A SYSTEM’S APPROACH FOR UNDERSTANDING THE
DYNAMIC COMPLEXITY IN MANAGING SCARCE WATER
RESOURCES

CASE STUDY ON
MANAGEMENT OF SCARCE WATER RESOURCES IN
THE HASHEMITE KINGDOM OF JORDAN

MASTER’S THESIS

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LUND, SWEDEN
NOVEMBER, 1999
Preface

This thesis research is the final requirement for the International Master’s Programme in Environmental Science at Lund University, Sweden. The research was performed in cooperation with UNDP-Jordan and represents an analysis on the dynamic complexity of increasing water scarcity in Jordan, where it is viewed as a system with certain behaviour. An effort was made to illustrate both the problems and highlights around management of Jordan’s scarce water resources. Furthermore, key driving forces behind the system and causal relationships between them were identified and simulated in qualitative mental models. It was considered important in this paper to provide the reader with information on the root causes of the problem and their interactivity and interdependency in as simple a manner as possible. Finally, a discussion on how the unsustainable behaviour of the system could be shifted into a more sustainable track is conducted.

At the beginning of the course, the topic of water resources management was completely new to the author due to her main background in chemical engineering and environmental studies. However, the intensive literature research facilitated the learning process. In addition, a combination of factors contributed in making this thesis period a very challenging and interesting time. Those worth mentioning are the author’s interest in problems of water shortage since water is a source of inspiration to her, and the exciting and ‘rich’ trip to Jordan for gathering information. A ‘rich’ trip in terms of gaining knowledge in the topic, new wonderful friends, open-mindedness and understanding for other cultures and beliefs.
ACKNOWLEDGEMENTS

This paper was prepared with the help and support of many individuals from different countries. Initially, I would like to thank my supervisor in Jordan, Dr. Iyad Abumoghli from UNDP, Jordan, for his time and help in reaching contacts and retrieving valuable information. Additionally, I would like to thank my supervisor in Sweden, Prof. Lars Bengtsson, Water Resources Engineering/Lund University, for his help at very short notices and encouragement.

Moreover, acknowledgement is made to M.Sc. Hördur Haraldsson for the support provided and the time allocated for our meetings. Special thanks for the staff of LUMES and colleagues, for their support and continuous encouragement during the course of my studies, without which this paper could not have been finalised in its present form on deadline.

Furthermore, I would like to express my deep gratitude to the following individuals; Tareq Emtairah for encouraging and provoking me to perform this thesis and help in organising my trip to Jordan, Semra Guner, for her continuous and never-ending support and friendship during the worse periods of my life; and Yazan Samara for being a dear friend and great tourist guide in Jordan, and for providing accommodation and required working environment in his office.

Last but definitely not least, I would like to express my gratitude, appreciation and love to my mum and dad, brothers and sister, for their support and for having patience with my extreme ups and downs in mood during this research.

Lund, Sweden, November 1999

Roba El-ghadban
EXECUTIVE SUMMARY

Increasing water scarcity is a major problem in many parts of the world today, exerting severe constraints to agricultural, economical and social development. The study area, Jordan, a dry and semi-arid country, with large and rapidly growing population, limited financial resources and scarce water resources suffer from severe water shortage. The severe imbalance between water supplies and demands are met today by the unsustainable fashion of overexploitation of already scarce water resources driving the problem into a worsening and chronic cycle. The unbalanced equation of resources, affecting socioeconomic development, need to be balanced. This study uses a system’s approach, where the problem of increasing water scarcity in Jordan is viewed as a complex web of interactions with certain behaviour, as a system with boundaries confined within the study area. Furthermore, a qualitative modelling approach is used, where the causal relationships and feedback mechanisms between selected key driving forces are drawn in mental models. This is to simplify observation and understanding of the system’s dynamic complexity and behaviour and how it operates. This gives a better understanding on how the behaviour of the system must change.

In the process of selecting key driving forces behind the system, drawn in the mental model, consideration is taken that the model should be transferable and applicable to other study areas, as well as allow deeper exploration of the system by further building on it and addition of other variables. Therefore, selected key driving forces in this study are common in all countries. These represent human-related factors including common values, growth factors, technological, economical, behavioural, and institutional/political factors. However, there are natural and environmental factors too but these are excluded from this study. Furthermore, the selected driving forces are explored with respect to their behaviour in the study area, and in terms of their positive and negative impact on the system. In addition linkages between them are identified leading to the following conclusions. The driving forces could be classified into the following: Human values influencing human attitudes toward nature were identified as the core values. Population growth and technological advance served as amplifiers for these values, while poverty and affluence served as indexes for basic human needs. Finally, the economic aspect was represented in the driving force, market operation. The political driving force is considered as a derivative of the human values.

Moreover, based upon the system analysis conducted and the characteristics of the study area, the author finds that a combination of approaches are required to shift the system’s behaviour into a sustainable fashion. A fashion based on the concepts of sustainable development and intergenerational equity. An economic efficient water resource management strategy based upon green values is found highly suitable to the task of changing the behaviour of the system. Green values endorsed through voluntary action among actors and sound government intervention should promote green technology, population stabilisation measures, design of efficient markets to allocate water resources, full cost pricing, restrictions on consumption of both water resources and water consuming materials, green affluent behaviour, elimination of poverty, and adoption of ecologically based values and lifestyles.

1 See Definitions.
DEFINITIONS

Sustainability and Sustainable Development
Sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own need (United Nations Conference on Environment and Development, 1987).

Intergenerational Equity
The report of the Legal Experts for the United Nations Commission on Sustainable Development (UN, 1977a) has identified three principles of intergenerational equity: comparable options, comparable quality, and nondiscriminatory access.

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<tr>
<td>CLD</td>
<td>Causal Loop Diagram</td>
</tr>
<tr>
<td>MWI</td>
<td>Ministry of Water and Irrigation</td>
</tr>
<tr>
<td>UNCED</td>
<td>United Nations Conference on Environment and Development</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
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<tr>
<td>WAJ</td>
<td>Water Authority of Jordan</td>
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<tr>
<td>WWT</td>
<td>Waste-Water Treatment</td>
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1.1 BACKGROUND

Increasing water scarcity is a major constraint to agricultural, economical and social development in many parts of the world\(^2\). Consequently, there is a growing recognition that effective management and allocation of water resources is a key to human survival\(^3\). It is one of the most debated issues in many research studies, literature books and reports, such as the report of the World Commission on Environment and Development, 1987, *Our Common Future*\(^4\). It is also the central theme in several international events, such as the United Nations Conference on the Human Environment in 1972 held in Stockholm, Sweden, and the United Nations Conference on Environment and Development (UNCED) in June 1992 held in Rio de Janeiro, Brazil\(^5\).

