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The Soft-Path Approach for Sustainable Water Management: An Analysis of Its Suitability in Abu Dhabi

Mariam Ahmed Sultan Al Suwaidi

United Arab Emirates University

College of Humanities and Social Sciences

Department of Political Science

THE SOFT-PATH APPROACH FOR SUSTAINABLE WATER MANAGEMENT: AN ANALYSIS OF ITS SUITABILITY IN ABU DHABI

Mariam Ahmed Sultan Al Suwaidi

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Governance and Public Policy

Under the Supervision of Professor Samiul Hasan

April 2018

Declaration of Original Work

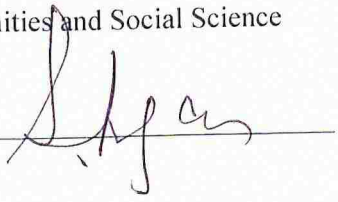
I, Mariam Ahmed Sultan Al Suwaidi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*The Soft-Path Approach for Sustainable Water Management: An Analysis of its Suitability in Abu Dhabi*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Samiul Hasan, in the College of Humanities and Social Sciences at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

Student's Signature: _____ Date: 15-Oct-18

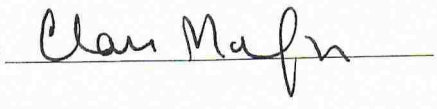
Approval of the Master Thesis

The Master Thesis is approved by the following Examining Committee Members:

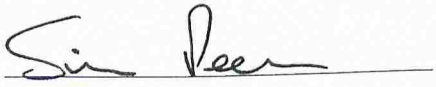
1) Advisor (Committee Chair): Dr. Samiul Hasan
   Title: Associate Professor
   Department of Political Science
   College of Humanities and Social Science

   Signature  Date 18.4.18

2) Member: Dr. Clara Morgan
   Title: Assistant Professor
   Department of Political Science
   College of Humanities and Social Science

   Signature  Date 18.4.18

3) Member (External Examiner): Dr. Simon Pearson
   Title: Senior Advisor-Priority Programs and Environment Agency- Abu Dhabi

   Signature  Date 18.4.18

This Master Thesis is accepted by:

Dean of the College of Humanities and Social Sciences: Professor Hassan Al Naboodah

Signature _____ Date 31 Oct 2018

Acting Dean of the College of Graduate Studies: Professor Ali Al-Marzouqi

Signature _____ Date 19/11/2018

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Declaration of Original Work

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Abstract

In Abu Dhabi, rapid population growth, exponential changes in lifestyle, steady depletion of natural resources, and increased reliance on desalinated water require stringent water regulation regime to secure a sustainable water future. The government of Abu Dhabi, in an attempt to regulate water usage, introduced or increased water tariff, in 2015, but did not achieve much success in reducing water use. The purpose of this research is to analyze a possible alternative approach to sustainable water governance in Abu Dhabi – (the 'soft-path approach'). This thesis outlines the water situation and need for sustainable water management in Abu Dhabi, discusses the theoretical basis and importance of the 'soft-path approach' in water management, and analyzes the applicability and institutional capability of the 'soft-path approach' in Abu Dhabi. The work is based on a comprehensive study of the relevant government documents, academic literature, and the evaluation of responses from several key personnel in the water sector in Abu Dhabi. The study reveals that Abu Dhabi water sector has embraced different aspects of the four principles of the 'soft-path approach' to water management. But it notes some deficiencies in the six dimensions of institutional capacity in implementing 'the soft-path' in Abu Dhabi and provides recommendations.

Keywords: Sustainability, soft-path approach, water management, institutional capacity.

Title and Abstract (in Arabic)

نهج المسار المرن لإدارة مستدامة للمياه: تحليل كفاءتها في أبوظبي

الملخص

يتطلب ازدياد النمو السكاني و التغييرات في أنماط الحياة في أبوظبي واستنفاذ الموارد الطبيعية بشكل مستمر وإزدياد الاعتماد على المياه المحلاة إلى خلق نظام لإدارة المياه لضمان مستقبل مستدام.

وقد قامت حكومة أبوظبي، في محاولة لتنظيم استخدام المياه، بزيادة تعرفة المياه في عام 2015، ولكنها لم تحقق الكثير من النجاح في التقليل من استخدامات المياه. يهدف هذا البحث إلى تحليل مسار أو نهج مختلف للحوكمة المستدامة للمياه في أبو ظبي "نهج المسار المرن". توضح هذه الرسالة الوضع الحالي للمياه والحاجة إلى الإدارة المستدامة للمياه في أبوظبي وتناقش الأسس النظرية وأهمية "نهج المسار المرن" في إدارة المياه، وتحلل قابلية التطبيق والقدرة المؤسسية لـ "نهج المسار المرن" في إمارة أبوظبي.

ويستند هذا البحث على دراسة شاملة للوثائق الحكومية ذات الصلة، والبحوث الأكاديمية، وتقييم الردود من عدد من المختصين في قطاع المياه في إمارة أبو ظبي. تكشف الدراسة أن قطاع المياه في أبو ظبي قد تضمن جوانب مختلفة من المبادئ الأربعة من "نهج المسار المرن" لإدارة المياه، ولكنه يشير إلى بعض نقاط الضعف أو التي تتطلب التحسين في "الستة أبعاد" للقدرة المؤسسية في تنفيذ "المسار المرن" في أبو ظبي، ويقدم بعض التوصيات الممكنة للتحسين والتطوير.

مفاهيم البحث الرئيسية: الاستدامة، نهج المسار المرن، ادارة المياه، القدرة المؤسسية.

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Dedication

Dedicated to my mother, who would be happy with this achievement

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List of Abbreviations

$	USD
%	Percentage
°C	Degree Celsius - Centigrade scale
AADC	Al Ain Distribution Company
ADDC	Abu Dhabi Distribution Company
ADSSC	Abu Dhabi's Sewerage and Services Company
ADWEA	Abu Dhabi Water & Electricity Authority
ADWEC	Abu Dhabi Water & Electricity Company
AED	U.A.E Currency
BP	British Petroleum
Dirhams	U.A.E Currency
DSM	Demand-Side Management
EAD	Environment Agency – Abu Dhabi
Emiratis	United Arab Emirates Nationals
ESCO	Energy Services Companies
GDP	Gross Domestic Product
HCWAS	Permanent Committee for Water and Agricultural Resources
IWS	International Water Summit
km	Kilometer
m	Metre
m^2	Meter Square
m^3	Metre Cube
MIG	Million Imperial Gallons

mm	Millimetre
MMCs	Muslim-majority Countries
OECD	Organization for Economic Co-operation and Development
ppm	Parts per Million
PPPs	Public-private Partnerships
PRS	Pearl Rating System
RSB	Regulation & Super Vision Bureau
SBAs	Separate Business Accounts
SCAD	Statistics Center-Abu Dhabi
SSM	Supply-Side Management
STEP	Strategic Tunnel Enhancement Program
STPs	Sewage Treatment Plants
TSE	Treated Sewage Effluent
U.A.E	United Arab Emirates
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPC	Abu Dhabi Urban Planning Council
USD	United State Dollar
USGS	United State Geological Survey

Chapter 1: Introduction

1.1 Problem Context

Water is the backbone of everything in life. Every single organism needs water to live. Despite 71% of the earth being covered by water, only 3% of the water is salt-free (fresh water). In addition, 70% of the fresh water is trapped in glaciers and icebergs, making it unavailable to humans (USGS, 2016). Further, due to geographical location and geological factors, water distribution across different geographic regions is not uniform. Some regions have large quantities of readily accessible fresh water, while others experience water scarcity. Further, pressure on the demand for fresh water is being exerted by the burgeoning world population and the effects of climate change. Earth's hydrologic system has been significantly altered in part by the impact of climate change and human activities (Science Learning Hub, 2009). Due to the massive exploitation of the different components of the hydrologic cycle, freshwater ecosystems are facing an increasing threat. The Arab region is among the parts of the world that have suffered significant sustainability challenges, especially related to water resources (Hefny, 2010). The United Arab Emirates (UAE), with comparatively higher economic and population growth in the region, faces a substantial water distribution problem as well.

Abu Dhabi Emirate is the largest of the seven emirates that form the UAE, covering 87% of the total area, 67,340 square kilometers (Abu Dhabi Emirate, 2017). The climate is hyper-arid, and the annual precipitation is merely 100 mm. At the same time, the rate at which groundwater is replenished is very low (less than 4% of the annual water consumption) (Mohamed, 2006).

The area is also characterized by high rates of evaporation, 2-3 m a year (Mohamed, 2006). Another challenge faced by Abu Dhabi is the absence of surface water resources on which the population can depend year-round. In essence, no renewable freshwater resources are available. While these water resources problems persist, the Emirate has also experienced an explosive increase in population as well as economic growth over recent decades (Dougherty et al., 2009). According to the Abu Dhabi Urban Planning Council (UPC)[1], the rapid economic growth of the Emirate has been accompanied by a tripling of its population in less than three decades (UPC, 2011). The average annual population growth rate currently equals 5.6% (Statistics Center Abu Dhabi, 2017, p. 114). At the same time, the projections of the Abu Dhabi Water and Electricity Company (ADWEC) indicate that water demand will increase by more than 30% by 2030 (ADWEC as cited in Chowdhury & Rajput, 2015). It is anticipated that the population will be three to five million by 2030 (UPC, 2011). Increase in the size of the population and massive changes in lifestyle are exponentially expanding the demand for water in Abu Dhabi, and which has tripled in the twelve years towards 2012 (Waterwise, 2017).

Based on the water demand and deficit forecasts by the Environment Agency for Abu Dhabi (EAD) (Appendix A), one will have a clear idea of why the current water management policy in Abu Dhabi needs improvement. The data predicts a continuous increase in demand, and in the absence of new resources for water production, the country will experience a deficit of 475 MIG (2,159.39 million m^3) on daily basis by 2030. Such a deficit is significant considering that it represents 60% of the current water consumption (Chowdhury & Rajput, 2015).

[1] In 2018, the Urban Planning Council became the Department of Municipal Affairs according to the Abu Dhabi Law No 5 of 2018

According to recent statistics (Appendix B), over the nine years 2005-2014 the supply of desalinated water in the Emirate increased from 163,217 MIG (742 million m^3) to 253,184 MIG (1,151 million m^3) (S. Pearson 2018, personal communication, 18 April). The total volume of desalinated water produced in 2015 by nine desalination plants was 274,875 MIG (about 1,249,606.48 m^3) (ADWEC, 2016).

The water ecology of the Emirate is complex, with limited availability of natural freshwater sources, the lack of rain, and salted ground water. As a result, it depends largely on desalinated seawater (Regulation and Supervision Bureau, 2016). Water for consumption in Abu Dhabi currently comes from three different sources: groundwater, desalinated seawater and recycled wastewater, with groundwater representing 61.1% (S. Pearson 2018, personal communication, 18 April). Desalination makes 33.9%, and 5.1% is treated wastewater.

As groundwater resources continue to be exploited to meet the socio-economic demands of Abu Dhabi, there is a problem with the way in which the water is being used. For example, a significant proportion of the groundwater supply continues to be channeled towards the agricultural, plantation and forestry sectors. In 2016, the annual groundwater use for agricultural purposes in Abu Dhabi equaled 442,798 MIG (2,013 million m^3) (Statistics Center Abu Dhabi, 2017). Until recently, agriculture, forestry and amenity planting have been expanding their irrigation areas without restrictions on water utilization. The concerns over water scarcity have been worsened by the demand from municipalities. For example, much of the population growth has occurred in urban areas such as Al Ain and Abu Dhabi City, causing an 8% increase in per capita consumption of water (Dougherty et al., 2009).

On the other hand, desalination plants have remained critical in the water infrastructure of Abu Dhabi. Although the desalination process ensures a continuous supply of high-quality Soft-Path water without damaging natural, freshwater resources, it has some negative impacts on the environment (Dawoud & Al-Mukka, 2012). In addition, the impact of climate change has already started affecting the sustainability of the water resources in the Emirate, with an increase in demand. For example, summer temperatures have become extreme while winters are often accompanied by changing precipitation patterns and increasing temperatures. Such changes could imply that more water will be used, even during winter, than before (Dougherty et al., 2009). Therefore, the main challenge for Abu Dhabi is how to ensure an appropriate water management system to meet future consumption demands. The Emirate needs to find a new approach, like the "soft-path" approach, to water demand management; this will be discussed in this study.

1.2 Problem Statement

The increasing population, rapid changes in lifestyle that exponentially increases demand for water, gradual depletion of natural sources of water, and a high level of dependence on desalinated water all call for water regulation in order to secure a sustainable future for Abu Dhabi. Sustainable water management is an essential part of the sustainable development at a larger scale: it aims to preserve the natural environment, the community, and economy. It means that sustainable water management has its roots in a balance between financial and social resources required to support the water system and meet competing water sector demands (Russo, Alfredo, & Fisher, 2014).

The government took a water demand approach to regulate use by reducing its generous water subsidies. In January 2015, a water tariff was introduced for citizens, and increased for expatriates. A higher tariff, including a progressive tariff above the threshold for Emiratis and expatriates, was introduced in January 2017 (Regulation and Supervision Bureau, 2017). So the questions are: Are these measures enough and what else can and must be done for sustainable water management in Abu Dhabi? In this regard, it is important to develop the objectives of the study which are directed towards finding solutions to the problem.

1.3 Objectives of the Study

There is a strategic need for understanding the current water use patterns, sources and supply of water, analyzing the current demand management measures, surveying possible integrated water demand management regimes, and suggesting possible policy measures for water regulation in the Emirate of Abu Dhabi. The major objectives of the research are therefore to:

- Analyze current and future water supply and demand in the Emirate of Abu Dhabi.
- Examine and evaluate the government's measures and their effects in regulating water demand in Abu Dhabi.
- Assess the suitability (including applicability and implementability) of the soft-path approach for sustainable water management in Abu Dhabi.

1.4 Research Questions

The following research questions will be investigated:

1. What is the current structure and possible forecast of water supply and demand in the Emirate of Abu Dhabi?
2. What measures have the Abu Dhabi government adopted to regulate water demand, with what affects? How has the revised tariff structure in Abu Dhabi affected demand and consumption of water?
3. Can and how an alternate comprehensive model of water management (the soft-path approach) be implemented in Abu Dhabi?

1.5 Methodology

A qualitative methodology is employed in the study. The primary aim of qualitative methods is the description of a subject and the relationships between the studied phenomena/objects/events. In qualitative studies, the hypothesis is usually inductive, i.e. the assumptions are based on the collected data (Creswell, 2014). The qualitative tools are exploratory and imply a free form of data collection, e.g. interviews. As a result, the qualitative approach is characterized by a high level of subjectivity. As stated by R. Whittemore, S. K. Chase and C. L. Mandle (2001), the validity of qualitative research can be estimated by the level of its dependability on other high-quality works and sources within the field of knowledge/discourse. Thus, to increase credibility of the research findings, the interview results will be analyzed by drawing on high-quality scholarly and professional evidence and supportive theoretical data. Further details on methodology including interview structure, sampling, literature review techniques, and so on are provided in Chapter 3.

1.6 Significance of the Study

Water can be conserved more efficiently using a soft-path approach (Brandes & Brooks, 2005), especially as the current approach to managing water resources by regulating demand is marred by certain inefficiencies that require solutions. While demand management has been the primary approach, the rate at which the demand for water is growing, compared to the rate of water production, is too high to guarantee sustainability. Consequently, it is critical for the stakeholders in the water sector to integrate a soft-path strategy into the current policy.

The soft-path approach has been documented as the best policy to complement the demand approach in order to reduce water usage even further (Brandes & Brooks, 2005). In a nutshell, it is based on four primary principles: treating water as a service, ecological sustainability, conserving water quantity and quality, and backcasting (Brandes & Brooks, 2005). The first principle refers to all activities aimed to the meet users' needs, as well as organizational cooperation and partnerships aimed at enhancing the service quality and efficacy. The principle of ecological sustainability implies the recognition of ecosystems as legitimate users of water and development of a supportive environment for sustainable water use. The third principle is associated with the creation of cascading water systems, i.e. utilization of wastewater as input for another use. Lastly, backcasting refers to the type of planning, which starts with defining future goals and visions and then looks backward to design necessary policies and regulations.

In Asia, China has taken the lead in transforming its water resource management by implementing large wastewater treatment programs to combat water shortages. Similarly, Australia, Japan and several states in the US (Florida, California) have successfully overcome water stress by harnessing reclaimed water, a principle within the framework of the soft-path (Leflaive, 2009). In Australia, additional measures include introducing efficient appliances in the market (washing machines that use 25 gallons of water (Leflaive, 2009). The states of California, Georgia and Texas in the US have also passed legislation in which new toilets should use no more than 1.28 gallons per flush (Christian-Smith et al., 2012). In the developing world, Namibia is a classic example of a success story where a reclaimed wastewater program serves 250,000 people with potable water (Leflaive, 2009). Abu Dhabi can borrow important lessons from jurisdictions that have applied practices that are advocated for the soft-path approach.

These examples demonstrate the application of soft-path principles in systems where water demand management is gradually being complemented by the new approach. While demand-based approaches ask the question how, water soft-path asks the question why. For example, demand management may ask how toilet flushing or irrigation can be done using less water. Conversely, the soft-path would ask why freshwater is being used to carry out these activities in the first place. This is why California and Florida have turned to reclaimed water for purposes of watering lawns and irrigation (Leflaive, 2009).

The main goal of soft-path management is to devise ways of conserving the available water sources and adopting practices that will satisfy water needs without looking for additional sources of water. Australia, with more efficient washing machines, demonstrates the application of new technologies. In addition to implementing new technologies, the water soft-path also proposes policies that overcome gaps in water resources. The approach emphasizes minimizing demand rather than increasing supply. A study in California showed that total urban water use could be reduced by 30% by applying off-the-shelf technologies that are more cost-effective than new water supply projects. The study also examined agricultural and rural water usage, and showed that total water usage in California could "decline by as much as 20% while still satisfying a growing population, maintaining a healthy agricultural sector, and supporting a vibrant economy" (Brooks & Holtz, 2009, p. 161).

By studying the suitability of the soft-path approach to water management in Abu Dhabi, it will be possible to put its benefits in context. For example, areas that are prone to environmental degradation will be protected while a long-term supply of water will be guaranteed. The essence of the study is to add to the existing body of knowledge important insights about the critical institutional elements that would facilitate a successful implementation of the soft-path approach in the Abu Dhabi Emirate.

1.7 Thesis Overview

Chapter 1: This chapter has outlined the water situation in Abu Dhabi, the need for sustainable water management, the research problem, the research questions, an introduction to the methodology, and the objectives and significance of this study. It identified the research questions and highlighted the main points to be covered by the whole research.

Chapter 2: The extensive literature review provides the theoretical foundation of water policy and management, conventional (supply-side) water management, and the soft-path approach. The chapter analyzes the factors and issues related to water management, especially in an arid/semi-arid area like Abu Dhabi, the impracticality of the supply-side approach to water management and the inappropriateness of the demand-side approach; it provides justification for, analyzes the components, and highlights the requirements of the soft-path as an alternative sustainable water management approach.

Chapter 3: This chapter covers the research methodology. It covers all the steps undertaken in collecting and analyzing data, the process and outcome of the face-to-face interviews with experts and various stakeholders from the water sector, the issues related to the application of the method, and the limitations of the study.

Chapter 4: This chapter analyzes the need for the soft-path approach by reviewing the increasingly higher volumes of water demand, current measures to manage supply and demand in Abu Dhabi, and the unsustainability of the current approaches.

In particular, Chapter 4 examines the effects of tariff reform on water demand and supply by looking at water use data before and after the introduction/raising of the tariff. The chapter is based primarily on a review of statistical data from the relevant authorities.

Chapter 5: This chapter provides analyses of the applicability and institutional capacity of the soft-path approach by reviewing the responses of interviewees from different parts of Abu Dhabi's water sector. The chapter is divided into two parts. The first section analyses the interviews in the context of the four major soft-path principles in order to evaluate the identified themes in terms of their implications for the soft-path approach. The second section analyzes the Interviewees' responses concerning eight themes that determine the institutional capacity for the soft-path approach: human resources, information resources, financial resources, political environment, policy and legal environment, community awareness, technological solutions and practical considerations. From these analyses of two parts including the first four and the institutional capacity, the gaps are identified and highlighted in chapter 6 as a part of recommendations.

Chapter 6: This is the concluding chapter in which all the information and data are consolidated to draw appropriate conclusions and make recommendations. In other words, it provides an analysis of the entire research and recommends a way forward in terms of the application of the soft-path approach in Abu Dhabi. It also suggests future research that may be conducted on this topic. That is, the purpose of this chapter is to inform policy changes and future studies.

Chapter 2: Review of Literature

2.1 Introduction

This chapter deals with the basic principles of water management as recorded in the literature. It analyzes the factors and issues related to water management outlined in the thesis overview above.

The first part of the review describes the current state of water in the world and in arid and semi-arid regions, in order to demonstrate the need for intervention in managing water resources in Abu Dhabi. The second part describes the three main approaches: supply management, demand management, and the soft-path approach. The final part defines institutional capacity, which is needed to analyze the Emirate's ability to implement the soft-path approach. Institutional capacity will be combined with the soft-path indicators to investigate the suitability of the soft-path approach.

2.2 Water Management in Arid/ Semi-Arid Regions

As many societies increasingly realize that water is no longer an unlimited resource, the myth of "superabundance" has waned (Binstock, 2010). The twenty-first century has been characterized by major shifts in water management strategies across the world (Pahl-Wostl et al., 2006). Today, water sectors aim to implement strategies that will ensure conservation and efficient use of water resources by all. Many are adopting technologies that will promote efficiency in water harvesting, distribution and use. More important are the efforts to change the attitudes of people towards water through public awareness campaigns, so that the users appreciate the value of water.

While this is the general trend, some regions are still engrossed in large projects intended to create a safer and more reliable water infrastructure (Binstock, 2010); the traditional approaches of building huge dams and pipelines for water distribution are examples of such projects (Gulbenkian Think Tank on Water and the Future of Humanity, 2013).

While the building of dams and pipelines are traditionally considered to be valuable initiatives in water conservation, they tend to be inefficient in the face of the myriad challenges to water management. According to UNESCO (2013), one of the most significant challenges, which the global community currently faces, is the threat to aquatic ecosystems and their increasing distress, due to human activities, resulting in pollution and the destruction of water catchment areas. At the same time, the increasing global population has put more pressure on the existing water resources as farming intensifies. The situation is worsened by inefficiencies in the way water resources are utilized for agricultural production (Hewitt, 2013).

Despite agriculture accounting for 70% of water withdrawals globally (Sentlinger, 2017), studies on the efficiency of water use in agriculture indicate a worrying trend. One such study evaluated how allocated water was used for food production in Colorado in terms of designated acres for irrigation, irrigation systems and cropland usage. By comparing the year 2002 (high drought period) with 2007 (control year) on the basis of these parameters, the researchers made an important observation: 63% of water allocated for irrigation was channeled towards the production of feedstock for animals. At the same time, 75% of food was grown on areas that had no irrigation (Hewitt, 2013).

Apart from the inefficiencies of water use in the agricultural sector, climate change and unsustainable groundwater abstraction are major threats to water availability, especially in arid and semi-arid regions (UNESCO, 2013). As the need for better water management strategies increases, many regions are adopting concepts, strategies and technologies that will give water efficiency and conservation the first priority in planning (UNESCO, 2013). It is a fact, however, that aggressive strategies geared towards water conservation have mostly been adopted in regions with significant challenges to water supply (Binstock, 2010). In arid and semi-arid regions, the response to water scarcity has been multi-pronged, generally including technological, policy and institutional changes (Pahl-Wostl et al., 2006).

As many societies across the world appreciate that water is a limited resource, better management strategies have become necessary. Climate change, population growth, changing lifestyles, and water inefficiencies in agriculture are some of the important factors that have necessitated a shift in water management. Consequently, the discussion on traditional water management approaches and the adoption of newer approaches is critical for a better understanding of these challenges to the water sector.

2.3 Water Management Approaches

Water management can be defined as "the actions governing the management, administration, and procedures used to implement and direct a formal Water Planning process by which water rights, water uses, and water diversions are evaluated, ranked, and allocated on the basis of specific public policy goals and objectives and designated, either by legislative mandate, regulation, fiat, or preferred use" (Water policy, 2017, para. 1).

Water management comprises three approaches: supply management, demand management, and the soft-path. At one extreme, supply management is focused on withdrawing as much water as possible through massive infrastructure projects. This approach is complemented by demand-side management, which is interested in devising cost-effective strategies to reduce water demand through "smart" technologies, consumer education and conservation-based pricing (Brandes & Brooks, 2005). At the other end of the spectrum, soft-path management aims to transform the factors that influence people's water use behavior (Brandes & Brooks, 2005). While discussion of water management previously leaned towards constructing dams, extending pipelines and drilling wells, it has become paramount for people to view water management in terms of these three approaches, as explained in the following section. Moreover, most regions in the world intend to move along this continuum in order to achieve sustainability goals (Brandes & Brooks, 2005).

2.3.1 Water Supply Management

The traditional approach to water management by hydrologists and water resource engineers has been to focus on the supply side (Chung et al., 2009), which has a narrow focus on supplying as much water as demanded by the consumers. Consequently, massive resources are invested in dams and water distribution systems (Gulbenkian Think Tank on Water and the Future of Humanity, 2013). A water supply system generally has different source and demand sectors, such as domestic, agricultural and industrial users. The system is designed to treat water from the sources and deliver it to the user via a distribution network (Chung et al., 2009).

In this regard, many costs are incurred, such as for treating water for agricultural or industrial activities (Dougherty et al., 2009). In essence, the two main components of water supply management, that is, demand fulfilment and hazard mitigation are unlikely to be met in a semi-arid region (Ahn & Kang, 2014). In demand fulfilment, meeting the water demands of the growing Abu Dhabi population would be difficult, not only because the availability of freshwater is scarce, but also because people's attitudes towards conservation and efficiency have not changed (Dougherty et al., 2009). In hazard mitigation, a water supply approach would fail as additional water sources are not available for exploitation (Patch, 2010).

It is a challenging task to develop an efficient water supply plan considering variations in water demand and uncertainties related to water resource availability, in addition to the fact that rapid urbanization and climate change will put further pressure on water resources in the future (Ahn & Kang, 2014). In the case of an arid/semi-arid region such as Abu Dhabi, supply-side management is not sustainable because water sources are scarce. As such, a continual freshwater supply cannot be guaranteed; the cheapest freshwater supply is already in use, and any additional supply will increase the cost (Brooks & Brandes, 2009).

