lake area with 33.3 km² which is about 2.5% of the present average lake area. Hence, a full supply of the present 120,000 ha irrigation area with 2,069 MCM/year could reduce the average lake area with about 50%. In reality this relation is much more complex as a result of the 3 part separately functioning hamouns with their own highly variable supply. Because of this the water cover of the lakes is very dynamic too. In dry periods the lakes can fall completely dry as has been the case in the period 2000-2005, temporary creating a desert like environment.

When the lakes start filling after a rainy period the ecology recovers. Reed start growing again and birds and fish return. This process has been going on for ages and proves that the system can absorb to some extent these natural dynamics. The question is if it also can absorb a more continuous decrease of inflow. A reduced water cover of the hamouns will not only hurt the ecological functioning of the lake. Also the livelihoods of the people that depend on the products and services of this system are endangered. The hamouns provide goods and services for all people in the Sistan Delta.
Discussing problems and objectives with the stakeholders in Sistan
7 Flow forecast from Afghanistan

Before an IWRM analysis can be carried out we have to know how much water can be expected from Afghanistan. The developments involved were described in previous chapter. This chapter presents a summary of the methods and tools to quantify the expected flow. A full description of the approach is given in Annex C.

7.1 Introduction

As part of the IWRM study in Sistan the project designed and developed a flow forecasting system. The forecasting system includes a component for making forecasts on a short-range, with 0 – 5 days lead time as well as a component for making long range forecasts, with 0 – 4 months lead time. The purpose of the system is to provide the water authorities in Zabol with information on the water supply to the Sistan Plain. The results of the long-range model are useful for taking decisions on the use and distribution of the water in the coming period. The results of the short-range model are mainly useful in case of flood.

Apart from flow forecasting, the components of the system allow for assessment of scenarios for upstream developments. Furthermore, the model provides Iran with information on the water availability in Afghanistan. This information can be used in negotiations on water distribution between the countries.

The tools comprising the flow forecasting system support the water managers of the Sistan-Beluchistan Regional Water Authority (SBRWA) in their decisions to operate their water management system. In this respect the aim of the system is to answer the following questions:

1. Can we expect much/average/little water in the next months?
2. Will there be a flood in the coming days?
3. If we have little water, how can we distribute the deficit?
4. If upstream irrigation increases of reservoirs are build in the river basins in Afghanistan, what will be the flow to Sistan?

The questions 1 and 2 are typically related to operational forecasting, which is done on a regular basis, e.g. daily to monthly; this is considered flow forecasting. The questions 3 and 4 are typically related to the design of the Sistan water management system and can be considered as support for scenario and water distribution strategy development as described in Chapter 8.

Can we expect much/average/little water in the next months?
This is considered the long-range forecast. With respect to this long-range forecast, data analysis shows that the main part of the flow to Sistan origins from snow melt in the mountains in Afghanistan. This snow falls in winter in these mountains and comes to runoff when the temperature rises in Spring and Summer and the snow starts melting. Maximum discharges in Sistan typically occur in April and May. If the amount of the water stored in the snow can be estimated in winter, the water volume that will arrive later in the year in Sistan can be estimated. This system is only applicable in the winter and spring period.

Will there be a flood in the coming days?
This is considered the short-range forecast. With respect to the short-range forecast, data analysis of the 1990-1991 event showed that considerable amounts of the flood volumes in that year (and therefore possibly also in other years) orginied from rainfall in the lower elevated
areas of the basin. Such rainfall events can typically only be predicted a short time ahead (in order of days). These type of floods occur typically between February and April.

**If we have little water, how can we distribute the deficit?**
During low flow years the volume of water provided by the Hirmand river and other tributaries from Afghanistan is insufficient to fulfill all water user requirements in the Sistan area. Therefore strategies need to be developed in advance how to distribute the deficits. This will be discussed in Chapter 8 (and Annex C), where the IWRM in the Sistan basin is discussed.

**If upstream irrigation increases of reservoirs are build in the river basins in Afghanistan, what would be the flow to Sistan?**
This is considered scenario development. With respect to the scenario development, analysis of the literature shows that in the current political setting of Afghanistan, lots of new developments can be expected with respect to irrigation schemes, reservoir building or extension of existing reservoirs. A most urgent development which effects needs to be considered is the extension of the Kajaki reservoir.

Four main tools have been developed to support answering these questions.

- **PCRaster-HBV.** A grid based hydrological model
- **RIBASIM-Hirmand.** A river basin model for the rivers contributing to the flow to Sistan. Besides the Hirmand river also other relevant tributaries like the Farah Rud and Khash Rud are included.
- **RIBASIM-Sistan.** A river basin model for the Sistan area
- **FFS-Hirmand (FFS).** A shell that links PRCaster-HBV to RIBASIM-Hirmand and allows the user for making Long-range and Short-range forecasts for the inflow to Sistan using the output of numerical weather prediction models. This system is referred to as the Flow Forecasting System (FFS).

![Figure 7-1 Location where the tools are applied](image-url)
Figure 7-1 shows the area where the tools are applied while Figure 7-2 shows how these tools are applied and how the results of the different modules are used in each other.

<table>
<thead>
<tr>
<th>Flow forecasting</th>
<th>Scenario analysis</th>
<th>IWRM -Sistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>weather forecasts</td>
<td>satellite images</td>
<td>historical precipitation &amp; evaporation</td>
</tr>
<tr>
<td>FFS</td>
<td>PCR-HBV</td>
<td>developments</td>
</tr>
<tr>
<td>Ribasim-Hirmand</td>
<td>timestep: days</td>
<td>PCR-HBV</td>
</tr>
<tr>
<td>10-100 days</td>
<td></td>
<td>Ribasim-Hirmand timestep: months</td>
</tr>
<tr>
<td>daily discharge at Hirmand Fork &amp; other rivers</td>
<td></td>
<td>45 years monthly discharge at Hirmand Fork &amp; other rivers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ribasim-Sistan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IWRM plan operational rules</td>
</tr>
<tr>
<td></td>
<td></td>
<td>recommendations for operation</td>
</tr>
</tbody>
</table>

Figure 7-2  Flow chart of the forecasting tools

The objective of this chapter is to describe the background, design, set up of the tools for the flow forecasting and scenario development. Also the predictive skill of the forecasting system is described. Further its objective is to inform on the way the modules both for forecasting model as for scenario building are used. The final objective is to recommend how to use the system as part of a flow forecasting centre.

7.2 Flow Forecasting procedure

The Flow Forecasting System (FFS) uses the following procedures:

1. Determine the precipitation volume that currently falls in the basin as well as the temperature and evaporation.
2. Forecast the precipitation that will fall on the basin in the period of interest as well as the temperature and evaporation.
3. Determine the initial hydrological conditions in the basin.
4. Simulate, using the results of step 3, the runoff to the rivers/channels with a hydrological model taking into account evaporative or other losses.
5. Simulate, using the results of step 4, the flow through the channels (hydraulic routing), taking into account water abstractions, diversions and reservoir operation (river basin modelling).

For steps 1-2, normally observed weather conditions are used. However these are lacking in this case, due to the difficulties for obtaining hydrometeorological data from Afghanistan. Therefore the FFS for the Hirmand basin makes use of the results of numerical weather models. These weather prediction models provide weather forecasts on a raster cells of approximately 1.25 degrees long/lat, on a 6-hourly – daily basis for the entire world. The models also provide the current global weather conditions, based on the integration of a vast number of real-time observations spread all over the world. These conditions form the initial conditions for the
weather predictions. The FFS makes use of both the predicted rainfall and temperature as well as of the current weather conditions provided by the weather prediction models. The current weather predictions are considered observed values.

In step 3, the model simulations start a number of days before present using the measured meteorological data over the last days. The model is updated using the observed precipitation and temperature. In the FFS Hirmand case, these are the predictions for the daily actual weather as provided by the weather models.

In step 4, the forecasted precipitation and temperature are used to predict the runoff from the land phase to the main river system.

In step 5 the predicted runoff is used as input for flow routing in the river network.

Combining the hydrological characteristics of the basin with the procedures for flood forecasting shows that steps 3, 4 and 5 are common in both the long range and the short range forecast. The combined system proposed has in common the way the water is simulated from the land phase to the rivers and the simulation of the water flowing through the river as well as the abstractions. In terms of modelling this is referred to as “hydrological modeling”, the “routing model” and the “river basin model” respectively. In the Flow forecasting system the hydrological modelling is done by the PCRaster-HBV model, the routing and river basin modelling is carried out by the RIBASIM-Hirmand model.