The thrust of these events was to show how the environment should not be treated in isolation from economic concerns\(^6\), where they stressed the necessity for the holistic approach as political, economic and environmental concerns are so interdependent. Guidelines for managing scarce water resources were also pointed out at these events. Box 1 summarises some of the major guidelines, all endorsed at these events. Moreover, there is a wide variety of approaches and options for management of water resources (Fig.1) as a result of the extra attention this issue has gained worldwide. All of them tackling certain aspects of the problem.

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**Box 1. Major Guidelines for Sustainable Water Resources Management**


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Consequently, relevant questions arising are: Why is water scarcity increasing in many parts of the world although all these guidelines and options exist? What is the crucial step in management of water resources? and so forth.


\(^3\) Ibid.

\(^4\) Ibid.

\(^5\) Ibid.

\(^6\) Ibid.
These questions are discussed in many books written on the topic of water resource management. There are many theories, focusing on one or several aspects of the problems. In Hempel, *Environmental Governance - The Global Challenge*, lack of comprehensive understanding of the root causes and their interdependency among actors is considered fundamental in management strategies for natural resources. Hempel argues that most approaches reveal something important about the causes of water scarcity, but no single explanation offers an understanding of the problem that is adequate in scope. It is only by combining approaches, concentrating on the key variables and on the linkages between them that a satisfactory understanding can be achieved. Therefore, it is the dynamic and multidimensional nature of increasing water scarcity, circular pathways and feedback mechanisms within the system, and not only the individual components, that must be understood by the actors; policy makers, consumers, investors, and so forth; if they are to be effective and cooperative.

The theory behind this study is in coherence with Hempel’s view on the importance of understanding the problem’s dynamics and the causal relationship between them. Lack of comprehensive understanding leads to competing perspectives and priority settings. This affects the choice of management approaches and options for solution, as well as the extent of public participation and commitment, which are all prerequisites for sustainable water resources management. Therefore, a better understanding of causation is treated as fundamental to sustainable water resources management in this study.

Moreover, in order to comprehend the interactions of the dynamics of increasing water scarcity, an area is selected as a case study. Since the Middle East region is considered as one of the most water-deficient and water-stressed regions in the globe, Jordan, as part of the Middle East, is selected as the case study for this thesis paper. Water scarcity affecting socioeconomic development is considered to be the gravest environmental challenge Jordan faces today. Mismanagement and misallocation of

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8 Ibid.
9 Ibid.
water resources among sectors, as well as other factors, are leading to an increase in water scarcity\textsuperscript{12}. To steer the development towards sustainability and intergenerational equity, it has become necessary to look at the problem as a complex web of interactions - social, economical and environmental\textsuperscript{13}. In other words, as a system, with certain behaviour and interrelated dynamics that need to be explored and comprehensively understood. This is necessary to adopt suitable management strategies and maximum involvement of actors within the system. Hence, the elegant statement by Allen is found appropriate;

"Data can become information if we know the processes involved. Information can become knowledge if we see the system that is operating. But knowledge only becomes wisdom when we can see how any system must change, and can deal with that reality."

Peter Allen,  
*Coherence, Chaos and Evolution in the Social Context*,  
*Futures* 26:597, 1994

**1.2 AIM AND OBJECTIVES**

This thesis study focuses on the very first step of water resources management, which is defining and understanding the dynamic complexity in managing scarce water resources in the selected case study - Jordan. Increasing water scarcity in the study area is viewed as a complex web of interactions with certain behaviour, as a system. The system’s behaviour is driven by key elements or driving forces exerting a positive or negative impact. The overall aim is to simplify understanding of the system and its behaviour in such a way that actors at all levels can reach a high level of understanding and problem awareness. Thereof, the objective is to simulate the dynamics of the problem and their causal relationship in qualitative mental models. This emphasises the following questions:

1. What will happen if present trends continue?  
2. How does the system operate?  
3. How must the system change?

**1.3 SCOPE AND LIMITATIONS**

The geographical area studied in this thesis is limited to Jordan. Initially, it has to be pointed out that it is the dynamic complexity of the problem, the author is trying to simulate, and not detailed complexity. The author also realises that reality is much too complex to simulate and that the results of such a study could be looked upon as an oversimplification of reality. However, it is important to be able to simplify it in such a way that all actors within the system gain a satisfactory perspective into the system. Furthermore, in the process of selecting driving forces behind the system, external ones, such as environmental conditions and regional political factors, are not included in the qualitative simulation. Selection of driving forces is performed within the system boundaries, Jordan.

**1.4 METHODOLOGY**

The methodology used for conducting this study was initiated by a literature survey on general issues within the field of water resources management and more specifically on

\textsuperscript{12} Salameh, Elias and Bannayan, Helen. 1993. *Water resources of Jordan - Present Status and Future Potentials*  
\textsuperscript{13} Ibid.
the water situation in Jordan. Basic background information and data concerning water resources, water use, technologies, pollution, future demand, etc. was provided during a visit to the study area. These were mainly retrieved from UNDP-Jordan as well as governmental institutions, such as the Ministry of Water and Irrigation in Jordan.

Since sustainable approaches always highlight the importance of viewing a problem as a complex web of interactions, a system's approach, is applied for this study. It is based on the methodology of system thinking developed by Jay Forrester. System thinking consists of two parts; qualitative simulation of dynamics and their practical application, quantitatively, using modelling software programmes. This study only uses the qualitative approach where mental models are developed, describing the causal relationships between the selected essential elements within the system. It enables a holistic understanding of complex problems and could be described as process thinking, understanding cause and effect between different components within a defined system\textsuperscript{14}. It also simplifies observation on which parameters are relevant to adjust in complex situations. Furthermore, selection of variables or driving forces have been done after a literature survey on root causes for environmental destruction in general. That is in order to make the qualitative model transferable and applicable in other countries with problems of water scarcity.

\textbf{1.5 THESIS STRUCTURE}

The thesis paper is structured as follows:

\textit{Section I} - It includes a general overview of the topic as well as objectives, scope of the study and limitations, as well as the methodology used for conducting this research.