Based on these considerations, water supply management seems to consider only an ideal situation where water resources are unlimited (Patch, 2010). In a dry environment such as Abu Dhabi, it is difficult to achieve sustainability with the supply-side approach. Moreover, it is a costly approach that cannot achieve hazard mitigation and demand fulfilment. Given these challenges, water demand management has complemented the supply side to mitigate some of the identified concerns (Patch, 2010).

2.3.2 Water Demand Management

Water demand management is more frequently acknowledged as an essential element of supply management (Brooks & Brandes, 2011). The operational definition of water demand embraces five components. The first component is the water quantity as determined by the intended use. In most cases, agricultural activities draw much of the available water (Sentlinger, 2017). This fact is confirmed by the International Water Management Institute which reiterates that agriculture is a strong competitor of water use compared to industrial and domestic uses. In fact, 70% of water resources globally are channeled towards agricultural production (Sentlinger, 2017).

In many Muslim-majority countries (MMCs), the component of water quality and quantity is exemplified by its scarcity by virtue of their geographical location. For example, the Nile is the primary source of water for Sudan, Egypt and Eritrea. Since these MMCs are largely arid and semi-arid regions, the majority of the population has settled along the Nile in order to access the water for various uses (Hasan, 2012) for primarily agriculture. The Food and Agriculture Organization (FAO) confirmed that 70% of water in MMCs goes to agriculture, 23% to industry, leaving only 7% available for domestic consumption (Hasan, 2012). In this regard, both water quality and water quantity in MMCs are largely influenced by the agricultural lifestyle of the population (Hasan, 2012).

The second component of water demand management entails the changes necessary to accomplish the task with less water or water of lower quality. In the Muslim world, a number of initiatives directed towards conserving water have been implemented, including adopting more efficient irrigation systems, treating and reusing wastewater for irrigation, and adopting crop varieties that are more tolerant to salinity and that demand less water to grow (Hasan, 2012). MMCs have also incorporated Western water-saving technologies in their water management policies (Absar, 2013). At the same time, the third component implies a focus on reducing unnecessary loss within the water distribution system (Brooks, 2005). The fourth component of water demand management emphasizes making water available during off-peak periods, while the fifth is concerned with capacity building so that water can still be available during drought (Brooks, 2005).

Water demand management and accurate forecasting will help decision makers to be ready for future changes, although many factors make forecasting difficult (Billings & Jones, 2008), including the following:

I. Population, economic cycle and technology:

Population growth is the main factor to increased water usage. Businesses and the economic cycle affect water needs through the fluctuation of industrial and commercial activities. Family income level may also influence water demand.

II. Technology:

Technology may affect water usage in several ways. For example, a new dishwasher may increase water demand while new irrigation system insulation may reduce water usage (Billings & Jones, 2008). In terms of rain harvesting, naturally engineered systems that capture storm water represent an important technological change for reducing demand. The technological component is also seen in wastewater treatment and recycling in organization for Economic Co-operation and Development (OECD) countries such as Japan, where 1,000 recycling systems were making treated wastewater available for non-potable use to apartment complexes and commercial buildings in 2003 (Leflaive, 2009). In the United Kingdom (UK), a green water treatment plant is used to biologically treat wastewater using ultraviolet light for use in gardens and toilet flushing. Sweden has installed filters in water taps so that households use less water (Leflaive, 2009).

III. Climate and seasonal variation:

The climate variable is a prominent factor in water demand management since different regions have varying climatic conditions that directly influence water use. For example, Abu Dhabi is geographically situated in an area of extreme summer temperatures (46-50 degrees Celsius) and low rainfall (100 mm annual average) (Mohamed, 2006). The high temperatures contribute to a high consumption of water for agriculture and domestic use. Seasonal variation changes water needs.

Typical peak demand occurs in summer, with outdoor activities such as swimming, while in some cold climates there is a winter peak flow system to avoid water freezing in pipes (Billings & Jones, 2008). It is important to understand seasonal demand patterns in order to plan the capacity of the distribution system. Short-term patterns are also important, as they contribute to maintenance scheduling for pumps and reservoirs (Billings & Jones, 2008). Due to climate change, the projected water demand in a country such as Abu Dhabi may change, for example with more water consumed in warmer winters (Dougherty et al, 2009).

IV. Price:

Price will often have an effect on short-, medium- and long-term forecasting. Water use and revenue are directly linked to price changes (Billings & Jones, 2008). Rate increases may change consumers' behaviors in the short-term, such as taking shorter showers or reducing the number of car washes. In the long-term, consumers may embrace this change and start to prefer goods that consume less water (Billings & Jones, 2008). Water pricing usually occurs with fixed and variable elements, i.e. a standard tariff for consuming water, and a variable tariff per unit or block for water use above the threshold (Arbués et al., 2003). When water pricing has a threshold, sequences of marginal prices for different consumption blocks (increasing or decreasing) may apply. Lower pricing is positive in terms of efficiency, but it may encourage overuse as the additional units will be marginally cheaper and the decrease of the marginal cost of supply to large users may be uncertain (Arbués et al., 2003).

Increasing block tariffs is effective to control water usage and is regarded as more equitable and redistributive (Arbués et al., 2003). Nonetheless, water demand is estimated, in general, to be inelastic as there is no substitute for its basic uses, and may depend on the following variables:

- Income
- Weather
- Resident population per account/household composition
- Housing characteristics
- Frequency of billing
- Indoor versus outdoor use, seasonal demands: winter and summer and peak-load pricing (Arbués et al., 2003)

V. Efficiency and conservation programs:

Water efficiency and conservation programs may affect water demand. Crisis programs due to drought or supply interruption may change the water usage in the short-term. Some programs that lead to structural changes are targeted at long-term water demand reduction, such as the use of low-flush toilets and drought-tolerant plants. An effective conservation program will minimize water usage (Billings & Jones, 2008).

VI. Other factors:

Physical depreciation of the water system and degradation of assets increase water loss from pipe leakage. Water loss estimation is important to a water demand model to provide a rational basis for demand and maintenance prediction (Billings & Jones, 2008).

According to Dougherty et al. (2009), the current water demand management system in Abu Dhabi is marred by inefficiencies due to laxity by the relevant stakeholders in conducting thorough inspections of the water distribution system. As a result, water leakages have not been properly assessed (Mahmoud & Abdaalh, 2014). The consequence of this is that water loss estimation has been difficult to make or document, for better water demand models to be implemented. Such gaps justify the need for a complementary management strategy (Dougherty et al., 2009).

2.3.2.1 Water Demand Management Tools

Demand management has several tools at its disposal in order to reduce peak or overall water demand. The first is water pricing through the implementation of tariffs, intended to encourage users to use less water because of the cost implications. In a scenario where the quality of life of the population continues to improve alongside a growing economy, people will gain more capacity to pay for the water. Therefore, they will continue to use water in any way they wish as long as they can afford it. Thus, the effectiveness of water pricing strategies is limited by other factors such as income and economic growth (Beacon, 2008). Another tool is the prevention of leakages within the water distribution system; while this is vital in managing the cost of supplying water, its efficiency depends on the culture of conservation. It also requires effective monitoring of leakages along distribution networks (Dougherty et al., 2009). Demand management may also promote technologies that are water-efficient, such as appliances, rainwater tanks and wastewater treatment (Beacon, 2008).

Water demand has only provided a partial solution to the problems associated with the supply-side approach. In fact, there are major efficiency and conservation issues that cannot be satisfactorily addressed using water demand management (Mahmoud & Abdaalh, 2014). The various tools for water demand management are associated with externalities that can be resolved by additional or complementary approaches such as the water soft-path.

2.3.3 Soft-Path Approach

A holistic approach to water management which goes beyond efficient demand management has been introduced: the soft-path approach. “The soft-path for water is a concept for long-range planning that includes quantitative and qualitative methods to design options for freshwater policy that are economically feasible, environmentally sustainable and socially responsive” (Brooks & Holtz, 2009, p. 158). Soft-path analysis was primarily developed 1970s to explore new forms of energy policy (Brooks, 2005). It was studied in different regions in North America and Europe and resulted in significant reductions in energy usage with no effect on the services delivered. In the 2000s, the soft-path concept was introduced for water services and the analyses were undertaken in Canada (Brooks & Holtz, 2009).

The word ‘soft’ in soft-path refers to less steel and concrete. This path is principally dependent on human initiative to find means around the current natural resource usage patterns without affecting the economic development that has enhanced the quality of life for so many people. In the soft-path approach, the role of water management moved from building and providing water supply infrastructure to improved services, like new sanitation forms, drought-resistant landscapes, conservation-oriented urban design, etc. (Brooks & Brandes, 2011).

In terms of the link between classical demand management and the soft-path strategy, it is important to note that both advocate water efficiency. The latter, however, moves beyond striving for efficiency to challenge the behavior, attitudes, practices and technologies that individuals, communities, and cities have adopted in their use of water (Brandes, 2011). In other words, soft-path management takes a holistic approach to water management by acknowledging the complex interaction between human activity and the natural environment (Brandes, 2011).

A soft-path approach "offers the potential for greater water savings than conventional demand management because it challenges assumptions based on routine planning and neoclassical economics that limit demand management mainly to cost-effective efficiency measures" (Brooks & Holtz, 2009, p. 158). While demand-based approaches ask the question how, water soft-path asks the question why. For example, demand management may ask how toilet flushing or irrigation can be done using less water. Conversely, the soft-path would ask why water is being used to carry out these activities in the first place. In this regard, the latter is committed to finding ways to conserve available water resources and adopting practices that will satisfy water needs without looking for additional sources (Brandes, 2011). A soft-path includes technologies and policies that overcome gaps in water resources by using approaches that emphasize minimizing demand rather than increasing supply (Brooks & Holtz, 2009).

Water demand management has been practiced for years and is mainly a short-term measure (Brooks & Holtz, 2009). Soft-path models are only applicable for long-term scenarios and planning with a minimum of 20 years (Brooks & Holtz, 2009).

As such, there is a difference between the two approaches in terms of their planning approach. For example, water soft-path departs from just forecasting future water demand vis-à-vis the supply, which is the case in demand management (Pacific Institute, 2017). Rather, it relies on "backcasting" in which stakeholders envision a particular time in the future where water will be used with greater care and efficiency (Karamouz, Moridi & Nazif, 2010, p. 188). In other words, the players in the sector think backward and then trace the history of water production and consumption to the present in order to know what policies are needed for future sustainability. It is thus a long-term planning process that capitalizes on changing habits, attitudes, and practices in order to increase water productivity (Brinkmann, 2016).

2.3.3.1 Characteristics of the Soft-Path Approach

There are four principles that differentiate the soft-path approach from traditional water supply and demand management. They are illustrated on Figure 2.1.

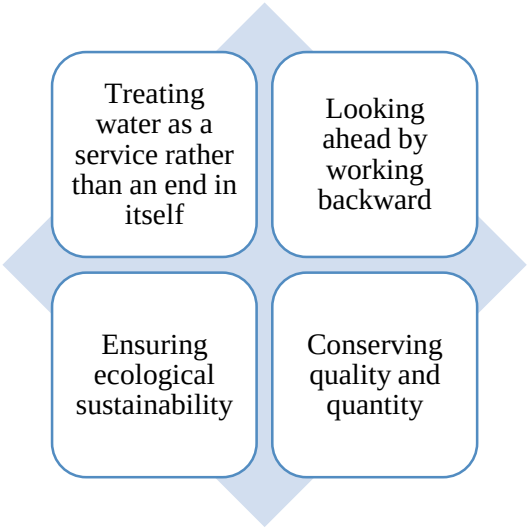

Figure 2.1: Soft-path Approach Principles

Source: Prepared by the Author based on Brooks & Brandes, 2011.

The first principle is treating water as a service rather than an end in itself, changing the notion of water as an end product. This difference in perception implies that this resource should be managed as a service, in a way that can satisfy the population, as a whole, as well as specific industrial needs for water throughout the various business sectors (Brooks & Brandes, 2011). Water is important to society to undertake specific tasks such as removing waste, cooling and growing crops. If water is treated as a service, it will become easier for decision makers to direct their attention to new technologies, rather than large-scale infrastructure. There will be more focus on efforts such as encouraging education, new designs for conservation, diverse farming methods, and changing practices to lower water usage (Brooks & Brandes, 2011). For example, water managers who consider water as a service can focus their efforts on educating land owners to adopt more efficient irrigation systems that use much less water while still promoting good crop management (Hamdan, 2013). A more detailed list of the criteria for the implementation of the given principle in practice is provided in Table 2.1.

The second principle is ensuring ecological sustainability. The soft-path considers the ecosystem as a legitimate user of water and aims to include the cost of water required to sustain ecosystems in any water cost assessment (Brinkmann, 2016). For instance, the total economic value of natural wetlands is higher than that of converted wetlands, so keeping the water may be more valuable to people than extracting it. Traditional water management does not necessarily disregard ecological effects, although it leaves them until the end and considers them constraints (Brooks & Brandes, 2011).

While the soft-path studies the ecological constraints from the start to ensure sustainability by controlling the volume of water extracted from natural sources, and by determining conditions on water quality to be returned to the ecosystem. The soft-path will reject any possible water source that puts ecological sustainability at risk or water that is revered for its beauty or culture, such as lakes and waterfalls (Brooks & Brandes, 2011). Failure to consider ecological sustainability can have serious consequences, as exemplified by the drying up of the Aral Sea, once one of the world's largest lakes. Soviet engineers embarked on a major irrigation project in the 1960's to support the cotton plantations in Uzbekistan and Kazakhstan (Howard, 2014). They diverted the waters of the two rivers that fed the lake (Syr Darya and Amu Darya) into dams, reservoirs and canals without assessing the ecological impacts of the decision and, as a result, by 2014, the freshwater lake's eastern basin had completely dried up (Howard, 2014).

The third principle entails conserving quality as well as quantity. Different end users require different water quality. A substance which is considered a pollutant to one user might be beneficial to another. It is necessary to conserve the quality of water as well as its quantity since it is not easy to find high-quality potable water in nature (Brooks & Brandes, 2011), and it is expensive to deliver to end users. People need small quantities of high-quality water for households and special industrial activities, and large quantities of lower-quality water for irrigation, cooling and industrial activities (Brooks & Brandes, 2011). The soft-path considers water quality at the beginning in order to meet the quality required by specific end-use. For example, water captured from a cooling system can be circulated for cleaning or other industrial use (Brooks & Brandes, 2011).

In order to meet the principle of quality and quantity conservation, water users must be informed of the importance of avoiding wastage. For example, it would be a waste of the precious resource to spray treated potable water onto agricultural fields and lawns. Instead, the stakeholders in the water sector should ensure that only treated wastewater is channeled towards agricultural activities. Conversely, the potable water sector should be carefully managed to ensure that potable water is supplied and used efficiently (Brinkmann, 2016).

The fourth principle is looking ahead to work backward. The soft-path involves new policies and programs that direct society toward water sustainability practices that are consistent with the quality of life (Brooks & Brandes, 2011). Traditional water management systems start from the present and create a forecast based on the current water management patterns and policies. In other words, water production is premised on meeting the current trends of consumption without paying attention to the impacts of production (Brinkmann, 2016). In contrast, soft-path planning works backwards, identifying policies and programs that are needed to reach the desired future vision. The decision or vision for the future generated by using backcasting is always accountable of stakeholders' interests and needs. It requires collaboration so water managers and the major stakeholders should engage in open discussion to determine the future they envision: water experts present their views and scientific knowledge while the members of communities present their opinions based on experience and need. In the case of the Aral Sea, the decision to divert the water of the two rivers was unilateral since the concerned communities were not consulted. Therefore, planning from future to present is a consultative process that goes beyond the views of water engineers (Binstock, 2010).

Table 2.1: Explanation and Criteria of the Soft-path Approach Principles

Soft-Path Principles	Explanation	Criteria
Treating Water as a Service	- Management of water in a way that can satisfy the population and industrial needs for the resource within all sectors.	- Provision of well-developed activities aimed to meet users' needs in water supply through: - Sufficient water production and development of infrastructure for water supply, - Utilization of water-efficient technologies, - Implementation of regulations aimed to intervene consumer behaviors.
Ensuring Ecological Sustainability	- Recognition of ecosystems as legitimate users of water and ability to meet current water demand for every resource user without impairing future supply.	- Development of a supportive environment for sustainable water use by maintaining ecological integrity and considering carrying capacity. - Establishment of restrictions on water use by understanding the abstraction potential and the ecological constraints. - Control of water quality and pollution by assessing quality of water going back to the eco-system.
Conserving Water Quality and Quantity	- Implementation of water conservation strategies aimed to preserve aquatic ecosystems, as well as quality and quantity of consumed water.	- Creation of cascading water systems (utilization of wastewater as an input for another use), e.g., water recycling, etc. - Development and implementation of standards for conservation of water quality and quantity.
Backcasting	- Planning, which starts with defining future goals and visions and then looks backward to design necessary policies and regulations?	- Development of a few alternative visions of the desirable future. - Analysis and weighting of current situations and resources based on the formulated visions of the future. - Accountability of stakeholders' needs and interests/consideration of social implications and objectives.

Source: Brooks & Brandes, 2011

Assuming that in community A there will be no new water source before 2050, the policy makers, water managers, professionals such as plumbers and architects, and representatives of the general public should come together to seek efficient and conservative approaches in order to meet the water demand in the future. Backcasting ensures that strategies and goals are clear from the start and that making slight adjustments will be easy to accommodate in the future (Lonergan, 2010). “This backcasting technique is in obvious contrast to forecasting, and it is an important practical differentiation from traditional approaches; it is also likely the most difficult part of soft-path analysis and planning” (Brooks & Brandes, 2011, p. 316). The soft-path can be applied at any level as long as there is enough data. Robust data will allow comprehensive review and analysis of water demand and usage options (Brooks & Holtz, 2009). The framework in Figure 2.2 below represents the steps of the soft-path approach developed by the Friends of the Earth in Canada (Forsyth, Hendricks & amachandran., 2009).

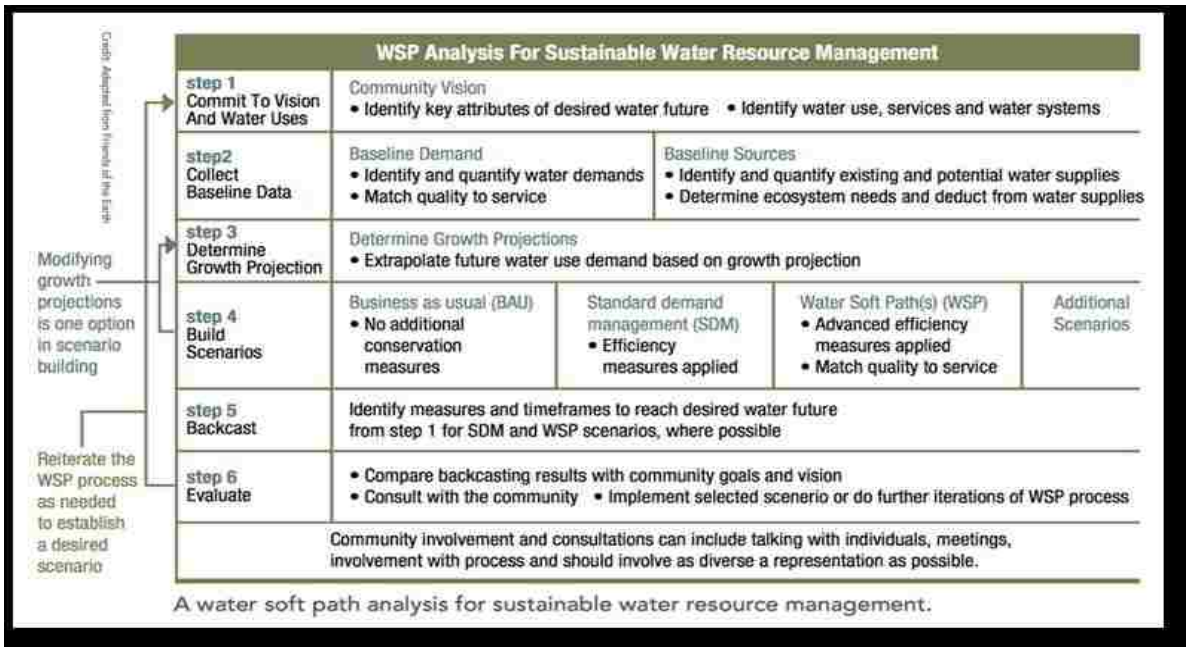

Figure 2.2: Water Soft-Path Analysis Framework
Source: Forsyth et al., 2009

The three water management approaches−supply-side, demand-side and soft-path− differ significantly in terms of philosophy, basic approach, fundamental question, primary focus, tools and primary disciplines, and the planning process. While the philosophy of the supply-side (SSM) approach is that water resources are virtually limitless, Demand-side management (DSM) emphasizes conservation since water is a finite resource (Brandes & Kriwoken, 2006). However, the soft-path approach views the finite nature of water through the lens of ecological considerations. The basic approach of the supply-side approach is reactive while that of DSM is short-term and temporary. Conversely, the soft-path approach focuses on long-term and permanent attitudinal changes that promote efficient use of water (Brooks & Brandes, 2011).

The central question in the supply-side approach is how projected water demands can be met in light of population growth and current water use. In DSM, the focus goes beyond meeting the demand for saving money and conserving the environment. In contrast, the soft-path approach seeks new ways of delivering water services in a socially sustainable manner. That is, the primary focus of the supply-side approach is building infrastructure while that of DSM is efficiency. In the soft-path approach, conservation is the primary concern. It follows that the supply-side approach employs extensive engineering solutions such as dams, while DSM focuses on incentives to reduce water demand. In contrast, the soft-path approach uses more comprehensive tools such as wastewater treatment, industrial innovation and new agricultural approaches (Brooks & Brandes, 2011). Table 2.2 summarizes these differences.

Table 2.2: Different Approaches to Water Management: A Comparison

	Supply-Side Approach	Demand-Side Approach	Soft-Path Approach
Philosophy	- Water resources are viewed as virtually limitless; the primary constraint is the capacity to access a new source or store larger volumes of water.	- Water resources are viewed as finite, to be used efficiently. - Conservation is key. - Economic cost-benefit analysis guides development choices between increased supply and managed demand.	- Water resources are viewed as finite and driven by ecological processes. - The focus is on a fundamental re-evaluation of the way we meet the services that water currently provides.
Basic Approach	- Reactive - Currently, a status quo approach, developing resources driven by exogenous human needs and wants.	- Short-term and temporary. - Generally used as a secondary approach, completing and deferring supply-side options often until future supplies are secured. - When used in a comprehensive, integrated and long-term fashion, DSM represents an incremental step towards a broader soft-path approach.	- Proactive. - Long-term, based on making attitudinal changes (which are not seen as outside the process, i.e. not exogenous) and on fostering new patterns of resource use.
Fundamental Question	- How can we meet projected needs for water given current trends in water use and population growth?	- How can we reduce the need for water to conserve the resource, save money and reduce environmental impacts?	- How can we deliver the services currently provided by water in new ways that recognize the need for long-term systemic changes to achieve social sustainability?

Table 2.2: Different Approaches to Water Management: A comparison (Continued)

	Supply-Side Approach	Demand-Side Approach	Soft-Path Approach
Primary Focus	- Built infrastructure.	- Efficiency.	- Conservation.
Tools & Primary Disciplines	- Large-scale, centralized, expensive engineering solutions. - Examples include dams, reservoirs, treatment plants, pumping stations and distribution systems.	- Innovative engineering and market-based solutions focused on any measure that increases the efficiency and/or timing of water use. - Examples include low-flow technologies, drip irrigation, conservation-based pricing, education and policies and incentives to reduce use.	- Encompasses the full suite of social sciences and generally relies on decentralized distribution coupled with management strategies aimed at ultra-efficient ways of meeting end-user demand. - The focus is on measures to deliver the services provided by the resource taking full environmental and social costs into account, and identifying new options to provide services associated with water use. - Examples include drought-resistant native landscaping, grey water reuse, ultra-low flow technologies, and dry sanitation. In addition, the soft-path encourages new forms of urban development (smart growth) and industrial innovation (e.g. new products, changes in agricultural practices and food preferences) that are inherently more sustainable.

Table 2.2: Different Approaches to Water Management: A comparison (Continued)

	Supply-Side Approach	Demand-Side Approach	Soft-Path Approach
Planning Process	- Planners model future growth, extrapolate from current consumption, plan for an increase in capacity to meet anticipated future needs, then locate and develop a new source of supply to meet that need.	- Planners model growth and account for a comprehensive efficiency and conservation program to maximize use of existing infrastructure. Increasing capacity would be a final option as part of a least-cost approach.	- Planners model future growth, describe a desired sustainable future state (or scenario) and then "backcast" to devise a feasible and desirable path to that future. Sustainability is built into the economic, political and socio-cultural choices made along the way.

Source: Brandes & Kriwoken, 2006

Each of the water management approaches has distinct characteristics that should be considered in order to gauge its efficiency. As global water resources become scarce, it is paramount for stakeholders to consider the merits and demerits of each approach in order to make progressive changes in water management. Examining the institutional requirements of the more progressive approach, soft-path, is fundamental to successful implementation.

2.4 Institutional Capacity

A successful implementation of water soft-path can only be achieved through careful consideration of the institutional factors at municipal and community levels (Patch, 2010). In order to examine the institutional capacity of Abu Dhabi for applying the soft-path approach, institutional capacity must be defined. William Patch (2010) carried out a study on implementing the soft-path approach to water management which illustrated that there are different definitions for capacity in the literature; nevertheless, all fit the five categories of capacities established by De Loë, Di Giantomasso and Kreutzwiser (2002) in their study on community water protection (Patch, 2010). The five capacity dimensions are:

i) Technical capacity: Technical capacity concerns the availability of staff with the skills and knowledge to undertake various tasks involved in soft-path management. Such tasks may include assessment of threat, data management, planning, responding to emergencies, and defining water resource (Patch, 2010).

ii) Financial capacity: In financial capacity, an institution's ability to implement a water soft-path is measured in terms of how much revenue it is able to access, its fiscal management policies, and its ability to access sufficient credit from other financial institutions (De Loë et al., 2002, p. 221).

iii) Institutional capacity: Institutional capacity considers the nature of the existing plans, by-laws, and policies and plans to gauge their relevance to the soft-path approach (De Loë, et al., 2002).

iv) Political capacity: The political capacity of an institution examines the effectiveness of its leadership and the will to establish important relationships with stakeholders such as community members, environmentalists and other advocacy groups in order to spearhead the agenda of water resource conservation (De Loë et al., 2002).

v) Social capacity: Social capacity delves into the details of awareness among members of the community in order to determine their level of appreciation of the policies or practices that are being advocated by the relevant stakeholders. It also entails the nature of community involvement (De Loë et al., 2002).