The main difference between the long and short range forecasting system is the way they deal with the input of the meteorological information such as rainfall, temperature and evaporation. This is because the lead time of both systems is very different.

**The short range forecasting system.** The lead time of the short range forecast is 10 days, which is used for flood forecasting. The source of the weather predictions are the 10-daily forecasts of the European Center for Medium-range Weather Forecast (ECMWF). The ECMWF provides gridded information for all required meteorological variables on a 6 hourly basis.

**The long range forecasting system.** The lead time of the long range forecast is 0-4 months. Essential in the long range system is that it uses a realistic estimate of the actual snow volume in the head waters of the Hirmand. In the current system this snow volume is estimated from a simulation with the PCRaster-HBV model of a historical period that starts at or before the winter period. The input for this simulation consists of precipitation and temperature, from which
the HBV model can derive the amount of snowfall and snow melt. In future versions of the system this estimate will be improved by interpretation of NOAA satellite images and/or MODIS satellite images, from which the spatial snow extent can be derived. In this approach the initial state for the snow cover in the HBV model is updated using the results of the satellite data on snow extent. As the satellite can only provide the extent of the area that is covered with snow, i.e. not the snow depth or snow water equivalents, this updating integrates the results from both the snow model and the satellite images. Once the snow cover is updated, the model simulates the expected flow in the following month. As precipitation and temperature cannot be forecasted more than 10 days ahead, for these variables long-range seasonal averages will be assumed.

7.3 Modelling the flow in Afghanistan

7.3.1 Basin schematisation for the PCRaster-HBV model

The PCRaster-HBV model is used to derive input series for RIBASIM. The RIBASIM model contains the various hydraulic structures along the river network. For each of these structures the HBV model will derive the “natural inflow”, i.e. the flow generated in the area between this structure and the closest located structure upstream. The boundaries of such areas have been derived with PC-Raster in combination with boundaries of “real” basins of, for instance the Hirmand, Arghandab, Farah and Khash. The delineation of the basins is based on the global elevation data set, GTOPO30 combined with the the actual drainage pattern. In total 19 areas were derived. The resulting areas are depicted in Figure 7-5.

GTOPO30 data base

The basis for the elevation map of the Hirmand was the GTOPO30. GTOPO30 is a global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer). GTOPO30 was derived from several raster and vector sources of topographic information. The data are hosted by the USGS

Figure 7-5 Defined subbasins in the PCRaster-HBV model.
7.3.2 The hydrological model PCRaster-HBV

The HBV concept has proven to be very suitable for modeling snow fall and snow melt, which are dominant factors in flood generation in these basins. HBV is used for this purpose in all Scandinavian countries as well as in Switzerland.

The basins are divided into a number of grid cells, approximately 30,000 of 0.03 degrees lat/long (so approximately 3 km). Although digital elevation data is available on a grid scale of 0.0083 degrees lat/long, the coarser resolution of 0.03 degrees lat/long is used for practical reasons (to reduce computation times and required computer memory). For each of the cells individually, daily runoff is computed through application of the standard version of the HBV model (see Annex B for details). The use of the grid cells offers the possibility to turn the HBV modelling concept, which is originally lumped, into a distributed model.

Figure 7-6 shows a schematic view of hydrological response simulation with the HBV-modelling concept. The land-phase of the hydrological cycle is represented by three different components: a snow routine, a soil routine and a runoff response routine.

![Schematic view of the relevant components of the PCRaster HBV model.](image)

7.3.3 River basin modelling with RIBASIM-Hirmand

The RIBASIM model is used for simulating flow in the river network, reservoirs, lakes and distribution of the water in the Hirmand basin. The runoff as computed with the HBV model for all subasins forms the main input of RIBASIM. To perform simulations with RIBASIM, a model schematisation of the basin was made up, in which all the necessary features of the basin are reproduced by nodes connected by links. Such a model schematisation is a translation - and a simplification - of the "real world" into a format which allows the actual simulation. Roughly speaking there are four main groups of elements to be schematised:
• Infrastructure (surface and groundwater reservoirs, rivers, lakes, canals, pumping stations, pipelines), both natural and man-made.
• Water users (public water supply, agriculture, hydropower, aquaculture, navigation, nature, recreation), or in more general terms: water related activities.
• Management of the water resources system (reservoir operation rules, allocation methods).
• Hydrology (river flows, runoff, precipitation, evaporation) and geo-hydrology (groundwater flows, seepage).

The river network
PCR-HBV calculates runoff for 19 sub-basins (Figure 7-5). Because of the various travel-time zones, these sub-basins are further divided in 1, 2 or 3 zones. In total there are 33 such zones. The outlet locations of all of these zones are the locations where the river network of RIBASIM starts. This means also that only the main rivers are included in the network. Figure 7-7 shows the river network of the RIBASIM model for the Hirmand basin and other Afghan tributaries (Farah, Khash, etc.).

Water demand (water abstraction)
Two types of water use take place in the basin: irrigation and combined domestic, municipal and industrial use. Irrigation is represented by ‘fixed irrigation’ nodes in the RIBASIM model. This means that each year there is a fixed demand per month, based on average climate data. Actual precipitation and evaporation are not taken into account. Although all areas, except Dasht-e-Nawar are included, the more upstream nodes were eventually switched to inactive. No data were available for these upstream data and the use of demands determined for lower areas, which less rainfall and higher evaporation were feared to lead to an overestimation of the demand. This concerns the sub-watersheds: Upper Hirmand (fixed irrigation nodes Upstream Olumbagh and Downstream Olumbagh), Ghazni, parts of Arghandab (fixed irrigation node Upstream Arghandab), of Arghestan (Upper Arghestan) and Tarnak (Upper Tarnak).
For domestic, municipal and industrial water use, nodes are included with the population numbers, water demand and return flow as discussed in Annex B. Actual data included in the various demand nodes are given in Appendix E of that Annex B.

**Hydraulic structures**

Diversions can be found at various locations in the basin, in the form of weirs and intake canals. At locations where irrigation schemes are included in the model this infrastructure is included as well. All diversions operate based on downstream demand. Only one diversion is currently inactive in the model: the direct link between the Hirmand river and the Goud-e-Zereh lake. It is not clear at present whether such a link indeed exists, but if proof for this is found, the link can easily switched to active.

Four reservoirs and two lakes are included in the network schematisation:

- Kajaki reservoir
- Argandab reservoir
- Olumbagh reservoir
- Bakhshabad reservoir
- Ghazni lake
- Goud-e-Zereh lake

Data for Kajaki and Arghandab reservoirs are included as described in Annex B. For the Olumbagh basin similar data as for Arghandab are used. Since Ghazni and Goud-e-Zereh are lakes, no main gates are included. The data used in the different nodes is included in Appendix C and D of Annex B.

**River Routing**

In the simulations of RIBASIM the water is distributed over all nodes and links in each time step. This means that within a time step, water can reach anywhere within the network. For monthly time steps this is acceptable, however, when the application is run with a daily time step, this is no longer realistic. River routing is required, which can be implemented in the RIBASIM schematisation by the use of so-called link-storage nodes. Each link storage is node is schematised to represent a delay of 1 day. For each sub-basin a link storage node is included for the zones with a travel time of 1-2 days, and another for the zones with a travel time of 2-3 days. This represents only the delay from the time of precipitation until it reaches the outlet of the sub-basin.

The travel time within the river is about four days from Char Burjak until Hirmand Fork. This is represented with another four link storage nodes.

### 7.4 Calibration of the model

Calibration of the model was done for the period of October 1990 until July 1991; a period during which three major flood events took place. For the Hirmand river at Hirmand Fork we compared simulated discharges with observed discharges and water levels. For other rivers like Farah Rud and Khash Rud this was not done since no measurements were available for this period.

#### 7.4.1 Results

Figure 7-8 shows for the first four months of 1991 computed discharge vs. observed water levels at Hirmand Fork. It shows that the predicted timing of the peaks is good. The predicted shape of the computed hydrograph, however, is much wider than the observed hydrograph.
Figure 7-9 zooms in on the month of February and shows observed water levels at Hirmand Fork in combination with the areal average precipitation as forecasted by ECMWF. The peak discharges are preceded by a number of days with heavy precipitation. As demonstrated in (Delft Hydraulics and WRC, 2003) this precipitation mostly came in the form of rainfall. The fact that the model is able to properly predict the timing of these February peaks means that the ECMWF weather forecast model can be relied upon identifying the occurrence of extreme precipitation events. The peak runoff events of April are a different story. These events mainly originated from snow melt in the mountains. Obviously, the model is capable of identifying these periods of heavy snow melt, which also indicates temperature predictions of ECMWF are reliable.

