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UNITED ARAB EMIRATES
MINISTRY OF ENVIRONMENT & WATER

United Arab Emirates

Water Conservation Strategy

2010

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CONTENTS

Boxes

Figures

Tables

ACRONYMS

AADC	Al Ain Distribution Company
ADDC	Abu Dhabi Distribution Company
ADPHE	Ajman Department of Public Health and Environment
ADSSC	Abu Dhabi Sewerage Services Company
ADWEA	Abu Dhabi Water and Electricity Authority
ADWEC	Abu Dhabi Water and Electricity Company
ASPCL	Ajman Sewerage Private Company Limited
ASR	Aquifer Storage and Recovery
BAU	Business-As-Usual
BP	Before Present
BOD	Biological Oxygen Demand
CAPEX	Capital Infrastructure Investments
CO2	Carbon Dioxide
DEWA	Dubai Electricity and Water Authority
DM	Dubai Municipality
DSM	Demand Side Management
EAA	Economic Affairs Authority
EAD	Environment Agency – Abu Dhabi
EDN	Effluent Distribution Network
EIR	Environmental Impact Report
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FEA	Federal Environment Agency (up to 2009)
FEWA	Federal Electricity and Water Authority
FM	Fujairah Municipality
GCC	Gulf Cooperative Council
GDP	Gross Domestic Product
GIS	Geographic Information System
GNP	Gross National Product
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH [German Agency for Technical Cooperation]
ha	Hectare
IAEA	International Atomic Energy Agency
ICBA	International Center for Biosaline Agriculture
IDA	International Desalination Association
ISO	International Organization for Standardization
IWA	International Water Association

IWPP	Independent Water and Power Producer
JICA	Japan International Cooperation Agency
Km^3	Billion cubic meters
kWh	Kilowatt Hours
LIBOR	London Interbank Offered Rate
lpcpd	Litters per capita per day
MAF	Ministry of Agriculture and Fishery
MEB	Multiple Effect Boiling
MED	Multiple Effect Distillation
MIS	Modern Irrigation System
Mm^3	Million cubic meters
MOEW	Ministry of Environment and Water
MSF	Multiple Stage Flash Distillation
MW	Mega Watt
NDC	National Drilling Company
OPEX	Operational Expenses
ppm	Parts per million
RAKMAEN	Ras Al Khaimah Municipality Authority of Environment and Nature
RO	Reverse Osmosis
RoC	Return on Capital
RS	Realistic Scenario
RSB	Regulation and Supervision Bureau (Abu Dhabi)
RW	Reclaimed Water
SEPA	Sharjah Environment and Protected Areas Authority
SEWA	Sharjah Electricity and Water Authority
TDS	Total Dissolved Solids
UAE	United Arab Emirates
UfW	Unaccounted for Water
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USGS	United States (of America) Geological Survey
WHO	World Health Organization

Units

AED 1.00	=	USD 0.270
USD1.00	=	AED 3.675
I Imperial gallon	=	4.55 litres
1000 Imperial gallons	=	4.55 cubic metres

Preface

The remarkable achievements in the United Arab Emirates' water sector over the last three decades have allowed the country to sustain water services for the growing population, thus sustaining high standards of living, and meeting the needs of agricultural activities and forestry and the growing industrial sector. However, the future growth of the water sector is increasingly constrained by the rapidly dwindling renewable water resources, the increasingly high costs of new water infrastructure investment and concerns about environmental sustainability. In response to the United Arab Emirates' government vision for the sustainable development of natural resources and achievment of water security, the Ministry of Environment and Water has taken the initiative to develop a strategic framework for the sustainable management of all water resources in the United Arab Emirates (UAE). This framework has been developed based on the scientific analysis of the main factors affecting the supply and demand for water in the UAE. A challenging feature of this strategy is to ensure that the water sector is responsive to the dynamic growth path that has been charted for the country while taking into account that renewable water resources in the UAE are among the lowest in the world.

The water conservation strategy is based on an integrated approach that considers meeting future water demand from a mix of investment in new water infrastructure and efficiency improvements of existing water supplies. The strategy embraces all water supplies - natural resources, desalination and reclaimed water - and all water uses. The strategy has been adopted based on careful studies of the available water resources and water use, and critical analysis of water institutions and policies in the country. To implement the strategy, the Ministry of Environment and Water has adopted its eight important outcome initiatives to guide the comprehensive management of water as an integrated resource. These initiatives provide important steps toward achieving water security in UAE. The outcomes are expected to be responsible national policies, rules, and regulations that will be designed to improve the management of the nation's precious water resources and enhance their contribution to the economic growth of the country.

This Strategy for Water Conservation represents a major achievement in the realization of the Government's vision to secure sustainable water resource development for future generations, and will be implemented, monitored and sustained through close coordination with all water sector related partners in the UAE.

Special appreciation goes to the International Center for Biosaline Agriculture (ICBA) for undertaking this study in partnership with the Ministry of Environment and Water and to all water and environmental authorities and organizations in UAE for their contributions in the workshops and provision of data and information for the development of this Water Conservation Strategy.

Dr Rashid Ahmed bin Fahad
Minister of Environment and Water

Introduction

The sustainable development and use of the United Arab Emirates' scarce water supplies is a major strategic challenge. Managing the resources of the country is complicated as it requires not only an operational balancing of burgeoning water demands against supply, but in the larger picture a consideration of policies for economic development, food and energy security, and the environment.

In October 2009 the MOEW made a decision to prepare a Strategy for Water Conservation. This follows directly from the Ministry's Vision of '*Conserving environment and the natural resources for sustainable development*' and one of its main goals of '*Developing and sustaining water resources*'. The focus on water conservation is a significant step in the water development process because previous plans had focused primarily on meeting unregulated and unconstrained demand for water. The Strategy identifies the key questions, assumptions, uncertainties and areas of risk to future water development. It is expected that proposals in this Strategy will lead to a discussion on national development policies for UAE's water so an agreement on the way forward can be formulated.

Based on a review of the available information, the main body of the report consolidates highly variable water resource and water use information from each of the seven Emirates into a common national framework. The analysis of these data covers present and predicted water resource availability from traditional sources, desalinated water supply, reclaimed water and all water uses including domestic, government, industrial, future mega-projects and agriculture. Based on this comprehensive analysis, the constraints and opportunities affecting future water availability and use are discussed in depth and these form the basis for the Strategy for Water Conservation. Given that sustainable water development and management requires effective and efficient governance, the Strategy provides an overview of the current institutional frameworks, laws, regulations and standards at the Federal and Emirate levels. Finally, eight MOEW initiatives are proposed to guide implementation of the Strategy.

The Strategy is supported by five standalone annexes that elaborate in greater detail the relevant technical, economic, environmental and institutional issues related to the development and management of UAE's water resources.

Executive Summary

Executive Summary

Background

The challenge of balancing water demand against supply is enormous for a country such as the UAE which is located within the hyper-arid and arid climate zones of the Arabian Peninsula. The demand for fresh water has increased with the remarkable economic development of the last thirty years, and concomitant accelerating population growth, higher living standards, and expansion of the agricultural, forestry and industrial sectors. The per capita water consumption is among the highest in the world, creating an enormous strain on the water budget. The burgeoning demand was initially met through pumping fresh but non-renewable groundwater; consequently many of the country's aquifers have now been depleted to great depths and deterioration in water quality has resulted in many places. To bridge the resulting supply gap there has been an enormous expansion of non-conventional water resources, particularly desalinated water. However, this has important implications for both energy supplies and environmental protection.

In reviewing the current water management situation in the UAE, it is important to start with the country's constitution. Under Article 23 of the UAE Constitution it is stated that natural resources are the property of the individual Emirates and so the principal institutions, laws, regulations and day-to-day management are predominantly found at this governance level. Yet water is in effect a national shared resource with the sea, groundwater and atmosphere acting as a common source and sink for the water production and discharge activities. The actions of one have implications for all Emirates and there is thus a need for a comprehensive strategic framework for water policy, planning and management to overcome some of the problems found from the current fragmentation and the disparities that exist between them.

Objectives

The strategy for conserving water resources in UAE aims to achieve the following objectives:

1. Provide an updated and integrated assessment of UAE's water resources and their use;
2. Provide an understanding of what governs water demand, allocation and use;
3. Identify the options to improve the efficiency of water allocation and use, reduce costs and improve the environment;
4. Make recommendations to strengthen Federal policy, laws and capacity to comprehensively oversee sound water resources management and use; and
5. Enhance water security and protect surface water and groundwater resources, marine, and the environment.

Water Resources

Water is supplied from three main sources:

1. Groundwater supply which supplies about 51%, mostly for irrigation uses, but some limited quantities are used for potable uses particularly in the Northern Emirates;
2. Desalinated water supply, which supplies about 37%, mainly for potable water uses, and in some places are also used for irrigation; and
3. Reclaimed water supply (also known as treated sewage effluent), which accounts for 12%, and mainly used for irrigating amenity areas.

UAE organizations operate around 70 desalination plants, representing about 14% of the total global capacity. The majority of these installations are in the Emirate of Abu Dhabi (about 67%) whilst Dubai has around 18%, and

Sharjah (10%) and the Northern Emirates (about 5%) having limited capacity. As with most aspects of water management in the UAE, the planning and managing of desalination projects is carried out at the Emirate level with little coordination either between them or with Federal institutions. The current cost for producing this water is about AED 7.16 (USD 1.95) per m^3, with annual production costs reaching about AED 11.8 billion (USD 3.22 billion) for the year 2008. There is an argument that with coordinated planning, regulations and management, economic savings could be made particularly in capital expenditure where future plants could be designed to the same or better standards.

Reclaimed desalinated water is becoming increasingly viewed as an important resource for certain areas of usage. More than 60 wastewater treatment plant exists in the UAE. While there is universal access to sewerage systems and septic tanks, wastewater can only be reclaimed from those connected to the sewerage systems. The percentage of people served with sewerage networks varies among the Emirates ranging from 0 to 95%. Currently, about 0.56 km^3 of reclaimed water are available in UAE, with two-thirds of this used for irrigating amenity and landscaping, and a third is lost to the sea or the desert.

The possibilities for the use of reclaimed water are controlled by a number of factors particularly with regards to its quality. As far as controls on the inputs to the sewerage network are concerned, between the Emirates there are currently different rules for connecting and discharging industrial and domestic wastewater to the system and concomitant variations in the sets of standards for the quality of effluent accepted. Further variables that can affect the reclaimed water quantity and quality include leakages of brackish groundwater into the network, which limits its subsequent use in growing vegetation.

Water Use

The increase in total water consumption is a growing problem in UAE, reaching about 4.6 km^3 in 2008. The agricultural water sector remains the largest consumer using about 34% of total water, whilst domestic and industrial water sector (32%), forestry sector (15%), and amenity (11%) are the other key areas, where losses accounts for the remaining 8%. These values highlight that in the overall water consumption, over 60%, is used to grow vegetation of one form or another (agricultural, forestry and amenity water uses). Given the importance of agriculture and recent rates of economic expansion it comes as no surprise to find that most water is consumed in Abu Dhabi Emirate (61% of the total water use), followed by Dubai Emirate (18%), whilst the Emirate of Sharjah and the Northern Emirates use about 21% of total.

Looking in more detail at domestic consumption, the average daily usage of 364 litres per capita per day (lpcpd) is much higher when compared with other developed countries such as the United States of America (295 lpcpd), Spain (270 lpcpd) and Greece (180 lpcpd). Urban water consumption rates continue to increase in the UAE. An increasing amount of this is used outside the actual home. A study undertaken by Abu Dhabi's Regulation and Supervision Bureau (RSB) indicated that the share of per capita water consumption in villas was about 3-9 times the water consumption in apartments where the water consumption is close to the global average of 200 lpcpd. That study showed that the increase in water consumption in villas was due to using desalinated water for irrigating the gardens and washing cars, which can obviously be replaced by using water of a lower quality.

It is little wonder that with predicted increases in population and economic development, the total consumption value is expected to double to about 10 km^3 by 2030, assuming current patterns and rates continue. The area of predicted greatest increase is in urban demand (household, industrial, commercial, institutions and public facilities) resulting from population and industrial/commercial growth under current economic development policies. Conversely, the demand for agricultural and forestry water is expected to decrease relative to today's values as a result of depleting groundwater resources, unless reclaimed or desalinated water resources are used as substitutes.

The resulting water supply-demand balance is expected to be in deficit in the mid-term, rising up to an average of 30% of total water demand by 2030. Whilst this demand varies across the Emirates with Abu Dhabi and Dubai expected to suffer shortages by 2017 and 2018 respectively, others, such as Sharjah, are better provisioned until 2024. The situation, however, is a little more complex between the Emirates, with Sharjah and the Northern Emirates already relying on imported desalinated water from Abu Dhabi Water and Electricity Authority (ADWEA) to meet the current water deficit. This is expected to continue until the currently-constructed desalination projects come online in the near future. Thus, it is expected that the future shortfall for the Northern Emirates will be about 10% of the total UAE water deficit.

Water Governance

The governance, and legal and regulatory systems are the foundations on which policy and management decisions are made and implemented. They determine the authority and roles and responsibilities of the various organizations involved and are the framework within which further ideas are developed. It is therefore important to understand the current systems in place in the UAE.