According to Patch (2010), the use of "capacity" is subjective and normative. Capacity and institutions are generally interrelated. He defined institutional capacity as the capacity described by De Loë et al. (2002). The present study will therefore use the same five dimensions.

Patch (2010) identified indicators of institutional capacity for implementing soft-path water management in municipalities, classified in eight themes as illustrated in Figure 2.3, to be used by municipal water institutions to find out the requirements, needs and prospects for soft-path implementation. Table 2.3 shows the classification of themes and the corresponding capacity indicators (Patch, 2010).

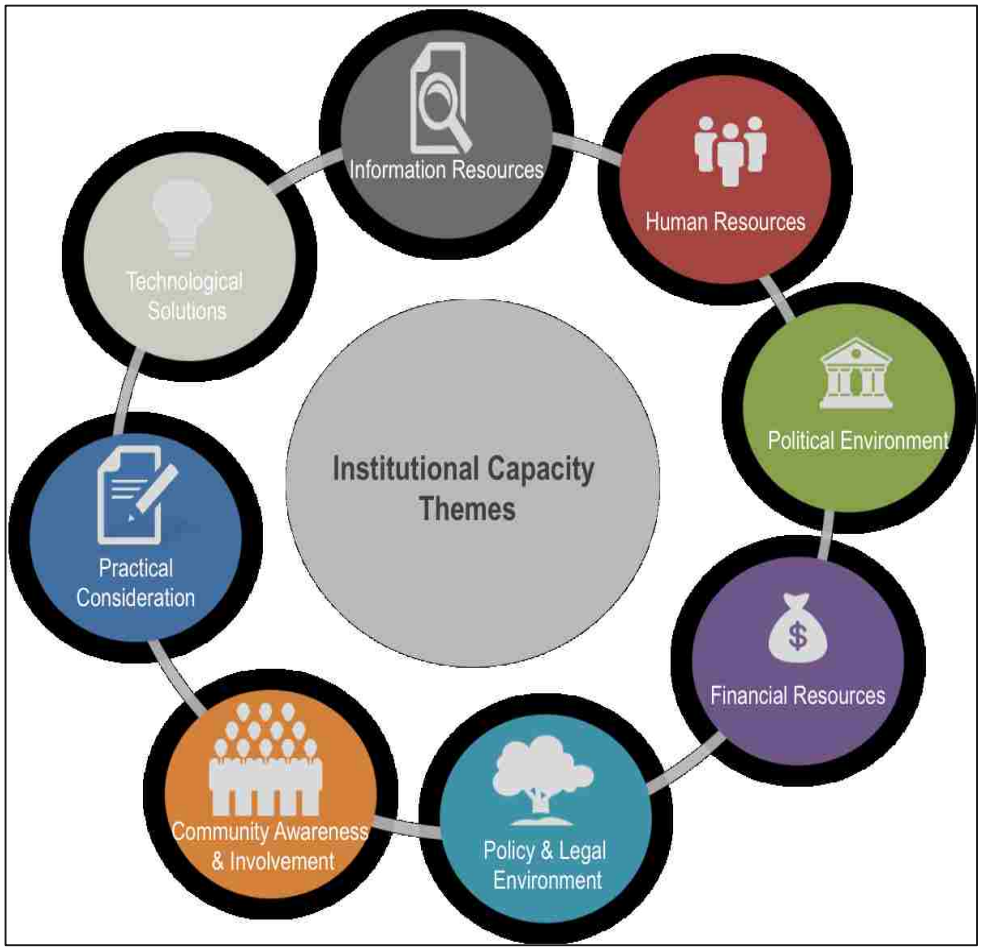

Figure 2.3: Institutional Capacity Themes

Source: Developed by the author based on Patch, 2010.

Table 2.3: Classification of Themes and the Corresponding Capacity Indicators

Theme	Indicators of capacity
Human resources	• Full-time, dedicated staff for managing water conservation programs.
Information resources	• The employees have access to recent and future data on water demand and population. • Continued and regular monitoring is conducted to ensure that data is up to date. • Information and data are shared among staff and stakeholders. • Staff have the ability to keep up with research and technology in the water sector. For example, climate change research, lab testing, policies, etc.
Financial resources	• Water sector considers a financial bottom line to ensure that it is efficient and cost-effective. • There is regular funding for water institutions to achieve water conservation. • Water sector guarantees a balanced and maintainable budget for water conservation. • There is a possibility for external funding to the water institution. • Lifecycle assessments are carried out for water supply and demand projects. • Water rates represent the full cost of water services and provision (including conservation, production, treatment distribution, operation and maintenance, and water source protection). • There are incentives for consumers such as residents, businesses, etc. to support water conservation.
Policy and legal environment	• The water sector has a clear goal of sustainability. • Water conservation is a long-term (more than one year) priority for the Emirate of Abu Dhabi. • The water sector has a water conservation plan/program that has been actively implemented. • Water conservation is integrated with other planning programs. • Water conservation is organized among different water sector departments. There might be one lead department. • Use of backcasting as a planning tool. • Water conservation is important for planning and constructing a new water supply infrastructure. • Water conservation program(s) and planning combine(s) a number of effective strategies and approaches that have not been extensively implemented (to date).

Table 2.3: Classification of Themes and the Corresponding Capacity Indicators (Continued)

Theme	Indicators of capacity
Political environment	• Water sector has a strong leadership for water conservation. • Water sector liaises its activities with other departments (horizontal linkages). • Water sector liaises with other local community organizations (horizontal linkages). • Water sector shares its activities with non-government, professional, and private sector organizations (horizontal linkages) • Water sector liaises with private-sector organizations (horizontal linkages). • Water sector liaises its activities with other levels of government (vertical linkages) (e.g. input into provincial building codes).
Community awareness and involvement	• Water sector actively engages the public in decision-making. • Water sector carries out public education and outreach program (s) for water conservation. • Education and outreach efforts represent public opinion about water conservation. • Indoor water conservation practices and technology are presented in water conservation program (s) and planning.
Technological solutions	• Outdoor water conservation technologies are included in water conservation program (s) and planning. • System-wide water conservation technologies are included in water conservation program (s) and planning.
Practical considerations	• Easy-to-implement and short-term considerations are important for water conservation program (s) and planning. • Water conservation program (s) and planning should start with methods that need little to no behavioral changes. • Social sciences as well as engineering in the sphere of water management.

Source: Patch, 2010

In order to assess the institutional capacity of Abu Dhabi with respect to the soft-path strategy, it is important to demonstrate the link between the five dimensions of capacity and the various indicators of institutional capacity. For example, Table 2.3 shows that technical capacity can be matched with the theme of human resources whose indicators of capacity include the presence of full-time municipal staff highly

trained in matters of water conservation. In addition, the staff should have access to further training since the policies and practices of water conservation keep changing (Patch, 2010).

The dimension of political capacity is another good example that demonstrates how the applicability of the soft-path approach and its components can be analyzed within the Abu Dhabi context. In this case, the relevant institutional capacity theme is the political environment. This is where leadership and advocacy in the area of water conservation are considered at the municipality level. For example, the extent to which water institutions work in collaboration with private entities, community organizations, and other sectors of government is paramount in determining political capacity (Bettini, Brown & de Haan, 2015). Strong leadership is crucial for encouraging the stakeholders to be committed to the vision of water conservation. At the same time, water institutions gain from a wide range of expertise and advice (Patch, 2010).

Social capacity can be matched with the theme of community awareness and involvement. In this case, the main indicators of capacity are the presence of public outreach and education programs to enlighten the public on the value of water conservation. In addition, capacity is determined on the basis of whether the stakeholders in the water sector are willing to involve members of the public in the decision-making processes (Buonocore, 2014).

Other aspects of assessment include the presence of community-based social marketing, outreach programs that connect neighborhoods, homeowners and individuals, and community events that promote water conservation. At the same

time, public awareness campaigns must be able to address the perceptions that impede the commitment of individuals to water conservation (Patch, 2010).

For example, some communities or individuals may harbor the myth of superabundance, which must be challenged. The rationale behind community awareness as well as involvement is to increase the chances of success, to tap into the community knowledge base, and to minimize opportunities for resistance in issues of water conservation (Wutich et al., 2013).

2.5 Conclusion

The global water situation has been changing over recent decades as the result of a wide range of factors such as climate change, population growth and expansion of agricultural activities. As a result, water managers have encountered new challenges that require more innovative solutions. This chapter highlighted the fact that the traditional approach to water management, that is, an emphasis on supply, is no longer feasible in the current situation. In an attempt to overcome the limitations of water supply management, water demand management is practiced in many parts of the world; through its five components, water managers have been able to minimize costs of water supply by introducing mechanisms for reducing demand. However, the effectiveness of this approach has been eroded by factors such as income, water leakages from pipes, climate, and population growth. The soft-path approach is therefore seen as a more progressive and economically feasible management approach that ought to be pursued by water managers, especially in arid and semi-arid regions. Based on this link and the departure from the demand management policies, it is possible for Abu Dhabi to make a smooth transition in its

water management strategy by incorporating the soft-path concept in its current policy.

Moreover, the ecological challenges that the Emirate is facing call for an approach that will work within ecological limits while also promoting community involvement in issues of water management. The successful integration of the soft-path approach will largely depend on the analysis of its institutional capacity at both community and municipality levels. The next chapter considers the methodology for determining the feasibility of the soft-path approach in Abu Dhabi.

Chapter 3: Methodology

3.1 Introduction

This chapter describes the methodology used in this research to answer the study question of whether soft-path water management can be analyzed and applied for sustainable water management in Abu Dhabi. Following the theoretical framework developed in Chapter 2, this chapter includes an explanation of the research process, selection of participants for the qualitative interviews, the actual interview structure and analysis, processes of data collection for interviews and literature review, final indicators, evaluation of the study area, and any limitations and ethical considerations.

3.2 Literature Review

A literature review of published documents, research articles, and statistical data was conducted to understand the water situation in Abu Dhabi. The process of collecting data for the review began with the researcher deciding on the scope of the topic. Databases used in the search included Google Scholar, Academic Search, ScienceDirect, Web of Science, as well as standard search engines such as Google. Inclusion criteria were peer reviews, publishing date between 2000 and 2017, government and organizational sources (.gov, .ae, .org) and other online sources possessing relevant information.

To test the institutional capacity of Abu Dhabi Emirate to implement the soft-path approach, the researcher adopted Patch's (2010) definition, which reviewed the concept within the context of countries classified as advanced economies (p. 18), with its eight themes and indicators (see Section 2.4 of this thesis).

The indicators were modified with a measurable description of the validity of the soft-path approach to water management in Abu Dhabi; the themes are listed in Table 2.2. The suitability of the soft-path approach is studied using its four principles: treating water as a service not an end in itself, ensuring ecological sustainability, conserving quality and quantity, and backcasting (Patch, 2010, p. 47).

3.3 Interviews

Collecting data from interviews and available studies allowed the researcher to obtain both personalized information on interviewees' attitudes towards the study topic as well as statistics and reports from various organizations that monitor the water situation in Abu Dhabi. The primary data was collected by the researcher through the face-to-face interviews with each participant separately in locations that were the most convenient for them; the researcher did not ask about the work or personal life of any of the interviewees.

An interview schedule was designed to help with time management and data collection, as well as later transcription and analysis. The time limit for each interview was one hour, and interviews were recorded for later transcription. As the number of individuals who can give an expert opinion on the suitability of soft-path water management in Abu Dhabi is limited, the interviews allowed the researcher to go deeper into the study questions and gather relevant and more reliable information than through a quantitative survey (Sargeant, 2012).

3.3.1 Sampling

A purposive sampling technique was utilized to collect data. This non-random selection tool implies a deliberate choice of participants: “individuals or groups of individuals that are proficient and well-informed with a phenomenon of interest” (Etikan, Musa & Alkassim, 2016, p. 2). Given the purpose of this study, it was valid to assume that organizations operating within the water sector could share their first-hand experience and knowledge to answer the formulated research questions and fulfil the research objectives. Along with experience and knowledge, participants in purposive sampling are chosen based on their “availability and willingness to participate, and the ability to communicate experiences and opinions in an articulate … manner” (Etikan et al., 2016, p. 2). Using this method, the researcher identified a viable group of individuals who were interested in participating.

No specific number of interviewees was set, although it was expected that a substantial number of them would bring multiple perspectives to the topic. From ten potential participants, four agreed to be interviewed and three suggested further individuals, making a total of seven participants. Five interviewees were from governmental water sectors in Abu Dhabi and two were private consultants working in different water issues in the region and internationally. Those who preferred not to participate were either unavailable or felt they had insufficient expertise concerning the topic. Potential interviewees were initially contacted by e-mail (Appendix C), and their quick response indicated high level of interest.

3.3.2 Structure of Interviews

The interviews were structured in two parts. Part one considered the four principles of the soft-path approach separately, allowing the researcher to differentiate between the categories of interview questions, structure their content for further analysis, and guide the conversation with participants. Subsequently, the principles served as a basis for the development of codes during analysis.

The order of the questions was chosen in such a manner that the interview included as many questions as possible about sustainability and the soft-path approach. Due to limited time, the researcher could not ask too many questions that were not linked to the study objectives. Table 3.1 lists the interview questions grouped by soft-path principle (for details, see Chapter 2).

Table 3.1: Interview Questions Linked to Soft-Path Principles

Treating water as a service rather than an end in itself	
1	How does the Abu Dhabi government see water as a service to ensure the continuance of good public health, enhance the economy, and allow the best lifestyle to the citizens (and residents)?
2	In your opinion, what role does water have in achieving Abu Dhabi Vision 2030?
Ensuring ecological sustainability	
3	Does the water sector consider water conservation as a priority?
4	How do different government/private sectors and the community support water conservation programs and planning?
5	What water conservation measures are taken in Abu Dhabi that can be regarded as a new source of water?
Conserving quality and quantity	
6	What life-cycle (i.e. from processing water to end-of-life management of waste) assessment conservation tasks are carried out for water supply and demand?
7	What are the incentives for water consumers to minimize water usage?
8	How does current water quality match the end-users' requirements, for example, domestic usage, irrigation, industrial activities, etc.?
Looking ahead by working backward	
9	Based on your experience, how easy is the access to data forecasting water demand and population data by water sector professionals?
10	How is the backcasting method (i.e. defining the desired future and planning backward to the current tasks needed to achieve that future) implemented by the water sector in Abu Dhabi to set goal(s) for future water use and conservation?

Phase two of the interview was around analyzing the institutional capacity to implement the soft-path approach through the indicators of the eight themes. It is important to mention that the indicators that were developed as a result of the data analysis were different from that of previous research. While this study took inspiration from Patch's (2010) themes, it focused on broader indicators because of

lack of resources to conduct more detailed interviews. Appendix D illustrates the indicators for each theme and the interview questions (for details, see Chapter 2).

To test whether these interview questions would work during face-to-face interaction with participants, a pilot (sample) interview was conducted. Such trials are essential because they allow researchers to understand possible issues that could arise while increasing the likelihood of the main study's success (Van Teijlingen & Hundley, 2002). While a pilot interview does not guarantee success, it fulfils an array of essential functions, such as providing a valuable insight into participants' reactions, that the researcher can take into account when performing the main interview (Van Teijlingen & Hundley, 2002).

3.3.3 Analysis of Interviews

After completion of the interviews with the seven participants, the contents of the interviews were transcribed into a digital format of word processor files. Each of the seven interviews was labelled with a number (1 through 7) to ease the process of identification and avoid any disclosure of participants' private information (Patch, 2010). To analyze the transcripts, matching was used for grouping the answers given by interviewees based on their similarities (Kohlbacher, 2006). The process of matching allowed the researcher to be more productive when dealing with a smaller number of interview transcripts while still finding connections between key topics that interviewees offered (Kohlbacher, 2006). Relevant themes arising from the research questions became a basis for the development of groups; each answer given by the interviewees was matched to a theme, and these matches were combined into groups for later analysis. This process involved the following:

- Becoming familiar with collected data: transcribing, re-reading and noting general ideas that prevailed in interviews (Vaismoradi, Turunen & Bondas, 2013)
- Generating codes: coding interesting features that are relevant to the research topic (Patch, 2010)
- Reviewing themes: determining whether the themes identified during the code generation process are applicable for grouping by topic (Vaismoradi et al., 2013)
- Defining groups: finalizing the definitions of groups identified during code generation (Vaismoradi et al., 2013)
- Reporting: selecting final examples, linking them to thematic groups, and producing a report (Vaismoradi et al., 2013). Reporting is the final step of the analysis process and was later used by the researcher to compile the findings and research conclusions

It is important to note that the codes included in the analysis of interviews were developed on the basis of concepts on which interviewees had similar opinions (Rubin & Rubin, 2005). As cited in Patch (2010), concepts are words or terms that, "represent an idea important to your research problem; themes are summary statements and explanations of what is going on" (p. 60).

After coding relevant themes, the researcher sorted them to determine what the coded data meant by looking for links and patterns that connected themes and concepts and writing about them in narrative form. Each theme was accompanied by a narrative that compared and analyzed the specific answers given by the interviewees. The transcripts were subsequently reviewed and re-checked by the

researcher to compose a narrative to ensure that the comparisons between respondents' interviews were used within the appropriate context. This information was later combined with the literature review to assess Abu Dhabi's institutional capacity to implement the soft-path approach.

This qualitative interview method allowed the researcher to evaluate the attitudes of study participants towards the phenomenon of soft-path water management in the context of Abu Dhabi (Wutich et al., 2013). The qualitative interviews served the following purposes:

- Evaluating the expert opinion about the viability of soft-path water management in Abu Dhabi
- Demonstrating the actual viability of the soft-path approach toward sustainable water management
- Collecting evidence regarding the applicability of the model within the Emirate

The final results of the study were retrieved from combining the literature reviewed on the soft-path approach and its principles, and current measures to evaluate the supply and demand of water in Abu Dhabi (based on the statistical data from relevant authorities) with indicators which the interviewees gave either in support of or against the viability of the soft-path approach to water management in the Abu Dhabi context. Such a combination of theory and practical research enabled a number of conclusions to be made.

3.3.4 Limitations and Ethical Considerations

One key limitation of the research is related to the fact that the soft path approach to water preservation and management is relatively new, which meant that the interviewees did not always have enough knowledge of the phenomenon and could not always give informed answers about the viability of soft-path water management in Abu Dhabi.

The use of face-to-face interviews during the collection of information had other limitations. One was the short time allocated for each interviewee to consider the scope of the questions asked in order to respond with sufficient information. In other words, the allocation of one hour for each interview without previously providing the interviewees with the relevant materials clearly restricted their opportunity to examine the questions in detail and to give well-informed answers.

For example, many of them could only refer the interviewer to the relevant websites of different bodies for further information on specific issues. Others were only able to state a few words, which meant that the methodological approach had not prepared them well for the interview. More often than not, a face-to-face interview is expected to be highly engaging, so the interviewees are able to provide detailed information. In the current case, it would have been better to send the questions through e-mail before scheduling the actual interview day. Nevertheless, it is expected that the current research will add to the body of available literature on the topic of soft-path water management.

During the interviews and their analysis, the researcher took measures to follow ethical guidelines and prevent the disclosure of participants' personal

information. These measures included sending consent letters to the participants, coding their personal information, and avoiding bias by eliminating possibilities for personal judgment and expression of opinions. All study participants were thanked for their contributions, pointing to their interest to explore the soft-path approach to water management in Abu Dhabi.

Overall, the research limitations are primarily associated with the nature of the applied methodology. Qualitative data collection tools, such as interviews, imply that the obtained information is subjective and, thus, can be prone to bias. This limitation was partially addressed through the analysis of Interviewees' responses by using governmental data and research evidence. Nevertheless, the targeted investigation of the implementation of the soft-path principle in Abu Dhabi through quantitative methodology could help verify and support the findings of the given study.

Chapter 4: The Need for an Alternative Approach to Water Management in Abu Dhabi

4.1 Introduction

Abu Dhabi Emirate is one of the most arid regions in the Middle East. Consequently, the climatic conditions and the higher level of salinity of the seawater have created immense challenges to water production and conservation (Chowdhury & Rajput, 2015). The situation is worsened by the high consumption of water in agriculture, industry and residential areas. Indeed, Abu Dhabi has a water consumption rate that is double that in most industrialized countries (Radan, 2016). As the water demand escalates due to the increasing population, the growing number and size of the cities, and the booming economy, the EAD has warned that the rate of water consumption is 26 times that of natural water production (Radan, 2016). It is thus essential to examine the current status of water needs, supply and demand in order to identify the place of the soft-path approach in water management.

This chapter examines the need for the soft-path approach by reviewing the available data on the increasingly higher water demand and lack of success of the current approaches to water management. It presents data on water demand from previous years to the present time, and estimated water demands for the future, as provided by the relevant authorities. It also evaluates the current measures of water supply and demand management in order to determine their sustainability. The effects of tariff reform on water demand and supply are considered in detail by analyzing the data on water use before and after its introduction and later increase. The evidence is used to justify the need for the soft-path approach.

The chapter is divided into six sections. The first section describes the population, geography, and climate of Abu Dhabi, and the second examines the impact of economic activities, relating to the non-oil sector, and population growth on water resources and demand. The third section describes the water supply situation and the related challenges, while section four explains the various water demand management methods. Section five relates the evidence presented in the paper to justify the need for the soft-path approach.

4.2 Abu Dhabi Emirate: Geography and Demography

Abu Dhabi Emirate is the largest of the seven emirates (states) of the UAE, covering an area of 67,340 square kilometers, or about 87% of UAE's total area. It also houses the UAE's federal capital (Abu Dhabi Emirate, 2017). Geographically, Abu Dhabi is an island in the Arabian Gulf. To the east is Oman, and to the south Saudi Arabia. Abu Dhabi is predominantly a desert country. The climate is thus hyper-arid with an annual precipitation of about 100 mm. The hottest month is August with an average temperature of 36°C, while January is the coldest with a temperature of 18°C. February receives the most rainfall of 20 mm on average (Annual weather averages, 2018). According to the mid-2016 population estimates, Abu Dhabi's population was 2.908 million, comprising 1.86 million males and 1.05 million females with about 2.36 million (91%) non-nationals (Statistics Center Abu Dhabi, 2017, p. 114). The spectacular economic growth of Abu Dhabi required an expatriate population and created the increasingly high demand for water unusual for an arid region.

4.3 Abu Dhabi Economy: Activities, Growth, and Impacts on Water

Abu Dhabi's economic and population growth are the two primary factors affecting water demand. Although water usage has traditionally been high due to the hot climatic conditions, the economic expansion following the creation of the UAE triggered an unprecedented demand for water. Over the past decade, Abu Dhabi has seen a major expansion of its non-oil sector as well as expanded economic opportunities due to the expansion of free trade. As its Gross Domestic Product (GDP) grows, Abu Dhabi's job market has attracted more expatriate workers. The subsequent economic output and population growth have resulted in more urbanization and the construction of more commercial and residential properties. At the same time, more industrial parks have been established alongside a growing agricultural sector to feed the population. When all these factors are combined, they have created a strong impact on water demand and water consumption per capita (Paul, Al Tenaiji & Braimah, 2016).

This section discusses diversification of Abu Dhabi's economy through the expansion of the non-oil economy, and its impact on water demand, considered in light of water use across different sectors of the economy and the subsequent population growth. The average annual rate of population growth from mid-2010 to mid-2016 is 5.6%, which means a total of three to five million by 2030 (Statistics Center Abu Dhabi, 2017). This section outlines the impact of the increase in economic activities and population size on water demand, and the ineffectiveness of the present water management system, highlighting the need for an alternative approach to water management: the soft-path approach. It is divided into the growth of the non-oil sector; population growth and water use in different sectors.

4.3.1 Growth of Non-Oil Sector

Abu Dhabi depended heavily on the oil sector to develop its economy. However, the need to control the balance of trade deficit in the non-oil sector has prompted efforts to expand the non-oil economy from 49% in 2014 to 64% by the year 2030 as part of its Vision 2030 economic strategy (Abu Dhabi, 2008, p. 127).

Figure 4.1 represents the contribution of the different non-oil sectors to the Emirate's GDP in 2012 and 2013. According to the Statistics Center Abu Dhabi (2017), the non-oil sector in 2013 contributed to a GDP of Dh.423.95 billion or USD115.42 billion at current prices (p. 18). The different sectors that contributed to the GDP with their percentage contribution are presented in Table 4.1. The key sectors of the non-oil economy include manufacturing and construction, which consume a lot of water.

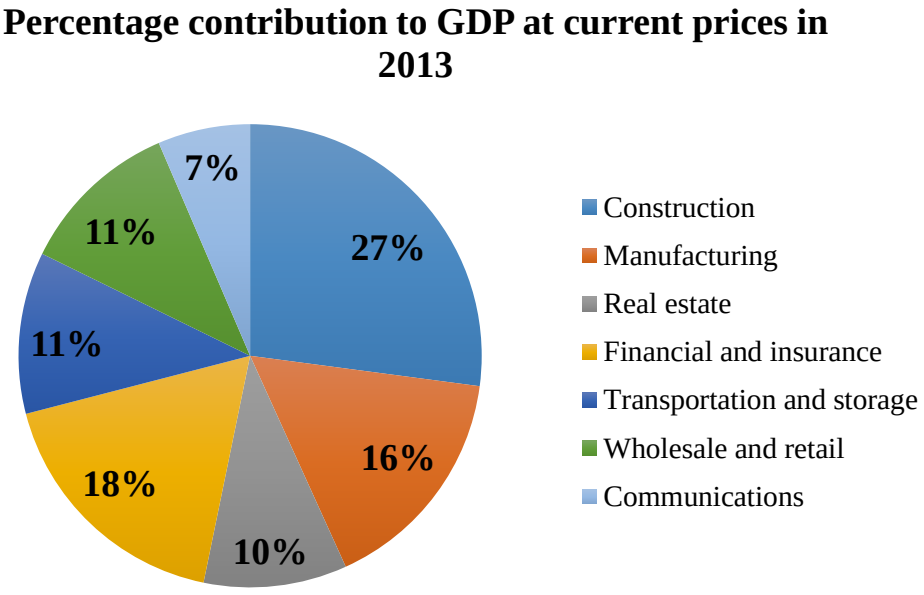

Figure 4.1: Performance of the Non-Oil Sector in 2013

Source: Statistics Center Abu Dhabi, 2017, p. 21

In addition to the above data, the contribution of fishing, forestry and farming activities to the 2014 GDP in Abu Dhabi was 0.6% or $1.66 billion (Statistics Center Abu Dhabi, 2017, p. 21). In the first quarter of 2015, the non-oil sector represented 50.7% of the GDP. A similar growth of the sector was recorded in the third quarter of 2015 in which the non-oil sector GDP grew by 7.1% in terms of fixed prices compared to 3.9% for the oil sector (Abu Dhabi Department of Economic Development, 2016). In the first quarter of 2016, the GDP increased by 6% compared to 2015. Of the 2016 GDP growth, the non-oil sector accounted for Dh527.846 billion (Statistics Center Abu Dhabi, 2017, p. 18).