Figure 7-8. Computed discharge versus observed water level at Hirmand Fork; Period of 22-12-1990 to 20-04-1991. Water levels are expressed in relation to a reference level of 490.13 m. above sea level.

Figure 7-9. Forecasted areal average precipitation and observed water levels at Hirmand Fork; February 1991. Water levels are expressed in relation to a reference level of 490.13 m. above sea level.

Figure 7-10 shows observed versus simulated flow volumes at Hirmand Fork. It is clear that the model highly overestimates observed flow volumes. This has been noted before in Delft Hydraulics and WRC (2003). The total simulated flow volume at Hirmand Fork over this period is almost three times as large as the observed flow volume. There are a number of possible causes for these large differences, as will be discussed in section 7.4.2. However, since hardly
any data from Afghanistan is available it is hard, if not impossible, to identify the actual cause(s). This poses a serious problem on the development of the flow forecasting system.

![Figure 7-10. Observed and predicted flow volumes at Hirmand Fork from October 1990 until July 1991.](image)

The project also performed a model run for the period of 1987-2002 with data recently provided by the ECMWF. This data set forms a sub-set of the ERA-40 data. Figure 7-11 shows that the strong overestimation of flow volumes by the model occurs for all years in this period.

Nevertheless, it appears that there is a strong correlation between observed and simulated flow volumes ($R^2=0.84$). So, even though volumes are overestimated, the model and the ECMWF data can still be very useful in predicting whether a period of high flow or low flow awaits the Hamouns.

![Figure 7-11. Observed versus simulated annual flow volumes.](image)

---

**ERA-40 data base**

ERA-40 was a project of the ECMWF to create a worldwide meteorological dataset with more than 50 input parameters such as temperature, sea wave height, humidity, sea ice cover, snow cover etc. The ERA-40 covers the period 1957 till 2002. In the first period, 1957 till 1972, only measurements at earth surface were available, but starting from 1973 more and more data obtained by satellites, became available. Therefore the ERA-40 period was separated in three sub periods (production streams). The first stream, from 1989 till 2002, is a period with a lot of data provided by satellites. The second stream from 1957 till 1972 is the pre satellite period. The third stream from 1972 till 1989 is the period where the input of data from satellites started, only a small amount of data from satellites was available.
7.4.2 Possible misconceptions leading to overestimation of flow volumes

The main problem to be solved with the flow forecasting model is the fact that it strongly overestimates flow volumes. In this section we address a number of possible reasons why the simulated and observed flow volumes of the flood period in 1991 differ so strongly.

**Flow measurements.** Figure 7-9 shows observed water levels at Hirmand Fork in combination with the areal average precipitation as forecasted by ECMWF. From this figure we see that the rainfall event of the beginning of February lasts for about four days. Normally, this means we can expect a flood hydrograph that lasts for even more than 4 days. However, the rise and fall of the hydrograph of the observed lasts for about 1-2 days. This is obviously counter-intuitive which places strong doubts on the validity of the observed water levels and, consequently, discharges.

**Meteorological input.** The meteorological input of the HBV model has been provided by the European Centre for Medium range Weather Forecasts (ECMWF). The data consists of zero-day ahead forecasts for precipitation, temperature and evaporation. Currently, ECMWF provides this data on a 0.5 degrees lat/long grid scale, but for the years 1990 and 1991, which were subject of the analysis, data is available on a 1.125 degrees lat/long grid scale. Since no measurements from Afghanistan are available this is the best available estimate of the actual meteorological input of the basin. However, these forecasts can be expected to contain some considerable errors. A comparison with a third data set for average global weather conditions suggest so. In other words, the inconsistent results from Figure 7-10 are probably not caused by a systematic bias of the model but are more likely to be due to incorrect data.

**Infiltration along floodplains.** The floodplains of the Hirmand river between Qale Bist and Hirmand Fork are rather wide. The width of the floodplain can easily be 20 to 30 times larger than the river bed. During flood periods, these floodplains inundate, and due to their relatively large widths, water depths and accordingly flow velocities are likely to be very low. Therefore, a significant part of the water may infiltrate into the floodplain soil.

**Snow evaporation.** The HBV model assumes that no evaporation takes place from the snow pack. The HBV model originally was set-up to simulate the runoff processes in Scandinavian basins where solar radiation is much lower than in Afghanistan. This assumption may therefore lead to a substantial underestimation of evaporation in the modelled basins and, consequently, overestimation of runoff. Therefore in the near future snow evaporation will be included in the HBV model.

**Losses to ephemeral deltaic branches.** Figure 7-12 shows a satellite image of the Sistan lake and plain, that was taken on the 25th of April 1990. In the upper right the Hirmand river is clearly visible. Its colour is green, indicating vegetation and agricultural activities in the floodplains. In the area where the Hirmand makes the curve in the northerly direction, there appear to be two deltaic branches. Their colours are not green, indicating no vegetation or agricultural activities are present, which means it had no flow for a long period of time. However it is possible that this branch becomes active during periods of high flow, such as the ones of February-April 1991. That would mean part of the Hirmand water takes a shortcut to the Hamouns and will never reach Hirmand Fork. In the current version of the hydrological model this (potential) loss of water is not taken into account. If the loss indeed occurs, this will mean the model overestimates the observed flow at Hirmand Fork. In (Favre and Kamal, 2004, p. 137) it is confirmed that this is actually the case. They state that: “The Goad-I Zirreh is now primarily refilled from a natural spillway east of Chahar Burjak centre (Nimroz) which drains water from the Hilmand river during flood periods through the Rod-I Beyeban (or Ram Rod)
and Shella-I Kusk channels. The Rod-I Beyeban joins the Rod-Shilehh in Iran and flows back into Afghanistan, while the Shella-I Kusk channels drain water directly into the Goad-I Zirreh.”

Figure 7-12. Satellite image of the Sistan lakes and plain on the 25th of April 1990, showing a.o. the existence of a deltaic branch upstream of Hirmand Fork.

7.5 Conclusions and potential improvements

The flow forecasting model in its current form makes use of numerical weather prediction models. In the near future also results of remotely sensed information on the snow cover in Afghanistan should be used.

The results so far are encouraging, however accurate quantitative prediction of the flow at Hirmand Fork remains difficult. Among various other reasons the meteorological input data seems the main source of the inaccuracies. As the data flow from Afghanistan to Iran is still virtually lacking, the information obtained from the weather models and the satellites cannot be validated using observed discharges, rainfall or temperature. Also the political situation in Afghanistan during the past years has reduced the availability of hydrometeorological data.

The current state of the system should therefore not be considered the final one. In the coming years regular re-calibration of the system is a prerequisite to obtain more and more reliable forecasts. This means that in its current form the system should be considered a prototype, which can be developed further, rather than a full-proof forecasting system. This also means that for the interpretation of its results and advice to the water management well qualified staff is needed. These people should have good knowledge of hydrology, hydraulics and remote sensing as well as on the basin characteristics of the Hirmand.

In case the relations with Afghanistan would improve the short range forecasting system could be significantly improved. If an online connection with the monitoring station at Qale Bist would be possible, this will allow for almost perfect forecasts with about 4 days lead time. Information on the releases at the Kajaki dam would further improve the forecasting quality and extend the lead time.
The short range forecasting system could in this case be replaced by a much simpler hydraulic routing system, ignoring the hydrology. The long range forecast might be improved if better, more reliable information on snow water equivalents would become available. As this snow falls in remote areas satellite information will remain the most reliable source. Significant improvements are not expected within short time.

7.6 Recommendations for operational use of the system

The developed flow forecast model is a prototype. The model should be further developed and calibrated in Iran by actually using the model in a Forecasting Centre. This section gives some recommendations with respect to such Centre.