The starting point for any analysis of the governance system in the UAE is its Constitution and the division of powers between the Federal and the Emirate levels of authority is clearly demarcated within. Whilst water is not mentioned explicitly in the Constitution, by implication of some of its provisions (Articles 23, 120, 121, 122) water resources and their regulation fall within the remit of the individual Emirates. As a result, legislation and regulations governing the management, development, protection, conservation and use of natural water resources engage mostly the Emirate level of legislative, executive and judicial authority, with the Federal-level Ministry of Environment and Water (MOEW) retaining a national policy/strategy, coordination and standard-setting authority.

The legal status of non-conventional water resources like desalinated water and reclaimed water is not explicitly defined in the Constitution (unlike electricity). It is assumed therefore, that they are the property of the relevant producer, and are for him/it to dispose of and allocate for further use. The role of the Federal legislature and executive is therefore more indirect and is given in various Federal laws, agreements and bi-laws which are centred on the protection of marine environments, the air and biodiversity and health of those involved. The actual implementation of these though is again given to the competent authority in each Emirate.

There is no clear indication as to responsibilities for water demand management from the Constitution except in Article 23, which states that the Federal government is '…responsible for the protection and proper exploitation of such natural resources and wealth for the benefit of the national economy'. Thus, there is an onus on the Federal legislature and executive to protect water resources and to ensure sustainable use of groundwater. However, the introduction of practical measures has to date have emanated from Emirate-level organizations.

The result of the constitutional emphasis on devolution to the Emirate level for most of water management roles and responsibilities has led to the development of various legal and regulatory systems overseen by their competent authorities. In the area of natural water resources each Emirate has its own organization and various laws have been enacted primarily to control the use of groundwater. The extent of implementation, and monitoring and enforcement, varies between the Emirates and all have found a certain resistance.

Possibilities for future water management

To date, water policies have been predominantly supply-side based. If this were to continue, to meet these projected shortfalls there would be a need to increase capital investment in both water desalination plants and distribution infrastructure, estimated at around AED 117 billion (USD 32 billion) over the period 2009 - 2030. The incremental annual operation and maintenance costs over this period would average about AED 202 billion (USD 55 billion) and the total bill for desalinating water could top AED 319 billion (USD 87 billion) over the same period.

There is a role for reclaimed water which could be increasingly substituted for expensive desalinated water in a number of areas. The recent advances in technology, regulations and public acceptance of this resource could relieve the deficit in certain sectors of usage.

Polices associated with water demand management have not played a large part in the current water strategies of the UAE, but if properly researched and formulated could achieve a significant reduction in both total consumption and related future investments in production capacity and infrastructure. A major area of consideration is use of large volumes of water in agriculture. This sector has cultural and social importance, but it has been in decline recently in terms of contributions to GDP falling from 3.5% in 2002 to 1.3% in the year 2008. Only 2% of the farmers depend on agriculture as an essential income with the majority of the workers being unskilled non-national labor. Various possibilities exist to try to balance the needs for food and water security including increasing the efficiency of water use or to move its use to crops of higher economic return.

Key initiatives

This Strategy provides a framework to sustainably manage the UAE's water resources over the period to 2021. As such it highlights the challenges and opportunities to better manage scarce and expensive water resources and provides a range of options to do so. Some of the options will be easy to implement, others less so. It also has to be recognized that because water management is devolved among the seven Emirates the type and quality of information about water resources and use varies widely – this is particularly so for the agricultural sector – and the availability of better information may favour some policy options more than others. Institutions to monitor and regulate water resources management will also evolve over time and may require policy responses different to those suggested in the Strategy. Consequently the findings in this Strategy should be reviewed every five years to keep it relevant and up-to-date.

In order to implement the Strategy, the following eight initiatives should be implemented:

Initiative 1: Develop legislation, standards and Federal mechanisms for integrated water resources management

To preserve, protect and enhance water resources management in UAE, and to appropriately allocate and effectively use water resources for the benefit of current and future generations:

- Coordinate the development of common regulations, standards, and specifications for economic, technical and environmental controls;
- Support stakeholder coordination and understanding;
- Integrate anticipated consequences of climate and environmental change;
- Monitor and evaluate progress towards achievement of national objectives;
- Ban water export; and
- Establish a national council to coordinate water and a forum for dialogue and coordination among stakeholders on water resources.

Initiative 2: Better manage natural water resources and enhance strategic reserve

- Introduce water budgeting at the national, regional and local levels that takes account of all water supplies and uses;
- Facilitate formation of a national water quantity and quality monitoring system;
- Guide and oversee the creation of a national water database;
- Improve the design and operation of dams in the Northern Emirates to improve retention of floodwater and groundwater recharge; and
- Promote zoning and artificial groundwater recharge.

Initiative 3: Develop national agricultural policy aimed at water conservation and increasing value to the economy

- Promote a new agricultural development model that is water conservative, environmentally benign, and commercially viable;
- Initiate research to deepen knowledge on UAE's agricultural economy and its use of water;

- Conduct a study with farmers to agree which parts of UAE's traditional agriculture should be retained as part of its cultural heritage;
- Agriculture and forestry compete for the same scarce water resources – a plan to assess the trade-offs and where they should be applied should be prepared; and
- Build on this knowledge to initiate an agricultural plan to better conserve scarce water resources.

Initiative 4: Manage efficiently desalinated water from a comprehensive and national perspective

- Introduce and apply economic optimization principles to design future desalination capacity;
- Reduce losses in water distribution and main lines;
- Create a national water grid system to enhance water security and cost efficiencies; and
- Further develop Aquifer Storage and Recovery (ASR) using surplus desalinated water where economically feasible.

Initiative 5: Rationalize water consumption to be within the global daily per capita water consumption rate

- Develop strategies to reduce the daily per capita consumption of water to the global average of 200 litres per capita per day (lpcpd);
- Review and adopt as suitable water efficient systems and technologies;
- Develop strategies to match water quality and different uses; and
- Design awareness programs and campaigns.

Initiative 6: Review and develop clear water pricing and subsidy policies

- Review and adjust water tariffs of all water sources for all customers to reflect more the water production and distribution costs; and
- Review and adjust government subsidies for all water resources and uses.

Initiative 7: Better manage effluent and reclaimed water

- Develop wastewater effluent discharge standards for UAE's marine and terrestrial environments and monitor their enforcement by the Emirate level authorities;
- Coordinate the development of common standards for wastewater collection, treatment, and reuse in different sectors;
- Monitor the enforcement of environmental standards by the individual Emirates;
- Assess network integrity to minimize leakage and inflows;
- Coordinate measures to increase use of reclaimed water; and
- Coordinate awareness raising campaigns to overcome public fears.

Initiative 8: Capacity building and strengthening of local expertise on the concepts of integrated water resources management

- Develop a body of expert knowledge and training to support national capacity in water resources technologies and management, particularly in non-conventional water resources; and
- Encourage greater participation of private water sector organizations in capacity building.

Chapter 1
Rationale for the Strategy

Chapter 1
Rationale for the Strategy

Water is among the scarcest commodities in the United Arab Emirates. Since the 1960s the growth in population, higher standards of living, and expansion of the agricultural, forestry and industrial sectors created a huge demand for more fresh water. Initially demand was met from fresh groundwater reserves but they are being depleted rapidly. To make up for the shortfall in the supply of natural resources, the UAE became increasingly reliant on non-conventional water supplies – desalinated water and reclaimed water – to maintain economic growth and quality of life. Because investment in new water supplies was only demand-driven and water was essentially provided free or at very low cost to the consumer, per capita consumption of fresh water grew rapidly and is now among the highest in the world. In addition non-conventional water generation, primarily through thermal desalination, has significant environmental consequences both locally and globally. Finding ways of balancing the demands from human and economic development with prudent management of water and the environment is the major challenge for the UAE.

Responsibility for water is spread widely

The UAE's Constitution clearly demarcates the division of powers between the Federal and the Emirate levels of authority. Under the Constitution, however, there is no clear indication as to responsibilities for water conservation and demand management although '*Society is …responsible for the protection and proper exploitation of such natural resources and wealth for the benefit of the national economy*.'[1] Subsequently the Federal legislature and executive have allocated authority for national policy and strategy overview to the Ministry of Environment and Water.[2] Whilst water is not mentioned explicitly, natural resources are the public property of the Emirates.[3] Natural water resources include rainfall, groundwater and water retained in surface water reservoirs. Non-conventional water resources included desalinated water and treated wastewater (subsequently called reclaimed water in this report) is not mentioned.

The Constitution requires the individual Emirates to '*coordinate their legislations in various fields with the intention of unifying such legislations as possible*'.[4] The constitutional emphasis on devolution, however, means that most organizations involved in water governance were developed at the Emirate level. As a result the institutional systems for water development and service delivery in the seven Emirates have developed relatively independently of each other and there are overlaps and omissions. Generally the transfer of ideas between the responsible Emirate organizations has been through national and international workshops whose recommendations are not binding on participants.

The balance between roles and responsibilities of the Federal government and the Emirate-level government are further affected by agreements made internationally and within the context of the Gulf Cooperative Council (GCC). The UAE is a signatory to 11 international agreements affecting stewardship of transnational natural resources and the environment, Table 1. Given the increasing number of international agreements on legal and regulatory standards and on various aspects of water, particularly desalinated water, action is required to translate them into implementation at the national and Emirate level.

Natural water resources

Groundwater is the primary natural resource. Although groundwater is used predominantly in agriculture a few of the Emirates use it also as a source of water for domestic consumption. It is also the only strategic reserve and there is thus a need to protect fresh groundwater resources to ensure water security during times of need. Surface water contributes little to the overall resource base but is locally important in the Northern Emirates.

Table 1: UAE is signatory to several international and regional agreements related to water and the environment

Scope of Agreement	Date of ratification and legal instruments in place
International	1990 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989)
	1995 United Nations Framework Convention on Climate Change (1992)
	1998 United Nations Convention to Combat Desertification (1994)
	1999 Convention on Biological Diversity (1992)
	2002 Convention on Persistent Organic Pollutants (2001)
	2002 Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC Convention) (1998)
	2005 Kyoto Protocol (1997)
	2007 Ramsar Convention (1971)
Regional	1979 Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978)
	2003 Convention on Conservation of Wildlife and its Natural Habitats in the GCC countries
	2005 Federal Decree No. (77) of 2005 regarding Protocol of Control of Marine Cross-Border Transport and Disposal of Hazardous and Other Wastes

Because of the independent management of natural resources at the Emirate level there is a wide and variable range of protection measures, controls and management of the UAE's natural water resources. Individual Emirate governments have generally exercised regulatory authority over most aspects of natural water resources abstraction, use and its protection from pollution.[5] As a result, institutions, legislation and regulations governing natural water resources development and management are found primarily at the Emirate level. Generally, with the exception of Sharjah, natural resources are managed by organizations that are separate from those that provide water services: domestic, commercial and industrial water supplies, and wastewater treatment use and disposal. In most Emirates, however, there is little active management of natural water resources.

Diversified responsibility for natural resources also means standardization and enforcement of regulations is very uneven. This tends to be problematic in any jurisdiction and the Emirates of the UAE are no exception. Principally the main reasons have been the lack of local expertise and a lack of adequately trained law enforcement capacity to support the multiple regulatory authorities. Groundwater, for example, is developed, regulated and managed by seven different organizations at the Emirate level – and one at the Federal level – a sub-optimal approach given its strategic importance. A coordinated and harmonized information, standardization, regulatory and management structure would bring a greater understanding and protection of the resource.

Non-conventional water resources

At the Federal level the Ministry of Energy is responsible for strategic decision-making in the area of water desalination but no clear mandate is given to any ministry for reclaimed water management. Prior to the 2010 ministerial re-organization, wastewater was managed at the Federal level by the General Secretariat of Municipalities whose responsibilities have now been absorbed within the new Ministry of Environment and Water.

Water service provision is the responsibility of each Emirate. Water production and management infrastructure are the property of the relevant producer, be they public or private, for then to dispose of and allocate for further use. Until recently these organizations were all public sector but in the last few years some Emirates have facilitated increased involvement of the private sector. Such moves were designed to expand infrastructure and to increase effectiveness and efficiency in various aspects of water delivery, particularly with regards to costs and service. The result is a range of specialist institutions with differing setups and ownership that range from full government ownership to public/private partnerships to concessions. For example Tanqia in Fujairah is a wholly private owned company with a 33 year concession, whilst the Sharjah Electricity and Water (SEWA) is completely government-owned but engages with the private sector for technical expertise.

There are also differences in the mandate and coverage of the various organizations and laws. Some Emirates regulate and manage the different supply systems separately whilst others combine them or link them to other sectors. Desalination, produced mostly by cogeneration at power stations, is managed within the same organizations as electricity production, whilst wastewater is sometimes managed alone (Fujairah, Ajman and Abu Dhabi) or as departments within larger structures, usually municipalities.