These statistics indicate the clear intention of the Abu Dhabi government to diversify the economy by investing in and prioritizing the non-oil sector. If the intention to expand the non-oil economy is implemented, the water sector will need to adopt more efficient ways of conserving the available water resources because this sector employs increasingly more expatriates than the oil sector.

4.3.2 Population Growth

Abu Dhabi's population is increasing at a rate that has created unprecedented levels of water demand. The Statistics Center Abu Dhabi (2017) has indicated an average annual population growth rate of 5.6% as from mid-2010 to mid-2016 (p. 114). The Emirate has experienced considerable pressure from the increasing demand for water and housing due to this population growth (Oxford Business Group, 2010, p. 129; Statistics Center Abu Dhabi, 2017, p. 11).

The data presented in Appendix E represents the peak water demand forecast made earlier by ADWEC. The data indicates that Abu Dhabi may experience an average increase of 57,631 MIG (262 million m^3) in water demand from 2011 to 2040 (ADWEC, 2016). Figure 4.2 shows the annual percentage change of water demand from 2011 with projected estimates from 2017 to 2030 with the minimal percentage change expected to occur from 2029 to 2030 at 1.76% (ADWEC, 2016).

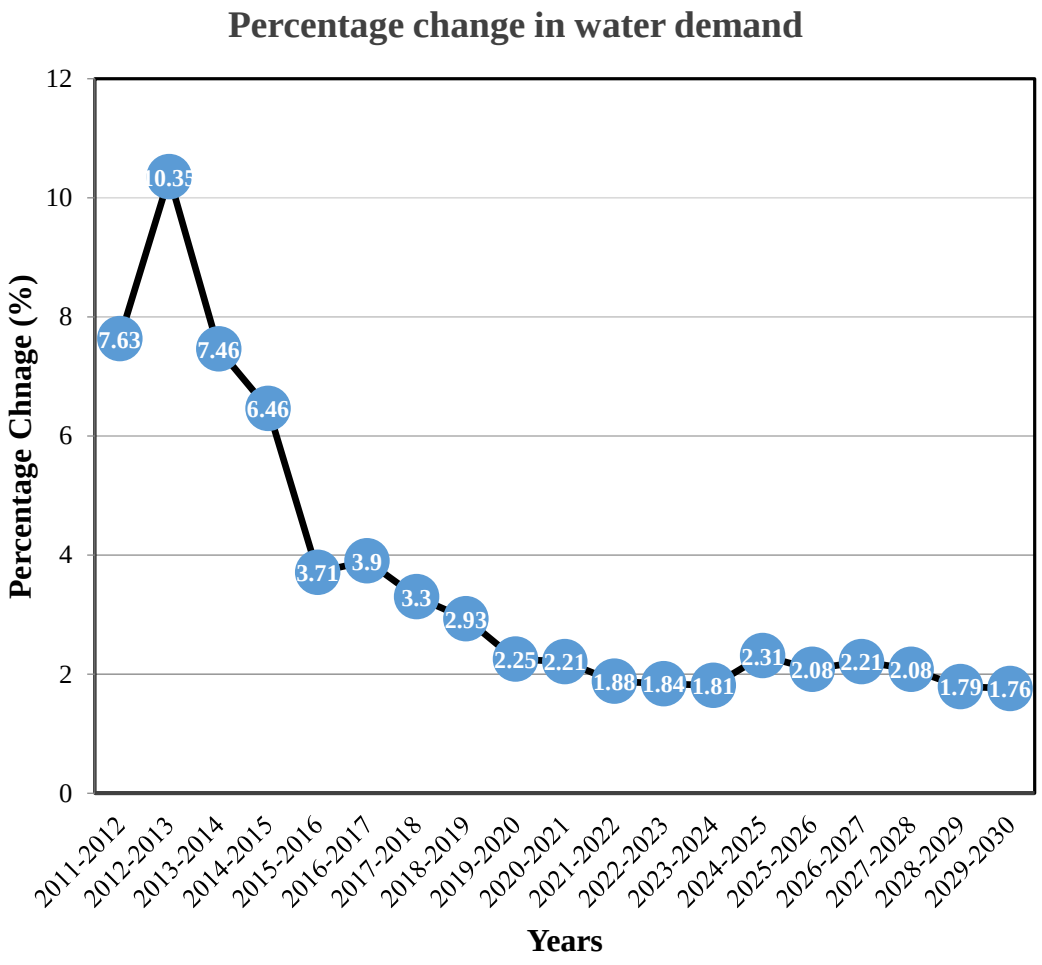

Figure 4.2: Percentage Change in Water Demand Based on ADWEC Demand Projections

Source: ADWEC, 2016

The total peak water demand in Abu Dhabi will increase from 648 MIG (2.95 million m^3) a day in 2011 to 910 MIG (4.13 million m^3) a day by 2040 (Appendix F; Statistics Center Abu Dhabi, 2017). The estimated per capita data for water demand between 2012 and 2030 is presented in Figure 4.3. It shows that the demand from 2018 to 2030 is predicted to decrease annually (ADWEC, 2016). However, the demand levels are still high, and incorporating the soft-path approach will further reduce the annual demand levels. This is because the soft-path approach will encourage better water management practices that will reduce demand.

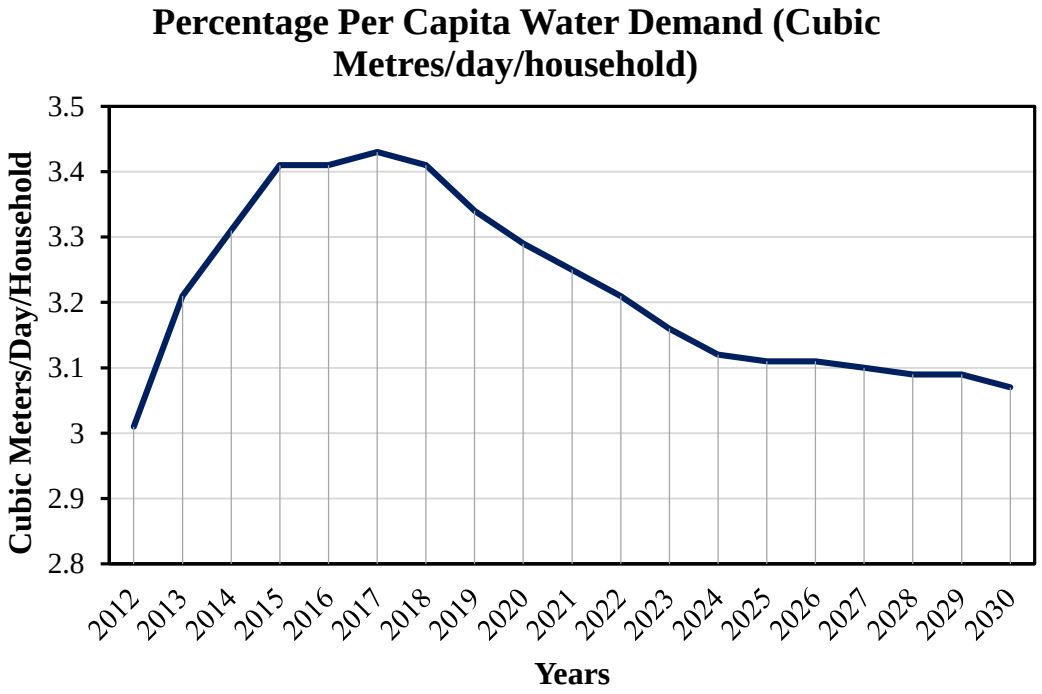

Figure 4.3: Per Capita Water Data between 2012 and 2030

Source: ADWEC, 2016

Considering the data presented above, it is important to examine the water consumption across different sectors in order to get a clearer picture of the water needs in Abu Dhabi.

4.3.3 Water Use in Different Sectors

Abu Dhabi has two major sources of water: groundwater and desalinated seawater. In addition to these sources, treated wastewater is a source mainly used for irrigation. Groundwater is a critical source since it constitutes 56.43% of the overall supply, followed by desalinated seawater at 34.44% (S. Pearson 2018, personal communication, 18 April). The latter is almost exclusively used for irrigation while the former is used for both irrigation and household needs. However, part of the total volume of water supplied to irrigation comes from treated wastewater, which accounts for 9.14% of total supply (Statistics Center Abu Dhabi, 2017). The volume of groundwater supplied in 2016 was 442,798 MIG (2,013 million m^3) a year (S. Pearson 2018, personal communication, 18 April). The total volume of supplied desalinated water equaled 270,241 MIG (1,228 million m^3) a year, while treated wastewater amounted to around 245,265 MIG (1,115 million m^3) in 2016 (Statistics Center Abu Dhabi, 2017).

According to the data provided in Table 4.1, domestic activities such as showering comprised the largest consumption of desalinated water from 2008 to 2015 (Statistics Center Abu Dhabi, 2017). Although agriculture is the largest consumer of water in Abu Dhabi, this fact does not apply when only desalinated water is considered, as most of the water for agriculture is sourced from groundwater (Statistics Center Abu Dhabi, 2017). Conversely, desalinated water is the primary source of water for domestic purposes. The data emphasize the need for effective domestic water management since desalination is the principal source for Abu Dhabi (Statistics Center Abu Dhabi, 2015).

Table 4.1: Consumption of Desalinated Water in Abu Dhabi from 2008-2015

Sector	**Desalinated water use by sector, million m^3**					
	2008	**2011**	**2012**	**2013**	**2014**	**2015**
Agriculture	26.5	30.7	56.9	56.2	55.2	196.1
Domestic	528.9	522.2	548.6	561.8	559.4	551.6
Commercial	73.9	150.5	144.6	151.5	165.7	218.1
Industry	5.2	17.9	18.3	19.4	22.5	26.5
Government	130.3	213.8	280.5	283.6	315.7	158.1
Other sectors	9.0	26.4	10.3	9.7	7.8	3.46

Source: Statistics Center Abu Dhabi, 2017

Figure 4.4 shows the annual rate of desalinated water consumption in Abu Dhabi Emirate with the 2016 consumption amounting to 245,463.6 MIG (1,115.9 million m^3) (Statistics Center Abu Dhabi, 2017). Overall, Figure 4.4 demonstrates a slight decrease in the consumption volumes from 2015 to 2016. Additionally, Table 4.2 shows the daily average consumption and daily average consumption per capita. In 2015, the annual volume of consumed desalinated water was 253,974.4 MIG (1,154.6 million m^3), with an average daily consumption of 695.1 MIG (3.16 million m^3) (Statistics Center Abu Dhabi, 2015).

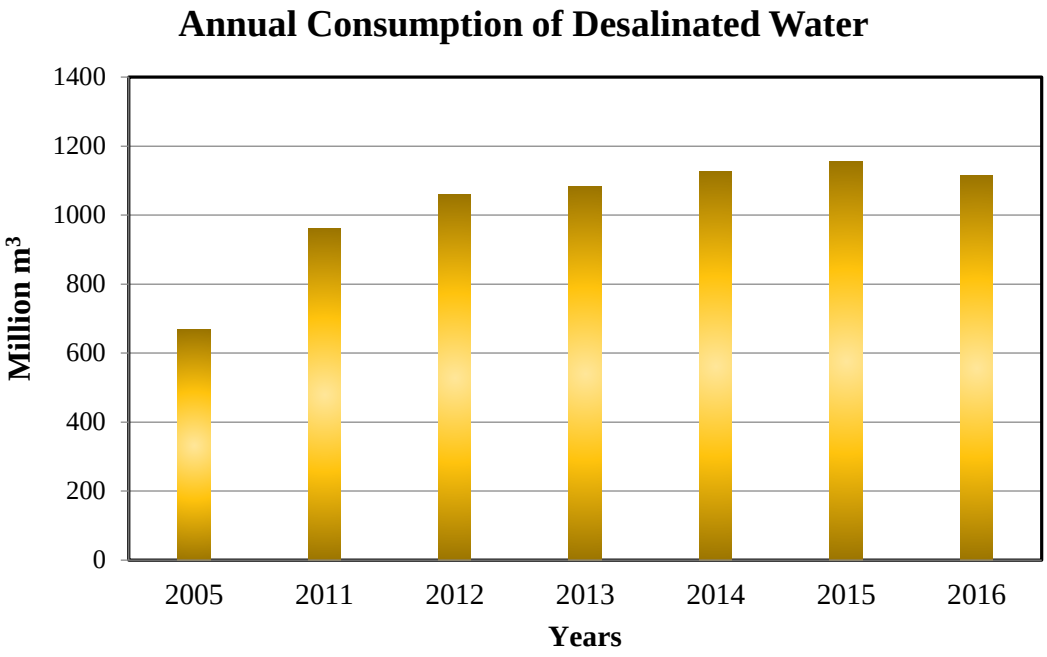

Figure 4.4: Annual Consumption of Desalinated Water, Million m^3
Source: Statistics Center Abu Dhabi, 2017

Table 4.2: Total and Per Capita Consumption of Desalinated Water

Year	Daily average consumption. (Million cubic metres)	Daily average consumption per capita (Million cubic metres)
2005	1.83	1.33
2011	2.64	1.22
2012	2.90	1.25
2013	2.97	1.19
2014	3.09	1.16
2015	3.16	1.14

Source: Statistics Center Abu Dhabi, 2015

As Abu Dhabi makes efforts to expand its non-oil sector, including manufacturing and construction, it is vital to establish an efficient water management policy. The pressure of population growth and expanding cities calls for the re-evaluation of the current methods of water supply in order to identify the deficiencies

and opportunities for improvement. In the next section, the current status of water supply and the associated limitations are explored.

4.4 Water Supply: Sources and Issues

Water availability is the main environmental challenge that Abu Dhabi Emirate is currently facing. The fact that Abu Dhabi depends heavily on groundwater creates a complex situation, considering that this is a non-renewable resource. At the same time, freshwater sources are scarce due to the high salinity of the water, coupled with the dry conditions and lack of rain (*Environmental atlas of Abu Dhabi Emirate*, 2017).

The main sources of water in Abu Dhabi are groundwater and desalinated seawater (see Table 4.3). The volume of groundwater is around 442,798 MIG (2,013 million m^3) (S. Pearson 2018, personal communication, 18 April). Most of the groundwater comes from the Bajada region where there exist some aquifers along the base of the mountains. The shallow aquifers regenerate their volume from surface water in rain but due to the high evaporation rate, only 10% reaches them. Desalinated water is mainly used for domestic purposes. It is a costly process and only nine desalination plants exist in Abu Dhabi. Treated wastewater is also used in irrigation of plants and highway landscaping.

Table 4.3: Water Supply Trend in Abu Dhabi

Quantity of Water Resources in Million Cubic Meters	**2016**
Average Groundwater Feed	2,013
Desalination	1,228
Treated Water	325.9
Total	**3,567**

Source: S. Pearson 2018, personal communication, 18 April

Despite the limited water resources, Abu Dhabi continues to have one of the highest per capita domestic water use in the world. The allocation of fresh water to agricultural and forestry sectors causes serious wastage. Only in recent years have amenity planting, forestry and agriculture been using water for irrigation without restrictions (Environment Agency Abu Dhabi, 2012). The construction of desalination plants is a costly process in addition to having potentially adverse effects on the ecosystem (Absal, 2010a). Therefore, the capacity to supply water sustainably in the longer term is limited by certain natural and environmental obstacles that need to be highlighted.

4.4.1 Depletion of Groundwater

One of the major natural hindrances to sustainable water supply is the fact that the Emirate depends heavily on groundwater abstraction and seawater desalination. As it was mentioned above, groundwater currently constitutes 61.1% of the total consumption (Statistics Center Abu Dhabi, 2017). Unfortunately, water experts have predicted that Abu Dhabi's groundwater resources may face total depletion by the year 2040 if no practical measures are taken to mitigate the current rate of withdrawal (Radan, 2016).

It is worth noting that desalination has been the pillar of economic prosperity and modern lifestyle in Abu Dhabi. Therefore, the depletion of groundwater could cause the collapse of the Emirate's economy and society unless better water management initiatives are implemented (Radan, 2016).

4.4.2 Minimum Replenishing

The fact that groundwater is a major source of water for Abu Dhabi's different sectors has created another environmental challenge: minimal replenishing. According to the Oxford Business Group (2016), the rate of groundwater removal is 23 times higher than the rate of natural recharge. Indeed, the difference between withdrawal and replenishing accounts for the predicted depletion of this important water resource. In addition, Abu Dhabi is geographically situated in an area of extreme summer temperatures (46-50^{o}C) and low rainfall (100 mm annual average) (UNEP, 2016). The high temperatures of Abu Dhabi contribute to a high consumption of water for agricultural and domestic use. The temperature also reduces the rate of water percolation into the ground due to the high rate of evaporation (2-3 m per year) (UNEP, 2016). Low water percolation further reduces the rate at which groundwater sources are replenished (Mohamed, Murad & Chowdhury, 2017).

The annual precipitation has been the lowest during the last ten years, thus slowing the rate of groundwater recharge. Since Abu Dhabi depends heavily on groundwater systems for water production, the low rate of natural recharge poses a serious threat to water supply. Moreover, excessive pumping of the groundwater for agricultural purposes has reduced the quantity and quality (Dougherty et al, 2009).

According to the Environment Agency Abu Dhabi (2012), only 3% of the groundwater was fresh in 2011, with nearly 80% saline and 18% brackish. These statistics indicate the worsening quality of the groundwater and the subsequent unsustainability of this water source.

4.4.3 Treat to Marine Species

The heavy dependence on desalination for the supply of water in Abu Dhabi has also created environmental and ecological challenges due to the release of large amounts of salts back into the sea. According to the Statistics Center Abu Dhabi (2015), 205,891MIG (936 million m^3) was produced from seawater desalination in 2015, compared to 140,120 MIG (637 million m^3) ten years earlier. The brine released from desalination processes has caused salinity levels of the seawater to go as high as 70,000 ppm (Radan, 2016), as compared to the natural salinity of 40,000 ppm. Such extreme salinity levels and the chemicals that are present in brine are a threat to marine species (Absal, 2010). Consequently, the fishing industry may suffer a major blow from the current desalination methods.

It is also important to note that drawing too much water from the Gulf near-shore regions is a threat to marine biodiversity because it tends to affect other oceanographic parameters such as dissolved oxygen and temperature (Absal, 2009). The growth of certain species of red tide such as *Cochlodinium polykrikoides* is also encouraged by high salinity and temperature levels in the water (Kim et al., 2004). In 2009, the authorities in Abu Dhabi indicated the possibility of red tides invading the beaches due to high salinity. Red tides are known to release poisonous substances such as neurotoxic and paralytic shellfish poisoning that kill fish and other marine life (Absal, 2009).

4.4.4 Financial Constraints and Wastage of Treated Water

A large part of water utilised for household purposes (e.g., toilet flushing, showers, washing machines, etc.) in Abu Dhabi is made available through desalination. Desalination plants are costly ventures that require massive investment. The construction cost of a single plant to desalinate 100 million gallons a day is Dh7 billion or USD 1.9 billion (Absal, 2010). The EAD has indicated that the current level of investment in desalination cannot sustain the water needs of the growing population and industry. As a result, only by doubling the investment will the country be able to be self-sufficient in clean water for multipurpose use (Graves, 2016). From a cost consideration, building additional desalination plants does not constitute a sustainable solution in the long-term (Absal, 2010).

The Emirate has a wastewater sector in which Abu Dhabi's Sewerage and Services Company (ADSSC) has established projects to ensure that wastewater from industrial, commercial and domestic sources is collected and treated before being supplied for irrigation and other use (Regulation and Supervision Bureau, 2015b). Projects such as STEP, are intended to increase the treatment capacity to175.98 MIG (0.8 million m^3) a day, up from 98.99 MIG (0.45 million m^3) (*Strategic Tunnel Enhancement Programme*, 2018). However, wastewater treatment projects are costly ventures that may meet budget constraints. For example, STEP will cost the economy $1.6 billion (*Strategic Tunnel Enhancement Programme*, 2018). In addition, there are problems of septic contamination and wastage. In terms of wastage, there is a concern that despite waste water being treated to tertiary levels, its re-use in 2016was only 51% while the remainder is discharged in the surroundings environment (Statistics Center Abu Dhabi, 2017).

Such huge wastages show that there is an inefficient use of treated wastewater. Consequently, greater investment is necessary to increase the connection between treatment plants and irrigation systems. Such additional financial demands have reduced the economic feasibility of wastewater treatment. In a nutshell, the water supply in Abu Dhabi is marred by a variety of environmental, conservational, financial and natural hindrances that must be understood within the current water demand management framework in order to develop solutions. Under these circumstances of water production and distribution, an examination of the various water demand management initiatives would inform the need for alternatives, the soft-path approach in this case.

4.5 Water Demand Management

Water demand management is characterized by the establishment of infrastructure with the aim of making water available in line with the needs of the population. Consequently, it is influenced by water conservation programs, technology, population, economic cycle and water loss through leakage. As per 2016, the annual domestic consumption water in Abu Dhabi is estimated to be between 103,825 MIG (472 million m^3) (Statistics Center Abu Dhabi, 2017). Such a high consumption, despite the scarcity of water resources, is driven by heavy water usage for outdoor and indoor activities (Chowdhury & Rajput, 2015). To limit the escalating demand for water, several demand management tools have been used by the water sector.

4.5.1 Water Demand Management Methods

The water sector of Abu Dhabi has applied several water demand management methods with the objective of reducing water losses through leakage and wastewater. More importantly, the objective of methods such as water pricing through tariffs is to ensure the prudent use of water by individuals because of the financial implications of using higher quantities of water (Billings & Jones, 2008). Ultimately, the water sector aims to reduce the overall demand in Abu Dhabi. Other factors such as the expansion of income and rapid economic growth have reduced the effectiveness of water pricing in lowering individual water demand.

4.5.2 Wastewater Treatment

In Abu Dhabi, wastewater treatment is concerned with collecting all the water that is discharged from industrial, commercial and domestic sources before treating it for reuse in irrigation. The use of wastewater treatment technologies to supplement the water needs of Abu Dhabi has become more important by the day for its potential to cater for the water needs in the agricultural sector. In essence, treated wastewater is an important source of water for irrigation (Environment Agency Abu Dhabi, 2013). As the economy expands and the population grows, it is expected that treated wastewater will become an even more important source of water for reuse (EAD, 2013). However, major obstacles are associated with treated wastewater projects, including the constraining budgetary requirements and wastage of the treated water. For example, about 49% of the treated water is released back into the environment without being put to productive use (Statistics Center Abu Dhabi, 2017).The a huge budgetary requirement ($1.6 billion) for the implementation of STEP are additional challenges in this sector (EAD, 2013).

In addition, wastewater treatment plants are prone to septic contamination, which must be resolved before it can become an efficient tool for managing water demand. Issues of septic contamination, wastage of treated wastewater, and the immense costs of implementing the relevant infrastructure programs should be handled through better planning. (*Strategic Tunnel Enhancement Programme*, 2018).

4.5.3 Water Pricing

A water tariff was implemented in 2015 as a way of enforcing better practices of water conservation among the expatriates and Emiratis (Utilities ME, 2014). The government imposed a progressive tariff system. For those living in flats, the rates are lower than for those in villas, as the latter are more likely to consume more water. Once the consumption exceeds the set limit, the water tariff becomes comparatively much higher to discourage higher consumption.

Emiratis living in flats had to pay 1.7 dirhams for every 1,000 liters of water consumed within a maximum daily usage of 700 liters (AADC, 2015). Those living in villas were charged the same rate up to 7,000 liters a day, but consumption exceeding this level attracted a higher rate of 1.89 dirhams per 1,000 liters (AADC, 2015). Expatriates were required to pay between 5.95 dirhams/1,000 liters up to 700 liters in flats and 5.95 dirhams/1,000 liters up to 5,000 liters in villas (AADC, 2015). Consumption exceeding this level would attract a higher rate of 10.55 dirhams per 1,000 liters (AADC, 2015; Table 4.4)

Table 4.4: Water Tariff in Abu Dhabi Introduced in 2015 and the Revised Tariff of 2017

Customer	Property	2015 water tariff AED/1,000 liters	Average Daily consumption litres/day	2017 (Revised Tariff) AED/1,000 liters.	Average daily consumption litres/day
Emiratis	Flat	1.70	up to 700	2.09	up to 700
		1.89	over 700	2.06	over 700
	Villa	1.70	up to 7,000	2.09	up to 7,000
		1.89	over 7,000	2.60	over 7,000
Expatriates	Flat	5.95	up to 700	7.84	up to 700
		10.55	over 700	10.41	over 700
	Villa	5.95	up to 5,000	7.84	up to 5,000
		10.55	over 5,000	10.41	over 5,000

Source: AADC, 2017; AADC, 2015

The revised tariffs of 2017 are shown in Table 4.4. This change constitutes an 18.7% increase from the 2015 rate (AADC, 2017). In particular, the original rate for Emiratis living in flats and villas was not sufficient to encourage a culture of water conservation. Less change was required for expatriates; those consuming up to 5,000 liters only have to pay an extra 1.91 dirhams, while those consuming more than 5,000 liters a day in villas will pay 0.14 dirhams less than the 2015 rate (AADC, 2017). Overall, the changes are needed to curb the high rate of water consumption in the domestic sector, which largely comprises residents living in flats.

The ADWEC peak water demand forecast from 2011 to 2040 (ADWEC, 2016) shows that demand increased steadily across all the three regions between 2011 and 2015. In fact, the 2015 tariffs did not reduce water demand for that year,

which increased by 36 units compared to 2014 data. However, the demand declined slightly in 2016 and 2017 for the Abu Dhabi and Al Ain region, but only in 2016 for Al Dhafrah region (ADWEC, 2016). The period of decline, that is 2017, coincides with the introduction of the revised tariffs, intended to encourage the adoption of water-saving practices by consumers. However, higher tariffs only have a temporary impact as long as the population has the financial capacity to pay more for its water.

Since the goal of the tariffs is to curb unsustainable water use practices, it begs the question whether the current policy and regulatory measures are sufficient to achieve this goal. Moreover, the data in Appendix F shows an average annual population increase of 5.6% between 2010 and 2016 (Statistics Center Abu Dhabi, 2017). In a scenario where the quality of life of the population continues to improve alongside a growing economy, people will become better able to pay for the water, and therefore continue to use it in any way they wish as long as they can afford it. In this respect, water pricing strategies are not the remedy to the current and future water demand in Abu Dhabi. A more practical approach should be gradually integrated into the current water demand management.