Location of the Forecasting Centre. The forecasting centre can be located in different places. We assume that the internet connections required can be (or are) made available almost everywhere. From a technical point of view there is little difference between locations and the location could even be outside Iran. The decision should be therefore made on other criteria. Some considerations to choose for the one or the other location are mentioned below in table. The starting point is that the forecasting centre can be located at SBRWA, WRI or IRIMO

<table>
<thead>
<tr>
<th>Location</th>
<th>Pro</th>
<th>Contra</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBRWA</td>
<td>Forecasts close to those who will issue warning or make use of the forecast. This eases communication between the groups</td>
<td>Maybe less knowledge available on the technical aspects than in the other organisations. Sufficient knowledge is needed in the current status of the system</td>
</tr>
<tr>
<td>WRI</td>
<td>Knowledge available to use the system in its current form. Also adaptations in the hydrological part can be made here</td>
<td>Far from users of the forecast, more difficult communication Relatively little knowledge on weather prediction and remote sensing</td>
</tr>
<tr>
<td>IRIMO</td>
<td>Extensive knowledge on weather prediction and remote sensing</td>
<td>Far from users of the forecast, more difficult communication Relatively less knowledge on the hydrological part of the system</td>
</tr>
</tbody>
</table>

It should be noted that lack in knowledge can be covered with dedicated training programmes.

Human infrastructure. The operational use covers three main tasks: image processing, operational flow forecasting and computer system management. The recommended educational background of the employees carrying out the image processing and the forecasting is MSc in Civil Engineering, environmental sciences or meteorology. The system management needs a BSc in Information Technology/computer sciences.

Online data collection. Operational use of the model needs daily collection of rainfall and temperature data. These data are produced by the ECMWF. There are several options to collect the data.

- Through the IRIMO
- Through a Dutch Meteorological Agency, Meteo Consult
- Direct contact between WRI and ECMWF (should be checked as it is ECMWF policy only to do business with research institutes and national meteorological organisations)
This means that in order to collect the required data a contract needs to be made with a meteorological data provider.

In the winter period (December – April) regularly (4 times per week) NOAA and MODIS satellite images need to be downloaded for monitoring the snow cover in the Afghanistan mountains. Not all days will be sufficiently free of clouds that reliable estimates of the snow cover can be made. Therefore in the period December – April preferably every day a check should be made if a useable image is available. Both the NOAA and MODIS satellite images are freely downloadable from the internet. In the current conditions to gather these data no further contracts are needed.

**Internet connections.** The largest files that need to be transferred are the NOAA satellite images. These are 12MB each. To keep the transfer time acceptable an internet connection allowing a transfer rate of 512 Kb/s is recommended. More important however is that the internet connections are reliable as without these connections forecasts are not possible.

**Computer requirements.** The forecasting model runs on standard PC’s. The operating system should be Windows XP with service package 1 or higher. A hard disk of 50GB or more is recommended for sufficient storage capacity. To limit computing time at least a 1.0 GHz processor with 256 MB RAM is recommended. For reliable forecasting, a separate computer, only used for forecasting is recommended. Regular back-ups of the results are needed to avoid loss of forecast results. Since the data volumes are relatively small, this can be done through a simple local area network.

**Archiving facilities** To allow for making hindcasts the precipitation, temperature and evaporation fields need to be stored, as well as the results of the snow mapping and the initial conditions. The total storage capacity for one year forecast is about 110 MB. This means that one CD-ROM is more than sufficient for one year data storage

**Budget.** An estimate was made for the annual costs to operate a forecasting centre. This budget was estimated at a minimum of € 20,000 annually. This includes 6 persons functioning part-time in the centre, the retrieval of meteorological data, computers, telephone and internet connections as well as annual on the job training. Added to these costs could be maintenance contracts of the software and an initial training of the forecasting staff. A maintenance contract would mean at least € 12,000 extra annually. An extra initial on the job training of 4 weeks for the staff would cost approximately € 26,000.
8  IWRM planning for the Sistan Inland Delta

8.1 Starting conditions for analysis

8.1.1 Delineation of the System

This section describes what components are being considered in the IWRM analysis. Although an integrated approach is followed it is necessary to restrict the analysis to those aspects that are of direct importance to the objective for the water resources development and management as stated in section 6.2.

Natural Resources Systems

The concept of IWRM is based on a river basin approach. This would mean that the project has to consider the whole Hirmand Basin. This is only possible if the analysis would be done in close cooperation with the Afghan authorities. As this is not the case (yet) the project has dealt with this situation in the following way:

- For the determination of the hydrological boundary conditions for the Sistan area the hydrology of the full Hirmand basin is analysed. Assumptions are made with respect to the water allocation in Afghanistan. Different kind of assumptions will lead to alternative hydrological scenarios at the inflow point of the Hirmand in Sistan, i.e. at the Hirmand fork.
- The Sistan area itself is analysed in detail. Measures and strategies are developed for this area. The results of these measures and strategies are evaluated in terms of the defined criteria/indicators.

For the first analysis (hydrological boundary conditions from Afghanistan) the whole basin of the Hirmand will be taken as well as the basins of the Farah and Khash. The infrastructure involved (dams, diversions, etc.) is modelled using RIBASIM based on information available in reports, on internet and from remote sensing images. This was described in previous chapter.

The second analysis covers the river basin downstream of Hirmand fork, including the Hamoun lakes up to the Shileh Emissary. The inflow of the Hirmand at Hirmand fork and of the other rivers into the Hamoun lakes are taken as boundary conditions. The analysis (and corresponding models) include:

- the Hamoun lakes and associated ecological values;
- the Chahnimeh reservoirs; the demand for Zahedan is taken as a boundary condition;
- no deep groundwater is assumed to be available;
- no water quality aspects are not considered; salinity of the Hamoun wetland is included in the sense that requirements for flushing are accounted for.

Socio-economic system

The natural resources system (NRS) provides water and related goods and services to the socio-economic systems. The socio-economic system makes use of this for several purposes. By using the water and related ecosystem, the socio-economic system has an impact on the natural resources system, e.g. through pollution of the water. People living within the boundaries of the NRS are expected to use the goods and services provided by this system. However, people from outside the area may be dependent on this system as well. Also, the regional economy is linked to the national or even international economic situation. Defining the boundaries of the socio-economic system is therefore less straightforward than the delineation of the natural resources
system. However, because the Sistan inland delta between the international boundaries and the Hamoun wetland is the only densely habited area in a desert environment, this area is chosen as analysis unit for the socio-economic analysis. Included are:

- water demands from agriculture and from domestic, municipal and industrial water supply (DMI), in relation to overall socio-economic development;
- ecological values in the area (in particular in the hamouns and Chanimeh lakes);
- employment/livelihood/poverty alleviation aspects related to water; and
- fisheries and other wetland products depending on the water in the hamouns.

Not included in the analysis are:

- the not-water related socio-economic aspects;
- socio-economic developments outside the Sistan area; and
- industrial pollution.

8.1.2 Computational Framework

The computational framework that is used in the analysis contains various components. The core model is the RIBASIM application for the Sistan area. RIBASIM is a 0-dimensional model that keeps track of the water balance in time. The model balances supply and demand and can be used to evaluate measures and strategies in terms of the defined evaluation criteria. The RIBASIM application includes a network schematization of all important water infrastructure (rivers, reservoirs, lakes, irrigation canals, public water supply trunk lines, intake structures, etc.). The schematization of the Sistan area for RIBASIM is given in Figure 8-1. A full description is given in Annex C.

RIBASIM includes modules that determine the demand for water of irrigated agriculture based on information about areas, cropping patterns, evapotranspiration, irrigation efficiencies, etc. For domestic requirements population numbers and per capita demand are directly entered into the model. For analysis of the ecological condition the sequence of steps is a little different. Various hydrological characteristics of importance to the wetland have been identified. Separately a database has been prepared in which ecosystem changes as a result of changes in these hydrological parameters are estimated. In a spreadsheet model the results of the RIBASIM simulation are processed to find at first the changes in the hydrological parameters as a result of the strategy and subsequently the changes in ecosystem condition. More information on water demand and how this is dealt with in RIBASIM can be found in Annex C. The socio-economic valuations follows the approach as described in Chapter 4.

The hydrological boundary at Hirmand fork is determined with a separate RIBASIM application for the Afghanistan part of the basin as described in the previous chapter. Inflow series for this application have been assessed based on analysis of available measurement series. The series and statistical characteristics are described in Annex A, whereas the generation of inflow series out of these data can be found in Annex C. The RIBASIM application for Afghanistan is described in Annex B.