\textit{Section II} - This section presents a profile of the study area, in order to give the reader an overview of the study area's status, in terms of socioeconomic indicators and current water sector characteristics and management. It is ended with a general description of the problem and projected consequences. The aim of this section is to give an answer to the first question emphasised in the objectives: what will happen if present trends continue?

\textit{Section III} - The dynamics of increasing water scarcity in Jordan is analysed using a system's approach. The system is visualised by following the guidelines for mental modelling, which is the first part in the method of system thinking developed by Jay Forrester (appendix A). The section aims to simplify understanding of the system and its behaviour.

\textit{Section IV} - It reflects the author's conclusions and theory on how the system must change, based on the conclusions drawn from the system analysis conducted in the earlier sections.

\textsuperscript{14} Haraldsson, Hörður. 1999. \textit{System Thinking and Mental Modelling of Complex Problems-Understand and Learn to Use System theories in Everyday Work.}
A necessary step in this study is to gain a general overview on the profile of the study area, in terms of socioeconomic indicators, water sector characteristics and management. This is to describe the nature of the problem and its consequences.

II.1 General Profile

The study area, Jordan, is part of the Middle East (Fig.3). It is a semi-arid country with a land area of about 89,000 square kilometers\textsuperscript{15}. The climate is mostly arid desert with a rainy season in west between November and April, yielding with less than 300 mm per year\textsuperscript{16}. For comparison, mean annual rainfall exceeds 300 mm over about two-thirds of the land area of the United States and over most of Europe\textsuperscript{17}.

![Figure 2. Location Map of Study Area](http://www.odci.gov/cia/publications/factbook/jo.html. Nov. 1999.)

Jordan has one of the world’s highest population growth rates (3.6% per annum) and is going through rapid industrial and agricultural development coupled with deterioration of water quality\textsuperscript{18}. As of 1999, the population reached about 4.33 million (Table 1). Population centers are confined to areas of higher precipitation, where approximately 78 percent live in urban areas and 22 percent in rural areas\textsuperscript{19}. An estimated socioeconomic profile of the study area is shown in Table 1.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (in millions)</td>
<td>4.33</td>
</tr>
<tr>
<td>Litteracy (percent)</td>
<td>87</td>
</tr>
<tr>
<td>Gross Domestic Product (GDP)</td>
<td>20.9</td>
</tr>
<tr>
<td>Composition by Sector (percent)</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>6</td>
</tr>
<tr>
<td>Industry</td>
<td>28</td>
</tr>
<tr>
<td>Services</td>
<td>66</td>
</tr>
<tr>
<td>Per Capita (US$)</td>
<td>5,000</td>
</tr>
<tr>
<td>Distribution of Workforce (percent)</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>7.4</td>
</tr>
<tr>
<td>Industry</td>
<td>11.4</td>
</tr>
<tr>
<td>Commerce</td>
<td>10.5</td>
</tr>
<tr>
<td>Construction</td>
<td>10</td>
</tr>
<tr>
<td>Transport and Communication</td>
<td>8.7</td>
</tr>
<tr>
<td>Other Services</td>
<td>52</td>
</tr>
</tbody>
</table>

Table 1. Socioeconomic Profile of Study Area


\textsuperscript{16} Ibid.

\textsuperscript{17} Ibid.

\textsuperscript{18} Ibid.

\textsuperscript{19} Ibid.
II.2 WATER SECTOR CHARACTERISTICS

The characteristics of the water sector in the study area is explored, in terms of available present water resources, present demands and projections for the future, as well as a brief presentation of current management of the water sector in Jordan.

II.2.1 Water Resources

Water demands in Jordan are met mainly by three resources, groundwater, surface water and reuse of treated wastewater. Table 2 shows that the contribution of treated wastewater resources is considered minor in the overall water resources budget, where groundwater and surface water resources are used in almost the same proportions.

<table>
<thead>
<tr>
<th>Water Resource</th>
<th>Water Use (in millions m$^3$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater Resources</td>
<td>582</td>
</tr>
<tr>
<td>Surface Water Resources</td>
<td>415</td>
</tr>
<tr>
<td>Treated Wastewater</td>
<td>59</td>
</tr>
</tbody>
</table>

Table 2. Water Resources Budget

Source: Committee on Sustainable Water Supplies for the Middle East. 1999. Water for the Future-The West Bank and Gaza Strip, Israel, and Jordan.

Furthermore, most of Jordan’s surface water resources, such as the Jordan River and Yarmouk River, is shared with its neighboring countries leading to water conflicts in the region$^{20}$. However, the peace treaty, in 1994, between Jordan and Israel, as well as the ‘peace pipelines’ between Jordan and Turkey will add further water supply in the area$^{21}$. Other choices for increasing water resources within Jordan are limited to seawater desalination, use of brackish water and increased treated wastewater reuse$^{22}$. However, a major limitation is the high costs of these options. Furthermore, the Jordanian groundwater resources are basically all exploited and in some cases the sustainable yields have been exceeded$^{23}$. Finally, on a per capita basis, available water resources are falling as a result of population growth. They are projected to fall from the current rate of about 240 cubic meter per capita annually to 90 m$^3$/cap/annum by 2025$^{24}$.

II.2.2 Water Use and Future Demands

A sectoral demand analysis is appropriate, to give an idea on how water resources are allocated among sectors. From the data shown below in table 3 on the water use per sector (domestic, agricultural, and industrial) and by water source (groundwater, surface water, and treated wastewater), it can be seen that water is misallocated. The agriculture is the principal user of water, accounting for 72 percent of water use, although it plays a relatively small economic role in the area, contributing by 6 percent to the GDP$^{25}$. This leads to the conclusion that improvements in irrigation efficiency, increased crop productivity, changes in the type of crops grown, and continued growth of wastewater and brackish water irrigation are all clearly required to reduce the freshwater used in agriculture insofar as needed for the growth of other economic

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$^{22}$ Ibid.


$^{25}$ Committee on Sustainable Water Supplies for the Middle East. 1999. Water for the Future-The West Bank and Gaza Strip, Israel, and Jordan.
sectors and improved living standards and the natural environment\textsuperscript{26}. Worth pointing out also, is the urgent need for decreasing use of groundwater resources and increasing use of wastewater. Appendix B shows projected future water demand of various sectors, where it is estimated to increase.