4.6 The Need for Soft-Path Approach to Water Management in Abu Dhabi

The evidence presented above suggests that, due to policy and institutional deficiencies, the supply of water in Abu Dhabi has been expensive because of over-dependence on desalinated water. The cost of desalination and wastewater treatment is already prohibitive and unsustainable.

Coupled with the near-depletion of groundwater reserves and the threat to the marine ecosystem, the current trajectory in terms of water production, supply and

consumption in Abu Dhabi is not practical for the growing economy. It will take the collaborative efforts of government, water managers and engineers, and environmentalists to raise the level of public awareness on sustainable water conservation as envisaged by the soft-path approach. Until people begin to reduce their water consumption from personal desire, and not for water tariffs or other fines, the goal of attaining sustainability in the water sector will remain out of reach.

4.7 Summary and Conclusions

As arid conditions continue to dominate Abu Dhabi, sustainable economic growth and overall prosperity will be enhanced by current water demand management approach, and sustainable soft-path approach. The water situation in Abu Dhabi will deteriorate as the population and economy grow, despite the introduction of water pricing. The research has demonstrated that the key demand management tools are subject to major limitations that can only be solved through a soft-path approach. As water experts continue to predict a possible water demand crisis in the future, it is high time for water managers to adopt the soft-path approach to ease the anticipated pressure on the available resources. Also, Abu Dhabi requires a water management policy that will incorporate its ecological challenges while ensuring optimal community involvement in issues of water management. The available data should continue to be a constant reminder that the soft-path approach may be the best alternative for Abu Dhabi. However, is this approach to sustainable water management suitable and implementable in Abu Dhabi? The next chapter attempts to answer these questions.

Chapter 5: Interviews and Analyses

5.1 Introduction

The objective of the present chapter is to examine and evaluate the applicability and institutional capacity of the soft-path approach in the Emirate, focusing on responses from seven interviewees from different areas of Abu Dhabi's water sector. Prior to the interview, the respondents were briefly informed about the essence of the soft-path approach for sustainable water management, as well as its major principles and criteria. Their reaction to the information provided varied from neutral to positive. Nevertheless, considering the newness of the given method, most of the interviewees had limited knowledge about it, so they were not able to provide comprehensive answers to all the questions regarding the applicability of the soft path in Abu Dhabi.

The chapter is an analysis of the suitability (consisting of the applicability and implementability) of the soft-path approach for sustainable water management in Abu Dhabi. As such, it is divided into two sections, corresponding to the two parts of the interviews dealing with the two parts of the suitability analysis. Section 1 (Applicability) includes the discussion and analysis of interviews in the context of the four major soft-path approach principles: treating water as a service, ecological sustainability, conserving water quantity and quality, and backcasting. The objective of this section is to evaluate the identified themes from the interviews in relation to the four principles of the soft-path approach to water management in Abu Dhabi.

Section 2 (Implementability) reviews and analyzes interviewees' responses concerning eight themes that determine the institutional capacity for the soft-path approach: human resources, informational resources, financial resources, political environment, policy and legal environment, community awareness, technological solutions, and practical considerations. The applicability of soft-path approach, in terms of its four major principles, and current strengths and limitations of the organisational capacity to implement the soft-path approach to water management, along with practical implications, are discussed in the conclusion to the chapter.

5.2 Section 1: Applicability

Section 1 of the interviews aimed at evaluating the applicability of the soft-path approach in Abu Dhabi, based on the four principles of soft-path water management. The responses from the seven interviewees were used to identify common themes. The analysis begins by defining and characterizing the four principles of the soft-path approach to relate each concept to the identifiable themes from the interviewees' responses. The claims of the interviewees are also discussed in detail by citing relevant literature and government documents before analyzing the outcomes of key projects and programs mentioned by the interviewees.

5.2.1 Treating Water as a Service

5.2.1.1 Definition

Management of water resources as a service is a central concept of the soft-path approach. It recognizes that people require a combination of services and goods to satisfy their needs. Within this combination of services is water. Therefore, water is managed as a means to an end and not an end in itself (see Section 2.3.3).

When water is regarded as a service, the water sector saves resources because the need for large infrastructural projects to satisfy water demand is reduced. Rather, the focus shifts to making partnerships between various providers so that their services are more responsive to the needs of water users. In other words, the implementation of this principle implies the cooperation between individuals, government, and companies to develop sustainable methods required to meet the water needs of businesses and people (Arscott, 2015). This principle indicates that the soft-path approach is opposed to focusing solely on water supply. Evaluating the interviews and focusing on treating water as a service, three main section are mentioned below: Discussion of the Interviewees Responses, Authenticating the Interviewees' Claims, and Analysis of Relationships between the Criteria and Interviewee Claims.

5.2.1.2 Discussion of the Interviewee Responses

The criteria of the soft-path principle are: sufficient water production and development of infrastructure for water supply, utilization of water-efficient technologies, and implementation of regulations aimed at managing consumer behaviors (Brooks & Brandes, 2011). Two themes emerge from the interviewee responses: (a) Investments in water production and wastewater treatment; and (b) Incentives to minimize water usage. Hence, in the authentication and analyses section, the discussion is developed highlighting these two themes. These identified themes logically correspond to the above-mentioned criteria of the principle in previous chapters and are discussed below.

(a) Investments in water production and wastewater treatment

The purpose of investing in water production is to ensure that water is supplied constantly and at a reasonable cost. All the Interviewees agreed that the water sector has invested in water production and distribution systems. Interviewees 3 and 6 said that this practice was in accordance with Law No. 2 of 1998, which requires that consumers remain connected to water without interruption.

All the Interviewees agreed that seawater desalination and wastewater treatment plants are a major investment. Interviewee 6 added that the cost for the production of desalinated water remains high and equals approximately DH 10 per 1000 IG (or 4.55 m^3). Thus, the government continually aims to cut costs by investing in new technologies and optimising the water production process (Interviewee 6). In addition, interviewee 6 noted that since the government is aware of the value of water for sustainable development, it has given the Abu Dhabi Sewerage Services Company (ADSSC) the mandate and money for the collection and treatment of wastewater.

Another investment is in irrigation technology. Interviewee 4 noted that local farmers are provided with assistance, namely, education and financial support, to improve irrigation technology and innovative irrigation. Additionally, to show that water is treated as a service, Interviewee 5 alluded to the 2016 first consultation document in which licensed tankers ensure the continuous supply of potable water and safe wastewater collection. The consultation provides a regulatory framework for the provision of water and wastewater services by tankers for the consumers, and maximize the investment benefits of mobile water delivery.

(b) Incentives to minimize water usage

For water to qualify as a service, people require additional motivation through government action to use less of it but still satisfy their needs. All the Interviewees mentioned that the progressive rates in water tariffs, as introduced by the government in Abu Dhabi, is a major incentive to less water use because the less they use the lesser the water rate. Interviewee 5 alluded to the fact that the tariff reform was necessitated by the high per capita water consumption in Abu Dhabi, which is one of the highest in the world. Interviewee 5 noted that activities, while potable and domestic use of water constitute less than 10% of total use, landscaping (which previously used to consume 43,993 MIG or 200 million m^3 per day), and irrigation were the greatest consumers of water in Abu Dhabi. Thus, the tariff reforms have influenced major changes including the increased use of treated wastewater for landscaping (Interviewee 5).

Interviewee 2, however, expressed the opinion that the progressive rate in tariffs for potable water are not high enough to act as strong incentives for water conservation. In addition, it was mentioned that tariffs for treated wastewater and groundwater are too low to reflect the actual costs involved in production and distribution. At the same time, Interviewee 6 reiterated that before 2015, water consumption habits were not strongly influenced by the need to conserve water. However, the structural changes in water tariffs to reflect the true cost of water production for higher volume users and a subsidized rate for the lesser volume users have made people rethink their lifestyles and water use because of economic implications (Interviewee 3).

Interviewee 1 noted that since the tariff introduction in 2015, people have been trying to use less water; consumers aim to be in the ‘green band’ where the rate is low, and not in the ‘red band’ where the rate is comparatively much higher. Interviewee 3 added that by having to pay separate tariff rates for water, consumers feel more responsible for their consumption habits. According to Interviewee 4, imparting through education system to reach larger population with water conservation and government regulation can impact further with imposing higher tariffs.

5.2.1.3 Authenticating the Interviewees’ Claims

It is important to verify from the published sources and other related data the information provided by the Interviewees, in order to enhance the credibility of the study findings. In this section, the relevant literature that supports the observations of the Interviewees with regard to the identified themes is cited.

(a) Investments in water production and wastewater treatment

Water production in such a water-scarce area as Abu Dhabi is a costly venture because of the need to use advanced technology to extract and desalinate sufficient amounts of water to meet the demand. In this way, treating water as a service can ease the investment burden because water creates more value to the users in return for a higher financial gain. However, it is worth noticing that the financial returns are crucial for reinvesting in both water infrastructure and innovative technological solutions in water services (Arscott, 2015).

In Abu Dhabi, much of the cost of water production is incurred through the construction of desalination plants. Additional investments are also made in building wastewater treatment plants and water distribution systems. The observation by all the Interviewees that desalination and wastewater treatment plants are the major investments in Abu Dhabi's water sector is supported by the literature and shows how water is treated as a service by the government. Desalination is the primary means of water production. In 2014, for instance, 92.4% of water production in Abu Dhabi was achieved through thermal desalination (Abu Dhabi Quality and Conformity Council, 2017). However, it costs millions of dollars to construct a desalination plant. In its latest bid to enhance water production, Abu Dhabi has planned to construct a desalination plant whose cost is estimated to be between USD 600 million and 1.2 billion (Davids, 2018). As stated by the Regulation and Supervision Bureau (2016)[2], the total production capacity of the nine desalination plants in 2016 equaled 270,241 MIG (1,228.54 million m^3). At the same time, it is worth noting that desalination is an energy-intensive process as the plants use electricity as well as solar energy. Nair and Kumar (2012) commented that the unit cost for desalinated water produced by multistage flash distillation equals USD0.52/m^3 in the Middle East, and Abu Dhabi in particular.

Similar efforts have been made to construct wastewater treatment plants and upgrade sewage disposal systems. According to the Regulation and Supervision Bureau (2016), Abu Dhabi has 40 plants for wastewater treatment "operated by the three major licensees across the Emirate in 2016, comprising 7,770 km of sewers, 40 STPs and 490 km of treated wastewater network" (p. 34).

[2] In 2018, the Regulation & Supervision Bureau (RSB) was changed to the Department of Energy according to Law No. 11 of 2018.

The consumer base for these catchments comprised 370,000 individuals and organizations. The key reason for investing in wastewater treatment is to supplement desalination and groundwater sources. The Strategic Tunnel Enhancement Program (STEP), “a huge gravity-driven hydraulic wastewater network tunnel” which will cost USD1.6 billion, is among the latest examples of megaprojects undertaken by the ADSSC in the wastewater sector (Strategic Tunnel Enhancement Programme, 2018).

The construction of a deep sewer tunnel will allow Abu Dhabi “to do away with 35 existing pumping stations which are on the verge of finishing their useful life” (Strategic Tunnel Enhancement Programme, 2018, para. 2). The project will help ADSSC increase the volume of treated water from about 450,000 m^3 per day to 800,000 m^3 (Strategic Tunnel Enhancement Programme, 2018).

(b) Incentives to minimize water usage

According to Arscott (2015), the effectiveness of incentives to reduce water usage is largely determined by how the consumers value water as a service. Where people undervalue water, strong incentives are needed in order to persuade them to place a higher value on water. This could happen by reducing the gap between what the users pay and the true value of water. In this case, a higher price would make the users rethink their consumption habits (Arscott, 2015).

The use of water pricing in Abu Dhabi as a strategy to minimize water usage is evident from the RSB and AADC websites, which describe the various water tariff rates for Emiratis and expatriates living in flats and villas (see Chapter 4).

The implementation of standard and variable tariffs means that water consumption up to a certain limit is charged at the same rate. Once the consumption units go above the threshold, any additional units attract a marginal price increase (Arbués et al., 2003). Water tariffs in Abu Dhabi were first introduced in 2015 and then revised upwards in 2017 in order to encourage greater water conservation (AADC, 2017).

According to Srouji (2017), water rates for non-nationals were introduced in 1997 but remained the same until 2015, the year in which Emiratis were first charged. The 1997 charge was AED 2.2/m^3 at a constant rate, which covered only 29% of the desalination and distribution costs (Srouji, 2017); this was increased in 2015 and set at a higher threshold than for Emiratis (see Chapter 4).

The ESCOs and the PRS also aim to increase water use efficiency. Overall, "ESCOs act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project" (Office of Energy Efficiency and Renewable Energy, n.d.). In Abu Dhabi, ESCO licensing was initiated under the ADWEA *Tarsheed* programme, which aims to help private and public entities to obtain bids for energy improvements at competitive rates. ESCO will enable private and public bodies to reduce their operating costs by investing in buildings that have implemented or are willing to implement the water and electricity efficiency standards. In addition, consumers will use less water and power towards the 2030 strategic objective of reducing the consumption by 20% (ADWEA, 2017).

Similarly, the PRS has established sustainability requirements that all commercial, residential and government buildings are expected to satisfy, so that all developments are sustainable. The PRS is classified into seven categories in which optional and mandatory credits can be earned by a project. For example, all building projects that are government-funded must become Pearl Rated by satisfying all mandatory credit requirements, such as the building capacity for energy conservation and reduction of water demand through re-use of water, in order to receive approval from the planning authorities (UPC, 2017). Water is an essential pillar of the PRS since Pearl aims to ensure efficiency in the distribution of water resources and a reduction of water demand (UPC, 2017).

5.2.1.4 Analysis of Relationships between the Criteria and Interviewee Claims

In order to evaluate the relevance of the interview results regarding Abu Dhabi's water sector, a discussion of achievements in the implementation of water tariffs as the major incentive to minimize water usage, as well as the realization of water production investment projects, is provided in the following paragraphs.

(a) Investments in water production and wastewater treatment

According to the Environment Agency Abu Dhabi (2017), "through a number of different entities, the emirate has made significant investments in technical innovations to improve groundwater levels", including the creation of solar-powered desalination units, etc. (p. 73). These projects helped to increase the quality and quantity of the water produced and, in this way, increased the capacity to use the resource for various purposes including potable, agricultural irrigation, etc.

In recent years, Abu Dhabi has also invested in four new large plants which added "a treatment capacity of 187MIGD (850,000 m^3/day) to serve more than 3 million inhabitants" (McDonnell & Silva, 2012, p. E-117). Considering that it is expected to substitute the use of expensive desalinated water with reclaimed water (McDonnell & Silva, 2012), such investments in wastewater treatment are essential. The Strategic Tunnel Enhancement Program (STEP) will also largely facilitate the achievement of this goal.

(b) Incentives to minimize water usage

The implementation of water tariffs in Abu Dhabi is one of the major water management initiatives that meets the soft-path approach criteria. Its results have been controversial so far. According to Srouji (2017), who commented that even after the nationals experienced the first water tariff in 2015, the impact on water demand in their households and villas was not significant. The price charged for water did not reflect the actual cost of production, distribution and supply. Specifically, Srouji compared the price elasticity of water demand between nationals and non-nationals following the implementation of the 2015 water tariff and concluded that it was higher among expatriates than Emirati nationals: an indication that non-nationals were more incentivized economically to adjust their water consumption downwards since their tariff rate was higher (Srouji, 2017). It is valid to say that the differences in the quantity of demand between nationals and non-nationals were largely defined by the level of income in the two groups. As Srouji (2017) notes, "income is a variable that contains its own elasticity measure and is a determinant of demand as well" (p. 10).

It means that higher incomes among nationals can lead to more water consumed and may contribute to the inability to change their consumption behaviors in line with economic stimuli.

To justify the reason for the revised 2017 tariff rates in which both segments of the population had to pay more than in previous years, Srouji (2017) presented some statistical findings: 47% of residents in villas who remained in the red band at the end of 2015 were nationals, while only 16% of non-nationals were in the red band. Similarly, 64.4% of residents in flats who remained in the red band at the end of 2015 were Emirati nationals, compared to 36.7% of non-nationals. Therefore, the 2015 tariffs required some adjustment to further reduce the national category in the red band who were contributing significantly to water overconsumption (Srouji, 2017).

As for such initiatives as the PRS, its potential to improve water conservation is exemplified by the outcomes of its implementation in Al Ghuraibah villas, which are ten kilometers from Al Ain City Centre. Under the Pearl Villa System, the project achieved a rating of '2', which means that it uses less than four liters per m^2 per day for landscape irrigation. It also achieved 7 credits for Precious Water, which translates to a 34.6% reduction in water consumption (Mohammed, Fathi & Zaki, 2014).

Lastly, the utilization of water-efficient irrigation systems is on the rise in Abu Dhabi. As stated by Kaber (2014), the Abu Dhabi Farmers Service Centre has distributed such technologies as inline pressure compensating dripline and adjustable online drip systems to "over 90 per cent of farms in the Western Region in the emirate and trained more than 6,000 workers in water-saving techniques" (para. 8).

These technologies can foster up to 46% reduction in agricultural water use (Kaber, 2014). Since these water-efficient irrigation systems help prevent overwatering and leaks, they can significantly contribute to conservation of the resource. There is also The Abu Dhabi Public Realm Design Manual (PRDM) prepared by the AD Urban Planning Council in 2010. The PRDM suggests that at least 80% of all public areas should consist of native plants. The use of native drought-tolerant tree and grass species in landscaping is to help in water conservation and continued ecological protection (Alam et al., 2017). The essential criteria, current condition and the identified gaps of treating water as a service are summarized in Table 5.1.

Table 5.1: Treating Water as a Service: Criteria, Current Condition, and Gaps

Essential Criteria of the Principle	Current Condition in AD Water Management Relevant to the Criteria	Gaps in the Application of the Criteria
1. Sufficient water production and development of infrastructure for water supply.	- Investment in seawater desalination and wastewater treatment plants, as well as sustainable irrigation systems.	- Need for designing efficient valve systems to detect and cut the flow in case of leakage.
2. Utilization of water-efficient technologies.	- Promotion of the use of water fixtures and water-efficient taps, as well as technologies for timely leakage detection and surveillance of water distribution structures.	- Need for developing sustainable irrigation systems for meeting future expected demands. - Need for updating the piping systems during maintenance with respect to new urban plan.
3. Implementation of regulations aimed at managing consumer behaviors.	- Implementation of progressive rates in water tariffs, promotion of sustainable urban developments (ESCO, PRS, and hard landscaping.	- Need for introducing new water tariff rates for high volume users to regulate consumer behavior.

Source: Column 1 is based on the discussion in the earlier section according to Thesis and Brooks & Brandes, 2011; Column 2 is based on the interviews and subsequent review of literature; Column 3 is prepared by the Author by comparing the criteria in Column 1 and the current condition in AD highlighted in Column 2.

5.2.2 Ecological Sustainability

5.2.2.1 Definition

This concept implies that water resources are utilized in a manner that maintains ecological integrity. In other words, the assessment of the ecological effects of utilizing water resources is a key priority. The ecological constraints are identified from the beginning to ensure that water is extracted from the ecosystem sustainably, and the quality of water that goes back to the ecosystem is assessed (Brooks & Brandes, 2011). Evaluation of interviews in this section is divided into three: Discussion of the Interviewees Responses, Authenticating the Interviewees' Claims, and Analysis of Relationships between the Criteria and Interviewee Claims.

5.2.2.2 Discussion of the Interview Responses

The criteria of ecological sustainability include: the development of a supportive environment for sustainable water use by maintaining ecological integrity and considering carrying capacity, the establishment of restrictions on water use by understanding the abstraction potential and the environmental constraints, and the control of water quality and pollution by assessing the water going back into the eco-system (Brooks & Brandes, 2011). Henceforth meeting this criteria, three themes were identified from interviews and are discussed under each section:

(a) Awareness campaign, (b) Regulating water usage, and (c) Wastewater treatment and discharge into the environment.

(a) Awareness campaigns

Community education may be regarded as core to the efforts aimed to create a supportive environment for sustainable water use (Patch, 2010). Interviewees 1, 3, 5 and 6 also mentioned the *Tarsheed* campaigns of the Abu Dhabi Water and Electricity Authority (ADWEA) and its distribution companies, which aim to create awareness of water conservation. Interviewee 4 mentioned that it is actively involved in similar awareness campaigns such as *Al Madaris Al Mustadama* or *Sustainable Schools*. Besides, Interviewees 1 and 6 alluded to the *Rethink* campaign that urges Emiratis and expatriates to rethink their lifestyles in relation to water consumption. According to Interviewees 1 and 2, Abu Dhabi hosts the International Water Summit (IWS) annually, in which water sector stakeholders from private and government entities hold exhibitions and conferences on water issues. Interviewees 1, 3 and 7 highlighted key awareness campaigns and research initiatives that focus on water conservation, to demonstrate how the Abu Dhabi government considers the environment. Specifically, Interviewees 1, 3, and 4 referred to the campaign *Stay in the Green* which was initiated by Waterwise in collaboration with Powerwise. Both of these bodies are initiatives of the Abu Dhabi Regulation and Supervision Bureau. The first one is devoted to the promotion of greater water efficiency across the Emirate, while the second is dedicated to the promotion of sustainable electricity use through public guidance and dissemination of information. Through *Stay in the Green*, the government encourages the water-users to be in the 'green band' to create a supportive environment for sustainable water use.

(b) Regulating water usage

The Interviewees commented that it is the responsibility of the government to ensure that a secure water supply is sustained by preventing wasteful exploitation of water resources. The laws, including Law No. 5 of 2016 concerning the Regulation of Groundwater in the Emirate of Abu Dhabi, ensure that water resources are exploited responsibly and sustainably. Laws and policies establish restrictions on water use based on the abstraction potential and ecological constraints.

Interviewee 3 reiterated that the regulatory framework in the water sector in Abu Dhabi is mature and strategies are implemented more effectively than in other similar sectors in the region. Among the key highlights from the interviews is the stringent regulation of groundwater abstraction through Law No. 5 of 2016 (Interviewees 1, 2, 3, 6, & 7). Interviewee 7 noted that EAD is mandated to monitor groundwater abstraction through this essential law, which states that all the ecological factors involved should be carefully assessed for groundwater to be used sustainably.

Interviewees 3, 4 and 5 mentioned that, under Law No. 2 of 1998 concerning the Regulation of the Water and Electricity Sector in the Emirate of Abu Dhabi, the Regulation and Supervision Bureau has the power to develop treated wastewater regulations that set the standards for the collection, treatment and safe disposal of treated wastewater in the environment. Along with this, Interviewee 3 added that the treated wastewater regulation (Law No. 18 of 2007) maximizes the use of treated wastewater by allowing licensed distribution companies to supply it.

(c) Wastewater treatment and discharge into the environment

The government in Abu Dhabi has been very strict in ensuring that wastewater is treated before being released into the environment. Without this procedure, nature would not be able to cope effectively with wastewater. Along with reduction of discharge levels, system plays a significant role in the control of water quality and pollution by assessing quality of water going back to the ecosystem.

As the quantities discussed in the 5.2.1 section, all the Interviewees emphasised the significance of wastewater treatment for a wide range of uses, including irrigation and landscaping. The Interviewees outlined the milestones that have been made towards greater utilization of treated wastewater in Abu Dhabi. For instance, according to Interviewees 2, 3, & 5, more treated wastewater is now being used for landscaping instead of desalinated water. Currently, over 70% of the total water volume used for landscaping is comprised of treated wastewater and, moreover, the authorities aim to increase its utilisation to 100% by 2030 (Interviewee 5). As stated by Interviewee 4, the establishment of new treatment plants such as Alwathba 1 and 2, as well as the realisation of STEP that will support the increasing use of treated wastewater, is a major milestone towards the attainment of the identified objective. Both water quality and water quantity are largely influenced by the agricultural lifestyle of the population (Hasan, 2012). The component of water quality and quantity is exemplified by its scarcity by virtue of their geographical location. For example, the Nile is the primary source of water for Sudan, Egypt and Eritrea. Since these MMCs are largely arid and semi-arid regions, the majority of the population have settled along the Nile in order to access the water for various uses (Hasan, 2012), but primarily agriculture.

Apart from it, Interviewee 4 mentioned that the water sector intends to reduce the discharge of treated wastewater to the environment to zero by 2020. In addition, the treated wastewater guidelines of 2010 provide a framework for the appropriate use of treated wastewater in irrigation. The objective of reducing the discharge of treated wastewater to zero will address the problem of under-utilization of treated wastewater mentioned by Interviewee 1.

5.2.2.3 Authenticating the Interviewees' Claims

The data collected through interviews with regard to the themes of awareness campaigns, wastewater treatment, treated wastewater discharge and relevant government regulations will next be explained with support from the literature.

(a) Awareness campaigns

The primary awareness campaign suggested by Interviewee 1 was *Stay in the Green*, supported through the Waterwise website, which enumerates the achievements of this and similar campaigns (Waterwise, 2013). According to Waterwise, this campaign has the same objective of persuading the community members to reflect on their water and electricity consumption, especially during summer when the consumption levels are the highest. However, it was primarily necessitated by the introduction of new water and power rates so that consumers would check their consumption of both utilities from their own knowledge. According to Waterwise (2013), during the first two weeks of the campaign's launch, over one thousand people came to test their knowledge of the concept of staying in the green.

Overall, the significance of the campaign by Waterwise derives from its focus on data sharing and the development of a comprehensive knowledge base, which may substantially assist in fostering desired behavioural changes in water and electricity consumers.

The *Tarsheed* campaign was mentioned by Interviewees 1, 3 and 6. It addresses goals for 2030, such as reducing water consumption in Abu Dhabi by 10% (*Tarsheed*, 2017). Its mission is "to interact with all classes of customers, using various relevant communication channels, in order to provide guidance on the efficient and effective use of electricity and water, encouraging and supporting them to adopt measures that will result in more efficient use of these resources, and thereby achieving targeted levels of demand reduction" (*Tarsheed,* 2017, para. 2). For example, *Tarsheed* collaborates with the ADWEA to reach 220,000 households in the city of Abu Dhabi with information about water-saving gadgets available on the market, such as economical shower heads and water-efficient taps (*Tarsheed*, 2017).

The other key initiative mentioned by Interviewee 4 is *Al Madaris Al Mustadama* or *Sustainable Schools*. This initiative aims to impart knowledge about environmental sustainability to students, teachers and parents and then to connect them to the Abu Dhabi community in order to pass on the knowledge for large-scale outcomes (Environment Agency Abu Dhabi, 2013). The campaign is premised on the fact that education is among the most effective means of attaining environmental sustainability because it imparts valuable knowledge and skills to the younger generation so that they can provide practical solutions to environmental challenges (Environment Agency Abu Dhabi, 2014).