Federal authority has been strengthened

Established in 2008, the Federal Ministry of Environment and Water's vision is 'conserving environment and the natural resources for sustainable development.'[6] The MOEW's primary role is developing strategic policies and plans for water, establishing national standards in certain areas, and for coordinating activities with the Emirates and with other Federal organizations. Specifically in the area of water it is charged with:

- Developing plans, strategies and policies in the field of water;
- Developing programmes that ensure output in various sectors including water to enable food security;
- Ensuring environmental protection in economic and social plans for the country;
- Evaluating water resources and determining programmes and means that ensure good management and conservation; and
- Proposing legislation to support the Ministry's functions.

As a first step in meeting these responsibilities the MOEW decided to undertake a comprehensive review of water resources management and water service provision in order to decide what needs to be done, when, by whom and where. The overall goal is to position the MOEW to oversee more effective and coordinated planning and management of water that ensures its security for future generations. Specifically this involves developing policies, criteria and standards for water conservation that will drive improved demand and supply management while meeting national environmental management objectives.

Strategic Objectives

There are four objectives:

- Update and provide an integrated assessment of UAE's water resources and their use;
- Provide an understanding of what governs water demand, allocation and use;
- Identify the options to improve the efficiency of water allocation and use, reduce costs and improve the environment; and
- Make recommendations to strengthen Federal policy, laws and capacity to comprehensively oversee sound water resources management and use.

The Strategy identifies the direction and scope of activities by MOEW and others needed over the long-term to achieve these objectives.

The following chapters systematically describe the evidence for water conservation and recommend that the Strategy is implemented through adoption of eight initiatives. Chapter 2 reviews available water resources and water uses. Chapters 3, 4, and 5 provides an overview of available water supplies - desalinated water, reclaimed water, and groundwater - and highlights issues related to demand, investments, and environmental consequences and costs. Chapter 6 discusses water conservation; approaches and priorities. Chapter 7 presents the governance and legal framework, and laws and regulations of water supply systems. Finally, chapter 8 presents the proposed strategy.

Chapter 2
Water Resources and Water Use

Chapter 2
Water Resources and Water Use

Water resources

Groundwater and desalinated seawater are the principal water resources of the UAE. Rainfall in comparison is a negligible resource except in the Northern Emirates and the plains west of the Omani Mountains. In contrast, reclaimed water is a resource that will increase with the rapidly expanding population depending on how it is collected and allocated. Total water resources and constraints on their use according to current knowledge and practice are summarized in Table 2.

Groundwater is considered for planning purposes to be a reservoir of fixed volume because replenishment from rainfall is almost negligible. Thus usable groundwater is the volume in storage that can be drawn upon when and where needed. In contrast desalination, reclaimed water and rainfall represent annually renewable volumes. Volumes of desalinated and reclaimed water are dependent on installed production capacity that generally expands with population growth that has averaged 6.6% over the last decade. Conversely groundwater in storage reduces over time as it is withdrawn because it is being mined. The only alternative supply to groundwater is desalinated water and its derivative, reclaimed water.

Table 2: The water resources of the UAE (2008)

Water Resource	Volume km^3	Status and Comment
Groundwater Storage	**583 = 100%**	
Fresh	20 (3%)	Mined from storage as natural annual recharge is negligible. Constraints are cost and quality. Annual mining is subject to demand.
Slightly brackish	190 (33%)	Slightly brackish water with salinity in the range 1,500 to 5,000 ppm of total dissolved solids can be used selectively on a moderately restricted range of plants and trees.
Brackish	148 (25%)	Salinity in the range 5,001 to 10,000 ppm allows use on a very restricted range of plants and trees.
Slightly Saline	225 (39%)	Salinity in the range 10,001 to 25,000 ppm is a potential resource for local desalination by Reverse Osmosis as it is less than half the salinity of seawater.
Generated per year	**2.41 = 100%**	
Desalination	1.70 (70%)	Renewable and expandable. Constraints are cost and environmental impacts.
Reclaimed water	0.60 (25%)	Renewable and expandable. Resource is dependent on desalinated water supplied for domestic and industrial use collected by the sewer system. Aesthetic issues may constrain use.
Groundwater recharge from dams	0.01 (<1%)	Highly variable from year to year.
Groundwater inflow	0.14 (6%)	Cross-border fresh water inflow from Oman.

Source: ICBA drawing on a variety of sources detailed in Annex 1. Numbers are rounded.

Water use

The demand for water in the UAE is driven up by population growth, high standards of living, industrialization, and expansion of agriculture and forestry. Going from almost zero in 1965, industry and manufacturing (excluding oil) expanded to account for 22% of GDP in 2008. Population has grown from 178,600 in 1968 to 5.6 million by 2010. Until 1988 the population expanded at an unprecedented rate of 15.6% in response to a massive demand for labor but more recently this has declined to slightly over 6% in the period to 2008. As national prosperity has increased the Federal and several Emirate governments have encouraged afforestation and agriculture through a generous program of subsidies.

Growth of water demand

In this section the growth of water demand from the major use sectors is summarized to determine the UAE's national water balance.[7]

Municipal and industrial demand

This demand group includes households, government, commerce, and industry in municipal areas. Water demand has tripled since the mid-1990s, Table 3.

Table 3: UAE's Municipal and Industrial Demand has grown rapidly over the last 40 years

	1968	1975	1985	1995	2008
Population, millions	0.2	0.7	1.3	2.4	4.8
Demand, Mm^3 per year	6	38	190	555	1,464

Sources: Pitman, 1997 and ICBA, 2010. Details in Annex 1.

Amenity and plantations

Following the leadership of the late H.H. Sheikh Zayed bin Sultan Al Nahyan, the Emirates embarked on a "greening program" which included parks, roadside afforestation and lawns, shelter belts and rural forests as part of game reserves. Excluding forests, the best estimate of municipal amenity and plantation water demand in 2008 is 495 million m^3 (compiled from various municipality and water authority data. ICBA, 2010).

Agriculture

Traditionally agriculture was limited to date groves in oasis areas fed by springs, *falaj* systems and shallow wells. Away from the natural springs, the culture was built around the rearing of camels, sheep and goats on rangeland. This traditional way of life changed with the discovery of oil and the adoption of a policy to green the desert. Then, as now, desert greening and expansion of agriculture was based on unlimited and free access to fresh and brackish groundwater reserves. As a result the farmed area increased from 3,000 hectares (ha) in 1968 to over 100,000 ha by 2008.[8] Even so, the emphasis on tree crops, vegetables and forage supplemented rather than displaced livestock. Indeed between the 1980 and 2008, the number of livestock increased from about 0.5 million to 3.3 million.[9] Forage crops to support the livestock industry accounted for 39% of farmed area in 2008 and accounted for 45% of total agricultural water use (see Annex 2 for more details).

The period of rapid expansion came to an abrupt halt in 2000 and thereafter slowly declined. Since 2000, cultivated area has been shrinking at a rate of 4,200 ha a year. It is not clear exactly why cultivated area ceased to expand after 2000 but likely causes are changes to the Federal and Emirate policies on agricultural subsidies, shortages of good groundwater quality, and increasing production costs; all of which reduced profitability.

Table 4: Growth of irrigated area and water use

	1968	1975	1985	1995	2008
Actual Irrigated Area, ha	3,041	8,220	24,424	54,920	91,558
Average Water use, m^3 per ha per year	25,000	26,000	29,000	28,200	17,000
Total Water use, Mm^3	77	213	700	1,110	1,565

***Source*:** Khan, A 1997 and ICBA, 2010 using MOEW 2009 Agricultural Statistics. Irrigation efficiency in 2008 is estimated to be 80%.

In 1991 only some 13,500 ha or 32% of the farmed area (MOEW, 2009) was equipped with modern irrigation technology that included sprinkler, drip and bubbler water application systems. Following water conservation efforts that started in the mid-1990s, driven by heavy subsidies, modern irrigation technology grew enormously to cover 97% – 91,558 ha – of the UAE's cultivated area by 2008. By 1995 average water use per ha was almost 30% less than a decade earlier and it continued to decline, Table 4. The relative contribution of improved irrigation technology and savings due to changing cropping preferences, however, cannot be easily determined.

Livestock

Direct water demand from livestock was about 20 million m^3 in 2008.

Forestry demand

The area under forestry grew from 58,000 ha in 1989 to 347,000 in 2008, principally in Abu Dhabi Emirate. A wide variety of plant species are being grown.[10] The forestry sector is heavily dependent on groundwater and competes with agriculture for the same resources. Modern irrigation systems are used but optimal tree growth has never been achieved. The efficiency of the drip and bubbler irrigation systems using brackish groundwater is difficult to maintain in desert climates because the emitters become easily clogged. Recently in some projects in Abu Dhabi Emirate, desalinated water has been increasingly used on forests to replace deteriorating groundwater quality (Dawoud, 2007), Table 5.

In this Emirate, average water use has decreased from 2,300 to 2,160 m^3 per ha per year between 1996 and 2006 in the Eastern Region, with more marked reduction in the Western Region from 3,820 to 1,990 m^3 per ha per year over the same period. In the Northern Emirates evapotranspiration would be slightly lower. Overall average water use is thus assumed to be about 2,000 m^3 per ha per year, Table 5.[11]

Table 5: Growth of forests has been rapid

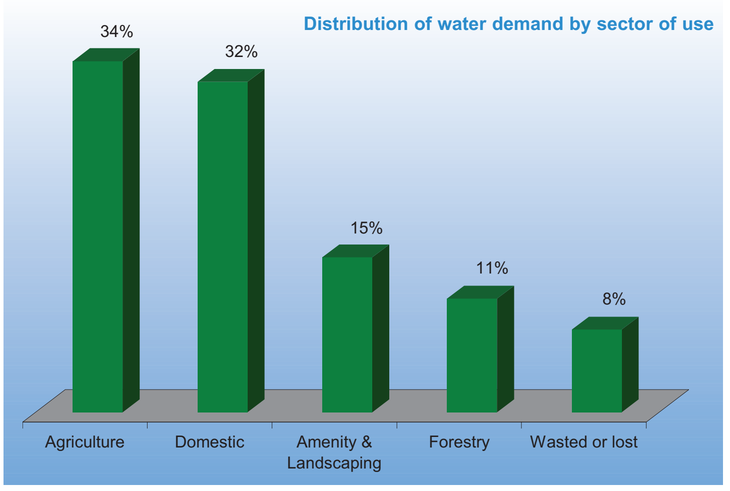
	1968	1975	1985	1995	2007
Forested Area, ha	1,910	6,800	34,400	116,600	347,000
Average Water use, m^3 per ha per year	2,000	2,000	2,000	2,000	2,000
Total Water use, Mm^3	4	14	69	233	694

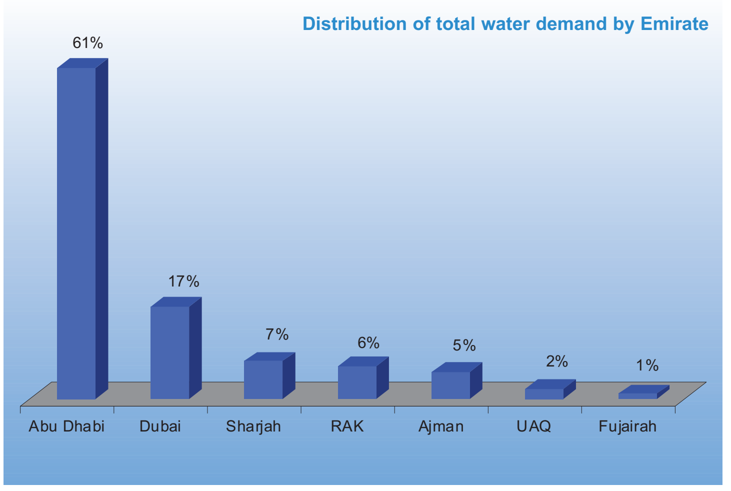
Sources: EAD, 2009 and ICBA 2010.

Total water demand

The UAE's total water demand in 2008 was estimated to be 4.6 km^3. On the basis of 2008 data (the latest available) agriculture is the single largest user of water, Figure 1. Almost 60% of all UAE's water is used for

Figure 1: Distribution of UAE's total water demand in 2008





Source: ICBA, 2010.

agriculture, forestry and urban greenery. Among the Emirates, Abu Dhabi accounts for 61% of national water demand primarily because most (39%) of agriculture and forestry demand is there, Table 6.