<table>
<thead>
<tr>
<th>Type of Use</th>
<th>Water Source (in million m\textsuperscript{3}/yr, except per capita use in m\textsuperscript{3}/yr)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>Groundwater</td>
<td>208</td>
</tr>
<tr>
<td></td>
<td>Surface Water</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Wastewater</td>
<td>0</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>241</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Groundwater</td>
<td>331</td>
</tr>
<tr>
<td></td>
<td>Surface Water</td>
<td>382</td>
</tr>
<tr>
<td></td>
<td>Wastewater</td>
<td>59</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>772</td>
</tr>
<tr>
<td>Industry</td>
<td>Groundwater</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Surface Water</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Wastewater</td>
<td>0</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>Total Water Use</td>
<td>Groundwater</td>
<td>582</td>
</tr>
<tr>
<td></td>
<td>Surface Water</td>
<td>415</td>
</tr>
<tr>
<td></td>
<td>Wastewater</td>
<td>59</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,056</td>
</tr>
<tr>
<td>Gross Water Use</td>
<td></td>
<td>244</td>
</tr>
<tr>
<td>Per Capita</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Sectoral Water Use.

Source: Committee on Sustainable Water Supplies for the Middle East. 1999. Water for the Future-The West Bank and Gaza Strip, Israel, and Jordan.

\textbf{II.2.3 Water Quality Issues}

Deterioration of water quality have severe and negative effects on human health, physical and chemical parameters of the environment and biodiversity\textsuperscript{27}. Furthermore, it also affect quantities of the already scarce water resources and hence increasing the gap in the imbalance between water supplies and demands\textsuperscript{28}. In some cases in Jordan, water supplies are becoming unusable, such as in the Dhuleil area\textsuperscript{29}. While in other cases aquatic ecosystems are disappearing, as in the Azraq Oasis, where habitat loss is obvious, and risk for desalinisation of freshwater aquifers exist\textsuperscript{30}. Therefore, protecting existing water resources from further degradation is of critical importance.

Generally, the quality of water resources is affected by several factors. These include human activities like disposal of solid and liquid wastes of urban and industrial areas, usage of biocides and fertilisers in agriculture, and return flows to surface and groundwater resources from irrigation water, as well as overexploitation of

\begin{itemize}
\item \textsuperscript{26} Committee on Sustainable Water Supplies for the Middle East. 1999. Water for the Future-The West Bank and Gaza Strip, Israel, and Jordan.
\item \textsuperscript{28} Ibid.
\item \textsuperscript{30} Ibid.
\end{itemize}
groundwater resources\textsuperscript{31}. Table 4 shows the major pollution producers, the affected environmental element and the affected group in Jordan.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Affected Env. Element</strong></td>
<td>Surface Water &amp; Ground Water</td>
<td>Ground Water</td>
<td>Surface Water &amp; Ground Water</td>
<td>Ground Water &amp; Soil</td>
<td>Ground Water</td>
<td>Surface Water &amp; Ground Water</td>
<td>Ground Water</td>
<td>Ground Water</td>
</tr>
</tbody>
</table>

Table 4. Water Pollution in Study Area (Major Producers, Affected Environmental Elements and Affected Group) Source: Salameh, Elias and Bannayan, Helen. 1993. Water resources of Jordan - Present Status and Future Potentials

\textbf{II.2.4 Water Sector Management}

The main governmental organisations in the water sector are the Ministry of Water and Irrigation (MWI) and Water Authority of Jordan (WAJ). These agencies are responsible for the planning of water resources, developing the potential water resources in the area, increasing their capacity and improving their quality, protecting them from pollution, supervising them and administering their affairs and putting forth programs and plans to meet future water needs\textsuperscript{32}. Other governmental agencies concerned with public health and environmental-water related issues also have supervisory roles, such as the Ministry of Health and Ministry of Municipal, Rural and Environment Affairs and Ministry of Planning\textsuperscript{33}.

Due to the fact that the water situation in Jordan is critical, and that it requires sophisticated and imperative management of water resources, as well as careful water administration, the government sought the assistance of the World Bank in conducting an impartial assessment and appraisal of the water sector\textsuperscript{34}. The weaknesses were diagnosed, and a set of measures were prescribed for sector recovery\textsuperscript{35}.

Furthermore, concrete steps has been taken towards sector recovery by the Ministry of Water and Irrigation. A water strategy has been formulated, and a water utility policy has been adopted\textsuperscript{36}. The strategy adopted stresses the need for improved resource management with particular emphasis being placed on the sustainability of present and future uses. Special care is given to protection against pollution, quality degradation and depletion of resources\textsuperscript{37}.

\textsuperscript{31} Salameh, Elias and Bannayan, Helen. 1993. Water resources of Jordan - Present Status and Future Potentials.
\textsuperscript{33} Ibid.
\textsuperscript{35} Ibid.
\textsuperscript{36} Ibid.
\textsuperscript{37} Ibid.
Additionally, a map for the future was charted\textsuperscript{38}, where water supply and demand tables were concluded to cover the period ending 2020, and the water deficits in future years were determined (appendix B and C) showing an increase in water deficits in the near future. The deficits are to be addressed through a dual approach of supply management and demand management\textsuperscript{39}. A water tariff structure has also been introduced and made effective as of October 1, 1997, and an project investment plan has been formulated to cover the period until the year 2010\textsuperscript{40}. Appendix D, which is the table of contents in the water sector investment plan 1997-2011, represents a summary of the projects identified as having potential to relieve Jordan’s water problems. However, most of these projects are awaiting funding.

**II.3 Problem Description**

Finally, after presenting, in brief, major characteristics of the study area and its water sector, the problem could be described as follows. The major challenges Jordan faces today, is the imbalance between Jordan’s water resources and water demands\textsuperscript{41}. On a per capita basis, Jordan has one of the lowest levels of annual per capita water use in the world, around 244 m\textsuperscript{3}/cap/yr. As a rule thumb, hydrologists designate water-stressed countries as those with annual supplies of 1000-2000 cubic meters per person\textsuperscript{42}. When the figure drops below 1000 cubic meters, nations are considered water-scarce - that is, lack of water becomes a severe constraint on food production, economic development, and protection of natural systems\textsuperscript{43}.

Water resources in Jordan depend mainly on precipitation within the country which makes it vulnerable to the impacts of potential future climate change. This is, however, not explored in this study. Furthermore, problems with freshwater quality and availability have multiplied and changed in response to growing population and economic activity over the past several decades\textsuperscript{44}. Moreover, misallocation of water resources among sectors is obvious (Table 3). Water shortage in Jordan is further exacerbated by the complexity of hydropolitics in the region, since it shares most of its surface water resources with neighboring countries, whose control has partially deprived Jordan of its fair share of water\textsuperscript{45}.