The initiative is designed in such a way that teachers will train the students, through an audit of water consumption, while the students will collaborate with their parents to create real solutions in different communities. The campaign targets students in order to make them aware of the ways of using water sustainably. It is worth mentioning that, not only does the *Sustainable Schools* initiative aim to raise awareness of the importance of water conservation among the educators and students but it also encourages them to carry out green audits with the purpose of evaluating their school's ecological footprint (Environment Agency Abu Dhabi, 2014). The Environment Agency Abu Dhabi (2014) encourages schools to apply the audit results consequently during the development of water conservation and other school-wide sustainability programs.

(b) Regulating water usage

In this part, the discussion on regulating water usage is mainly developed based on interventions of government regulations. In relation to the claim that government regulations are important for ecological sustainability in Abu Dhabi, Law No. 5 on Groundwater Regulation issued in 2016 is a classic example. Under this law, the landowners and private sector bodies cannot exploit groundwater on their property without obtaining a license from the EAD, because the government now owns all groundwater resources. Thus, the law is crucial for groundwater sustainability since it will facilitate conservation and replenishment of these important water resources.

Additionally, Law No. 17 of 2005 covers such issues as ownership of sewerage systems and the responsibilities for wastewater management among the main stakeholders, and Law No. 2 of 1998 concerning the Regulation of the Water

and Electricity Sector in the Emirate of Abu Dhabi embraces a large number of issues including the promotion of water research, training staff within the water sector, capacity planning and forecasting, and development of safe water distribution systems (Regulation and Supervision Bureau, 2015a). The given law establishes multiple governmental bodies, such as the Abu Dhabi Water and Electricity Authority, states their responsibilities, and provides general operational rules within the Emirate's water and electricity sector.

The Abu Dhabi government has also undertaken key projects to understand the groundwater resources for better planning. An example is the Well Inventory Project under the EAD, to research and gather information about groundwater parameters such as well characteristics, water pollution, salinity and the water table (Environment Agency, 2017). Three stages are included in the Well Inventory Project, launched in 2016 and intended to last for 30 months (*EAD launches Abu Dhabi Groundwater Well Inventory Project*, 2016). Stage 1 involved establishing an inventory of all operational and non-operational wells. In stage 2, soil samples from different areas were collected and analyzed in order to create a soil classification. Stage 3 then involves the development of the first groundwater atlas in the Emirate (Environment Agency Abu Dhabi, 2017).

(c) Wastewater treatment and its discharge to the environment

Wastewater treatment is vital because it ensures greater control of water quality and pollution, as well as conservation. In other words, it is a method of reducing water wastage by capturing water that would have gone to waste and restoring its quality to usable standards (Abu Dhabi Quality and Conformity Council,

2017). By treating wastewater, the need to extract more water from the ecosystem as well as the possibility of ground water contamination are significantly reduced.

Currently, Abu Dhabi has more than 57 wastewater treatment plants (Regulation and Supervision Bureau, 2016) and, according to 2014 statistics, the Emirate recycled 100% of 850,000 m^3 of wastewater produced during a single day (Kader, 2014). This means that the wastewater treatment process is properly adjusted in Abu Dhabi. If poorly treated, wastewater discharge may adversely impact the environment due to a high concentration of bacteria and other pollutants (Environment Agency Abu Dhabi, 2017a).

5.2.2.4 Analysis of Relationships between the Criteria and Interviewee Claims

To understand if the interview results on awareness campaigns, regulating water use, wastewater treatment and its discharge methods are consistent with the sustainability principle, the major projects and laws associated with these themes are analyzed below.

(a) Awareness campaigns

Through the *Tarsheed* initiative, ADWEA has successfully installed nearly 13,000 sustainable, automatic shut-off water taps in over 800 public mosques and has developed manuals to educate facility managers on water usage reduction (Tarsheed, 2017). The campaign has also reached 220,000 households with the goal of educating them about the availability of gadgets that can help them use water more efficiently and, at the same time, provide them with notifications about potential water leakages (Tarsheed, 2017). Therefore, residents are more knowledgeable than before about how they can access water-efficient products (Tarsheed, 2017).

Among 135 schools participated in *Al Madaris Al Mustadama*, the per capita/ per day water use was reduced from 32.7 liters in 2015 to 25.88 liters in 2017. In addition, 1,499 teachers have been trained in water auditing in schools and how to implement mitigation measures (Environment Agency Abu Dhabi, 2013).

(b) Regulating water usage

Altogether, current regulations including Law No. 17 of 2005 and Law No. 2 of 1998 cover a wide range of government and institutional responsibilities and duties, indicating that significant efforts are being made to achieve sustainable water management. These documents show that the government is making significant efforts to promote water security in the Emirate. However, although there are many active regulations on wastewater treatment, the Environmental Agency Abu Dhabi (2017a) claims that "the limited quantities of wastewater transferred by tankers are not accepted for disposal by ADSSC networks due to quality" (p. 10).

It is worth noting that the Regulation and Supervision Bureau (2010) issued the Recycled Water and Biosolids Regulations with the purpose of ensuring the high quality of treated wastewater in the Emirate by outlining the functions and duties of the responsible bodies. Additionally, the Environment Agency Abu Dhabi (2011) has published the Wastewater and Marine Water Quality Monitoring guidelines in order to minimize the harm to the environment from treated wastewater discharge. It indicates that the legal framework controlling both the processes of water production and the quality of the resource is comprehensive and requires only minor changes (identified above).

(c) Wastewater treatment and its discharge to the environment

The level of wastewater treatment has increased in the Emirate from 150 million m^3 to over 300 million m^3 from 2005 to 2015 (Environment Agency Abu Dhabi, 2017a). It is expected that the generation of wastewater will continue to increase further, and this raises concerns regarding the inability of the water sector to cope due to infrastructural inefficiencies and the need for technological upgrades (Environment Agency Abu Dhabi, 2017). For example, it is stated that a significant percentage of treated water contains high concentrations of total dissolved solids, reducing the quality of the resource and, consequently, decreasing the chance for its reuse (Environment Agency Abu Dhabi, 2013). Moreover, "sewers that allow seepage also allow leakage of sewerage into the surrounding areas, leading to a public health concern" (Environment Agency Abu Dhabi, 2013, p. 5).

However, the major problem is that the rate of its discharge to the environment also remains high, equating to 49% (Environment Agency Abu Dhabi, 2017a). According to Interviewee 4, wastewater treatment cannot have the optimum benefits in terms of water and ecological conservation if most of the treated water is discharged back into the environment. At the same time, the discharge of treated wastewater back into the environment is a threat to sustainability because it leads to a greater rate of use of costly desalinated water and scarce groundwater (Environment Agency Abu Dhabi, 2017a). Therefore, Abu Dhabi's water management action plan has prioritised minimising the discharge of treated wastewater in order to promote sustainability (Environmental Agency Abu Dhabi, 2014b). Table 5.2 shows the essential criteria, current condition and gaps of the ecological sustainability.

Table 5.2: Ecological Sustainability: Criteria, Current Condition, and Gaps

Essential Criteria of the Principle	Current Condition in AD Water Management Relevant to the Criteria	Gaps in the Application of the Criteria
1. Development of a supportive environment for sustainable water use by educating the public, maintaining ecological integrity, and considering carrying capacity.	- Active promotion of community awareness through multiple programs: *Stay in the Green*, *Tarsheed*, et cetera. - Well Inventory Project allows better understanding of the carrying capacity of groundwater resources and their abstraction potential.	- Need for introducing awareness among university and schools through education and practice of sustainable water usage.
2. Establishment of restrictions on water use by understanding the abstraction potential and the ecological constraints.	- Laws for water use control and water protection (e.g. Law No. 2 of 1998, Law No. 17 of 2005, et cetera) provide guidelines for sustainable water use. - The abstraction of groundwater is monitored under Law No. 5 of 2016.	- Need for more laws on sustainable water usage.
3. **Control of water quality and pollution by assessing the quality of water going back to the eco-system.**	- Wastewater and Marine Water Quality Monitoring guidelines and Recycled Water and Biosolids Regulations create a supportive environment for the sustainable treatment of wastewater and prevention of environmental harm due to its discharge.	- Need for the modification of infrastructure and technology implemented at wastewater treatment plants to prevent the leakage of sewage and to increase the quality of treated wastewater. - Need for new wastewater tankering regulations.

Source: Column 1 is based on the discussion in the earlier section according to Thesis and Brooks & Brandes, 2011; Column 2 is based on the interviews and subsequent review of literature; Column 3 is prepared by the Author by comparing the criteria in Column 1 and the current condition in AD highlighted in Column 2.

5.2.3 Conserving Water Quantity and Quality

5.2.3.1 Definition

This principle advocates water conservation by matching water quality with different uses (see Section 2.3.3). Since potable water of high quality is not easily available in nature, it is paramount to balance investments so that activities that require low-quality water have sufficient supply while the more expensive potable water is available at a reasonable cost (Brooks & Brandes, 2011).

5.2.3.2 Discussion of the Interviewee Responses

The criteria for 'Conserving Water Quantity and Quality' principle are the creation of cascading water systems (that is water recycling and the utilisation of wastewater as an input for another use), and the development and implementation of standards for conservation of water quality and quantity (Brooks & Brandes, 2011). The interviews in connection to this principle and criteria, revealed the following themes: (a) Implementation of cascading water systems, and (b) Water quality standards.

(a) Implementation of cascading water systems

Cascading water systems primarily imply regular high-quality treatment of wastewater and its consequent utilisation as an input for another use. In other words, the given system establishes a cycle of production, utilisation, wastewater collection, treatment, and reuse (Brooks & Brandes, 2011). When asked about the implementation of cascading systems in Abu Dhabi, as well as their efficacy, Interviewees 1, 2, and 5 stated that, currently water cascading is not sufficiently used; yet the efforts towards the achievement of better outcomes are being

undertaken. For example, treated wastewater should be used primarily for industrial cooling activities and landscaping, and the volume of treated wastewater use for landscaping continues to increase (Interviewee 5 & 2). The same idea was expressed by Interviewee 6 who, however, noted the absence of a standard for district cooling. They also opined that in spite of some regulations encouraging the utilisation of treated wastewater in district cooling activities, it remains impossible due to various network deficiencies.

Interviewee 3 mentioned the network/infrastructure deficiency for collecting and distributing treated wastewater in irrigation as well that fails to prevent the use of potable water for irrigation. Interviewee 5 stated that nearly 505 MIG (230 million m^3) of desalinated water was utilised in agriculture, and expressed concern that the quality of this resource is rather high to be used for irrigation. Interviewee 2 considers that treated wastewater should be used instead, although even it sometimes has high salinity, which could affect the crops under irrigation. Interviewees 4 & 7, however, were not aware of water cascading in Abu Dhabi.

(b) Water quality standards

The main aspect related to conserving the quality and quantity of water involves water quality standards, which are essential because they form the framework upon which water quality is matched with water uses. All the Interviewees agreed that water quality regulations have been implemented in Abu Dhabi. For example, Interviewee 3 noted that the water used for domestic purposes in Abu Dhabi is supposed to be wholesome as per the Water Quality Regulations issued by the Regulation and Supervision Bureau (2014). The objective of Water Quality Regulations as highlighted by Interviewees 2 & 3 is to promote public health

by ensuring that water quality matches use. They stated that the regulations are intended to ensure that all the water supplied for such uses as food production, drinking, cooking or washing does not contain elements or substances that would pose a threat to public health.

5.2.3.3 Authenticating the Interviewees' Claims

In this section, the literature that supports their observations with regard to the themes identified in the discussion part is provided.

(a) Implementation of cascading water systems

The claims by Interviewee 5 that desalinated water is used for irrigation in Abu Dhabi contrasts with the findings by the Masdar Institute that irrigation is primarily done using treated wastewater (Azar & Raouf, 2017). At the same time, the claim by Interviewees 5 & 2 that wastewater is increasingly being used for landscaping is well supported by the literature. The wastewater treatment and disposal sector has also promoted the use of wastewater in agricultural activities. For example, 51% of the total volume of treated water in 2015 was channeled towards irrigating green areas (Abu Dhabi Quality and Conformity Council, 2017).

Currently, the sustainability standards and regulations in Abu Dhabi, such as the Recycled Water and Biosolids Regulations, control the quality of treated wastewater utilized for irrigation and landscaping. Nevertheless, although the UPC aims to promote ecological sustainability through the efficient and increased use of treated wastewater (UPC, 2011), currently no law forbids the use of water from other resource in agriculture, district cooling, and landscaping. The Regulation &

Supervision Bureau (2016) states that the development of the framework for regulating district cooling is in progress.

(b) Water quality standards

The RSB website provides information on the standards expected of water for food production, drinking, cooking and washing.

Additionally, Recycled Water and Biosolids Regulations, discussed in the previous section, aim to control the quality and quantity of treated wastewater production (Regulation and Supervision Bureau, 2010). Overall, all these regulations are consistent with the RSB's mission "to regulate and supervise the delivery of a safe, efficient and economic water, wastewater and electricity sector in the Emirate of Abu Dhabi" (Regulation and Supervision Bureau, 2015, para. 1). They are aimed at matching the quality of resources with their purposes, which helps in minimising potential harm to public health and the environment.

5.2.3.4 Analysis of Relationships between the Criteria and Interviewee Claims

The purpose of this section is to evaluate the consistency of the interview findings with the principle of conserving water quality and quantity and to assess the major outcomes associated with 'cascading water systems', and the 'development and implementation of standards for conservation of water quality and quantity'.

(a) Implementation of cascading water systems

Considering that the risk of groundwater source depletion is extremely high in the region, there is a need to increase sustainable utilization of treated wastewater, targeting current irrigation and district cooling needs. According to interviewees 1, 2,

and 5, the current water cascading is not enough, and efforts undertaken are not enough in bringing the expected outcomes. Moreover, as mentioned by interviewee 3 the network/infrastructure deficiency fails to prevent use of portable water for irrigation.

Conserving Water Quantity and Quality is through creation of cascading water systems (that is water recycling and the utilization of wastewater as an input for another use), and the development and implementation of standards for conservation of water quality and quantity (Brooks & Brandes, 2011).

(b) Water quality standards

The production of potable water in Abu Dhabi is consistent with the Water Quality Regulations introduced by RSB. All the Interviewees agreed that water quality regulations have been implemented in Abu Dhabi. For example, Interviewee 3 noted that the water used for domestic purposes in Abu Dhabi is supposed to be wholesome as per the Water Quality Regulations issued by the Regulation and Supervision Bureau (2014). Currently, the sustainability standards and regulations in Abu Dhabi, such as the Recycled Water and Biosolids Regulations, control the quality of treated wastewater utilized for irrigation and landscaping (UPC, 2011). Table 5.3 summarizes the essential criteria of the principles, current condition and gaps of conserving water quality and quantity.

Table 5.3: Conserving Water Quality and Quantity: Criteria, Current Condition, and Gaps

Essential Criteria of the Principle	Current Condition in AD Water Management Relevant to the Criteria	Gaps in the Application of the Criteria
1. Creation of cascading water systems (utilization of wastewater as an input for another use).	- Compliance with Water Qualsity Regulations.	- Need for more investment in the creation of cascading systems for re-use of treated wastewater and increase cost-efficiency and sustainability of water distribution. - Necessity to improve the network/infrastructure for collection and distribution of wastewater to ensure reliable facility as a part of cascading water systems.
2. Development and implementation of standards for conservation of water quality and quantity.	- Recycled Water and Biosolids Regulations control the quality of treated wastewater. - Use of native drought-tolerant tree and grass species in landscaping.	- Identified regulations do not impose strict restrictions on the use of groundwater and desalinated water for irrigation, district cooling, and landscaping. - Need for finding out suitable locations and assign for plantations with objective of more ground water conservation.

Source: Column 1 is based on the discussion in the earlier section according to Thesis and Brooks & Brandes, 2011; Column 2 is based on the interviews and subsequent review of literature; Column 3 is prepared by the Author by comparing the criteria in Column 1 and the current condition in AD highlighted in Column 2.

5.2.4 Backcasting

5.2.4.1 Definition

The use of backcasting to plan and manage future water requirements is a core principle of the soft approach to water management. It involves envisioning potential sustainable future scenarios in terms of resource management and their backward analysis that aims to identify existing barriers to a sustainable future and what needs to be done to attain it (Binstock, 2010).

The creation of a vision for the future generated by using backcasting implies a high level of accountability of stakeholders' interests and needs (Brooks & Brandes, 2011). Therefore, it requires collaboration, with water managers and major stakeholders engaging in open discussion to determine the future they envision (Binstock, 2010).

5.2.4.2 Discussion of the Interviewee Responses

The criteria of backcasting include the development of a number of alternative visions of a desirable future, the analysis and weighting of current situations and resources based on the formulated visions of the future, and the accountability of stakeholders' needs and interests/consideration of social implications and objectives (Brooks & Brandes, 2011). The themes identified from the interviews, as discussed below, match two criteria of 'backcasting': (a) Development of future scenarios and analysis of current situations, and (b) Accountability of stakeholders' needs.

(a) Development of future scenarios and analysis of current situations

The interviews revealed that the water sector in Abu Dhabi uses forecasting rather than backcasting as the primary planning method. Interviewees 1 and 3 noted that demand forecast is a requirement of the Regulation and Supervision Bureau. Utility companies also prepare five-year plans (Interviewees 2 & 3). The respondents raised a concern regarding the uncertainty introduced by some of the current planning methods, i.e. seven-year forecasts, indicating that government organizations prefer methods which are associated with a higher level of prediction accuracy (Interviewees 2, 3, 6 & 7).

It is clear that such an element of backcasting as visioning is implemented in Abu Dhabi unsystematically and to a limited extent. For instance, it was mentioned above (see section 5.2.2) that one alternative desirable future in the Emirate is complete avoidance of treated wastewater discharge to the environment (Interviewees 4 & 5).

However, when it comes to determining actions with respect to future goals including those outlined by Abu Dhabi Vision 2030, the government still relies mainly on statistical forecasts, which Interviewee 3 defined as an important source of guidance in setting Abu Dhabi's goals and programs.

(b) Accountability of stakeholders' needs

The majority of respondents (Interviewees 1, 2, 4, 5 & 7) all stated that the public and community members are not involved in the process of decision making. However, Interviewees 3 and 6 did not agree. All respondents confirmed that the water sector pays attention to such vital stakeholder needs as environmental and

health safety, high quality of resources, and their availability when developing water management strategies and future goals. Along with this, all the Interviewees mentioned that the governing bodies of Abu Dhabi consider long-term economic needs when planning water conservation and production initiatives.

5.2.4.3 Authenticating the Interviewees' Claims

To verify the credibility of the interview results, the literature on the topic is evaluated in the following paragraphs.

(a) Development of future scenarios and analysis of current situations

The data identified in the literature confirms that forecasting the most widely used method of planning in Abu Dhabi. As stated by Chowdhury and Rajput (2015), such organizations as the EAD and ADWEC regularly develop water demand projections based on the estimated rates of population growth and water consumption.

At the same time, the abundance of the formulated future goals and objectives, for instance, the avoidance of treated wastewater discharge into the environment by 2020, indicates that officials envision desirable futures when designing action plans. However, there is no evidence that the backward analysis approach is being implemented in the Emirate.

(b) Accountability of stakeholders' needs

According to Lund (2015), along with economic objectives, water management serves the society including public health, preservation of ecological integrity, support of recreational activities, and creation of desirable

urban/community environments. The consideration of social needs, which is observed in the development of policies and programmes aimed at increased water productivity in the Emirate and changed consumer behaviors, helps fulfil these goals. However, even with a sufficient level of stakeholder accountability, the management of natural resources using centralized planning is associated with limited community participation. At the same time, Vergragt and Quist (2011) state that greater stakeholder engagement in decision making and backcasting provides such benefits as the increased ability to analyze the contextual elements of desired future visions, to investigate complex and uncertain futures, and to drive action and innovation more effectively.

5.2.4.4 Analysis of Relationships between the Criteria and Interviewee Claims

The outcomes of current planning procedures in Abu Dhabi are evaluated in the following paragraphs. The section is objected to observe the consistency with respect to interview finding and principle of backcasting associated with ‘development of alternative visions’, ‘analyzing and weighting current situation’, and ‘accountability of stakeholders’ needs and interests’.

(a) Development of future scenarios and analysis of current situations

Compared to forecasts, backcasts do not aim to reveal what the future may be but rather aim to clarify if different policy goals are feasible to implement, as well as any implications they may have (Vliet & Kok, 2013).

The results of the interview make it clear that the water sector in Abu Dhabi has several desired endpoints, which it expects to achieve within a certain period, including the reduction of discharge of treated wastewater to zero by 2020. It is also

apparent that some milestones towards the achievement of these desired futures are identified, such as improvement in the wastewater treatment infrastructure. Although these steps seem valid, the implementation of the backward analysis that explores the feasibility of desired future scenarios could assist decision makers in Abu Dhabi's water sector by gathering and assessing evidence about the effectiveness of planned management actions (Vliet & Kok, 2013). At present, evidence for the implementation of the identified analysis method in the Emirate is lacking in both literature and Interviewees' responses.

(b) Accountability of stakeholders' needs

The laws, regulations and other initiatives analyzed above (see sections 5.2.1, 5.2.2 and 5.2.3), such as the PRS, Water Quality Regulations, ESCO and *Tarsheed*, demonstrate that the water sector strives to support economic prosperity without compromising human safety and environmental sustainability. Additionally, Abu Dhabi's five-year water strategy has made informing all stakeholders in the public sphere a priority so that their views can count towards better planning (Environment Agency Abu Dhabi, 2014a). It means that the water sector has a tool for the collection of stakeholders' feedback regarding water management. However, Interviewees noted only a limited level of stakeholder involvement, which indicates a major applicability gap. Table 5.4 shows the essential criteria, current condition and gaps of the backcasting.

Table 5.4: Backcasting: Criteria, Current Condition, and Gaps

Essential Criteria of the Principle	Current Condition in AD Water Management Relevant to the Criteria	Gaps in the Application of the Criteria
1. **Development of various alternative visions of the desirable future for sustainable water management.**	- Formulation of future goals and objectives for sustainable water management in the Emirate.	- Forecasting remains a preferable planning method that is highly demanding. - Need for developing alternate visions of sustainable water management.
2. **Analysis and weighting of current situations and resources based on the formulated visions of the future.**	- Assessment of the current water management with observation of increasing trend of demand and implementing strategies.	- Need to evaluate the effective strategies found successful and improve on it.
3. **Accountability of stakeholders' needs and interests.**	- Consideration of stakeholders' needs, both social and economic, during the determination of sustainable volumes of supply**.** -	- Low level of community involvement in decision making (i.e., the lack of sufficient feedback from community members).

Source: Column 1 is based on the discussion in the earlier section according to Thesis and Brooks & Brandes, 2011; Column 2 is based on the interviews and subsequent review of literature; Column 3 is prepared by the Author by comparing the criteria in Column 1 and the current condition in AD highlighted in Column 2.

5.2.5 Conclusion

This chapter served toward fulfillment of research questions focusing on the current structure of water supply, measures taken by government to regulate water demand, revised structure of tariff, and implementation of soft-path approach as an

alternate comprehensive model. The purpose of this chapter was to analyze the applicability and institutional capacity of the soft-path approach based on the observation of responses obtained from interviewees in various parts of water sector of Abu Dhabi. The Interviewees made important observations in their responses to different questions. These responses were used to construct several themes under the four principles of the soft-path approach so as to determine the feasibility of applying the soft-path approach in Abu Dhabi.

Firstly, under the principle of treating water as a service, the following themes were identified: investment in water production and wastewater treatment, and incentives to minimize water usage, including the promotion of water-efficient technologies. The current situation was analyzed with comparison to relevant literature in order to observe the interviews and compare with literature. Secondly, the themes identified with in the principle of ecological sustainability were: creation of a supportive environment through awareness campaigns, control of water quality and preservation of marine eco-systems through wastewater treatment practices and reduction of its discharge, and the establishment of restrictions on water use through government regulations. In addition, the themes noticed when observing the principle of conserving water quality and quantity were water quality standards, and implementation of cascading water systems. Finally, the principle of backcasting had the following two themes: development of future scenarios and analysis of current situations, and accountability of stakeholders' needs.

It was noted that all the Interviewees' claims were widely supported by the literature, and the study objectives were achieved. The interview results indicate that Abu Dhabi has laid a firm foundation for the soft-path approach by focusing its

efforts to create water conservation awareness, promote wastewater treatment, and increase efficiency in water use. Therefore, this support from literature makes the responses from interviewees more reliable and validating answers to the research questions. This investigation has provided insight of Abu Dhabi in terms of water supply and demand, the measures taken by government to regulate was demands, and way of implementation of soft-path approach.

However, few limitations were observed in the analysis and planning methods associated with backcasting. It was noticed as a result of lack of sufficient cascading water systems due to infrastructural inefficiencies, a low rate of treated wastewater reuse, leakage of sewage, and reduced quality of treated wastewater were observed.

5.3 Section 2: Implementability

Section 2 is primarily focused on the review and analysis of the Interviewees' responses concerning eight themes that determine the institutional capacity for the soft-path approach: human resources, informational resources, financial resources, political environment, policy and legal environment, community awareness, technological solutions, and practical considerations. As with Section 1, its objective is to assess the suitability of the soft-path approach in the Emirate's water sector. In order to assess the capacity of Abu Dhabi to implement the soft-path approach, Interviewees' responses regarding the identified themes are discussed and authenticated by using research evidence. Consequently, the outcomes of the key programmes and practices noted by the respondents are evaluated and a conclusion concerning the major strengths and weaknesses is drawn.

5.3.1 Institutional Capacity: Interviews Responses

Respondents were asked to provide answers regarding the implementability of the soft-path approach in Abu Dhabi based on the eight themes of institutional capacity**.**

The responses of the seven Interviewees, as well as the evidence retrieved from the government literature, were analyzed under each of these eight themes to demonstrate if it is feasible to utilize the soft-path approach in Abu Dhabi at the present time.

Human resources: The theme of human resources is concerned with the full-time availability of specially trained staff to manage water conservation programs (see section 2.4). Considering this, the following questions were asked: Do the staff in the water sector have access to water conservation training and further education? Is there full-time dedicated staff in the water sector responsible for water conservation? The answers to these questions were expected to address the issue of availability of skilled staff dedicated to water conservation and the management of sustainable practices in the water sector.

The responses to the questions on human resources were mixed. Three respondents (Interviewees 2, 3 & 5) said there were full-time staff dedicated to water conservation within their respective organizations, and only one (Interviewee 4) said there were no such staff in his organization. The other three (Interviewees 1, 6, & 7) said not all entities have full-time staff dedicated to water conservation. In terms of access to training, Interviewees 2, 3, 4 and 5 said that their staff members have access to training in matters of water conservation while Interviewees 6 and 7 said

access to such training is not always available. Interviewee 1 had no information on the question of access to training. Hence, this points out that there is limited access for full-time staff to training.