Once the water allocation in the Sistan area is determined by the computational framework, the impacts of this water allocation are calculated in terms of the criteria / indicators related to the objective of the WRM of the area (see Chapter 6). The impacts on agricultural production are calculated by the agricultural module in RIBASIM. The other impacts (e.g. on employment, etc.) are calculated by special modules outside RIBASIM. A multi-criteria analysis tool could be used in the final stages of the analysis to support decision making.
8.1.3 Analysis conditions

The analysis conditions describe the assumptions and conditions under which the analysis will be carried out.

Temporal and financial conditions
The analysis will be carried out under the following conditions:
- Base year of analysis (t₀): 2005, being the most recent year with complete data sets
- Financial base year (price level): 2004
- Time horizon: 2025
- Discount rate for investments: 7%

Level of detail
The level of detail for the socio-economic data and results is the Shahrestan level, i.e. the entire Sistan basin in Iran is considered as one system. However, for the ecosystem the three Hamouns are analysed separately. Also attention is paid to the different groups of Hamoun users, to two groups of farmers and to urban people.

The time step of the IWRM analysis (using RIBASIM) is monthly. This timestep is considered sufficient to model the performance of the system under both high and low flow conditions. Typical flooding events are not included in the IWRM analysis as these will require a totally different time scale (hours) and modelling approach (dynamic).
8.1.4 Scenarios (external developments)

External scenarios specify developments that are outside the control of the water managers and decision makers involved in the Sistan project. The following scenario elements can be distinguished (see also Section 6.3):

- economic growth in the area in combination with demographic developments;
- upstream water management developments in Afghanistan (influencing the amount of water that will be available for Sistan);
- climate change, resulting in changes of the runoff in the Hirmand.

The problems and possible solutions for the Sistan area are complex and difficult to analyse. It is strongly recommended not to make this even more complex by considering too many possible external developments. For that reason it is suggested to assume only one scenario for (the ‘average’) economic growth and demographic developments for the area. For the same reason possible changes in runoff due to climate change will not be taken into account. This leaves us only one scenario element that we have to consider: the inflow from Afghanistan as a result of upstream water management developments.

The scenario for the future development of water resources in Afghanistan considers an extension of the irrigated area, enlargement of the Kajaki reservoir and the construction of three new reservoirs: a new Arghandab reservoir, the Olumbagh reservoir upstream of the Kajaki reservoir and the Bakhashabad reservoir on the Farah. Inflow scenarios are created by simulating present and future water resource use and management in the RIBASIM-Hirmand application. Details on the creation of scenarios can be found in Annex C. Average inflow values for the two scenarios are presented in Table 8-1. Scenario 1 refers to the present situation in Afghanistan and Scenario 2 is the possible future development situation in Afghanistan.

Table 8-1 Water availability under four scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>minimum annual inflow (MCM)</th>
<th>average annual inflow (MCM)</th>
<th>maximum annual inflow (MCM)</th>
<th>Average increase due to treaty (MCM/year)</th>
<th>number of years (out of 45) during which annual inflow &lt;810 MCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-a</td>
<td>1759</td>
<td>5508</td>
<td>16062</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1-b</td>
<td>1775</td>
<td>5873</td>
<td>16062</td>
<td>65</td>
<td>0</td>
</tr>
<tr>
<td>2-a</td>
<td>785</td>
<td>3156</td>
<td>12304</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2-b</td>
<td>787</td>
<td>3250</td>
<td>12304</td>
<td>94</td>
<td>1</td>
</tr>
</tbody>
</table>

An additional factor which could influence the amount of water available from Afghanistan would be the compliance (or non-compliance) with the treaty between Iran and Afghanistan that deals with minimum flows at Hirmand Fork. Two additional scenarios (variants b) were created to investigate the impact of the treaty. It turned out that the treaty would provide only an additional amount of 60-80 MCM/year (Table 8-1), which is about 1-3% of the average annual flow. Because of this very small effect, it was considered unnecessary to identify additional scenarios for treaty-compliance.

Summarising: two scenarios will be considered in the water resources analysis for Sistan: scenario 1-b and 2-b.
8.2 Overview of measures that can be taken

8.2.1 Quantity - supply oriented measures

The inflow from Afghanistan forms the main supply, but besides negotiation there is nothing Iran can do to increase or even ensure the supply. The only way to increase supply is to increase storage capacities and reduce unnecessary evaporation and infiltration. The 4th Chahnimeh reservoir is already under construction. Although the first priority of Chahnimeh operation is drinking water supply, increased storage may leave water for other purposes. To optimise storage the feeder canal should be optimised to enable large inflows during occasional floods. A measure practised in Israel is adding a substance to the reservoir water which prevents evaporation. A last option to increase the supply is to import water from other areas of Iran. This could be by transporting water from another reservoir or by desalination of water at the Persian Gulf. Probably those measures are very expensive and it would be better to first consider ways to reduce demand.

Given the variable flow conditions of the Hirmand River agriculture in the Sistan area would very much benefit of a good prediction of the availability of water during the growing season. Based on such predictions decisions can be taken about the area to be cropped.

8.2.2 Quantity - demand oriented measures

Given the limited possibilities to increase the supply a better solution for the management of the system could be to reduce the demand which will enable to use the available water more efficiently (more crop per drop). The main object for reducing the demand seems to be agriculture.

General

The harsh climatic conditions in summer with high temperatures, low relative humidity and high winds makes the Sistan Plain unsuitable for irrigated agriculture in summer. Large amounts of water are needed in summer to keep the agricultural crops alive and frequent irrigations are needed. That much water is not available in Sistan during the summer period and consequently the major part of Sistan Plain is kept fallow without crops during that period. Natural drainage conditions are also not very favorable in Sistan Plain, resulting in relatively high groundwater tables at the end of the growing season. During the hot summer season, the lands without crops evaporate the water at the soil surface, leaving the salts behind. At the beginning of the winter cropping season large amounts of water are needed to flush the salts out of the (top) soil system. Also internal drainage conditions are not very favorable in Sistan Plain with low to very low hydraulic conductivity. Flushing of salts is therefore implemented by surface drainage to field drains, or simply to local depressions where the drainage water is left to evaporate.

Lowering the groundwater table

Considerable water savings could be attained by lowering the groundwater table at the end of the winter growing season. One method to prevent high groundwater tables at the end of the growing season is to reconsider the last irrigation given to the winter crop. If one last irrigation turn during the season could be avoided, it would save not only the water of that irrigation gift, but also part of the leaching requirement at the beginning of the next season. Lowering the groundwater table by sub-surface drainage is another alternative that could be considered. Subsurface drainage is not cheap, however, especially because the soil hydraulic conductivity is low and a dense system would be required. Such a drainage system would need to lower the groundwater table below the critical depth of capillary rise, say 1.5 to 2 meter below land surface. Such deep drainage system is very expensive.
Relocating agriculture in Afghanistan
Considering the climatic conditions in Hirmand River, agriculture would be best situated in the upstream part of the basin. More crop per drop could be attained in the irrigation schemes in Afghanistan, compared to irrigated agriculture in Sistan Plain. Presently in the upper Hirmand river basin, during summer crops like cotton are still grown (total cropping intensity is about 150% there. Less summer crops in the upstream Hirmand River Basin could save water for the winter growing season in Sistan Plain. This direction of solution would require the possibility of storing the summer flow of Hirmand River until the following winter growing season in the Sistan Plain.

Shortening the staggering period
Due to uncertainty in water supply during the growing season, farmers spread their risks by not planting all their fields at the same time. This results in a large staggering period of about two months after the optimum sowing time of their winter and early summer crops. If this uncertainty can be removed, either by creating additional reservoir capacity, or by an early warning system, shorter staggering periods could be practiced. A staggering period of 15 days instead of the present 60 days would reduce water requirements with about 15%.

Improving irrigation efficiency
Present irrigation efficiency is estimated at less than 40%. This means that the net crop water requirements need to be multiplied with a factor 2.5 to compute the water releases at the main intakes. Improvement of the irrigation efficiencies needs a better managed infrastructure and investments. Investments alone are not enough to improve irrigation efficiency however. It also needs a close cooperation between farmers and water managers, to release the proper amounts at the proper timings, when farmers need it for their crops. More importantly, water allocations need to be planned at the beginning of the crop season, when farmers are planting their crops. As long as it is still uncertain how much water will become available during the growing season at the start of this season, better irrigation efficiency is very difficult to be obtained. The uncertainty results in farmers that are not motivated to invest in agronomic measures. This is illustrated by the crop yields of about 2.5 ton/ha for wheat, compared to 6 ton/ha irrigated wheat elsewhere in Iran.