Table 6: The distribution of water demand by Emirate and use, 2008

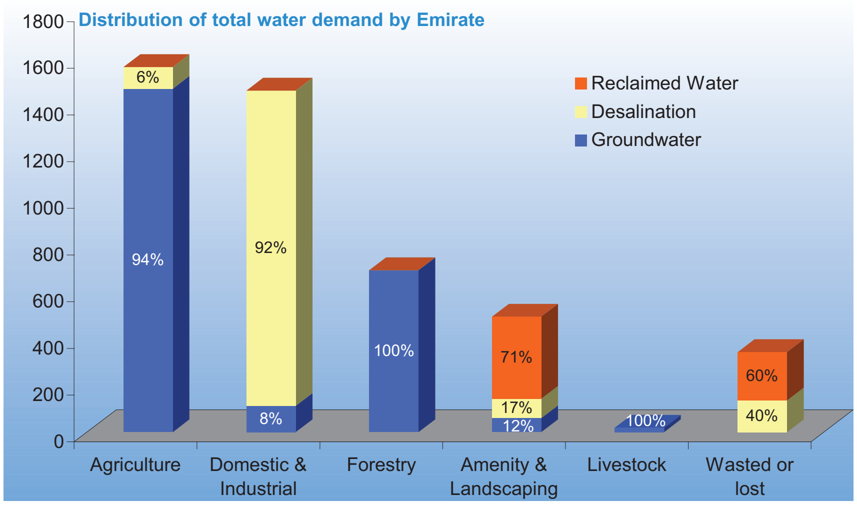
	Abu Dhabi	Dubai	Sharjah	RAK	Fujairah	Ajman	UAQ	Total
Agriculture, landscape, amenity & forests	38%	7%	4%	4.4%	4%	2.1%	0.5%	60%
Municipal & Industrial	18%	8%	3%	1%	1%	0.1%	0.2%	32%
Wasted/lost	4%	2%	1%	0.4%	0.4%	0.1%	0.2%	8%
Total	**61%**	**17%**	**8%**	**6%**	**5%**	**2%**	**1%**	**100%**

Present demand-supply balance

Total water demand is supplied from groundwater, desalinated water and reclaimed water, Figure 2. Currently all water demand is met; although some of the northern Emirates depend on transfers of desalinated water from Abu Dhabi.

Stored groundwater is the major supply source for agriculture and forestry. In some Emirates groundwater supplements municipal and industrial water supplies but it only meets 2% of that demand. Similarly it supplies 1% of amenity and landscaping demand.

Figure 2: Sources of water supply to the major water use sectors, 2008



Desalinated water is used primarily to meet domestic and industrial demand. According to official 2009 data from ADWEA some desalinated water – about 85 million m^3 a year – is used for agriculture near Abu Dhabi city and Al Ain and a further 50 million m^3 is used for landscaping to make up for shortfalls in reclaimed water (RSB/GTZ, 2009). As is discussed later, actual volumes of desalinated water used in agriculture are probably significantly larger. About 15% of total desalinated water produced is probably lost through leakage from the water distribution systems and equal to about 3% of UAE's total water supplies.

Reclaimed water is the primary supply for amenity and municipal landscaping. About 37% of the total current supply is discharged to either the desert or the Gulf because the development of the distribution infrastructure has not kept pace with the levels produced that have expanded with population growth.

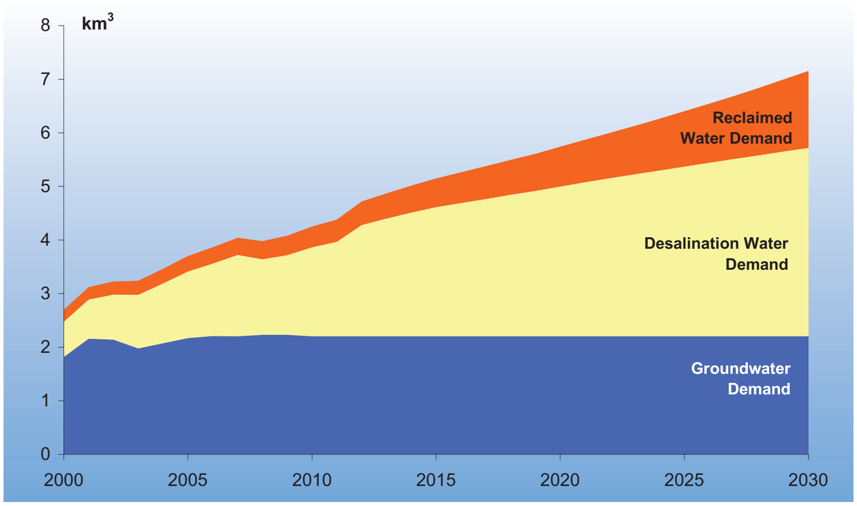
Future demand-supply balance

UAE's total water demand is expected to increase by a half over the next 20 years (under the realistic scenario[12]). While all municipal and industrial water demand can be met by building new infrastructure, including new desalination capacity, this is not the case for either agriculture or forestry that relies on mining groundwater. The first part of this chapter describes total future water demand for each source of supply and the likely financial investment needed. The second part of the chapter reviews each source of supply and identifies opportunities and constraints. It also shows that groundwater cannot sustain present levels of water use and that improved groundwater planning and management is needed. Alternative water demand scenarios are discussed in Annex 2.

FUTURE WATER DEMAND

The UAE's total annual water demand, as explained in the following chapters, is expected to increase from 4.4 km^3 in 2008 (excluding current reclaimed water losses) to 7.1 km^3 in 2030, Figure 3 (see annex 2 for more details). Groundwater demand has been assumed to be constant at 2.2 km^3 a year throughout this period. In practice, however, it is likely that this demand will be unable to be met because of resource constraints.

Figure 3: Projection of UAE's water demand to 2030



Source: ICBA, 2010.

Demand for desalinated water over the same period almost doubles from 1.7 km^3 to 3.5 km^3 a year – and this is the major factor accounting for the overall increase in projected demand. The volume of reclaimed water depends on how much desalinated water is used in households and flushed to the sewerage system. Typically about 90% of water used within households can be reclaimed, which is far greater than the present utilization of about 63% of reclaimed water. It is expected that all future reclaimed water of about 1.4 km^3 will be fully utilized in both amenity and landscaping or in a restricted range of agricultural production.[13]

FUTURE WATER SUPPLIES

The characteristic of each water supply, their costs and environmental consideration related to their use are described in the next three chapters. These chapters discuss the demand and characteristics of each water supply. The factors affecting demand are examined to determine the rationale and potential targets for water conservation. Because demand for desalinated water is growing fastest, that is examined first. Reclaimed water, dependent of desalinated water production, is looked at next. Natural resources – groundwater and its sources of recharge – are examined last.

Chapter 3
Desalinated Water

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Desalinated Water

Desalination infrastructure

About 70 desalination plants have been constructed in the UAE. The numbers very much depend on how they are counted because many sites have several desalination plants. Of the 70, Umm Al Nar, for example, although one site, includes four plants and Taweelah has three plants. Plants fall into two main categories: those that are constructed to utilize heat from thermal power generation known as thermal co-generation plants (Multi-Stage Flash MSF and Multiple Effect Distillation MED); and independent reverse osmosis (RO) plants that use electrical power to force salty water through membranes that strip salts from the water, Box 1.

On the basis of limited UAE data available, thermal plants in operation and under planning account for 81% of desalination capacity and RO accounts for 19%, Table 7.

A notable characteristic to all the plants constructed to date is that each has been a “one-off”, subject to different design and performance standards even within single Emirates. This is the result of having no uniform UAE

Box 1: The growth of desalination in the Gulf region

High oil prices in 1973 sparked the growth in seawater desalination in the Middle East. The inflow of funds allowed the Gulf States to invest in the development of their infrastructure on a grand scale. This included investments in power and water. For desalination the only viable technology available was MSF which was invented in 1958. The new MSF process offered improved energy efficiency coupled to ease of operation and was a vast improvement on the previous technology of Multiple Effect Boiling (MEB). By 1975 large plants of 20,000 m^3/day were being built. All of the Gulf States invested heavily in this technology and have continued to invest in it to the present. The process today is much as it was then but the units are larger – up to 60,000m^3/day and reliability has been improved through the use of better material and an improved understanding of the process. To be cost effective, the MSF process has to be coupled to a power plant which can supply low grade steam. This is often referred to as waste heat. This is a misnomer. The steam used by an MSF plant could be used to generate more electrical power. By tapping this steam at a higher temperature than necessary, the power output of the power station is reduced. Even so, capital costs have fallen and the process is well understood and reliable. Most importantly it provides security of supply.

Commercialization of RO for seawater desalination plants started in the 1980s and subsequent growth has been rapid – it is now the preferred technology outside the Gulf States. Initially the RO membranes were expensive, pre-treatment not well understood and energy consumption was high. Since then membrane prices have fallen, their performance improved, pre-treatment is better understood and energy consumption has dropped dramatically. Although the Gulf State remains the most important market for desalination plants, designing RO plants for operation in the Gulf has to overcome the problems caused by red tides, high salinity and seawater temperatures. This affects RO plants but makes little difference to distillation plants. Globally, membrane desalination processes (mostly RO) accounted for 56% of worldwide online capacity in 2006 and their share is rapidly increasing.

Combining MSF and RO enables more efficient use of energy and the UAE commissioned, at the time, the largest desalination hybrid plant in the world at Fujairah in 2003. It can potentially produce 624,000 m^3/day. The plant was situated on the Gulf of Oman to mitigate the high salinity and temperature problems in the Arabian Gulf. Almost two-thirds of the water is produced by five MSF units coupled with the power plant and over a third is from seawater RO. This is a more flexible system as RO helps to reduce the electricity demand when there is a mismatch between the water and electricity demand in the summer. Singapore has similarly recently completed the world’s largest diameter seawater RO plant (10,000 m^3/day) as part of its ‘Renewables Strategy’ and has reduced energy use by 30% compared with MSF.

Sources: EAD Abu Dhabi, 2009. This material is based on the World Bank. 2004. Seawater and Brackish Water Desalination in the Middle East, North Africa and Central Asia; and, Water and Wastewater Asia. January/February 2008.

Table 7: Characteristics of UAE's desalination technology existing or planned in 2008

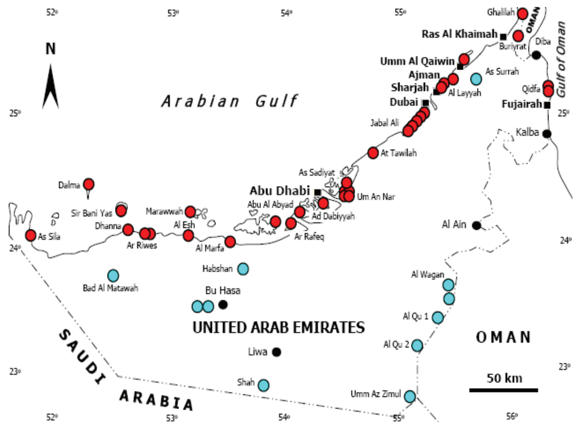
Energy Source	Technology	Number	Total Capacity (Mm^3/year)	Share of Capacity	Average plant size (Mm^3/year)
Thermal	MSF	20	1,307	57%	65
Thermal	MED	5	133	6%	27
Thermal	Steam	6	415	18%	69
Electrical	RO	25	422	19%	17
Total / weighted average		**56**	**2,277**	**100%**	**41**

Source: ICBA based on Emirate data. These data are partial as information on all existing and under implementation plants was not available. Descriptions of desalination technology are given in Annex 1.

standards and an over-reliance on the plant suppliers for technical design and consultants for advice. This ad hoc approach poses significant institutional challenges for the uniform standard that will be required if a national water grid is implemented.

Generally, desalination plants are located along the coast to access seawater (Figure 4 indicated in red), while the smaller RO plants are located on islands in the west where they access seawater, or inland where they access either brackish or saline groundwater (blue). Two-thirds of the desalination capacity is located in Abu Dhabi Emirate (Figure 5). Umm Al Quwain Emirate is the only one that relies on brackish groundwater supplies.

Figure 4: Location of the UAE's major desalination plants

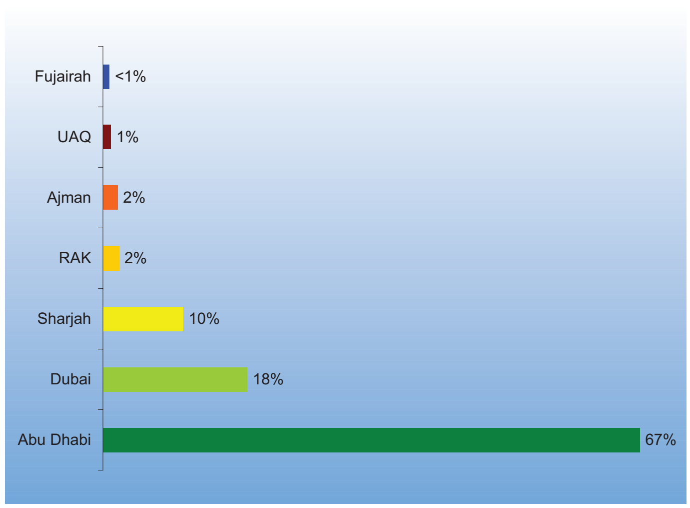


Source: Alasam and Rizk, 2009.

The MSF process is the preferred technology because it has significant economies of scale, is relatively energy efficient, has proved to be very reliable for many years over its many years of operation in the GCC Region and with good maintenance a plant can last 25 years.

Advocates of MSF argue that its main advantage is that MSF uses 'waste' heat from steam generated for electricity. In fact, the steam used by MSF plants could be used to generate more electrical power; thus MSF reduces power station output. MED is more energy efficient than MSF but is better suited to smaller-sized plants. RO initially had a poor experience in the region due to the high seawater salinity – 50% greater than the open oceans – and the abundance of marine life. Subsequently with further technical development, the RO technology has overcome these problems and is being used successfully for fairly large-scale production using lower salinity Indian Ocean water, as the experience with the Fujairah plant demonstrates. Importantly, the efficiency of RO increases as salinity reduces thus making it ideal for desalinating brackish groundwater.