For Abu Dhabi to secure a sustainable and safe water supply, it requires professionals who are specially trained in water conservation. The Abu Dhabi government has responded to this need in significant ways. For example, the Environment Agency Abu Dhabi (2016b), claims that it provided internal training for staff, covering both general environmental protection activities, as well as emergency responses. Further, opportunities for the training of full-time dedicated staff in water conservation were realized following the joint initiative of 2013 referred to as the Water Resources Management Strategy for the Emirate of Abu Dhabi (Environment Agency Abu Dhabi, 2016a). The primary purpose of this initiative is to ensure that Abu Dhabi rapidly achieves efficient management and conservation of its three key water resources, in line with the Emirate's Vision 2030 (Environment Agency Abu Dhabi, 2014b). The initiative is taken; however the implementation process must be strengthened strategically to associate the training access effectively for full-time staff in water conservation.

Information resources: To manage the programs effectively, it is essential to have access to information resources including the current and future projections of water demand and population. At the same time, it is possible to achieve maximum benefits associated with this data when it is shared among different staff members (see section 2.4). The questions related to the given theme had the purpose of elucidating whether the level of information resource management is sufficient in Abu Dhabi to facilitate and improve the implementation of the soft-path approach.

When asked whether employees have access to data on water demand, six Interviewees (Interviewees 1, 2, 3, 4, 5 & 7) said that the staff members are able to access the latest water demand data, while Interviewee 6 said that access is only available in some entities. When asked if staff monitor the results of any water conservation programs/policy changes/interventions, three respondents (Interviewees 3, 4 & 6) said the staff monitors the results of water conservation programs, and ongoing interventions. Interviewees 2 and 5 said this only happens in some entities, while the remaining two (Interviewees 1 & 7) had no information on this question. This indicates the poor monitoring in terms of regular monitoring of data and observing up to date because only three staff responded positively.

On the question about the information sharing and cooperation among stakeholders, four respondents (Interviewees 1, 3, 4 & 6) said there was information sharing among the stakeholders in the forms of partnerships, collaborations, and development of knowledge management networks, while three others (Interviewees 2, 5 & 7) said that only in some entities do stakeholders share information. This indicates that information is partial present, and it is observed to reinforce partnership and collaboration. Answering the question about the use of the latest research and technology in the water sector, Interviewees 3, 4 and 6 said that the staff keeps up with the recent statistical data on water consumption and demand in the Emirate, as well as the research evidence related to them and the advancements of technology within the sector. At the same time, Interviewees 1 and 5 said they do not use such information, and the other two (Interviewees 2 & 7) said that the staff only in some entities keeps up with the latest research and technology.

These responses clarify that staff is not careful about the research evidences and is poorly concerned about the recent statistical data and advancement of technology. This also points out that staff is not putting efforts in significantly observing the water consumption pattern of demand in Abu Dhabi. Lastly, answering the question regarding the awareness of possible effects on water resources of future climate change in Abu Dhabi water sector, only three respondents (Interviewees 3, 6 & 7) said the water sector keeps up with the possible effects of climate change, while Interviewees 1 and 5 said this does not happen. Interviewees 2 and 4 said this happens only in some entities. Hence, it can be inference that staff of water sector is partially concerned with possible future impact of climate change of Abu Dhabi.

During the interviews, six interviewees indicated that the staff members in the water sector were able to access the latest water demand data. This claim is supported by the publication of water and energy data by the Statistics Center (SCAD) where water professionals can request accurate and updated statistical data (Statistics Center Abu Dhabi, 2016). ADWEC, RSB, EAD and ADWEA also make their annual statistical reports available on their websites.

Financial resources: The theme of financial resources is equally important as it is concerned with funding water conservation efforts and allocating budgets within financial institutions. The matters discussed during the interviews under the given theme contribute to the understanding of whether the water sector has sufficient financial resources needed to maintain the implementation of the soft path.

Answering the first question: Does the water sector maintain its financial bottom line? Interviewees 2, 3 and 5 said that the water sector maintains its financial bottom line, while Interviewees 4 and 6 said that this was not always the case. At the same time, Interviewees 1 and 7 did not provide answers to this question. These responses reflect that financial resources are not managed in effective manner and taking into account the cost-effective measures. Regarding the question about the predictability and continuity of annual budgets, three Interviewees (Interviewees 1, 2 & 3) said that it is constant and predictable while Interviewees 4 and 5 said the budget is not constant or predictable. Interviewee 6 said the annual water budget is not always predictable, and Interviewee 7 had no information. This indicates that annual budget is predictable most of the time as partially it is agreed by the interviewees.

When replying to the question about the reflection of the full cost of water services and provision in water rates, only Interviewee 3 thought that water rates reflect the full cost of water services and provision, while Interviewees 1, 2 and 7 said the rates do not reflect the cost of some water services. Interviewees 4, 5 and 6 said this is not the case for all water services. These responses entail full cost of water services as varying for different services as most of the interviewees agreed in that. This factor will affect in the monitoring of the water rate provisioned to conservation, production, treatment, operation and maintenance, and water source protection. At the same time, none of the Interviewees had credible information to share regarding the funding for water conservation efforts, external funding sources, and lifecycle assessments of water supply and demand projects.

For conservation efforts to be sustainable, water rates should represent the full cost of water services because, in this way, then only it becomes possible to maintain high quality services and invest the collected income in their improvement (Patch, 2010). In terms of financial resources, the claim by Interviewee 3 that water rates reflect the full cost of services and provision is supported by the revised water tariffs which show that water and power bills now reflect the actual cost that is incurred by the ADDC in supplying the resource (ADDC, 2017). The increased rate in water tariffs was mainly due to the reduction of the government subsidies in water and power which, in turn, was prompted by budget cuts associated with lowered government revenues because of low oil prices (International Trade Administration, 2018). Nevertheless, in spite of recent budget cuts, the International Trade Administration (2018) states that the government prioritizes investments in water conservation practices, such as water-efficient technology, desalination, and public education.

Policy and legal environment: According to Patch (2010), “the policy and legal framework is a significant determinant of capacity because it creates an enabling environment that gives a water institution its mandate, its authority, and the limits to its authority” (p. 36). The legal environment includes different laws, plans, and programmes. It was intended that the discussion of the given theme would help ascertain if current policies and laws are well integrated with water conservation efforts and efficient land use as per the soft-path principle.

When answering the question regarding the existence of an active water conservation plan/program in the water sector, six respondents (Interviewees 1, 2, 3, 4, 6 & 7) were of the opinion that the water sector in Abu Dhabi has an active water conservation plan. For his part, Interviewee 5 had no information. This is supporting that Abu Dhabi bringing effective and active implementation of water conservation plan/program and making staff aware of it. This also contributes in putting a clear goal of sustainability. Additionally, concerning the integration of water conservation into land use planning, five respondents (Interviewees 3, 4 5, 6 & 7) thought that water conservation is integrated into land-use planning, but Interviewee 2 felt that the integration is not complete. Interviewee 1 did not provide an answer to this question. At the same time, regarding the integration of water conservation into economic planning, Interviewees 3, 4 and 6 said that water conservation is integrated into economic planning while Interviewees 2 and 5 felt the integration is not complete. Interviewees 1 and 7 did not provide information to this question. All of the above responses supportively reflect that water sector of Abu Dhabi is leading other department for water conservation using planning in terms of land use and economic planning.

Answering the question about the contribution of different government departments to water conservation programs and planning, four respondents (Interviewees 1, 3, 4 & 6) felt that the government departments contribute to water conservation programs and planning, while three (Interviewees 2, 5 & 7) felt that the government departments are not fully involved. When talking about the strategies included in water conservation programs, four Interviewees (Interviewees 1, 3, 4 & 5) said there are strategies for reducing outdoor water use, but the others had no information on this question.

From the responses, it is understood that government is involved majorly behind implementation of water conservation programs and planning. Lastly, in terms of the way water infrastructure is sized and its ability to meet increasing water demand, Interviewees 2, 3 & 6, said it is sized according to the demand, while Interviewees 7 and 5 felt it is "somehow" sized according to the demand. Interviewees 1 and 4 did not provide any comments on this matter.

Abu Dhabi has the Water Resources Management Strategy that prioritizes water conservation and the integration of efficient water use practices (Government of Abu Dhabi, 2014). In this initiative, the Abu Dhabi Executive Council has teamed with the UAE to update its 2009 water master plan to ensure a reduction of pressure on the three key water resources: groundwater, desalinated water and treated wastewater (Environment Agency Abu Dhabi, 2014). It is clear that water conservation is integrated with economic planning because the government sees it as the key to further economic growth in the Emirate (Government of Abu Dhabi, 2014). For example, through infrastructure development initiatives, it aims to minimize water transmission and distribution losses, as well as the discharge of treated wastewater (Government of Abu Dhabi, 2014). Additionally, the imperative to ensure high indoor and outdoor water efficiency included in the Abu Dhabi Environment Vision 2030 may serve as an example of the integration of water conservation into land-use planning (Government of Abu Dhabi, 2014). The literature findings indicate that sustainability is an explicit goal of Abu Dhabi's water policy.

Political environment: The soft-path approach considers the political environment where cooperation between leadership in the water sector, government and private-sector organizations is taken into account (see section 2.4). The main questions related to this theme are as follows: Is there collaboration between water sector organisations? Does the water sector liaise with private-sector organisations? Does the water sector liaise with all levels of government? Does the water sector/your organization publicly advocate water conservation? The answers to these questions were intended to reveal the degree of the integration and the efficacy of governance of water conservation efforts at all governmental and community levels.

The results of political environment analysis showed that all the seven Interviewees agreed that there is collaboration among the different types of organizations in the water sector. Henceforth, it is observed that government is involved with collaboration this can be due to the share of activities of water sector with other non-government and private organization as a part of horizontal linkages. In the political environment, there is evidence of collaboration between the government and private sector entities. Public-private partnerships (PPPs) are expected to support sustainability efforts through the integration of private sector technologies, and funds with the public initiatives (Government.ae, 2018). For example, RSB has partnered BP to develop the ForeseerTM tool for better forecasting of water and energy resources towards Vision 2030 (British Petroleum, 2018). Additionally, all the Interviewees agreed that the water sector actively advocates for water conservation in the Emirate. The numerous community education and awareness campaigns discussed in Section 1, such as *Tarsheed* and *Stay in the Green,* encouraging citizens to use the resource efficiently (Waterwise, 2013) verifies this assumption.

It is also worth noting that the Abu Dhabi water sector and distinct agencies regulating it, including ADWEA, ADSSC, EAD, are closely related to the federal UAE structure and the Ministry of Climate Change and Environment, in particular (International Trade Administration, 2018). This indicates that the activities of local entities are coordinated at distinct political levels.

Community awareness and involvement: As stated by Patch (2010), "involving the public in decision-making allows access to 'local knowledge' of the day-to-day local experiences of individuals in the community and this knowledge can be used to increase the effectiveness of policies by uncovering problems and potential solutions" (p. 42). The practices related to the given theme include community education and outreach programs, which increase individuals' participation in water conservation.

The major questions asked under the given theme were: Does the water sector sponsor outreach programs and education to promote water conservation? Is the importance of water conservation addressed in the community? Does the water sector promote indoor high-efficiency appliances? All the participants said the water sector sponsors outreach programs on water conservation. In addition, the seven participants said the importance of water conservation is addressed in the community. They also agreed that the water sector promotes indoor high-efficiency appliances. In terms of greywater system and wastewater reuse, Interviewees 2, 3, 4, 5, 6 and 7 were of the opinion that it is encouraged, while Interviewee 1 said the use of greywater and wastewater reuse was not sufficiently encouraged by the water sector.

It was also asked whether the public is involved in decision-making. Only Interviewee 3 said that the public is involved in decision making while Interviewee 6 said the involvement can be observed only among such stakeholders as water distribution companies, and governmental agencies. The remaining five (Interviewees 1, 2, 4, 5 & 7) said that the public is not involved. This indicates that there is low level of involvement of public with respect to water sector involving for decision making.

The success of sustainability projects in any nation is determined by how well public participation is implemented (Patch, 2010). The findings indicate that the government strives to increase understanding of the value of water resources in Abu Dhabi's community. For instance, the various awareness programs including the *Tarsheed* campaign, *Stay in the Green*, and *Al Madaris Al Mustadama* have all acted as platforms for informing and educating communities about issues of water conservation and their roles towards achieving the goal of sustainability. Additionally, the *UniverCity Outreach Program* and *Al Madaris Al Mustadama* are among the outreach programs implemented by the water sector in Abu Dhabi to promote the involvement of communities in water conservation efforts (UPC, 2011). Nevertheless, public involvement also implies that individuals' interests are considered in decision-making (Patch, 2010). By giving members of the public the opportunity to understand the issues involved and to express their opinions, decision-making processes become more transparent and free from manipulation.

Abu Dhabi's five-year water strategy has made informing all stakeholders in the public sphere a priority so that their views can count towards better planning (Environment Agency Abu Dhabi, 2014a). Nevertheless, as per the Interviewees'

claims, the actual feedback from the Emirati citizens regarding water conservation efforts remains scarce.

Technological solutions: In water conservation programs, there is a wide range of technological solutions. However, the soft-path approach is primarily concerned with the evaluation of water conservation technologies that promote outdoor water conservation and that prevent system-wide water losses (Patch, 2010). The matters discussed under the given theme include: the encouragement and regulation of the use of automatic irrigation systems, the repairing of water leakages, and compliance with the repair protocols.

The responses on technological solutions showed that the water sector encourages automatic irrigation systems since six participants (Interviewees1, 3, 4, 5, 6 & 7) provided affirmative answers. However, Interviewee 2 said the automatic irrigation systems are not encouraged. Five participants (Interviewees 2, 3, 4, 5 & 6) said that automatic irrigation systems are not mandated within the legal framework, which means their use is not required by the law and local policies. Interviewee 7 provided no information on this problem, while Interviewee 1 said the automatic irrigation systems are mandated. As for repairing the leaks, Interviewees 1, 3, 4, 5 and 6 all agreed that it was also encouraged among home owners. However, Interviewee 2 disagreed, and Interviewee 7 did not comment.

When asked about the presence of leak repair schedules, three respondents (Interviewees 4, 5 & 6) said that only some entities had a leak repair schedule, while Interviewees 1 and 2 said that there is no leak repair schedule. Interviewee 7 did not give a response, while only Interviewee 3 thought that the leak repair schedule was present in all entities.

Irrigation technologies are important for outdoor water conservation, considering that agriculture and landscaping consume most of the water in Abu Dhabi (Abu Dhabi Quality and Conformity Council, 2017). For this reason, Abu Dhabi has supported the use of automatic irrigation to reduce water consumption in the agriculture farms. A case in point is the USD 9.8 million automatic irrigation projects completed by the Abu Dhabi Municipality which have replaced manual irrigation systems on farms. The given automatic system is capable of preventing the use of potable water in irrigation by replacing it 100% with treated wastewater and save about 15% of treated wastewater, thus facilitating the irrigation of new areas (Abu Dhabi Municipality Parks & Recreation Facilities Division, 2017). Nevertheless, while the use of efficient water technologies and practices is encouraged, there is currently no law regulating the utilization of automatic irrigation systems in Abu Dhabi and forbidding the implementation of manual ones, which is the primary implementation gap.

Practical considerations: The given theme refers to the feasibility of the implementation of current water conservation initiatives (Patch, 2010). The questions asked during the discussion of practical considerations included: Are the water policies, regulations, and guidelines issued by water sector organizations easy to implement?

Does the water sector pay attention to social science’s contribution to water conservation, such as awareness, media and behavioral changes? The replies and evidence helped to understand whether the integration of soft path into the water sector in Abu Dhabi would require a more aggressive and long-term strategy or vice versa.

The answers to practical considerations showed that most of the water policies, regulations and guidelines are easy to implement, according to Interviewees 3, 4, 5, 6 and 7. Interviewee 2 said the policies are not easy to implement, while Interviewee 1 made no response to the question. In Abu Dhabi, the ease of implementing policies can be defined mainly by the fact that each governmental agency in the sector has clearly stated responsibilities and functions, which do not overlap. For instance, ADWEA is responsible for the supply and distribution of the resource, while EAD is responsible for the monitoring and assessment of the resource use (Food and Agriculture Organization of the United Nations, 2008). Additionally, many strategies and policies have clearly defined objectives, targets, and timelines, such as the reduction of groundwater abstraction for agricultural use to 1.400 million m^3 by 2018 (Government of Abu Dhabi, 2014). Additionally, the five-year water strategy in Abu Dhabi set certain targets which included a 100% reuse rate of the treated wastewater by 2018, compared to 51% in 2010 (Environment Agency Abu Dhabi, 2014b). The effective year for usable groundwater reserves is also targeted to increase from less than 55billion liters to more than 74 billion liters by 2030 (Environment Agency Abu Dhabi, 2014b). Through integrated and efficient utilization of water resources, Abu Dhabi aims to reduce domestic consumption (liters/capita/day) from 614 in 2010 to less than 340 by 2030 (Environment Agency Abu Dhabi, 2014b).

As for the second question provided under the theme of practical considerations, the water sector approaches water issues by applying social science knowledge. It means it takes into account the fact that fresh water is a limited resource that should be exploited with great efficiency and that the available water is needed by humans, animals and plants (Environment Agency Abu Dhabi, 2014).

5.3.2 Summary of the Main Points

The responses in Section 2 of the interviews demonstrate areas of strength and weakness in the institutional capacity. The strongest themes based on the number of respondents are human resources, policy and legal environment, political environment and practical considerations. The themes of information resources, financial resources, community awareness and involvement have some minor gaps, while the theme of technological solution has major gaps. This means, overall, Abu Dhabi has a sufficient foundation and the essential capacities needed to implement the soft-path approach, yet some changes and improvements are still needed in order to achieve better outcomes. The ‘essentials’ mentioned in the Table 5.5 are listed based on the previous classification obtained from Table 2.3 ‘indicators’ in accordance with Path (2010). These were used to formulate questions regarding institutional capacity as listed in Appendix D. The findings are summarized below in Table 5.5.

Table 5.5: Implementation of the Soft-Path Approach in AD: Analyzing Institutional Capacity

Theme	Essentials	Implementation	Gaps
Human resources	- Knowledge and skills necessary to manage water resources effectively.	- Strategic goals include the development of professional and skilled personnel in water management. - Provision of new training opportunities.	- There is limited access to training as two Interviewees stated that access to training is not always available in the governmental entities.
Information resources	- Ability to access and share data on water supply and demand.	- The majority of organizations have regular access to essential information resources. - Information sharing is observed to reinforce partnership and collaboration.	- Poor monitoring of data. - Staff is not effective in accessing and implementation of recent research evidence. - Less efforts towards observing water consumption pattern and advancement of technology. - Less efforts for observing impact of future climate change.
Financial resources	- Funding. - Cost management.	- The government invests in water conservation and protection programs. - Water rates reflect the full cost of services.	- Recent budget cuts indicate that the budget in the water sector is not always constant and predictable across the sector. - The cost-effective measures are not taken into account. - Systematic monitoring of water rates for different services is not provisioned.
Policy and legal environment	- Formulation of clear sustainability goals and alignment of water conservation initiatives with other planning activities.	- Water Resources Management Strategy that prioritizes water conservation and the integration of efficient water use practices. - Water conservation efforts are integrated with economic and land-use planning. - Sustainability is an explicit goal of Abu Dhabi's water policy.	- Sizing of water infrastructure to meet the demand.

Table 5.5: Implementation of the Soft-Path Approach in AD: Analyzing Institutional Capacity (Continued)

Theme	Essentials	Implementation	Gaps
Political environment	- Cooperation among sectors and leaders.	- The activities of the local governmental bodies are coordinated with federal ones. - The water sector actively advocates for water conservation. - The water sector collaborates with private and community organizations. - Different agencies in the water sector collaborate well.	- No significant gaps were identified.
Community awareness and involvement	- Ability of the public to influence decision making. - Community education.	- The government aims to promote community awareness regarding sustainable practices and their significance.	- The level of community involvement remains relatively low.
Technological solutions	- Advanced water management and information management technologies.	- Promotion of widespread implementation of automatic irrigation systems for outdoor water conservation, as well as leakage monitoring among households.	- Limited adherence to leak-repair schedules. - There is currently no law regulating the utilisation of automatic irrigation systems in Abu Dhabi.
Practical considerations	- Consideration of social tendencies in strategic planning. - Provision of implementation feasibility.	- Policies and strategies are feasible to implement. - The water sector pays attention to social science's contribution to water conservation.	- No significant gaps are identified.

Source: Column 1 and 2 are based on Patch (2010); Column 3 and 4 are based on the interviews, as discussed in the text.

5.4 Conclusion

The analysis of results from both Sections 1 and 2 reveals that there are both strengths and limitations in organizational performance in relation to the soft-path implementation. Four principles of the soft-path approach are covered to varying degrees by various programs, laws, policies and government actions in Abu Dhabi's water sector. The major strengths related to the applicability of the soft-path approach included increase in investment in wastewater treatment, laws for water use control and water protection (e.g. Law No. 2 of 1998, Law No. 17 of 2005, et cetera) provide guidelines for sustainable water use, the abstraction of groundwater is monitored under Law No. 5 of 2016, water recycling and waste water treatment, and formulation of future goals for sustainable water management in Abu Dhabi. The major strengths related to the implementability of the soft-path approach are the availability of skilled human resources and opportunities for their development, supportive legal and political environments, and the feasibility of the realization of distinct water conservation policies and programs.

As for the weaknesses, the water sector has barriers to a more successful application of soft path principles, such as the lack of sufficient cascading water systems due to infrastructural inefficiencies, poor monitoring of demand patterns, less efforts in observing the water consumption patterns, less concerned with climatic change impact in future, and increased use of treated wastewater for irrigation, district cooling, and landscaping. Major strengths include: provision of new training opportunities, majority of organizations have regular access to essential information, information sharing, government investments in conservation and protection programs, and cooperation of active local government.

The major weaknesses associated with the institutional capacity to implement soft path are the lack of predictable budgets, low levels of community involvement in decision-making, the lack of laws regulating the utilization of automatic irrigation systems in Abu Dhabi, and the limited adherence to water leakage schedules. The identified gaps and weaknesses indicate that some improvements are required in certain areas of performance. Potential solutions that may improve the situation will be discussed in the following chapter.

Chapter 6: Conclusions and Recommendations

6.1 Introduction

Abu Dhabi Emirate is one of the United Arab Emirates Arabian Gulf countries that are experiencing major water shortages challenging its continued economic prosperity threatening the environment. Considering the depleting level of ground water, low supply of fresh water, and increasing level of annual water consumption, there is a need for water conservation and efficient use, as discussed in Chapter 4. The initiatives and management practices within by the water sector, collaboration between the government and community stakeholders, show that the government in Abu Dhabi is very much aware of the water security situation which is also evidenced in the government's efforts to ensure that the scarce water resources are used sustainably. However, a more integrated approach to water demand management, like the 'soft-path approach' may be required for managing scarce water resources in Abu Dhabi.

The findings indicate that many of practices in which the Abu Dhabi water sector currently engage meet soft path principles. The soft-path approach challenges the traditional water management and planning methodologies that mainly focus on water demand and cost-effectiveness. Nevertheless, it builds on the conventional methods and includes a broader range of conservation measures (Brooks & Holtz, 2009). It seems that the main activities currently realized in the Emirate are focused on the encouragement to change in water use habits among the residents. The soft path also implies the focus on services provided by energy input instead of looking at water as an end in itself (Brooks & Holtz, 2009).

The promotion of water efficient technologies (automated irrigation systems and taps) and sustainable urban developments (EBSCO, PRS) in Abu Dhabi can be highlighted in this regard. However, there are still a lot of gaps in the application of the soft-path approach. For example, to manage water in a "soft" manner, Brandes and Brooks (2005) recommend including water efficient technologies that do not need water as much. An example of such a technology/practice is the cultivation of native drought-tolerant plants for landscaping and other purposes. There is also a need for establishing a well-functioning cascading water systems.

The implementation of the soft-path approach is also feasible from the perspective of current institutional capacities. For instance, the government has sufficient active water conservation plans, laws and policies to which stakeholders are required to adhere to. At the same time, the institutional capacity of Abu Dhabi to implement the soft-path approach is weakened by the low level of community involvement in decision making. The involvement of large numbers of stakeholders and a meaningful participation of the public in decision-making is important because it helps determine an optimal cost-benefit ratio in terms of desires, preferences, and needs of the community and the Emirate in general (Brandes & Brooks, 2007). Another institutional weakness seems to be weak supportive environment for the implementation of efficient water technologies and initiatives. This chapter deals primarily with recommendations on improvement required to increase efficiency in implementing a soft-path approach to water management in Abu Dhabi. At the end, the chapter raises possible future research questions.

6.2 Recommendations

This section offers major recommendations for further improving the applicability and implementability of the ‘soft-path’ approach to water management in Abu Dhabi. The practical recommendations have been developed based on the limitations and gaps summarised in Tables 5.1, 5.2, 5.3, 5.4, and 5.5. The recommendations are linked to the ‘soft-path’ principles and respective criteria as well as the ‘institutional capacity’ themes identified in Chapter 2. The Section is divided into two: the first part deals with the recommendations related to implementation of the four principles of the soft-path, and the second part deals with the eight themes of institutional capacity essential for the implementation of the soft-path approach to water management in Abu Dhabi.

6.2.1 Recommendations based on the Implementation of the Four Principles

The recommendations provided in below sections are in the light of four principles, however some sections may include points related to two or more principles.

6.2.1.1 Development of a Supportive Environment for Sustainable Water Usage

Overall, active laws and regulations implemented in Abu Dhabi create a favorable environment for sustainable water management as they effectively address a large number of issues. However, although there are many active regulations on wastewater treatment, the Environmental Agency Abu Dhabi (2017a) claims that “the limited quantities of wastewater transferred by tankers are not accepted for disposal by ADSSC networks due to quality” (p. 10). This indicates a need for new wastewater tankering regulations.

After addressing essential criteria related to treating water as a service, following gaps were identified:

- Sustainable irrigation systems must be developed for meeting future expected demands in order to have sufficient expansion of infrastructure for water supply.
- Efficient valve systems must be designed to detect and cut the flow in case of leakage in order to utilize the water with efficient technologies in implementation.
- Piping systems must be updated during maintenance with respect to new urban plan.
- Suitable locations must be assigned for plantations with objective of more ground water conservation.

Another significant issue concerning the supportive environment is the legal framework for the universal use of automated irrigation systems in agriculture and landscaping. The imposition of stricter rules and timelines regarding the implementation of the given technology can help reduce water losses considerably. Thus, the water regulatory framework should be re-examined to ensure that this problem is addressed.