Greenhouses
The greenhouse vegetable cultivation using groundwater that has started during the recent prolonged drought period should be stimulated to continue. On locations where the groundwater quality is good, this greenhouse cultivation could contribute to lowering the groundwater table in these areas, and thereby preventing secondary salinization.

Specific measures
The following measures (developments) might be considered with respect to agricultural water demand:
- increase (or decrease) the command area of irrigation system
- use of Chahnimeh reservoirs for high-yielding crops (e.g. horticulture)
- change of cropping patterns (to less water-consuming crops)
- use of modern (less water consuming) irrigation techniques
- reducing the losses in the irrigation system (lining canals, etc.)
- use of subsidies as incentive for changing cropping patterns or the use of modern irrigation techniques

Other options
Because of the harsh conditions in the region agriculture remains a low efficient economic activity. Therefore, the possibility of shifting from agriculture as the largest employment sector
towards industries and services should be considered. Raising awareness may help to reduce domestic water supply.

### 8.2.3 Improving water quality

The main threat for the quality is an increase in salinity in the lakes. As mentioned above two causes are relevant:
- saline inflows from irrigation drainage water; and
- reduced flushing of the Hamouns.

Salt is a natural phenomenon, available in the soil. The only measure to decrease the amount of salt entering the Hamoun system is to connect all drainage canals to separate basins, where water evaporates and the salt accumulates. This partly has been done already, actually not for salt but to contain pollution by agricultural fertilizers, herbicides and pesticides. Additional drainage basins could be considered.

To increase the flushing of the hamouns the first measure would be to increase, through various measures, the amount of water flowing into the Hamouns. A particular issue is the Shileh weir that reduces the flushing of the lakes. Computations with the models might give information about the effect of that weir and if lowering the weir would benefit the water quality in the lakes. If this is the case such increased water quality should be balanced against the additional water available in the lakes as a result of the storage behind the weir.

### 8.2.4 Restoring the ecological values

The most important ‘ecological’ measures are to ensure the inflow to the hamouns and to improve the management of the ecosystem. Changes in the natural inflow to the hamouns are mainly determined by the amount of withdrawals for irrigation and public water supply. Management of the ecosystem should prevent the degradation of the system even when sufficient water is available as was the case before the present drought period. The ecological values of the hamouns can be restored by a number of measures.

1. Promotion of fish ponds, to provide other ways of income for the fishermen.
2. Prohibiting cultivation of diploid grass carps and promoting the cultivation of triploid (sterile) grass carp.
3. General reduction of the pressure on the system (strive for a comparable pressure as in the early 1970’s as a reference).
4. Reducing the Hamoun-Hirmand area, to promote a smaller scaled wetland system along the eastern shores, and to promote flushing of the Hamouns.
5. Lowering or even removal of the Shileh weir, when it appears that the weir obstruct the flushing capacity of the Hamouns.
6. Investigation of the possibilities of Chahnimeh 4, to assign part of this reservoir a wetland function with a less extreme fluctuating water level (comparable fluctuations as is normal in the Hamouns).
7. Replanting reeds in areas that were known to support large reed beds in the past.
8. Influencing the distribution of water at Hirmand fork.

**Ad 1. Fish ponds**

From an ecological perspective, different species are relevant than from a socio-economic perspective. Socio-economic useful species could be cultivated in ponds instead of being released into the Hamouns. Care should be taken in the selection of the species to cultivate.
Ad 2. Prohibiting cultivation of diploid grass carps
Even when grass carps are cultivated in ponds and not introduced to the Hamoun wetland, there is still a chance that they escape and affect the reed areas by establishing a vital population in the Hamouns. Triploid grass carps, a mutation with three pairs of chromosomes, cannot reproduce. Cultivating this type of carps does not pose a risk for the reeds, and is a common way of producing grass carps in other parts of the world.

Ad 3. Reducing pressure on system
Different measures can be taken to reduce the pressure on the system. Some are positive (stimulation) and some are negative (fines).
   a. Maintaining current legislation which prohibits catching of birds and fish during respective breeding and spawning season
   b. awareness campaigns: sustainable use
   c. family planning
   d. incentives: wetland guards, eco-tourism, also for farmers giving up cultivation…
   e. compensating people for temporary not using the wetland resources
   f. relocation of people

Ad 4. Reducing Hamoun area
When there is not sufficient water, restoring only part of the wetland area is a possibility. To increase the average depth, either a dike can be constructed, or a part can be deepened. From these two options a dike is preferred; deepening will take considerable more effort; also flushing is easier with dikes compared to deepening. A depth of 0.5 - 3.0 m is preferred, deeper areas are not required from an ecological point of view.

Ad 5. Lowering or removal of Shileh weir
The motives for the construction of the Shileh weir at the south end of Hamoun-e-Hirmand are supposedly been to prevent the Hamoun-e-Hirmand from drying out as a result of natural erosion of the sill to the Shileh. If it appears that the Shileh weir is limiting the frequency of spills from the Hamouns into the Goud-e-Zereh, it might be recommendable to lower or even remove the weir in order to prevent salinity problems in the Hamouns.

Ad 6. Chahnimeh 4 as ecosystem
Whether Chahnimeh four is suitable as an alternative ecosystem depends on the presence of shallow areas and on the frequency, timing and magnitude of water level fluctuations. Preferable fluctuations are comparable to the fluctuations in the Hamouns, following the seasons in a similar way. Fluctuations higher than 2 m are generally considered undesirable for an ecosystem.

Ad 7. Replanting reeds
Planting reeds is only useful when the requirements for reeds are met. However, once these requirements are met, reeds will also return without planting. Planting can only speed up the recovery of the reed areas.

Ad 8. Influencing distribution of water at Hirmand fork
By opening the Zahak and Sistan barrage, or with additional dredging, it is possible to increase the % of Hirmand flow flowing into the Sistan. This is useful for the Hamoun-e-Hirmand, but will negatively affect the flooded area of Hamoun-e-Puzak and Hamoun-e-Saberi. From an ecological point of view Hamoun-e-Puzak and Hamoun-e-Saberi are more valuable than the Hamoun-e-Hirmand. Maintain the flooding of Hamoun-e-Saberi also contributes to a limitation of the sandstorms.
8.3 Playing with some first strategies

The information available so far and further needed calibration and fine-tuning of the models did not permit a final kind of analysis in the period that the Netherlands team contributed to the project. To show the potential of the approach and the tools some first strategies were developed, mainly for illustrative purposes and to get a first impression of the kind of strategies that can be evaluated and the impacts that can be expected. The following strategy components were selected:

1. to increase the agricultural area to 245,000 ha
2. to decrease of the agricultural area to 21,000 ha
3. construction of the Chahnimeh-4 reservoir (used only for public water supply)
4. to allow the Chahnimeh reservoirs to be used for irrigation supply also.

Combination of these elements resulted in 5 strategies:

- **Strategy 1**: an increase of the present irrigation area of 120,000 ha with an additional 125,000 ha, using the Chahnimeh reservoirs for irrigation is not allowed
- **Strategy 2**: decrease the present 120,000 ha irrigated area to only 21,000 ha
- **Strategy 3**: the construction of Chahnimeh-4, to be used for public water supply only
- **Strategy 4**: allow the Chahnimeh reservoirs to be used for irrigation supply of the present 120,000 ha also
- **Strategy 5**: increase the irrigation area till 245,000 ha while allowing the use of the Chahnimeh reservoirs to supply water to irrigate this area.

These strategies were analysed for Scenario 1-b (no change of the inflow from Afghanistan) as defined in Section 8.1.4. Strategy 2 (decrease of irrigated area to only 21,000 ha) was also analysed for Scenario 2-b in which the withdrawal in Afghanistan will substantially increase. This resulted in:

- **Strategy 6**: decrease the present 120,000 ha irrigated area to only 21,000 ha in case the inflow from Afghanistan will reduce substantially.

The results of the analysis are shown in the score-card as given Table 8-2. The score-card presents the impacts of these strategies in terms of the criteria (indicators) as defined in Section 6.2.

8.3.1 Results for scenario 1-b

The score-card presents besides the 5 strategies for this scenario two additional columns:

- **Reference Case**: this case describes the ‘ideal’ situation for the area. As reference case the situation of the 1970s is taken, which is considered to have been a good period.
- **Base Case**: this case describes the present situation.

Both cases are used for comparison of the impacts of the alternative strategies.