Figure 5: Distribution of UAE's desalination capacity among the Emirates



Source: ICBA, 2010.

Cost of desalinated water

Desalinated water is the most expensive source of water because of high capital and operating costs, Table 8. These costs include the full capital, operational and maintenance costs over the life of a plant and are based on typical medium-sized installations. There are economies of scale with larger MSF plants. Thus for example, water production was about AED 3.08/m^3 (USD 0.84/ m^3) for the Taweelah A2 MSF distiller. It is not known if subsidized or global market prices are used for the cost estimate so actual economic costs could be higher. The main reason for the lower costs for the RO process is that it does not require energy to heat the water and the energy cost for pumping and power is about AED 0.48 (USD 0.13/m^3). In comparison, MSF total energy costs are AED 1.29/m^3 (USD 0.35/m^3 of which AED 0.88/m^3 (USD 0.24/m^3) are used for heating.

Table 8: Costs of Desalinated Water

		MSF	MED	RO
Investment Cost	USD/m^3/day	1,200-1,500	900-1,000	700-900
Total Water Cost	USD/m^3	1.10-1.25	0.75-0.85	0.68-0.82

Source: World Bank, 2004 ibid. Assumptions: Plant capacity 30,000 m3/day; plant life 20 years, interest rates 7% and labor at USD 45,000/year.

Average costs of desalinated water in the UAE are not very readily available partly because of the number of different technology supplies, the range of cogeneration pairings and the proprietary nature of commercial water supply operations. Complicating the picture further each Emirate has different ways of financing and subsidizing production, operation and maintenance and distribution costs. A notable first towards developing a process for arriving at cost standardization has been the creation of Abu Dhabi's independent and autonomous Regulation and Supervision Bureau (RSB).[14] This was essential. Without the RSB, the commercialization of the Emirate's water sector and the establishment independent water and power producers (IWPPs) may have led to profiteering from their monopoly of water supplies. Thus within Abu Dhabi all suppliers of water services are required to comply with rigid technical and reporting standards for all costs so that the regulatory process of setting allowable profits is unbiased and uniform. On the basis of this approach RSB estimated the actual cost of desalinated water generation was AED 7.6 or USD 2.07 per m^3 in 2009.[15] Consequently, assuming this would apply to the whole of the UAE (as Abu Dhabi provides two-thirds of desalinated water), total desalinated water production costs for 2008 were AED 11.6 billion, or USD 3.16 billion. This is equivalent to almost 2% of UAE's non-oil GDP.[16]

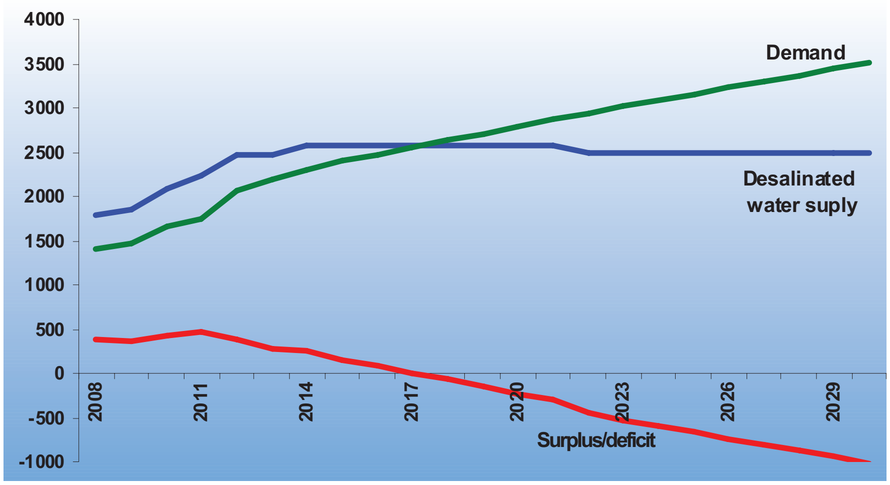
Future demand for desalinated water

The major drivers of future desalinated water demand are population growth, development of mega-projects and industrialization. The population baseline used for forecasting is the 2005 population census and population projections developed by various master plans. The same sources also supplied projections of future of non-domestic water demand. Because future population growth rates and industrial development are uncertain, this Report authors looked at several differing population and industrial growth rates as described in Annex 2. Two development scenarios were modeled. The first, Business-as-Usual (BAU) assumed growth rates continued the trends of the last five years. The second scenario took the detailed demand forecasts developed for Abu Dhabi by Abu Dhabi Water and Electricity Company (ADWEC) in 2009 and added the additional demand for the other Emirates based on slightly slower population and industrial growth rates. Because it is based on a more realistic foundation it is called the Realistic Scenario. While the longer-term demand forecast is much larger under the BAU scenario, the most important finding is that both scenarios show that current desalination capacity will be unable to meet demand after about 2017. UAE's future desalinated water demand forecasts presented below are based on the Realistic Scenario.

The projection of Realistic Scenario for future demand for desalinated water and its sources of supply is shown in Figure 6. The kink in the demand curve between 2009 and 2012 shows the impact of increasing the water distribution network in Abu Dhabi that currently constrains demand. The supply of desalinated water increases steadily until 2015 according to current plans to replace redundant plant and increase overall production. Beyond 2018 the overall supply-demand balance becomes negative indicating that significant new investment will be required.

The national supply-demand balance based on the Realistic Scenario shown hides considerable variation among the Emirates. Abu Dhabi will experience supply shortfalls after 2018 and this is projected to reach 0.4 km3 a year by 2030. Dubai has a similar problem after 2014 and its shortfall will reach 0.4 km^3 by 2030. Sharjah currently has a water deficit that is met from imports from Abu Dhabi, but if the proposed Al Humreh plant is commissioned by 2014 it will have a small surplus until 2020 when it again falls into small deficit. In contrast Ras Al Khaimah's current small deficit will be relieved by a new project in 2011 and it will have a surplus until the end of the planning period. Fujairah, Ajman and Umm Al Quwain Emirates will all experience growing deficits after 2010. Nationally, the overall deficit of desalinated water supply is projected to be 1.14 km^3 by 2030. Abu Dhabi, Dubai and Sharjah will account for more than 95% of this shortfall.

Figure 6: UAE's Future Demand and Supply of Desalinated Water – there will be a shortfall after 2017



Source: ICBA, 2010.

These longer-term shortfalls will still occur despite near-term investment that is expected to total over AED 51.38 billion (USD14 billion) to 2016, Figure 7. In addition annual operation and maintenance costs will increase from AED 4.4 billion (USD 1.2 billion) to AED 9.91 billion (USD2.7 billion) over the same period. Thus cumulative overall costs of desalination will require a total expenditure of about AED 110.1 billion (USD 30 billion) to 2016.

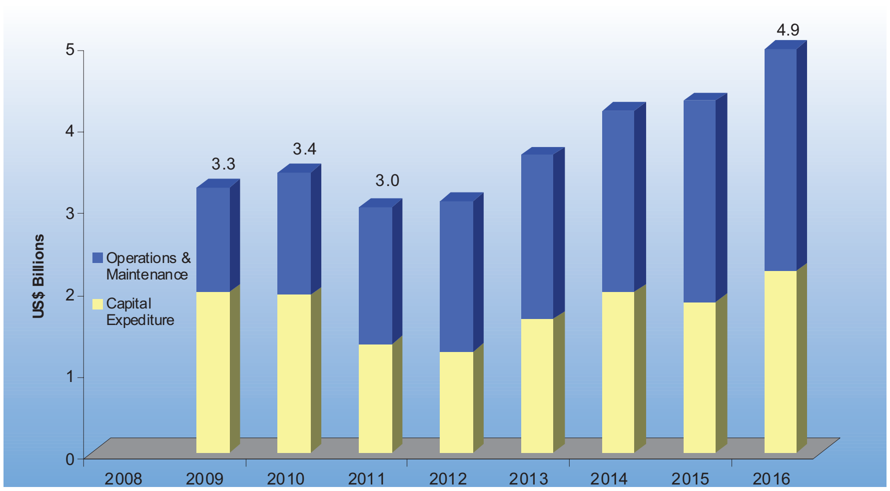
To meet the projected shortfall beyond 2017, and assuming present costs apply pro rata, an additional capital investment of about AED 66.06 billion (USD 18 billion) would be required for desalination plants in the period to 2030. Incremental annual operation and maintenance costs over this period would average about AED 11.01 billion (USD 3 billion) a year or AED 143.13 billion (USD39 billion), giving total expenditure of AED 209.19 (USD 57 billion) over the period 2017-2030.

Taking both near-term and longer-term financing needs into account, the bill for desalination could top AED 319.29 billion (USD 87 billion) between 2009 and 2030. As discussed in Chapter 6, water conservation could reduce this bill by almost half.

Financing may be an issue

Apart from the likely amount of investment required there is also a question of how it will be financed. While the commercial tranche of AED 3.5 million (USD 950 million) of the AED 8.07 (USD 2.2 billion) term financing for Abu Dhabi's Shuweihat 2 IWPP was oversubscribed using private financing for the

Figure 7: Planned Annual Investment in Desalination and Water Distribution Networks to 2016



Source: GWI, 2010.

Independent Water and Power Producer (IWPP), a similar attempt to procure the Hassyan I power and desalination plant by Dubai Electricity and Water Authority (DEWA) is under negotiation.[17] Dubai has announced in early 2010 that it will also follow the IWPP financing model for some future capacity expansion. This will require either the establishment of Emirate-level RSBs or, more sensibly, a national RSB to bring coherence and standardization to sector investment and operations. Given the scale of the investment required there probably be also a need for Federal credit guarantees that would minimize investors and financiers' risks, and thus reduce costs.

Demand forecasts need improvement

Finally, accurate water demand forecasts are an essential first step in planning water investments. Currently each Emirate estimates future water demand for desalinated water using differing time horizons, methodologies and assumptions. There is no uniform national standard.

Forecasting can be particularly difficult in rapidly urbanizing environments where past patterns of water usage are less likely to be reflected in future rates. Future potable water demand is derived from information on a number of different social, economic, political and natural environmental variables including the following:

- resident and seasonal population numbers, density and distribution;
- number, market value and types of housing units;
- per capita income;
- water and wastewater prices and rate structures and the way these affect consumption;
- commercial and industrial activity and mix;
- conveyance efficiencies and water losses;
- urban water use efficiency from implementation of Best Management Practices;
- irrigated acreage in residential, commercial and public use;
- other water uses; and
- climate and climate change conditions.

In deriving values for future demands, many different methodologies have been developed using various statistical approaches for accounting for uncertainty and risk. These include both deterministic and probabilistic methods, and recently multi-criteria analysis and artificial neural networks have been used. Since 2006, ADWEC have adopted a probabilistic approach in which uncertainties around various variables are represented by probability distribution curves. A major uncertainty is the use of desalinated water for agriculture. In addition an allowance has been made for continuous improvements in per capita consumption and landscape water saving improvements resulting from demand-side management.

There is limited information on demand forecasts, and only Abu Dhabi makes its demand forecasts publically available with clear statements of assumptions, methods and baselines. A similar approach applied to the whole of the UAE would ensure that uniform standards and methodology are applied to the UAE's demand forecasts.

Environmental costs of desalination are large

Desalination produces large quantities of warm, concentrated brine that has to be disposed of in an environmentally safe way. It also uses high levels of energy to convert seawater to freshwater and in doing so is responsible for considerable volumes of greenhouse gas emissions.

Brine production and the environment

The impacts of feed water abstraction and brine disposal on the marine ecosystem are potentially high in the near-shore environment. The main hazards are entrapment of marine life on the intake side and the effects of direct discharge of brine from desalination plants at high temperatures into cooler waters.

The volumes of water processed by desalination plants to obtain fresh water is very great with conversion efficiencies ranging from 25% for MSF technology to better than 50% for RO, Table 9. On the basis of the mix of UAE's desalinated technology (Table 7), 4.8 km^3 of sea water were pumped to desalination plants to produce 1.75 km^3 of desalinated water in 2009. Pumping this very large volume of seawater and then distilling it accounts for the high energy use in the desalination process.

Table 9: Brine production from the desalination process

Environmental Requirement or impact	Distillation		RO
	MSF	(MED)	
Volume of saline feed water per m^3 of fresh water	4	3	2 to 2.5
Volume of brine effluent per m^3 of fresh water	3	2	1 to 1.5

Source: World Bank, 2004. Seawater and Brackish Water Desalination in the Middle East, North Africa and Central Asia. Comparisons are based on a plant capacity of 32,000 m3/day.

Brine Disposal

Brine disposal from desalination plants is recognized as an environmental hazard. It is estimated that in 2009 about 3 km^3 was pumped into the Gulf from the UAE; a relatively small volume was also discharged to the Gulf of Oman from the Fujairah desalination facility.

Each stage of the desalinization process either adds or concentrates chemicals, most of which are discharged in the brine at the end of the process. Chemicals are frequently used to control marine growth, particularly mollusks around the intake structures supplying the desalinization plant. Within the plant, seawater or brackish/saline groundwater is again subject to chemical and mechanical treatment to remove suspended solids and control biological growth. During the application of energy to the treated seawater, brine is concentrated and returned to source including all of the chemicals added during the treatment process. The desalinated water is further treated with chemicals to prevent corrosion of the downstream infrastructure and water distribution network. Typically calcium hydroxide is added to increase the hardness and alkalinity, and sodium hydroxide is added to adjust the acidity of the water.