All of the above mentioned reasons are leading to a chronic and worsening imbalance between water supply and demand. In order to sustain the needs of the growing population and economic activity, highland aquifers are being overdrawn resulting in lowered water tables and declining water quality\textsuperscript{46}.

\textsuperscript{39} Ibid.
\textsuperscript{40} Ibid.
\textsuperscript{41} Salameh, Elias and Bannayan, Helen. 1993. *Water resources of Jordan - Present Status and Future Potentials*.
\textsuperscript{43} Ibid.
\textsuperscript{44} Salameh, Elias and Bannayan, Helen. 1993. *Water resources of Jordan - Present Status and Future Potentials*.
\textsuperscript{45} Ibid
\textsuperscript{46} Ibid
In conclusion, present trends cannot continue. Present consumption is already met by overexploitation of groundwater resources in some areas. Also, further development of surface water resources is not only costly but has in some cases political implications since they are mostly shared with other neighbouring countries\textsuperscript{47}. This unsustainable and vicious cycle of overdrawing highland aquifers need to be broken and a multi-disciplinary and cross-sectoral approach designed to reduce demand through conservation, efficiency and better management.

\textsuperscript{47} Salameh, Elias and Bannayan, Helen. 1993. Water resources of Jordan - Present Status and Future Potentials
SECTION III
UNDERSTANDING THE DYNAMICS OF WATER SCARCITY

This section examines the causal relationships that underlie threats caused by increasing water scarcity. It does this with the aid of qualitative mental models of driving forces. The purpose of the models is to identify the human values, consumptive behaviours, growth factors, technological and economical factors, as well as institutional structures, within the study area, that result in water scarcity, and to explain systematically how they interact. External factors, such as environmental conditions and regional politics, are not included in the modelling.

III.1 FRAMING THE PROBLEM

In general, the problem of scarce natural resources could be framed as shown in Fig.4. There are, of course, causal realtionships, circular pathways and feedback mechanisms, that are not shown in this figure. These will be explored further on.

Sustainable socioeconomic development requires natural resources, in both quantitative and qualitative dimensions. However, in order to achieve long-term sustainable socioeconomic development, there has to be a balance between supplies and demands of these natural resources. Extraction of resources should not exceed the regeneration rate. In addition, consideration should be given to the fact that some natural resources are non-renewable.

![Diagram of Natural Resource Dynamics]

Furthermore, the balance between supplies and demands is affected by several factors interacting with each other. These could be natural factors, such as climate change factors, or human-related factors. Figure 4 only shows the human-related factors, yet,

49 Ibid.
it has to be highlighted that there is a mutual impact between natural factors and human-related factors. For example, emissions caused by human activities have proven to induce further climate change, and drought situations have severe impacts on the supply-demand balance.

Moreover, imbalances between supplies and demands of natural resources lead to environmental destruction in three overlapping ways - contamination (pollution), eco-simplification (lost natural complexity) and natural resource depletion. All arise as a result of human activities and exert an impact on socioeconomic development eventually. The impact it has on socioeconomic development varies a lot, depending on the initial condition of an area. In developing countries, people are initially living in poor conditions, in terms of finance and, in some cases, in terms of ecological poverty. Further environmental destruction does not improve the situation. On the contrary, the problem will expand. In developed countries, people are wealthier, at least in terms of financial resources. They are not as vulnerable for further environmental destruction as developing countries are, since they have the means to avert crisis, in the short-term at least, as well as maintain further socioeconomic development. However, on a per capita basis, materialistic affluence is common among wealthy people of all countries, where they consume far more natural resources than people in poor countries. This leads to further worsening in the supply-demand balance. Finally, this worsening imbalance could only be shifted into the right direction by effective and preventive management of natural resources.

In order to really comprehend the basic frame of the problem as shown in figure 4, it has to be modified for the problem this thesis is studying, which is increasing water scarcity in Jordan. Figure 5 is a simple mental model showing the causal relationship between the different aspects of the problem. Socioeconomic development or human activities requires water for different purposes. However, in Jordan, the immediate cause of increasing water scarcity is that water extraction exceeds the rate of water regeneration. This is leading to declining water quantities directly and indirectly through the pollution these activities cause that deteriorate water quality below the

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51 Ibid.
53 Ibid.
54 Ibid.
limits for usage\textsuperscript{56}. Eventually, depletion of water resources and other water-related ecosystems and their services will have severe impacts on socioeconomic development\textsuperscript{57}. Water resources will not be able to meet the demands from the various sectors (agricultural, domestic and industrial). This is already apparent in Jordan, where there are several overexploited water resources and others with bad quality\textsuperscript{58}.

III.2 IDENTIFICATION OF DRIVING FORCES AND CAUSAL RELATIONSHIPS

By combining knowledge about human values, consumptive behaviours, growth, technological, economical and political factors, excluding environmental factors, a list of key driving forces and a model of their interactions could be constructed. The model should be constructed in such a way that it is transferable and applicable in other areas suffering from water shortage\textsuperscript{59}. There are a number of factors or variables identified as key driving forces in models constructed to explain causes of environmental destruction in the world\textsuperscript{60}. These could be applied to problems in water resource management at a national level. Each factor is linked in a particular way to one of the other variables and provide a partial explanation for increasing water scarcity. The model illustrated in figure 5 is used as a basic model, since it frames the problem, on which the driving forces will be added to. Addition of driving forces to the basic model is illustrated in figure 6. The mental model illustrated in the figure gives a complete picture of how these driving forces interact using circular pathways and feedback mechanisms, and therefore, it is advised by the author to follow the circular pathways while reading their explanations in the text to follow. The following key driving forces in this study have been carefully selected after a literature survey on root causes for environmental destruction in general and on determinants for water use in the various sectors in the study area.