Most of the results presented in the table are self-explanatory. Some specific remarks and conclusions that can be drawn from this score-card are:

- **Base case** (present situation). Note the rather low supply/demand ratio for irrigation (0.63) which means that in many years there will be insufficient water available to cultivate the full present irrigation area.
Table 8-2  Scorecard of some preliminary strategies

<table>
<thead>
<tr>
<th>Criteria information (on case)</th>
<th>Year 2005</th>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
<td>120,000</td>
<td>245,000</td>
</tr>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
<td>120,000</td>
<td>245,000</td>
</tr>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
<td>120,000</td>
<td></td>
</tr>
</tbody>
</table>

**Domestic water supply**

<table>
<thead>
<tr>
<th>DMI raw water supply (Zabol+Zahedan)</th>
<th>Months supply &lt; demand</th>
<th>%</th>
<th>33.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
<td>120,000</td>
<td>245,000</td>
</tr>
</tbody>
</table>

**Economy - agriculture**

<table>
<thead>
<tr>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
</tr>
</tbody>
</table>

**Economy - hamouns**

<table>
<thead>
<tr>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
</tr>
</tbody>
</table>

**Ecology hamouns**

<table>
<thead>
<tr>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
</tr>
</tbody>
</table>

**Environment / Health**

<table>
<thead>
<tr>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
</tr>
</tbody>
</table>

**Income (return period of years with < 50% of reference income)**

<table>
<thead>
<tr>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
</tr>
</tbody>
</table>

**Perception & Experience**

<table>
<thead>
<tr>
<th>Scenario 1-b</th>
<th>Scenario 2-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area in Sistan</td>
<td>120,000</td>
</tr>
<tr>
<td>Average inflow from Afghanistan</td>
<td>5875</td>
</tr>
</tbody>
</table>

### Strategy 1 (increase of irrigation area without reservoir use)

- Increase agricultural production
- Increase irrigation area
- Increase demand for water
- Increase reliability of supply
- Increase ecological conditions
- Increase income conditions
- Increase return period

The agricultural production will increase somewhat but the reliability of the supply drops to a level (supply-demand ratio of 0.42) that will be unacceptable for farmers. The ecological conditions of the hamouns deteriorate clearly as well as the related income conditions for the hamoun users. The return period of a dry Hamoun-e-Saberi increases with corresponding dangers for sand storms. Also the return period of flushing of the hamouns increases (once in 17 years now) which will result in an increase of the salt concentration of the hamouns.
8.3.2 Results for scenario 2-b

Besides above five strategies also the impacts have been calculated of a strong decrease of available water from Afghanistan (scenario 2). This is only done for the base case (present situation Sistan with no Chahnimeh 4 and only 120,000 ha irrigation) and for a strategy in which the irrigated area in the Sistan area decreases substantially. From the results given in the last two columns of Table 8-2 it becomes clear that such scenario will have disastrous effects for the agricultural activities in the Sistan delta and for the hamouns.

- **Strategy 6** (as strategy 2 but with lower inflow from Afghanistan). Compared to the base-case for this scenario the situation improves somewhat but the general condition remain very poor. Stopping withdrawal in Iran cannot compensate for the additional withdrawals upstream.

It is noted the effects of an increase of the demand in Afghanistan is much more than a similar kind of increase in Iran. This is due to the fact that a development in Iran will mainly influence the Hamoun-e-Hirmand, leaving the two other hamouns (Hamoun-e-Puzak and Hamoun-e-Saberi) intact. Developments in Afghanistan will influence all three hamouns and will result in a near complete collapse of the ecology of the hamouns.

8.3.3 Discussion

At first it should be noted that the system is rather complex and that many aspects in the analysis are linked in sequence: Ribasim calculates the water distribution, the results are used to estimate ecosystem conditions which are in turn used to estimate socio-economic values. Uncertainties resulting from insufficient understanding of the system are added on top of each other with uncertain outcomes as a result. Hence, above results should be considered with great care, in particular the conclusions with respect to the hamoun related effects. At the other hand, the calculated impacts seem reasonable and can be used to support the decision making process. Basically the following overall conclusions can be drawn:

- The use of water for irrigated agriculture is mainly restricted by the variability of the supply and not by the total supply.
- This makes sustainable irrigation of the present 120,000 ha in the Sistan Delta only possible if use can be made of the storage capacity of the Chahnimeh reservoirs for irrigation water also. Only in that case a sufficient reliable supply can be guaranteed needed for
economically sound agricultural practices. Also in this situation it seems recommendable to use reservoir water for high yielding crops only (e.g. horticulture or glass house crops).

- Further increase of the irrigation area without the use of the Chahnimeh reservoirs does not make sense at all. Even if use can be made of the Chahnimeh reservoirs the reliability of the supply will be too low to sustain normal irrigated agriculture.

- There is a direct relation between the use of water for irrigated agriculture and the environmental conditions in the area. Water used for agriculture will not be available anymore for the wetlands, resulting in a lower average water cover of the hamouns and corresponding impacts on ecology and health.

- Developments upstream in Afghanistan can have disastrous impacts for Iran. The Chahnimeh reservoirs will take care that the public water supply will not be endangered but the availability of water for irrigation will substantially decrease and the average area of the hamouns will be much smaller. The frequency of a complete drying out of the hamouns as happened in the period 2000-2005 will increase with all related problems for ecology and health (sandstorms). The increase of use in Afghanistan will have much more effect on the hamouns than a similar increase in Iran as the last one will only influence the Hamoun-e-Hirmand while the withdrawals in Afghanistan will influence the ecological more important Hamoun-e-Puzak and Hamoun-e-Saberi as well.

- Developing the water resources in the whole basin and the Sistan delta while at the same time protecting the hamouns requires an intensive cooperation between Afghanistan and Iran.

**Improving system knowledge**

As mentioned above, the results and conclusions should be considered with great care. A sensitivity analysis, in which model simulations will be made with structured changes in parameters, should provide insight in what the main uncertain parameters are. This can be parameters for which the model results react largely to only small changes, or this can be parameters for which the model may not be that sensitive, but for which the range of possible values (the uncertainty) is very large. The results of such a sensitivity analysis will be the starting point for additional research to reduce the knowledge gaps.

It is clear that the hydrology of the wetlands is not clearly understood. The DEM, used for deriving level-area-volume relationships of the Hamoun, turned out not to be very reliable. The only data of the Hamoun hydrology are satellite images with inundated areas and reed covers. No measurements of water levels has taken place.

**8.4 Institutional aspects**

Above analysis has a very strong technological emphasis. Quantified information is given based upon which objective decision making can take place by balancing the interests involved. As explained in Sections 1.2 and 1.4, IWRM is more than just that. IWRM is a process in which all stakeholders should participate to ultimately agree upon an equitable and socio-economic acceptable development and management of the region. This applies to the Sistan area in Iran but also to the whole basin, including the areas in Afghanistan.

In the present project little attention could be given to required institutional cooperation and developments. In the remainder of the project and subsequent stages of IWRM planning for the area it will be needed that more emphasis will be given to the institutional aspects. This involves three levels:

- First of all the involvement of SBRWA in the project should be improved. They should consider the project as *their* activity and the results of the project as *their* results (ownership). So far SBRWA tend to consider the project as a consultant project which
results they will start evaluating when the final reports are finished. The IWRM approach requires that they are more actively involved.

- Secondly all other stakeholders in the region should be involved and participate, in particular representing agriculture and environment. Contacts have been established in the project by were mainly restricted to information exchange. Non-organized stakeholders should be included as well.

- Finally, IWRM requires cooperation at river basin level. This means that Afghanistan should be included in the analysis at a similar level of detail and Afghan stakeholders should participate.

Involving all three levels would be ideal. Given the present situation in Afghanistan it is not likely that a full participation of that country can take place at short notice. However, the first two levels should be possible and should be strived for.
Chahnimeh reservoirs
- to be used for irrigation also?
9 Preliminary conclusions and recommendations

The analysis described in this report has been at reconnaissance level only. Data and information have been collected and analysed. Models have been developed that describe the system. This all has resulted in a much better understanding of the functioning of the water resources system in Sistan and the issues involved. However, before final conclusions and recommendations can be made additional information and analysis is needed.

Based on the information described in this report the following preliminary conclusions can be drawn. These conclusions are partly based on observations in the field, partly on the quantitative analysis that has been carried out.