The range of chemicals added to the intake waters is large. In thermal combination desalinization plants biocides, sulphur dioxide, coagulants (such as ferric chloride, carbon dioxide, poly-electrolytes), anti-scalants (such as polyacrylic acid, sodium bisulphite, anti-foam agents), and polymers may be used. RO plants in addition use hydrocholoric acid, citiric acid, copper sulphate, acrolein, propylene glycol, glycerine, or sodium bisulphate. In addition to these additives, the water is of a much higher density because of the large increase in total dissolved solids. The salinity of the brine discharge from desalinization plants may be more than twice the salinity of Gulf water and at a significantly higher temperature. Salinity of effluents typically ranges between 46,000 and 80,000 parts per million (ppm). In addition, the combined effects of higher temperatures, salinity and chemical additives reduce the oxygen in the water and make it less soluble. Without proper dilution and aeration, a plume of elevated salinity low oxygen discharge may extend over a significant area and can harm near-shore ecosystems.

Overall, copper and chlorine are the most serious environmental threats from seawater concentrate discharge. Chlorine is one of the major polluters added to the feed water to prevent biofouling on heat exchange surfaces in MSF plants; it is little used in RO plants. Chlorine is a strong oxidant and a highly effective biocide; it also leads to oxidation by-products such as halogenated organics. Residual levels of chlorine in the effluent discharge may therefore be toxic to marine life at the discharge site. In the USA the Environmental Protection Agency (EPA) places the limits for exposure at 13 and 7.5 micro-grams per litre for short and long-term exposure respectively. In Kuwait it was found that concentrations up to 100 micro-grams – 10 times the toxic levels for humans – were found one km from cogeneration plants outfalls.[18] It is believed these levels pose high risks to some marine phytoplankton, invertebrates and vertebrates. Halogenated compounds are generally persistent in the marine environment and some are carcinogenic to animals.

Heavy metals enter the brine stream as the plant's internal surfaces corrode. Copper contamination is the major problem in MSF plants but in RO is almost absent because of the use of nonmetallic materials and stainless steel. RO brine though generally contains trace levels of iron, nickel, chromium and molybdenum. Heavy metals tend to enrich suspended materials and sediments and affect soft bottom habitats such as those found in the Gulf. Many benthic invertebrates feed on this suspended or deposited material with the risk that the metals are enriched in their bodies and passed up the food chain.[19]

In the UAE measures to mitigate the adverse consequences of brine disposal appear to be few although there are varyingly strict regulations on the quality of the discharge. Different coastal and marine ecosystems are likely to vary in their sensitivities to concentrated discharge. Generally salt marshes and mangroves in placid water marine environments have the highest sensitivity to brine disposal.[20]

Environmental Impacts of Brine Disposal

The coastal waters of the UAE are a rich habitat for marine organisms and Gulf fisheries, until recently, were an important part of the traditional economy. Over 280 species have been recorded and the coastline accommodates the largest known population of the dugong (*Dugong dugon*) outside Australia. Sea-grass colonies are a vital habitat for much of the marine fauna.[21] The largest area of coral reefs in the southern Gulf lies within Abu Dhabi and they support fisheries, habitats critical for the maintenance of biodiversity and recreation. Coastal mangrove forests provide breeding and shelter for at least 43 species of phytoplankton and 29 species of fish, and also provide habitat for birds. Much of the attraction of the UAE to tourists is related to marine-based activities and beach-side residence – the Palm Jumeirah development being a prime example. Thus conservation and biodiversity maintenance in the near-shore environment has to have a high priority in coastal zone management.

Catastrophic coral bleaching events occurred in 1996 and 1998 and research has associated these with prolonged elevation of seawater temperature resulting from El Nino events. Coral mortality up to 98% occurred and in the Jabel Ali Wildlife Sanctuary species diversity was reduced from 43 to 27 species.[22] This highlights the sensitivity of local ecosystems to enhanced water temperatures.

The effect of brine discharge on the Gulf's fauna is unknown. Research results elsewhere have produced a range of findings. A comprehensive study of a thermal desalination plant in Key West, Florida, found that the heated brine effluent, which was highly contaminated with dissolved copper, markedly reduced biotic diversity over an 18-month period.[23] In contrast, in Spain there were major impacts on seafloor communities from brine discharges that raised near-shore salinity to over 39,000 ppm.[24] Specifically nematodes (worm) prevalence increased from 68 to 96% over two years and other species declined. Studies in Spain on sea grass habitats showed that even brief exposure – 15 days – to salinities in excess of 40,000 ppm caused a 27% mortality of plants.[25] Generally, research indicates that the 38-40,000 ppm zone represents a tolerance threshold for marine organisms.[26] Clearly, brine discharge from desalinization plants has the potential to significantly impact near-shore environments and ecology.

The impact of brine and cooling water disposal on fisheries is also unknown. There are over 350 commercial fish species and 14 shellfish species inhabiting the continental shelves of the Arabian Sea, the Gulf of Oman and the Arabian Gulf.[27] A comparison of surveys of the UAE portion of the Arabian Gulf and the East Coast Region conducted by FAO in 1978 and one commissioned by EAD in 2003 found that stocks of bottom-feeding (demersal) fish had declined by 81%.[28] In contrast the same survey found the stocks of surface feeding (pelagic) fish remained about the same as 1978. A key finding was:

> *Most importantly this reduction in the abundance in both the Arabian Gulf and the East Coast Region was apparent for both commercial and non-commercial species indicating that commercial exploitation may not be the only factor involved.*

In summary, the Gulf is a fragile ecosystem with high recreation and tourism potential. Increased demand for desalinated water using existing technology will increase brine discharges to it and will probably jeopardize its amenity and recreational value and cause harm to its fragile ecosystems. More research is needed to fully understand the environmental impact of brine disposal and to determine if it is implicated in rapidly declining fish stocks. Changing desalination technology towards a greater share of RO, if found to be cost-effective, could go a long way to mitigating these concerns.

Desalinated Water Production, Energy Use and the Atmosphere

The interdependency of water and energy exacerbates environmental problems. Population growth will require increasing amounts of water which, in turn, require more energy to access water resources and distribute water. Since this increased electrical demand is largely met by fossil fuel-fired electrical cogeneration plants, more greenhouse gases are emitted that contribute further to global warming. These interdependencies, which are usually ignored in water and energy planning, create a downward spiral among electrical generation, climate change and water supplies that is cumulative and non-linear.

Water use in itself will not affect the atmosphere of UAE although there may be micro-climate modification in the vicinity of newly-introduced vegetation and agriculture. However, the secondary impacts of desalinization and the use of electricity to pump water around the extensive water distribution system (and from groundwater) within the UAE, and for collecting, treating and distribution wastewater require power generation. Power for water will, in turn, generate greenhouse gases. An alternative perspective is that desalinated water is greenhouse gas neutral and the only issue is improving pumping efficiency and reducing energy use. This perspective sees desalination as a useful by-product from the steam produced by fossil fuel electrical power generation and the incremental contribution of water production to greenhouse gas emissions is negligible. However, the steam has an alternative use for secondary cogeneration of electricity thus allowing a reduction in primary power production and capacity. This, in turn, would allow a reduction in greenhouse gas emissions below the cogeneration power-water option. If potable water can be produced by a more energy-efficient technology, it would lower greenhouse gases.

Desalination

No consistent set of emissions data for all of the UAE's desalination plants was available for this report. However, power station emissions are monitored by Abu Dhabi Emirate and we can use this to make an estimate for the whole of the UAE. Total emissions in Abu Dhabi from power and desalinization plants produce 13.5 million tonnes of gases and particulates per year, and carbon dioxide forms 99.65% of these emissions.[29] The next largest emission is nitrous oxide and nitrogen dioxide which total 34,000 tonnes per year. While the volume of nitrous oxide is relatively small, it is 200 times more effective as a greenhouse gas than CO_2 and is thus equivalent to 6.8 million tons of CO_2. Thus total CO_2 emissions equivalent for Abu Dhabi electricity production is about 20 million tonnes a year.

Electricity production in Abu Dhabi represents 45% of UAE's total production. On this basis, total CO_2 emissions equivalent for UAE's electricity production is thus about 45.5 million tonnes a year. In terms of direct CO_2 emissions Abu Dhabi's power plants fit well within the expected range of international efficiency standards for gas-fired facilities– about 380 grams equivalent per kWh. In the UK for example, the range is 362 to 575 grams.[30]

Determination of the share of total energy used that goes to water production in MSF plants is complex. Theoretical and empirical studies

Table 10: Energy use in desalination

	Desalination Technology		
	MSF	**MED**	**RO**
Operating Temperature	< 120º C	<70º C	Ambient
Main Energy Source	Heat	Heat	Electric
Thermal Energy Demand per m^3	12 kWh	6 kWh	None
Electrical Energy Demand per m^3	3.4 kWh	1.5 kWh	4–7 kWh
Total Energy per m^3	15.4 kWh	7.5 kWh	4–7 kWh

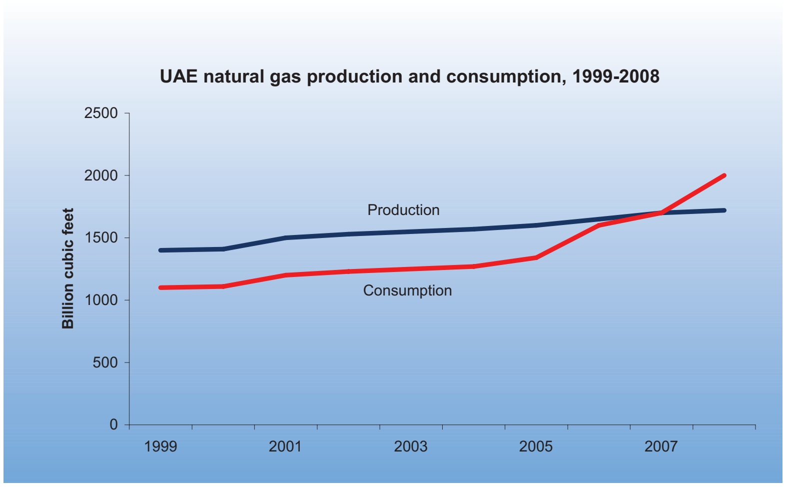
Source: Cherfane, 2009.

indicate that Saudi Arabia's cogeneration MSF plants at Al Jubail 24 and 46 % of electrical energy produced is used for water production depending on the accounting method used and the power to water ratio.[31] Earlier studies in Abu Dhabi yielded similar results.[32]

Thus a rough estimate of Greenhouse Gas production attributable to UAE's desalination water sector is between 11 and 21 million tonnes of CO_2 emissions equivalent a year. In terms of total emissions of 127 million tonnes of CO_2 equivalent a year, desalination accounts for between 9% and 17% of the national amount.[33] This estimate needs considerably more work to define the exact level of UAE's energy production used for desalination. In addition, large amounts of energy are also required in addition to pump the desalinated water to consumers through several thousand km of pipelines.

There are also considerations of energy availability and cost. Earlier the UAE's surplus of natural gas did not impose a constraint on desalination technology. That is no longer the case (Figure 8) as natural gas is now imported from Qatar's North Field to Abu Dhabi, Dubai, and Fujairah in the UAE, and then on to Oman through the Dolphin natural gas pipeline.[34]

Figure 8: Natural gas now has to be imported



Source: cabs@eia.doe.gov. 2010.

Recent Developments

Some of the adverse environmental consequences of energy use for desalination may be mitigated in the future by two recent developments. First, UAE has created the Emirates Nuclear Energy Commission in a plan to reduce reliance on fossil fuels (Box 2). Not only would this reduce greenhouse gas emission, it would have also a profound impact on the choice of future desalination technology. However, building a nuclear power station will require a lengthy process to satisfy the IAEA's regulatory requirements and it may be some years before nuclear power comes on line. Secondly, UAE has embarked on an ambitious program of carbon capture to store between 6 to 8 million tonnes of oil-generated CO_2 into deep underground storage. While this does not directly affect cogeneration desalination plants, likely knock-on effects will be greater attention to reduce CO_2 in other sectors.

Box 2: Fuel for the future: Nuclear Power - the UAE's 2008 Policy Paper

Annual peak demand for electricity is likely to rise to more than 40,000 MW, but the known volumes of natural gas that could be made available to the nation's electricity sector would be insufficient to meet 20,000 – 25,000 MW of power generation capacity by 2020.

While the burning of liquids (e.g. crude oil and/or diesel) was found to be logically viable, evaluation of this option revealed that a heavy future reliance on liquids would entail extremely high economic costs, as well as significant degradation in the environmental performance of the UAE's electricity sector. While an evaluation of coal-fired power generation established its lower relative price compared to liquid-fired power generation, its widespread use within the UAE would have an even more detrimental effect on environmental performance, while also raising thorny issues related to security of supply. Evaluation of alternative energies, including solar and wind, suggested that, while these options could be deployed in the UAE, even aggressive development could only supply 6-7% of peak electricity demand by 2020.