\centering
\includegraphics[width=0.5\textwidth]{figure5.png}

\caption{Causal Loop of the Interactions between Selected Driving Forces}

\textsuperscript{56} Salameh, Elias and Bannayan, Helen. 1993. \textit{Water resources of Jordan - Present Status and Future Potentials}
\textsuperscript{57} Ibid.
\textsuperscript{58} Ibid.
\textsuperscript{59} Lamont C. Hempel, 1996. \textit{Environmental Governance - The Global Challenge.}
\textsuperscript{60} Ibid.
**Human Population Growth**

Of all the driving forces resulting in environmental destruction, rapid population growth is regarded by most environmental writers to be the most powerful. It is directly proportional to the amount of water extracted, leading to overexploitation of water resources and other natural resources related to water systems, to meet the growing demands. In Jordan, the annual growth rate is 3.6%. Furthermore, population growth creates demand for new technology to expand the carrying capacity to sustain the growing population. However, if population growth exceeds the carrying capacity of an area, there will not be sufficient resources to sustain the population, which will eventually lead to a crash in the system.

**Technological Advance**

Technology advances have direct and indirect capacities of both salvation and ruin on the environment. Advance in technology determines how much expansion of the carrying capacity is possible. It is considered to be the most unpredictable variable affecting future environmental quality. Technology’s impact on the problem is hard to characterise. For example, pumping technology allows for increasing water supplies by reaching out to deep groundwater resources. However, there is a risk for overexploiting these resources. There are many examples of technology advances that have been an advantage in certain cases but disadvantage in others. Yet, it could be stated that advances in technology exert an impact, positively and negatively, on quantities of water extracted (water-saving technology), supplies of water (pumping technology) and the quality of it (wastewater treatment facilities).

A common argument with regards to the impacts of technology on environment is that it is not technology itself that exert the impact on environment, it is in which manners the technology is used that affect the environment. This shows the connection between human values and choices of technology. Green values, recognising environmental concerns in selection of options, promote for adoption of green technology saving water and improving quality. For example, the reduction in Israeli water use of more than 200 millions cubic meter per annum between 1985 and 1993 was accomplished almost entirely in the agricultural sector through the use of improved irrigation methods and water delivery systems. Other common values does not take environmental concerns into account. This leads to less sustainable choices of technology that might cause more damage than good.

In Jordan, poor technology in all sectors leading to inefficiency in water use is considered a huge problem. This is apparent due to the high water demands the sectors have, but that does not meet their contribution to economic growth. For

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62 Ibid.
67 Ibid.
68 Ibid.
70 Committee on Sustainable Water Supplies for the Middle East. 1999. *Water for the Future - The West Bank and Gaza Strip, Israel, and Jordan*.
example, agriculture accounts for 72 percent of the water used, but only 6 percent of the GDP, and 7 percent of the workforce\textsuperscript{71}. Water-saving technologies are required in all sectors, as well as improved wastewater treatment. In addition, average water losses, unaccounted for in the distribution network reaches up to 50 percent\textsuperscript{72}. For the sake of comparison, in Israel, the average 1990 water loss in the largest municipalities was 3 percent\textsuperscript{73}. Therefore, maintenance of pipe and sewage systems are necessary. Furthermore, population growth and technology are mutual factors affecting each other. Advances in technology serve both as potent stimuli (medicine leading to reductions in mortality) and indirect responses to population growth\textsuperscript{74}. Nevertheless, advances in technology requires resources, in terms of financial and natural resources\textsuperscript{75}. An imbalance in supplies and demands will affect technology through the depletion of water resources required in industries, leading to losses in productivity and financial resources.

Poverty and Affluence

Over one billion individuals, living in poverty are devouring habitat and natural resources in their search for food, water, energy and other necessities of life\textsuperscript{76}. Therefore, poverty is a major factor in the unsustainable fashion of resource extraction among the poor. Moreover, a materialistic affluent lifestyle, encourages environmental destruction through overconsumption and through lack of concern for natural resource depletion\textsuperscript{77}. However, both poverty and affluence could exert a positive impact on the system’s behaviour. Poverty and population growth are related, where absolute poverty would lead to higher mortality rates and a decrease in the number of resource consuming humans. In addition, affluence does not necessarily have to negatively affect the system’s behaviour. If materialistic affluence could be greened, where wealth would be devoted to protect and enhance the environment. This could be achieved through a change in common consumptive values and attitudes.

While visiting Jordan, the huge gap between poor and rich in the country was very clear and obvious. There are areas with millions of dollars worth houses and areas with people living in very poor conditions, with hardly enough food and water for the day. Trends of poverty and affluence leading to overconsumption of water resources and deteriorating water quality were apparent. Lack of financial resources is apparent when reading the Program for Water Sector Investment 1997-2011, written by the Ministry of Water and Irrigation in Jordan. Most projects for decreasing demands, augmenting supplies and maintaining water quality are awaiting funding\textsuperscript{78}. Unnecessary consumption of water resources was also noticed in wealthy households, where water was used for gardening, washing cars and so on. Although, wealthy households could afford buying water-saving technology to save water consumption in gardening, washing etc., it is hardly used\textsuperscript{79}. The same implies for other sectors too.

\textsuperscript{71} Committee on Sustainable Water Supplies for the Middle East. 1999. Water for the Future-The West Bank and Gaza Strip, Israel, and Jordan.
\textsuperscript{72} Ibid.
\textsuperscript{73} Ibid.
\textsuperscript{74} Lamont C. Hempel, 1996. Environmental Governance - The Global Challenge.
\textsuperscript{75} Ibid.
\textsuperscript{76} Lamont C. Hempel, 1996. Environmental Governance - The Global Challenge.
\textsuperscript{77} Ibid.
Market Operation

A driving force, of economical nature, is the existence of markets and their operation. Most economists argue that a free market is the best way to achieve efficiency in resource allocation as well as reduce or recover negative residuals\textsuperscript{80}. They argue that, in order to bring marginal demand and marginal supply into a more harmonious alignment with ecological imperatives, internalisation of costs of environmental damage in purchase price of consumer goods and services are required\textsuperscript{81}. This will lead to voluntary reduction actions among the different sectors, in terms of adopting water-saving technologies and decreasing demands. However, market failures and failures to have markets are very common and are often explained to be the results of absence of assigned property rights, a failure to recognise economic value in vital ecological resources and services, government intervention or even lack of government regulations\textsuperscript{82}.

In Jordan, current pricing policies emphasise affordability by setting prices low enough so that water bills remain low\textsuperscript{83}. Water policies are rarely designed as part of demand-management programs and rarely result in prices that reflect the true value of water\textsuperscript{84}. Innovating proper pricing policies for water will force the various sectors to adopt greener technologies and behaviour leading to reductions in water demands as in the case of Israel. In 1987, reductions in Israeli water use from 1,987 million m\textsuperscript{3}/yr to 1,420 million m\textsuperscript{3}/yr in 1991 - with no net loss in agricultural production or economic growth - were achieved\textsuperscript{85}. This example indicates what can be accomplished in the way of demand moderation through combining green values, in terms of efficient pricing policies and stringent regulations, and green technologies.