- The present poor ecological conditions of the Hamouns at the Iranian side appear to be mainly the result of mis-management and not a result of years of drought in the area. In fact, the recent drought has created the conditions for the Hamouns to recover. The improved conditions are:
  - less pressure from population and cattle (less fishing, grazing, reed-cutting, etc); and
  - the disappearance of introduced exotic fishes in the system, in particular the grass carp.

- After the winter floods of 2005 the Hamouns appear to recover. Reed vegetation re-grows from seeds and rhizomes and (native) fish has returned to some extent. Small number of wetland birds have been observed as well. A full recovery has certainly not taken place yet but the signs are positive. This is in particular true for the Hamoun-e-Puzak and Hamoun-e-Saberi. The Hamoun-e-Hirmand remains in a critical situation.

- Based on available information and tools an ‘IWRM’-plan for the Sistan Inland Delta can be developed. The main focus of such plan will be the balancing between the socio-economic values of irrigated agricultural development in the Delta and the socio-economic and ecological value of the hamouns. Such IWRM-plan will provide contributions to:
  - decision making on development and management in Iran, in particular with respect to being careful with investment decisions on the further development of the system (more reservoirs, more irrigation);
  - as input to an overall IWRM-approach to the Hirmand basin, to be jointly carried out by Afghanistan and Iran.

- The drinking water demand is low compared to the demand of agriculture and the ‘demand’ of the hamouns. The present capacity of the Chahnimeh reservoirs is sufficient to guarantee a reliable supply for both the Sistan area as well as the agreed upon delivery for Zahedan.

- Agriculture is a very water consuming activity in the region. The climatic conditions are far from ideal for irrigated agriculture. The expected yield does not justify major investments and the negative impacts on the ecology of the hamouns should be considered. At the other hand agriculture is of major importance for the people and a balance should be sought between using water for agriculture and the value that water has for maintaining a healthy ecosystem in the hamouns.
The quantitative analysis (resulting in the score-card) shows that:
- the use of water for irrigated agriculture in Sistan is mainly restricted by the variability of the supply and not by the total supply; the use of (the Chahnimeh) reservoirs will improve the performance of irrigated agriculture; a further increase of the irrigated area in Sistan without being allowed to use the reservoirs for irrigation water also is not feasible;
- there is a direct relation between the use of water for irrigated agriculture and the environmental conditions in the area; further increase of irrigation water will decrease the average water cover in the hamouns and will have corresponding negative impacts on ecology and health;
- developments upstream in Afghanistan can have disastrous impacts for Iran; these developments will have much more effects on the hamouns than similar developments in Iran as the Iranian developments will influence only the Hamoun-e-Hirmand.

Developing the Sistan basin and protecting the hamouns requires an intensive cooperation between Afghanistan and Iran. This cooperation should be based on a mutual agreement on ‘sharing’ the resources and a joint development and management of the river basins. The present treaty between Iran and Afghanistan has a very limited value for Iran and mainly guarantees a sufficient supply for drinking water purposed only. The treaty contributes hardly to sustainable irrigated agriculture in Iran or to the protection of the ecosystems in the hamouns. With the construction of the Chahnimeh reservoirs the treaty has decreased in importance even more.

Above conclusions are based on available information and the tools developed in the project and should be considered with great care. These results are constrained by the following:

- Very little recent information is available from Afghanistan, both at the supply side (hydrology, hydraulics and management) as well as the demand side (agricultural developments in Afghanistan). The developed flow forecast model is a good first step in getting better boundary conditions from Afghanistan but should be further improved, preferably in cooperation with Afghanistan, e.g. by:
  - using recent hydrological monitoring data,
  - implementing a snow-melt correction module; and
  - improving the hydrological model.

- The physical characteristics of the Hamoun system are insufficiently known. The present available DEM of the Hamouns is a good start but need to be improved, in particular at the Afghanistan side. The dynamics of the system (floods and droughts) are very important for the ecosystem and should be better understood.

- The same applies to the ecological functioning of the hamouns, in particular of the fish (how do they survive and where do they come from after a drought?) and of the wetland birds (where do they stay during a drought and what kind of water conditions (depth, area, etc.) do they require?).

- Finally, to be able to make a better link between hydrology/ecology and the socio-economic system, an improved understanding and figures on wetland production and (socio-economic) costs of sandstorms will be useful. This will require further discussion with the population/stakeholders to understand their preferences and possible side-effects of proposed measures.
The following recommendations are given for the further analysis on IWRM within present project:

- First a further elaboration is needed of the results of the preliminary analysis as given in previous chapter. The basic question to be answered is if these results are logical and understood. If not we should analyse what has caused these results and improve our data and/or models. Next we should elaborate on the criteria. Are these the criteria that the stakeholders need to evaluate and decide upon different measures and strategies?

- Once we understand and agree with the results of this preliminary analysis a full IWRM analysis can be carried out. The measures and strategies considered should be extensively discussed with the stakeholders, in particular SBRWA. Ultimately this will lead to the IWRM plan that the overall project is supposed to deliver.

- Finally an operational plan can be developed, based on the agreed upon IWRM plan. This operational plan will tell the responsible authorities what they have to do or what they can expect depending on the predicted and actual water availability from Afghanistan.
References

Agricultural Bureau Zabol, 2005. Leaflet (in farsi). Translation of leaflet is included as appendix E in Annex E.


Development Alternatives Inc. 2004. Rehabilitation needs assessment for the Middle Helmand irrigated agriculture system.


# ANNEX

## Key information project

<table>
<thead>
<tr>
<th>Project number:</th>
<th>PvW-02.044 (Partners for Water)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name of Project:</strong></td>
<td>Integrated Water Resources Management for Sistan Plain, Iran</td>
</tr>
<tr>
<td><strong>Location:</strong></td>
<td>Iran</td>
</tr>
<tr>
<td><strong>Budget:</strong> Ministry of Energy (I.R.Iran)</td>
<td>€ 600.000</td>
</tr>
<tr>
<td></td>
<td>Delft Hydraulics</td>
</tr>
<tr>
<td><strong>Project duration</strong> Nederland contribution:</td>
<td>January 1st, 2004 until November 30th, 2005</td>
</tr>
<tr>
<td></td>
<td>Iranian contribution:</td>
</tr>
<tr>
<td><strong>Iranian Policy Responsibility:</strong></td>
<td>Ministry of Energy (I.R.Iran)</td>
</tr>
<tr>
<td></td>
<td>Iran Water Resources Management Company</td>
</tr>
<tr>
<td></td>
<td>P.O.-Box 14155-6597</td>
</tr>
<tr>
<td></td>
<td>Tehran</td>
</tr>
<tr>
<td></td>
<td>Iran</td>
</tr>
<tr>
<td><strong>Main contractor</strong> (Iran) &amp; Technical Coordinator</td>
<td>Water Research Institute (Part of the Ministry of Energy)</td>
</tr>
<tr>
<td></td>
<td>Dr. Yazdandoost (Director)</td>
</tr>
<tr>
<td></td>
<td>P.O. Box 16765-313</td>
</tr>
<tr>
<td></td>
<td>Tehran</td>
</tr>
<tr>
<td></td>
<td>Iran</td>
</tr>
<tr>
<td><strong>Main contactor</strong> (Netherlands)</td>
<td>WL</td>
</tr>
<tr>
<td></td>
<td>Team Leader WL</td>
</tr>
<tr>
<td></td>
<td>P.O. Box 177</td>
</tr>
<tr>
<td></td>
<td>2600 MH Delft</td>
</tr>
<tr>
<td></td>
<td>The Netherlands</td>
</tr>
<tr>
<td><strong>Project beneficiaries:</strong></td>
<td>Sistan-Baluchistan Regional Water Authority, Provincial Department of Environment, Directorate of Jihad-e-Agriculture of Sistan and Baluchestan</td>
</tr>
<tr>
<td><strong>Netherland Project Partner(s):</strong></td>
<td>Delft Hydraulics (WL)</td>
</tr>
<tr>
<td></td>
<td>ITC</td>
</tr>
<tr>
<td></td>
<td>Alterra</td>
</tr>
<tr>
<td></td>
<td>RIZA</td>
</tr>
<tr>
<td><strong>Iranian Project Partner(s):</strong></td>
<td>Water Research Institute (WRI)</td>
</tr>
<tr>
<td></td>
<td>Absaran (Consulting Engineers)</td>
</tr>
<tr>
<td></td>
<td>Dr. Behrouzi (individual consultant)</td>
</tr>
</tbody>
</table>