Stacked against the above options, nuclear-powered generation emerged at a proven, environmentally promising and commercially competitive option which could make a significant base-load contribution to UAE's economy and energy security.

Source: ADWEC, 2008. op. cit.

Chapter 4
Reclaimed Water

CHAPTER 4
RECLAIMED WATER

OVERVIEW

Wastewater has to be treated to satisfy environmental and public health concerns and, in that sense, it is a 'free resource'. To date the Emirates' good judgment has been to maximize its use for the public good as much of the treatment costs are met primarily by the Emirate governments. In most western economies, in contrast, wastewater treatment costs are borne generally by consumers on the principle that the 'polluter pays' and a sewerage surcharge is typically included as part of the water tariff.

Reclaimed water is a valuable resource to address water scarcity. This is particularly so in arid regions where there is a premium on conservation and maximizing water use through recycling. Its primary advantage is as a substitute for better quality water, particularly expensive desalinated water and fresh groundwater. The quality of reclaimed water can be adjusted through appropriate stages of treatment. Globally, reclaimed water has a wide range of uses including potable, irrigation, industrial processing and cooling. For health and aesthetic reasons reclaimed water is not used currently on food crops in the UAE, but it is used for forage crops, recreational and amenity area, and landscaping. In Dubai a small amount is used for groundwater recharge.

Reclaimed water is a significant and growing resource in the UAE. To date it has been used primarily for greening of urban areas following the vision and direction of the late H.H. Sheikh Zayed bin Sultan Al Nahyan, President of the UAE and Ruler of Abu Dhabi. This effort has been continued by H.H, Sheikh Khalifa bin Zayed Al Nahyan, the President of the UAE and Ruler of Abu Dhabi. As a result Abu Dhabi and Al Ain are lush green landscapes supporting thousands of trees, shrubs and large grassed areas in and around the cities. In addition to amenity value, this greening provides rich habitats for flora and fauna. Dubai and the other Emirates have embarked on similar landscaping and amenity plantations, including international standard golf courses and racetracks, aimed at making them into international sports, conference and tourist destinations.

Throughout the UAE wastewater is treated to the tertiary level making it suitable for a restricted range of irrigation uses. The total amount of reclaimed water produced was approximately 0.56 km^3 in 2008[35] (ICBA, 2010) and this is expected to increase (where collected) at the rate of UAE's population growth, currently about 6.6 per cent annually. Less than two-thirds is beneficially used; one third is disposed either into the Gulf or to the desert.

FUTURE AVAILABILITY

There are no readily available predictions of future availability of reclaimed water for the Emirates. In the UAE the standard assumption is to assume that 90% of household water consumption, estimated to be 300 lpcpd, is available. As a result the prediction is that by 2030 that the volume of reclaimed water will be 1.44 km^3 a year – about two and a half times present availability (See Annex 1 for more details).

In reality not all wastewater will be available for reuse. This is for two reasons. First, only part of the population is served by centralized collection systems, Figure 9. Second, even where there is sewerage, a substantial proportion of wastewater will not be captured by the sewerage system for treatment and reuse.

Population served by centralized sewerage collection

The weighted average population served by centralized wastewater collection is 77%. The distribution of access to the sewerage system is shown by Emirate in Figure 10. Currently it is difficult to determine how much of the septic tank and local systems allow collection of wastewater for reuse. Many septic tanks are emptied by tankers regularly and taken to centralized sewerage treatment works – as is the case in parts of Dubai. An increasing trend in new developments and mega-projects is to collect and treat the wastewater generated and use it within the development – the Palm Jumeirah is typical. Consequently it is likely that wastewater from some future mega-developments will not be available for public allocation and use.

To ensure predictability of future public wastewater treatment investment and reuse of reclaimed water, a more formal national system of regulating wastewater treatment and reuse will be required. Until such a system is in place firm capacity predictions of future public wastewater treatment infrastructure cannot be made.

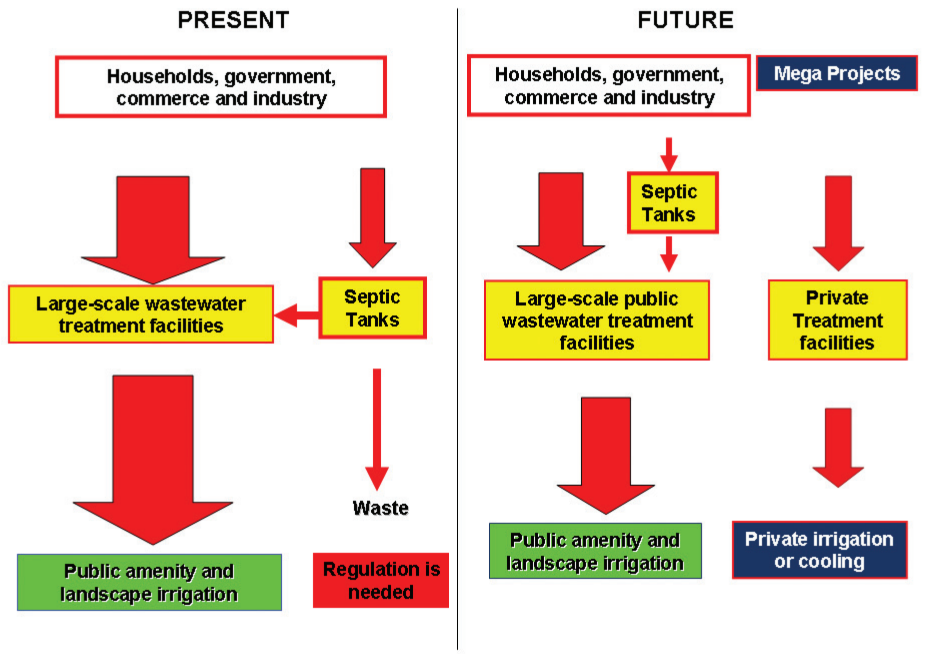
Volume of potential wastewater collected

Even when there is sewerage, not all wastewater is returned to the sewer. In some cases, industry reuses untreated wastewater for secondary purposes such as processing or cooling where much of the volume may be lost to evaporation. Currently, industrial use is estimated to account for about 4% of water use. While this is expected to expand in future, the rate of expansion is uncertain particularly given the current global economic climate.

Household wastewater will remain a primary resource

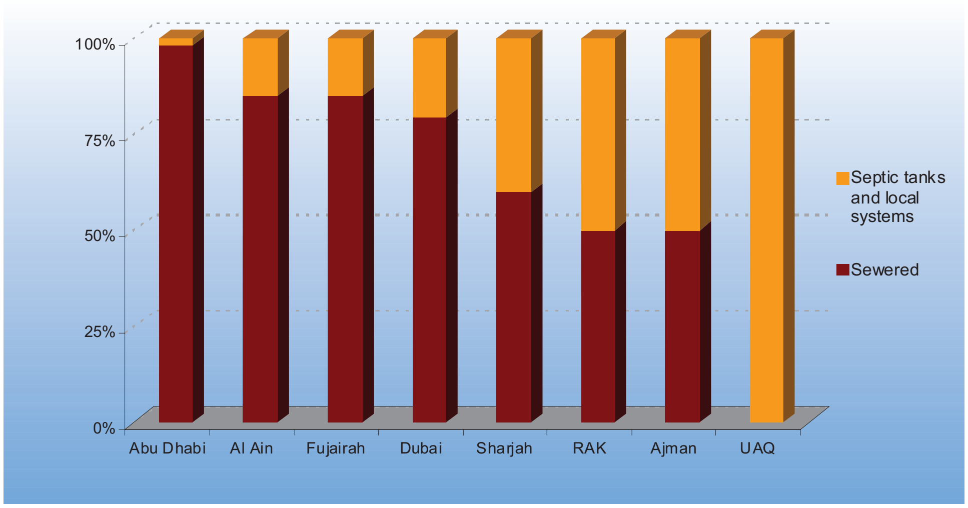
Not all potable water consumed by households is used for domestic purposes. Large volumes are used for activities outside the house for gardens, landscapes, water amenities and washing cars. Most of this water is evaporated and cannot be reused. Both ADWEC and RSB, concerned at the high levels of household water consumption, undertook household surveys in Abu Dhabi Emirate, Table 11. In flats (apartments) where there are full data and no external water use, average daily water consumption was between 170 lpcpd and 220 lpcpd. Average daily use is thus about 195 lpcpd. Assuming that 10% of this is lost by evaporation and ingestion, potential wastewater availability is about 176 lpcpd, or rounding say 180. This daily per capita volume is fully in accord with international experience.

Figure 9: The growth of mega-projects will significantly reduce the share of wastewater available for public reuse for amenity and landscaping



Source: ICBA, 2010.

Figure 10: The share of wastewater collected in centralized sewerage system varies considerably across the UAE



Source: ICBA, 2010 using the latest complete data (2008).

It is also apparent from the household survey data that households with gardens – villas – may use up to 10 times more water per capita and none of this is available for reuse.

Wastewater inflow to the sewerage system exhibit considerably higher per capita inflows than we would expect from internal household use. In Abu Dhabi metropolis the average daily inflow during 2008 was 397 lpcpd. In Al Ain it was 261 lpcpd.

There are two reasons why inflow to the sewers could be larger than would be expected. First, inflow from industrial and commercial sources could be higher. Second, the sewers could be acting as drains.

Table 11: Residential daily water consumption by household type in Abu Dhabi

Nationality	Property type	Gross consumption (l pcpd)	
		Min	**Max**
Expatriates	Flats	170	220
	Villas	270	730
UAE nationals	Flats	165	-
	Villas	400	1,760
	Shabiyats	610	1,010
Overall average		**525**	**600**

Source: RSB. 2008. Water and electricity consumption by residential customers. This is based on volumes and accounts from the Water Supply Companies and occupancy levels from the 2005 Census and the PB Power surveys (2005 and 2007)

Increasing discharge of industrial wastewater to sewers is evidenced by the elevated levels of heavy metals in sewage. However, industrial wastewater production is only a very small share of total wastewater produced – about 4% in 2008 – and this is too small to account for the difference. It is possible that a proportion of household water use in garages and pools finds its way back to the sewerage system. It is widely reported by ADSSC that the sewerage systems leak and in both Abu Dhabi and Al Ain the higher water table causes the sewers to become drains. There is strong evidence for this from recent photographic surveys that show leakage into the sewerage system, Figure 11.

Leakage to sewers is substantial

Shallow groundwater in both the coastal zone and inland has led to in an increased salinization of sewage in a number of the Emirates over the last few years.

Al Ain data illustrates this well. In 2005 the water table was generally below the sewer level; but by 2008 it had risen in many places above the sewer level allowing inflow of brackish groundwater into sections of leaky sewer. Over the same time period the concentration of total dissolve solids (TDS) doubled from a base level about 1,000 parts per million (ppm) to over 2,000 ppm. Similarly Chlorine increased from about 250 ppm to 500 ppm. In contrast the concentrations of Ammonium Nitrogen and biochemical oxygen demand (BOD) derived from raw sewerage declined slightly giving fairly conclusive proof that salinization of sewerage was from sewer leakage.[36]

Reclaimed water quality is a problem

In a number of Emirates the sewage inflows have much higher total dissolved solids and electrical conductivity than would be expected from domestic wastewaters. Because this is difficult to remedy using tertiary wastewater treatment, the resultant reclaimed water is only suitable for a restricted range of uses.

Rehabilitating sewerage systems has many benefits

These findings indicate that efficiency measures should be introduced taking into account the whole wastewater cycle – currently the primary focus is on wastewater treatment. Systems that leak and act as drains for groundwater may also allow untreated sewage to contaminate groundwater when the systems are surcharged – a public health hazard. Sealing sewerage systems will remove that hazard.

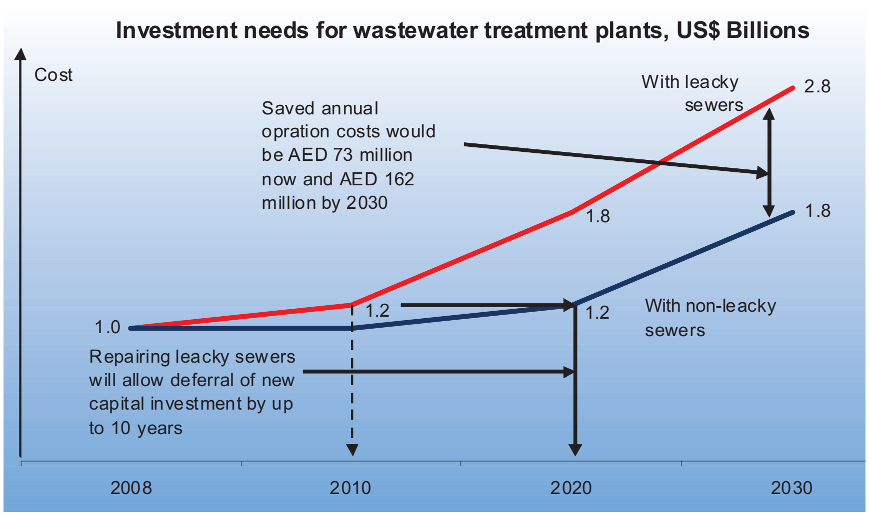
From a financial perspective there are two ways of looking at this problem. First, reducing the volume of inflow will enable development of new capacity to be delayed and reduce investment and treatment costs, Figure 12. In this case about AED 0.27 (USD 1) billion investment in future capacity expansion could be saved. Cumulative annual savings in operating costs over the period to 2030 would be of the order AED 8.81 billion (USD 2.4 billion). Second, this benefit should be traded off against the costs of installing improved – and separate – urban drainage and the benefits it will produce. Better urban surface water drainage, for example, would reduce or even eliminate the substantial economic and commercial disruption caused by the heavy rainfall and resultant flooding of February 2010.