Human Values

Moreover, governance of environmental problems is also a driving force. Many environmentalists explain environmental destruction to be a result of failures in human governance, where political institutions and policies fail to demonstrate ecological wisdom and foresight\textsuperscript{86}. However, in this study, failure in governance is treated as a derivative of human values and beliefs influencing attitudes toward nature.

The basic values that humans act upon toward nature are anthropocentrism and contempocentrism\textsuperscript{87}. Beliefs about ethnicity, race and religion play an important role too\textsuperscript{88}. However, they are difficult to assess and are therefore not included in this study. Nevertheless, human values discussed in the study are derivatives of these beliefs.

Anthropocentrism refers to the preoccupation with human progress and domination at the expense of other species\textsuperscript{89}. It encourages activities where there are immediate benefits to human beings, even if these activities cause pollution or resource depletion.

\textsuperscript{80} Lamont C. Hempel, 1996. Environmental Governance - The Global Challenge.
\textsuperscript{81} Ibid.
\textsuperscript{82} Ibid.
\textsuperscript{83} Committee on Sustainable Water Supplies for the Middle East. 1999. Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan.
\textsuperscript{84} Ibid.
\textsuperscript{85} Ibid.
\textsuperscript{86} Ibid.
\textsuperscript{87} Lamont C. Hempel, 1996. Environmental Governance - The Global Challenge.
\textsuperscript{88} Ibid.
\textsuperscript{89} Ibid.
However, anthropocentric views are not necessarily incompatible with the goals of environmental protection. Contempocentrism, on the other hand, involves the human preoccupation with the present, often at the expense of future generations - both human and nonhuman\textsuperscript{90}. Both account for a wide range of activities causing environmental destruction. The values are key driving forces behind the system in Jordan, where the Azraq Oasis is an example of how these non-green values have affected the quantities and quality of water leading to loss of habitat\textsuperscript{91}. Further overexploitation will lead to desalination making the water unusable for both present and future generations\textsuperscript{92}. However, these could also shift the system's behaviour into a more positive track, if it is clear that a healthy environment serves human interests\textsuperscript{93}, if they are green values.

In this study, green values refer to values incorporating environmental and intergenerational equity concerns, that lead to voluntary action among the different actors at different levels to reduce demands and protect quality. The same values also lead to stringent regulations and policies driving the system into reducing demands and protecting quality too. The result of adopting such values affect choices of technology, affluent behaviour, population growth and efficiency of markets either through voluntary action or sound government intervention.

Finally, the interactions between the selected driving forces are shown in figure 6, using circular pathways and feedback mechanisms. The author realises that the causal loop diagram could be viewed as complex and hard to follow. However, the text written explores each driving force, will hopefully simplify the following and comprehension of the circular pathways and feedback mechanisms in the causal loop diagram.

### III.3 CONCLUSIONS

To summarise and conclude the results of the system analysis conducted, it could be stated that a satisfactory perspective into the system and how it operates is achieved. Key driving forces are identified as well as their causal relationship. It is difficult to rank each factor in terms of its past importance, present power, or future potentials. However, these driving forces represent the fundamental belief structures that influence most human attitudes toward nature, the triggering factors by which human values are extended or expanded, and indexes of basic human needs and wants. Hempel categorises driving forces into core values, amplifiers, indexes and incentive structures. In the model of this study, human values are thought of as core values since they influence most human attitudes toward nature. Population growth and technology advance serve as amplifiers in the model extending or expanding human values\textsuperscript{94}, while poverty and affluence serve as indexes of human consumption patterns. Finally, operation of markets represent incentive structure in which consumption takes place.

Furthermore, a more sophisticated approach to modelling the dynamics of management of scarce water resources in Jordan is to expand the boundaries of the system and add new driving forces, such as environmental and regional hydropolitical conditions. In

\textsuperscript{90} Lamont C. Hempel, 1996. \textit{Environmental Governance - The Global Challenge.}

\textsuperscript{91} Committee on Sustainable Water Supplies for the Middle East. 1999. \textit{Water for the Future-The West Bank and Gaza Strip, Israel, and Jordan.}

\textsuperscript{92} Ibid.

\textsuperscript{93} Lamont C. Hempel, 1996. \textit{Environmental Governance - The Global Challenge}

\textsuperscript{94} Ibid.
addition, a quantitative simulation of the developed mental model, using modelling software programmes, would further simplify observation and understanding of the system's dynamics and behaviour. It would result in graphs showing behaviour patterns of the different driving forces. This will allow experimentation and elaboration of different scenarios. Finally, a common question arising around modelling approaches, is how applicable or transferable is the model to other areas. In this case, the model is considered highly applicable and transferable, since all the selected driving forces arise more or less in all countries. Therefore, it could be used to explore the dynamics of water resource management in developed countries and other developing countries. The main thing is identified, and that is the interactions between the driving forces.
SECTION IV
CONCLUDING DISCUSSION

To conclude this study, the author refers to what Peter Allen wrote (section I.1): "Knowledge only becomes wisdom when we can see how any system must change". The earlier sections explored the present system's characteristics, behaviour and operation and its future consequences. In the concluding discussion, the author leads a discussion on how the system must change. The discussion is based upon the results of the system analysis conducted in section III.

Increasing water scarcity in Jordan is characterised by its dynamic complexity and severe impacts on human health and socioeconomic development and other water-related ecosystems in the study area. Therefore, 'green' changes in the behaviour patterns of the identified driving forces is considered necessary to achieve a positive change in the behaviour of the whole system. A combination of approaches, strategies and measures are found to be required to avert a water crisis in Jordan and sustainably improve the quality of life for both humans and non-humans, present generations and future generations. A combination of approaches including green technologies, population stabilisation measures, design of efficient markets to allocate water resources, full cost pricing, restrictions on consumption of both water resources and materials requiring water, elimination of poverty, and adoption of ecologically based values and lifestyles. However, one of the main driving forces, that is often neglected, is education aiming at ecologically-based learning, starting from a young age. The hierarchal order of these measures could be discussed. Implicit in such changes is the need to redesign and strengthen political institutions and policies and adopt a dynamic and comprehensive water strategy attacking the root causes of increasing scarcity.