6.2.1.2 Utilization of Water-Efficient Incentives Aimed to Minimize Water Usage

Better ways to stimulate the change in water consumption behaviors among Emirati nationals are required as they are less incentivized economically compared to the non-nationals. As stated by Srouji (2017), “to achieve aims of an effective water tariff design, it is preferable to have a relatively higher elasticity in demand curve, so that there is a higher decrease in consumption when price is increased” (p. 11).

Since it was observed that income elasticity interferes with the responsiveness to economic incentives among Emirati nationals, there may be two primary ways to modify their consumption behaviors (Paul, Al Tenaiji & Braimah, 2016). Firstly, it is possible to increase water tariffs, so that it covers both production and supply costs and contributes to the greater reduction in water demand (Beacon, 2008). Secondly, it is the implementation of awareness campaigns targeted at affluent population groups. A balance between the two is recommended as it may ensure greater public acceptance and social equity.

After addressing essential criteria related to ecological sustainability, following gaps were identified:

- Awareness among university and schools through education and practice of sustainable water usage must be developed to ensure sustainable measure are taken to minimize water usage.
- The government must establish new regulations for new wastewater tinkering to ensure water is used with subsequent understanding.

- Government must consider modification of infrastructure and technology implemented at wastewater treatment plants to prevent the leakage of sewage and to increase the quality of treated wastewater. In this manner, the government can implement control over the water pollution.

Also, government must subsidize the leakage fixing as a part of adherence to the water conservation culture and fixing the distribution pipelines, valves, and taps under the command of local community or the residents (Mahmoud & Abdaalh, 2014). In addition, government must take initiative to consider cultivation of drought-tolerant species as a part of landscaping project also creating the awareness among the community and residents for such plantations. Because, as stated by Alam et al. (2017), "native plants have a capacity to adapt to hostile arid environmental conditions which is an important factor to select them for landscaping" (p. 730). Compared to exotic and introduced species, they require less water and overall maintenance. Not only can the cultivation of drought-tolerant plants restore the native ecosystem, but this can also contribute to greater water use efficiency. Thus, governmental agencies must make deliberate efforts to research and promote these plant species by educating farmers, collaborating with other organizations and sectors, and developing relevant guidelines and laws.

6.2.1.3 Creation of Cascading Water Systems

The findings of the literature review conducted in Chapter 4 revealed that the depletion of groundwater resources and their minimal replenishing represent a major problem in Abu Dhabi. It was also identified that desalination is utilized as the primary alternative method for production of water.

Considering the urgent need to preserve groundwater and taking into account the high costs associated with the desalination process, there is a need to invest in other techniques of water production. More investment in the creation of cascading systems for re-use of treated wastewater is one of the promising alternatives to support the conservation efforts and increase cost-efficiency and sustainability of water distribution (Brooks & Holtz, 2009). After addressing essential criteria related to cascading systems, following gaps were identified:

- The network/infrastructure for collection and distribution of wastewater must be improved to ensure reliable facility as a part of cascading water systems. For instance, the Environment Agency Abu Dhabi (2017a) states that in order to address the network/infrastructure deficiencies, which interfere with the improvement of cascading water systems in the Emirate, the governing bodies should invest in the construction of transfer trunk lines in order to facilitate the utilisation of treated water.

- Strict restrictions on the use of groundwater and desalinated water for irrigation, district cooling, and landscaping must be implemented in order to keep standards controlling the quality as well as quantity of water.

The current low rate of treated wastewater reuse may be addressed through the construction of transfer trunk lines and an increase in the treatment design capacity to handle the growing volumes of used water. The first recommendation can help allocate treated wastewater across sectors and industries more efficiently, improving the overall utilization of treated wastewater. The second will help address the identified infrastructure deficiency which currently contributes to the low percentage of wastewater reuse.

6.2.1.4 Backcasting and Community Involvement

The data identified in the literature confirms that forecasting is by far the most widely used method of planning in Abu Dhabi. However, in addition to forecasts, it is recommended that organizations in the Abu Dhabi water sector implement the four major steps involved in backcasting:

1) Identification of a desired endpoint and creation of plausible future alternatives related to it;
2) Identification of possible milestones and obstacles during the analysis that starts from the desired goal back to the present;
3) Utilization of identified milestones and obstacles for the assessment of current resources and formulation of robust actions; and
4) Development of strategies based on the analysis results (Vliet & Kok, 2013).

After addressing essential criteria related to backcasting, following gaps were listed:

- Forecasting planning method must be adopted that is highly demanding because it can help in future and for sustainable water management.

- Strategies that were previously effective in water management must be revisited and improved further to ensure the current situation are addressed and future visions are developed.

- The public and community must be involved more in decision making and it must be done by taking feedback from them about conservation efforts.

Additionally, the effectiveness of water conservation laws will achieve their objectives when members of the public feel that they are part of the changes in the water sector since they are potentially the main force for transformation.

This means that communities should be actively involved in decision-making processes as they are among the key stakeholders in water conservation efforts. It was mentioned throughout discussion that Abu Dhabi's five-year water strategy has made informing all stakeholders in the public sphere a priority so that their views can be included and used to help towards better planning (Environment Agency Abu Dhabi, 2014a).

It is, however, also necessary to mobilise community members to obtain their feedback. Thus, besides educating people about the value of water resources, awareness campaigns must provide the Emirati citizens with the necessary information about existing feedback and surveillance tools such as web sites. Along with conservation advocacy, the given marketing approach is consistent with the soft-path principle.

6.2.2 Recommendations for Improving Institutional Capacity

6.2.2.1 Human Resources

The water sector must provide the staff with full access to training. Training activities are key to personnel and professional development and can help in achieving the Emirate's Vision 2030 of initiative for achieving efficient management according to Environment Agency Abu Dhabi (2014b).

6.2.2.2 Information Resources

The water sector should make the latest research on water issues available to all water staff in order to enhance their knowledge base and make the relevant changes in the water sector.

In other words, the technological and research knowledge that the staff will access will help them to be better prepared for the application soft-path approach (Binstock, 2010). In addition, the staff must take responsibility and efforts to observe the impact of current situation of water consumption as well as the impact of future climate change. Further, they must also keep track of advancement in the technology.

6.2.2.3 Financial Resources

The water budget should be reviewed based on the realigned priorities so that it becomes predictable. By being predictable, the financial resources will be allocated more effectively across the priority areas. Systematic method must be adopted to monitor the water rates for different services to observe the full cost structure. This information must be incorporated to take cost-effective measures.

6.2.2.4 Policy and Legal Environment

As a part of water resource management with growing demand, the water sector must consider the sizing of water infrastructure to meet the growing demand. Further, improve on the new wastewater tankering regulations as discussed in section 6.2.1.1. This is important to ensure that the water regulatory framework includes all type of legal amendments. Water sector must be integrated with other planning programs to legally bound the responsibility and provide sustainable legal

environment. Also, rules must be imposed strictly ensuring firm legal bonds for regulating water usage.

6.2.2.5 Community Awareness and Involvement

The concern of saving water and minimum water usage must be delivered to community in order to increase their level of participation and involvement in the decision making. As previously highlighted in section 6.2.1.1 and 6.2.1.2, awareness among university and schools through education and practice of sustainable water usage should be focused to generate more awareness and involvement. In addition, the involvement of community must be heavily put to decision making to reflect better conservation impacts because they are essential stakeholders who can bring about the change as also discussed in section 6.2.1.4. Besides that, continuous feedback from the community must be taken as well to observe their involvement.

6.2.2.6 Technological Solutions

The maintenance of the long distribution pipelines must be carried out and the leakages must be repaired based on schedules. This will improve systematic approach towards management of water distribution systems. Further, in Abu Dhabi, automatic water irrigation systems must be developed that can more importantly support the advanced technologies.

6.3 Future Research

The government is very much eager to achieve a greater level of sustainability in water consumption and management, and currently promotes and utilizes many methods that relate to the essential principles of the soft-path approach e.g. development of a supportive environment for sustainable water use or

establishment of restrictions on water use. This research, based on scholarly and professional sources, identify a few promising methods and solutions.

Further research, focusing on the issues identified in this research can be undertaken to understand the water situation and effects of the governmental efforts so that more ways are found to achieve sustainability in water in Abu Dhabi in the near future. The major future study ideas are presented below.

6.3.1 Water Valuation

First, the research findings revealed that various water use control practices are characterised by distinct effectiveness regarding improving water consumption behaviours among the Emirate's residents. The major research implication of this is the need for a deeper understanding of the impacts of water pricing in the community members, especially the citizens. It may be useful to further investigate price elasticity of water, as well as the behavioural characteristics of consumers, to develop more effective and targeted pricing policy as well as awareness campaigns and conservation incentives that would lead to more efficient resource consumption.

6.3.2 Sector-Relevant Soft-Path Solutions

Secondly, since it was identified that agriculture and landscaping consume most of the water resources in Abu Dhabi, it is pivotal to investigate all possible solutions that may lead to greater efficiency of water use in both the public realm and industry. Potential solutions mentioned in the paper include the use of treated wastewater for irrigation, adherence to stricter irrigation schedules, development of climate-appropriate urban landscapes, human resource education, and so on. It is

suggested to evaluate possible impacts of every practice on water conservation efforts to identify the most appropriate and effective ones.

Therefore, in order to meet the criteria of the soft-path principle for conserving water quality and quantity, Abu Dhabi must increase the level of reusing treated wastewater. As an example, future research could focus on the investigation of irrigation-efficient technology use in agriculture. Study is suggested to ascertain the full potential of benefits associated with the technology, including economic advantages and lower resource burdens at individual, organisational and national levels. It is also recommended to evaluate farmers' current levels of knowledge about available innovative irrigation technologies and ways to operate them. This data will help to develop effective targeted education strategies and promotion campaigns to support water conservation efforts.

Additionally, there is a need for research of the local flora and the development of guidelines for the cultivation of drought-tolerant species, and increased use of treated wastewater for irrigation, district cooling, and landscaping.

Further investigation into the effectiveness of economic stimuli, which were intended to increase as a result of the 2017 revision of water tariffs, in changing the behaviours of Emirati nationals is also essential. It is possible to suggest that some improvements in current initiatives could result in more successful implementation of soft path. It is observed that the green sector in the UAE currently "depends completely on exotic species and irrigation water mostly from nonrenewable ground resources" (Alam, Khattak, Ppoyil, Kurup, & Ksiksi, 2017, p. 737).

Compared to native plant species, exotic species, utilised in local landscapes mainly for aesthetic reasons, require high maintenance and water-intensive support systems. At the same time, Alam et al. (2017) state that the present-day level of knowledge about flora in the UAE is low and there is a real need to promote the use of native plants in urban landscaping in order to achieve more sustainable water distribution.

An Abu Dhabi public realm design manual issued in 2010 indicates that at least 80% of all public areas should consist of native plants (Alam et al., 2017). In order to attain this goal, further research of the flora in the Emirate must be encouraged. Moreover, guidelines for drought-tolerant cultivation in agriculture must be introduced to help achieve better outcomes in water conservation.

6.3.3 2017 Water Tariffs Revision

Evidence regarding the effectiveness of economic stimuli, intended to increase as a result of the 2017 revision of water tariffs, in changing the behaviours of Emirati nationals. Hence, the outcomes of the revised 2017 water tariffs should be investigated as there are currently no studies that demonstrate how these new tariffs have affected water demand.

Therefore, future studies in Abu Dhabi should target on quantifying the gains made from the implementation of water tariffs. This research will enable a better understanding of pricing-behaviour dynamics.

6.3.4 Implementation of the Soft-Path for Water

To understand the effectiveness of the soft-path approach and its suitability for the Emirate in greater detail, it is suggested to conduct empirical research of the soft-path implementation. The scope of this future study should be sufficiently narrow to facilitate the collection of demographic, consumption and technological data over time. It is also possible to implement a control trial design in the given project and to compare the study sample with control data gathered within an area where the softpath will not be implemented, to contrast different management methods and evaluate their effects. Qualitative research of the water sector can again be implemented to discuss with the sector leaders the issues related to the implementation of the soft-path approach. In this study, the sector environment can be evaluated as a whole within the framework and criteria of the soft-path principles in order to identify whether or not current managerial and leadership practices meet them.

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Appendices

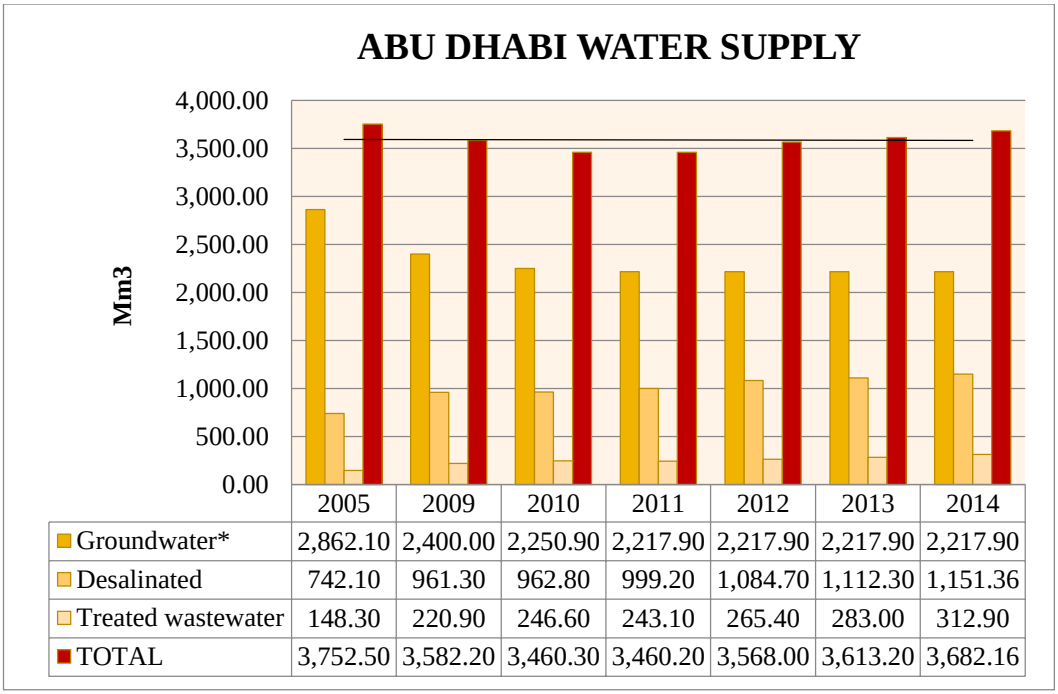
Appendix A: Water Demand and Water Deficit Projections in Million Imperial Gallons per Day for the Abu Dhabi Emirate

Data from Chowdhury and Rajput, 2015.

Year	Available water capacity	Water demand	Required water capacity	Water deficit
2016	830	960	1,007	-177
2017	830	987	1,030	-200
2018	827	1,013	1,066	-239
2019	826	1,039	1,090	-264
2020	825	1,065	1,113	-288
2021	830	1,091	1,136	-261
2022	850	1,117	1,159	-267
2023	850	1,143	1,182	-293
2024	850	1,169	1,205	-319
2025	850	1,195	1,228	-345
2026	850	1,221	1,251	-371
2027	850	1,247	1,274	-397
2028	850	1,273	1,297	-423
2029	850	1,299	1,320	-449
2030	850	1,325	1,343	-475

Appendix B: Water Supply in Abu Dhabi (2005-2014), million m^3 per year

Data from Statistics Center Abu Dhabi, 2017



	2005	2009	2010	2011	2012	2013	2014
Groundwater*	2,862.10	2,400.00	2,250.90	2,217.90	2,217.90	2,217.90	2,217.90
Desalinated	742.10	961.30	962.80	999.20	1,084.70	1,112.30	1,151.36
Treated wastewater	148.30	220.90	246.60	243.10	265.40	283.00	312.90
TOTAL	3,752.50	3,582.20	3,460.30	3,460.20	3,568.00	3,613.20	3,682.16

* Groundwater for 2012, 2013, 2014 and 2015 is estimated to be the same for 2011 until the finalizing the well inventory results later in 2017

Appendix C: Interview Invitation Letter

Dear Participants,

This letter is an invitation to participate in a study I am conducting as part of my Master's degree in Governance and Public Policy at the United Arab Emirates University. The thesis is "The Soft-Path Approach for Sustainable Water Management: An Analysis of Its Suitability in Abu Dhabi".

The interview questions are divided into two sections to examine the suitability of the soft-path approach in Abu Dhabi and to understand the institutional capacity of Abu Dhabi to implement this approach.

Please note for the purpose of this thesis that "soft-path approach for water management" is a concept for long-range planning that involves quantitative and qualitative methods to develop options for freshwater policy that are economically feasible, environmentally sustainable and socially acceptable.

The four principles of the soft-path approach are:

- Treating water as a service rather than an end in itself.
- Ensuring ecological sustainability
- Conserving quality as well as quantity
- Looking ahead by working backwards.

Participation in this interview is voluntary. You may choose not to answer some questions. The information you provide will be entirely confidential. Names and details will not appear in any thesis or report.

If you have any questions regarding this study, or would like additional information, please contact me by e-mail at U201570129. You can also contact my supervisor, Dr Sami Hasan at samiulh@uaeu.ac.ae.

I hope that the results of my study will be of benefit to the Emirate water management organizations, as well as to the broader research community.

I look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Mariam Al Suwaidi

Appendix D: Themes, Indicators of Capacity and Grouped Indicator Questions

Themes	Indicators of capacity	Indicator questions
Human resources	- Full-time, dedicated staff for managing water conservation programs	- Do the staff in the water sector have access to water conservation training and further education? - Is there full-time dedicated staff in the water sector responsible for water conservation?
Information resources	- The employees have access to recent and future data on water demand and population. - Continued and regular monitoring is conducted to ensure that data is up to date. - Information and data are shared among staff and stakeholders. - Staff are able to keep up with research and technology in the water sector. For example, climate change research, lab testing, policies, etc.	- Do employees have access to data on water demand? - Does the staff monitor the results of any water conservation programs/ policy changes/ interventions? Is the data kept up to date? - Do stakeholders cooperatively share information and data among themselves? - Do the staff keep up with the latest research and technology in the water sector? - Is the water sector in Abu Dhabi up to date with the possible effects on water resources of future climate change?
Financial resources	- Water sector considers a financial bottom line to ensure that it is efficient and cost-effective. - There is regular funding for water institutions to achieve water conservation. - Water sector guarantees a balanced and maintainable budget for water conservation. - There is a possibility for external funding to the water institution. - Lifecycle assessments are carried out for water supply and demand projects. - Water rates represent the full cost of water services and provision (including conservation, production, treatment distribution, operation and maintenance, and water source protection). - There are incentives to consumers such as residents, businesses, etc. to support water conservation.	- Does the water sector maintain its financial bottom line? - Does the water sector allocate and regulate funding for water conservation efforts? - Is the annual budget constant and predictable each year? - Is it possible for water institutions to get external funding? - Are water supply and demand projects supported by lifecycle assessments? - Do water rates reflect the full cost of water services and provision? - Are there any incentives to support the conservation of water resources?

Themes	Indicators of capacity	Indicator questions
Policy and legal environment	- The water sector has a clear goal of sustainability. - Water conservation is a long-term (more than one year) priority for the Emirate of Abu Dhabi. - The water sector has a water conservation plan/program that has been actively implemented. - Water conservation is integrated with other planning programs. - Water conservation is organized among different water sector departments. There might be one lead department. - Use of backcasting as a planning tool. - Water conservation is important for planning and constructing new water supply infrastructure. - Water conservation program (s) and planning combine(s) a number of effective strategies and approaches that have not been extensively implemented (to date).	- Does the water sector have a clearly identified goal? - Does the Emirate of Abu Dhabi see water conservation as a long-term priority? - Does the sector have an active water conservation plan/program? - Is water conservation integrated into land use planning? Is water conservation integrated into economic planning? - Have various government departments contributed to water conservation programs and planning? - Is backcasting used as a tool for planning? - Is water conservation important for the development of a new water supply infrastructure? - Are there any innovative developments and programs that are related to water conservation? - Does the water conservation program include strategies for reducing outdoor water use and summer peak demand? Is the water infrastructure an appropriate size to meet demand?
Political environment	- Water sector has a strong leadership for water conservation. - Water sector liaises its activities with other departments (horizontal linkages). - Water sector liaises with other local community organizations (horizontal linkages). - Water sector shares its activities with non-government, professional and private sector organizations (horizontal linkages) (e.g. LEED). - Water sector liaises with private-sector organizations (horizontal linkages). - Water sector liaises its activities with other levels of government (vertical linkages) (e.g. input into provincial building codes).	- Does the water sector/your organization publicly advocate water conservation? - Is there collaboration between water sector organizations? - Does the water sector liaise with local community organizations? - Does the water sector liaise with non-government organizations? - Does the water sector liaise with private-sector organizations? - Does the water sector liaise with all levels of government?

Themes	Indicators of capacity	Indicator questions
Community awareness and involvement	- Water sector actively engages the public in decision-making. - Water sector carries out public education and outreach program(s) for water conservation. - Education and outreach efforts represent public opinions about water conservation. - Indoor water conservation practices and technology are presented in water conservation program (s) and planning.	- Is the public involved in decision-making? - Does the water sector sponsor outreach programs and education to promote water conservation? - Is the importance of water conservation addressed in the community? - Does it help individuals to understand the value of water resources? - Does the water sector promote indoor high-efficiency appliances (e.g. toilets, washing machines, showerheads)? - Are greater systems and wastewater reuse encouraged by the water sector?
Technological solutions	- Outdoor water conservation technologies are included in water conservation program (s) and planning. - System-wide water conservation technologies are included in water conservation program (s) and planning.	- Does the water sector encourage automatic irrigation systems? - Are automatic irrigation systems mandated to control unnecessary watering? - Is repairing water leaks encouraged for homeowners? Is there a leak repair schedule?
Practical considerations	- Easy-to-implement and short-term factors include important water conservation program (s) and planning. - Water conservation program (s) and planning should start with methods that need little or no behavioral changes. - Social sciences as well as engineering participate in the sphere of water management.	- Are the water policies, regulations, guidelines, etc. issued by water sector organizations easy to implement? - Does the water sector pay attention to social science's contribution to water conservation, such as awareness, media, behavioral changes, etc.?

Appendix E: Peak Water Demand, million m^3

Data from ADWEC, 2016

Diversified Regional Gross Demand (losses included)	2011	2012	2013	2014	2015	2016	2017	2018	2019
Abu Dhabi Region	402	426	453	465	483	479	472	468	475
Al Ain Region	178	197	185	206	219	209	211	218	223
Western Region	68	83	98	98	96	95	96	97	103
Forecast Sum of Regional Peaks	**648**	**706**	**735**	**769**	**798**	**783**	**779**	**783**	**801**
Forecast System Peak for Abu Dhabi Emirate	***648***	***706***	***735***	***753***	***788***	***758***	***753***	***769***	***776***
Regional Diversity Factor					99%	97%	97%	97%	97%
Abu Dhabi Emirate Auxiliaries	7.3	8.8	9.0	9.1	9.4	9.0	8.9	9.0	9.2
Emirate of Abu Dhabi System Peak + Auxiliaries	**655**	**715**	**744**	**762**	**798**	**767**	**762**	**768**	**785**

Diversified Regional Gross Demand (losses included)	2020	2021	2022	2023	2024	2025	2026	2027	2028
Abu Dhabi Region	477	480	483	486	491	497	500	504	507
Al Ain Region	230	235	237	238	238	238	239	240	241
Western Region	111	117	121	125	126	128	130	132	134
Forecast Sum of Regional Peaks	**818**	**831**	**841**	**849**	**855**	**862**	**869**	**876**	**882**
Forecast System Peak for Abu Dhabi Emirate	***791***	***803***	***812***	***819***	***826***	***833***	***838***	***845***	***851***
Regional Diversity Factor	97%	97%	97%	97%	97%	97%	97%	96%	96%
Abu Dhabi Emirate Auxiliaries	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.0	10.1
Emirate of Abu Dhabi System Peak + Auxiliaries	**800**	**812**	**821**	**829**	**836**	**843**	**848**	**855**	**861**

Diversified Regional Gross Demand (losses included)	2029	2030	2031	2032	2033	2034	2035	2036	2037
Abu Dhabi Region	511	515	518	522	526	531	535	537	540
Al Ain Region	242	242	243	243	244	245	246	246	247
Western Region	136	138	140	142	144	146	148	150	152
Forecast Sum of Regional Peaks	**889**	**895**	**901**	**908**	**914**	**922**	**929**	**933**	**939**
Forecast System Peak for Abu Dhabi Emirate	***857***	***863***	***869***	***874***	***880***	***886***	***891***	***895***	***900***
Regional Diversity Factor	96%	96%	96%	96%	96%	96%	96%	96%	96%
Abu Dhabi Emirate Auxiliaries	10.2	10.3	10.3	10.4	10.5	10.5	10.6	10.6	10.7
Emirate of Abu Dhabi System Peak + Auxiliaries	**867**	**873**	**879**	**885**	**891**	**896**	**902**	**906**	**911**

Diversified Regional Gross Demand (losses included)	2032	2033	2034	2035	2036	2037	2038	2039	2040
Abu Dhabi Region	522	526	531	535	537	540	543	545	546
Al Ain Region	243	244	245	246	246	247	248	249	249
Western Region	142	144	146	148	150	152	153	155	156
Forecast Sum of Regional Peaks	**908**	**914**	**922**	**929**	**933**	**939**	**944**	**948**	**951**
Forecast System Peak for Abu Dhabi Emirate	***874***	***880***	***886***	***891***	***895***	***900***	***905***	***908***	***910***
Regional Diversity Factor	96%	96%	96%	96%	96%	96%	96%	96%	96%
Abu Dhabi Emirate Auxiliaries	10.4	10.5	10.5	10.6	10.6	10.7	10.8	10.8	10.8
Emirate of Abu Dhabi System Peak + Auxiliaries	**885**	**891**	**896**	**902**	**906**	**911**	**915**	**918**	**921**

Appendix F: Average Annual Population Growth Rates by Citizenship and Gender, Mid-year 2010 to 2016

Data from Statistics Center Abu Dhabi, 2017, p. 114

Citizenship and Gender	Mid-year 2010	Mid-year 2016	Percentage average annual growth rate
Grand Total	**2,094,480**	**2,908,173**	**5.6**
Male	1,460,794	1,857,618	4.1
Female	633,686	105,0555	8.8
Citizens	**437,483**	**551,535**	**3.9**
Male	224,498	282,632	3.9
Female	212,985	268,903	4.0
Non-citizens	**1,656,997**	**2,356,638**	**6.0**
Male	1,236,296	1,574,986	4.1
Female	420,701	781,652	10.9