The strategy adopted should be able to convert the unbalanced equation where poor water resources, deteriorating water quality, limited financial resources and rapidly expanding human resources are resulting into limited socioeconomic development. The author tends to agree with Salameh and Bannayan, Water Resources of Jordan - Present Status and Future Potentials. They argue that it would be wiser to invest these resources in the industrial sector rather than the agricultural sector. More human and financial resources invested in the industrial sector consisting of low water-consuming type of industries, will lead to improved national economy. While investment of human and financial resources in the agricultural sector requires a relatively high quantity and quality of water resources and low economic yield.

Based on the model constructed in figure 6, economic efficient strategies based on green values aims for improving economy. This means that more financial resources could be allocated to minimising water losses in distribution network systems, improving wastewater treatment plants and conservation measures among all sectors in general. These actions will give a more direct and positive effect on the system's behaviour, where water demands will decrease, increasing water resources. Nevertheless, more financial resources could then be allocated to improve the living standards of the people and promote ecologically-based learning and problem

95 Lamont C. Hempe1, 1996. Environmental Governance - The Global Challenge
96 Ibid.
awareness among the actors at the local level. This will further drive the system into a sustainable track, since green values will further drive the system positively by stabilising population growth.

![Causal Loop of Economic-Efficient Water Management Strategy](image)

**Figure 6. Causal Loop of Economic-Efficient Water Management Strategy**

The strategy described by the author is a water management strategy based on economic efficiency and driven by green values with socioeconomic and political consideration and is illustrated in figure 7. The causal loop is a derivative of the causal loop in figure 6. The main driving force behind the success of such a strategy is green values, including voluntary action among actors based on environmental and problem awareness, as well as sound government intervention through stringent regulations and economic incentives. Only by that, the system could behave as described.

In conclusion, any strategy adopted for sustainable management of water resources, and natural resources in general, should be based on understanding the root causes of the problem and their interdependence and interactivity, rather than reductionism. This maximises the involvement and participation of actors; consumers, policy-makers, investors, etc. This is a crucial prerequisite that will drive the system into behaving in a more sustainable fashion, by reducing demands and quality deterioration and allowing for further socioeconomic development for both present and future generations without leading other species into extinction.
REFERENCES


BIBLIOGRAPHY


APPENDIX A

PRACTICE OF SYSTEM THINKING

This appendix aims to introduce system thinking and its practice. All information on system thinking is gathered from the following references: Haraldsson, Hördur. 1999. *System Thinking and Mental Modelling of Complex Problems – understand and Learn to Use System Theories in Everyday Work*, and Hannon, Bruce and Ruth Matthias. 1997. *Modeling Dynamic Biological Systems*. These references give a very good introduction and view on the practice of system thinking.

Practice of System Analysis

1. *Statement of purpose and goals* - It is important to formulate the purpose of the study and concrete goals and strategies to achieve the objectives.

2. *Definition of system boundaries* - When defining system boundaries, one has to keep in mind that the ability to grasp the total dynamic of the problem weakens in proportion with the number of variables added, and very often generalisation is the key to understanding complex systems.

3. *Identification of main driving forces behind the system* - The next step is to list all key variables relevant for the study. There are two types of variables in a system, *endogenous* and *exogenous*. Endogenous variables are the elements that are interactive within the system, influencing all the other variables. Exogenous variables are factors that are not enclosed by the system boundary but influence the system. They are not influenced by variables enclosed within the system.

4. *Development of hypothesis and Drawing causal loop diagrams* - After stating goals and defining system boundaries, a hypothesis should be developed. The next step is to draw Causal Loop Diagrams (CLD). The CLD approach is a powerful tool to structure and conceptualise the problem or system using circular connections, since systems always behave in a circular organisation forming feedback loops. The effects of the last element influence the input of the first element, which results in a self-regulation of the whole system. Summarised explanation of the causal loop concept (adopted from Roberts *et al.*1983) is illustrated in table.

5. *Creation of reference behaviour patterns* - A reference behaviour pattern is a graphical representation of the behaviour over time of one or more variables in the system analysed. It is used to chart the understanding of the system and is the step prior to quantitatively simulation of the developed mental models, using modelling software programmes, such as STELLA.
APPENDIX B
PROJECTED WATER DEMAND OF VARIOUS SECTORS IN STUDY AREA

APPENDIX C
TOTAL DEMAND, AVAILABLE SOURCES AND DEFICIT IN MCM

APPENDIX D
LIST OF PROJECTS ADOPTED BY THE INVESTMENT PLAN 1997-2011

Water Projects
Ongoing Rehabilitation - Various Cities
Disi Amman Water Conveyor
Future Projects to be Defined (Groundwater Reduction Program)
Municipal Water Networks Rehabilitation (Several Cities)
Amman Water and Wastewater Management Contract
Amman Municipal Water Network Restructuring Phase I
Mujib Weir Conveyor and Southern Ghors Infrastructure
Desalination Works - Pilot Project
Deep Groundwater Investigations
Small Dams (Ibn Hamad, Karak, Meddein)
Water Harvesting, Badia Region
Wadi Araba Development Project
Wadi Mousa Supply
Community Infrastructure Project
Sakeb Municipality
Lajoon Wells
Wadi Zarqa Ma'in, Zara Springs Project
Feedan Dam
Dead Sea Infrastructure
Desalination at Aqaba
Jafar and Shedia
Miscellaneous Small Projects - Network Expansion
Miscellaneous Small Projects - Supply Expansion
Dier Alla - Zai Amman II
Amman Municipal Water Network Rehabilitation II
Jordan Rift Valley Improvement Project
Rehabilitation of Southern Ghors Irrigation Stage I

Wastewater Projects
Amman/Zarqa Wastewater Project
Ain Ghazal Pre-treatment Plant and Conveyor
South Amman Wastewater Project Phase I
Jordan Valley Sanitation - 3 Plants
Irbid Stage I
Irbid Stage II
Future Projects to be Defined
Miscellaneous Small Projects
Sakeb Wastewater System
Wadi Mousa Wastewater Project
Jordan Valley Sanitation - Septic Disposal
Community Infrastructure Wastewater Project
Ramtha Wastewater Project
Aqaba Wastewater Infrastructure
Dead Sea Wastewater Infrastructure

Peace Projects
Regulation of the Yarmouk River
Desalination Conveyor to Urban Jordan (50 + 10 MCM)
Wastewater Treatment Plant
Storage on Jordan River and Side Wadis