Likely availability of reclaimed water

Estimates of future reclaimed water availability for differing levels of mega-development are shown in Figure 13. Under the 'Business-as-Usual' model (the blue curve) it is assumed that all wastewater is collected by the public sewerage systems at the rate of 300 lpcpd. Under this scenario annual availability would increase from about 0.6 km^3 in 2010 to 2.3 km^3 in 2030. This scenario is unlikely for two reasons. First, because per capita collected volumes will decline as public health concerns, water conservation and cost containment efforts seek to make the sewerage system watertight. Second, mega-developments and industry will seek to retain all their generated wastewater for internal use, be it for processing or amenity and landscaping.

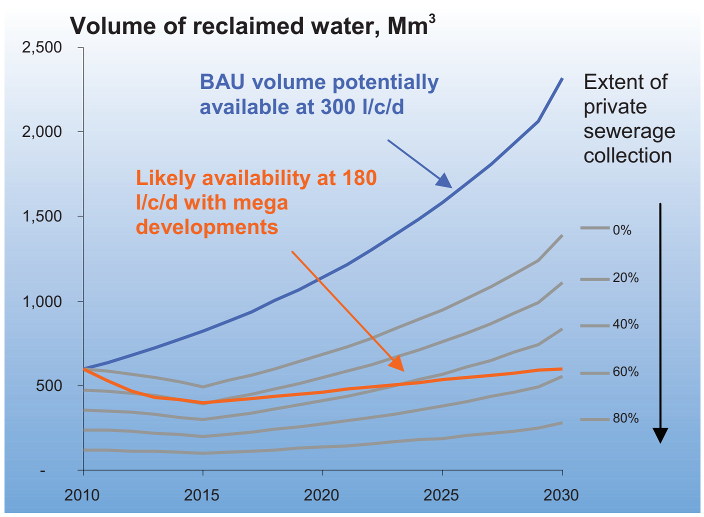
The most likely scenario is that the volume of reclaimed water in the public domain may stay fairly constant. In the example shown in Figure 13, the red line shows the likely trend. By 2015 the private sector captures 20% of reclaimed water. This could be expected to increase to about 60% by 2030. Thus public sewerage and reclaimed water generation systems would serve more efficiently about 8 million of the anticipated UAE population of 20 million in 2030, a third more than the current population of 5 million. Clearly much depends on the pace of self-contained mega-projects and population growth.

Figure 12: Rehabilitating sewers not only removes the risk of contaminating shallow groundwater it also reduces longer-term costs



Source: ICBA, 2010.

Figure 13: Potential and likely availability of reclaimed water for public use



Source: ICBA, 2010.

From a Federal water planning perspective the above discussion raises five pressing issues:

- reclaimed water has to be considered in the context of whole water cycle and urban drainage – a comprehensive planning approach is required;
- developing a national policy on the role of private reclaimed water service providers;
- enhancing Federal coordination of reclaimed water services planning with municipal, industrial and private development to more clearly define the public service provision;
- ensuring national standards for sewage collection, treatment and reclaimed water use; and
- ensuring adequate sector regulation and management.

A first step for better regulation is to ensure that the quality of water entering the sewerage system is free from major pollutants that may jeopardize subsequent reuse.

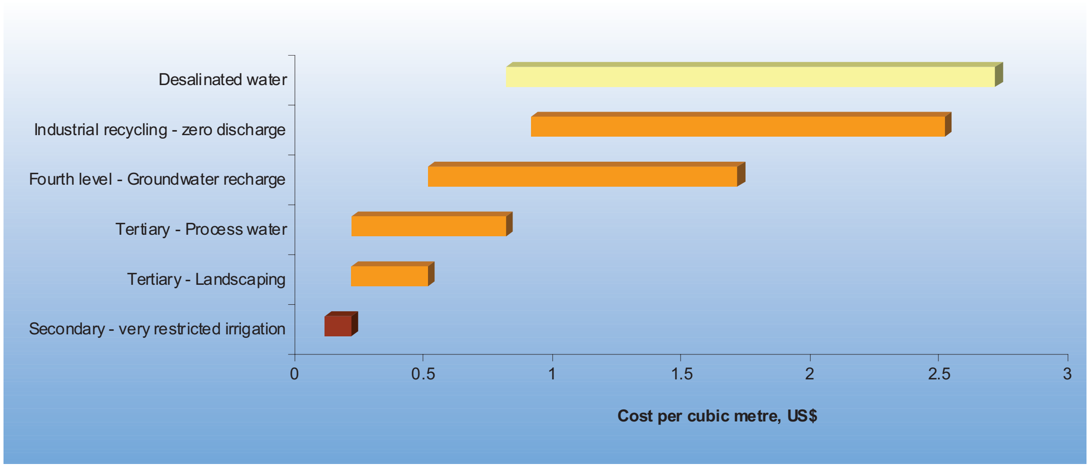
Costs of reclaimed water

Cost estimates for wastewater reclamation vary widely, and are based on particular assumptions and cost allocation principles. The cost of secondary treatment of wastewater is often used as a baseline for comparing the expenses of tertiary and advanced treatment facilities for reuse. The total capital costs for a standard secondary treatment plant are AED 1.73/m^3 (USD 0.47/m^3). Of the total, 24% is taken up by primary treatment; 40% by secondary treatment; 22% by sludge treatment, while control, laboratory and maintenance take up 14%.

Reclaimed water is not low-cost. Costs can be minimized when water reclamation facilities are in the vicinity of potential reuse applications; and when no additional treatment is required beyond that carried out at the reclamation facility. Reuse schemes incur costs in terms of wastewater treatment; operation and maintenance of treatment facilities; conveyance, storage and distribution; possible on-farm expenses (for instance, irrigation systems); and the operation and maintenance of all reuse facilities as well as metering. The cost of storage, conveyance and distribution is determined by a number of factors, including the distance between a treatment facility and reuse site; the lift of reclaimed water to the surface for use in irrigation; the size of the irrigated area; and the size of a potential reservoir for storage.

A range of total costs for water reuse based on international experience is given in Figure 14. Distribution costs may vary from AED 0.18-1.32/m^3 (USD 0.05-0.36/m^3). Implementing reuse may add on average AED 0.73 /m^3 (USD 0.20/m^3) to the cost of the wastewater treatment process. The production costs of quaternary effluent are of the same order of magnitude as desalinated water. This is not surprising as both are treated to internationally-accepted potable standards.

Figure 14: Cost of Reclaimed Water and Comparison with Desalinated water



Sources: After Labre, 2009 and RSB.

In the UAE, the most transparent costing comes from the Emirate of Abu Dhabi, and the production costs of tertiary and quaternary effluent are in the same range as reported in the graph, Table 12. On the basis of the latest ADSSC feasibility studies, capital investment for high-end tertiary wastewater treatment is AED 8.44 /m^3 USD 2.3/m^3 and for fourth-level treatment is AED 15.05/m^3 (USD 4.1/m^3).

Table 12: Reclaimed water tariffs required to cover all costs in Abu Dhabi, 2009

Location of Treatment Plant	Tertiary Treatment AED/m^3 / USD/m^3	Fourth Level Treatment AED/m^3 / USD/m^3	Total – all costs AED/m^3 / USD/m^3
Wathba	1.56 / 0.42	2.04 / 0.55	3.60 / 0.98
Saad	1.52 / 0.41	1.59 / 0.43	3.11 / 0.85
Allahamah	1.62 / 0.44	1.45 / 0.39	3.07 / 0.84

Source: ADSSC/Cardno, 2009. These tariffs covered full repayment of an IWPP concession of 25 years that covers repayment of capital costs, depreciation, and all operations and maintenance costs.

Future investment in reclaimed water

Given the uncertainty about population growth and the role of independent and private mega-projects it is very difficult to predict infrastructure development that will require public (i.e. Emirate) financing. Much will also depend upon the level of water treatment required, on the sort of utility model adopted - public sector provided and managed; or a mixed approach of public utilities for existing municipalities and private utilities for mega-developments. The increasing preference for efficient and highly regulated IWPPs will require Emirate policy decisions on privatization of utilities that look after treatment of wastewater and distribution of reclaimed water, with associated regulatory structures and frameworks.

The public policy options for the provision of wastewater treatment, based on the operating model and costs discussed above are shown in Figure 15. The least cost option (A) is a mixed public-private model – in this case a gradual transition to 60% private operations by 2030 – treating wastewater to the tertiary level. Water produced would be suitable for amenity, landscaping and some agriculture but not food crops according to current UAE preferences.

Figure 15: Policy options for wastewate sector financing 2010-2030

	3rd level treatment	4th level treatment
All Public	Capital USD 4.2 O&M USD 1.8 Total USD 6.0 **Intermediate Cost (C)**	Capital USD 7.4 O&M USD 4.9 Total USD 12.3 **Most Cost (D)**
Mixed Public and Private	Capital USD 2.0 O&M USD 1.1 Total USD 3.1 **Least Cost (A)**	Capital USD 3.6 O&M USD 3.2 Total USD 6.8 **Intermediate Cost (B)**

Source: ICBA, 2010.

Improving water quality to potable fourth stage standards doubles the cost of the public-private model. Overall costs of this option (B) are similar for an all-public model treating water to tertiary standards (C). The most expensive option would be the all-public model treating water to potable standards (D). Given that there is unlikely to be sufficient reclaimed water to meet current municipal demand – that will be about 40 percent of total future demand – the simplest choice would be option A. This would gradually allow transfer of the majority of the costs associated with collection, management and allocation of wastewater and treatment to autonomous mega-developments. The primary public role would be thus sector regulation and management of public municipal amenity spaces and landscapes.

Demand for reclaimed waters

Potential demand for reclaimed water exceeds current supplies. Even so, as much 40% of UAE's reclaimed water is discarded - it is dumped to either the Gulf or the desert. The primary reason is that many municipal irrigation systems do not have the infrastructure, capacity or connections to distribute potentially available water. There are clearly substantial opportunities for conservation and better use of reclaimed water.

Abu Dhabi. The most extensive and notable reclaimed water usage has occurred in Abu Dhabi Municipality. The Municipality's Sewerage Project Committee was established in 1975, and subsequently developed a policy for allocating reclaimed water from Mafraq's wastewater treatment plant for irrigation in order to conserve the potable water supplies. The early infrastructure was able to provide 90% of the irrigation water for 15,000 hectares of forest land, landscaped areas, public parks and gardens, ornamental plants, a golf course and a 250 ha animal fodder farm at Al Wathba. The irrigation infrastructure capacity has been increased but it is still insufficient to fully utilize all the reclaimed water available. As a result 35-40% of Abu Dhabi Municipality's reclaimed water is currently discharged to the sea. At current prices this is equivalent to throwing away AED 95.42 million (USD 26 million) a year and spending AED million 528.48 (USD 144 million) on a replacement, desalinated water; total cost of this policy AED 623.9 million (USD 170 million) a year.

At the same time, in Abu Dhabi, the Municipality has tapped alternative water resources: in 2008, landscaping and amenity used desalinated water to provide 22% of its demand, reclaimed water 42% and groundwater 8%. The overall shortage of water for landscape and amenity use caused ADSSC to prepare a Master Plan (2008) that recommended a new policy for water-conserving amenities planting. Under this Plan the current water-intensive landscaping designs are to be converted to dry landscaping that will use desert and xerophitic plants that are better suited to the arid climate.

The inclination to develop policies and mechanisms to fully capture the 35-40% of reclaimed water that is dumped and use it for agriculture is fraught with difficulty. There is a problem of inflowing brackish water through leakage into the reclaimed water pipes. Any moves to reduce this leakage will result in a decline in total water quantity but improve quality. Therefore, alternative uses are not viable given municipal demand for desalinated water that is almost five times more expensive. There is also the equity issue of using free resource that benefits the amenity most urban residents – reclaimed water cost is wholly subsided by the public sector – for the private benefit of a few farmers. The option selected by ADSSC to increase water use efficiency while maintain the public good of landscape and amenity plantations, providing that it substitutes reclaimed water for desalinated water, is a win-win situation.

At **Al Ain**, the situation is different because the increased availability of desalinated water at negligible costs has reduced demand for reclaimed water; half the reclaimed water is being disposed to nearby evaporation-seepage lagoons and wadis. Thus AED 33.03 million (USD 9 million) a year of reclaimed water is being wasted. Worse, it has been replaced by expensive desalinated water that costs AED 172.49 million (USD 47 million) a year to produce. Thus the policy of allowing substitution of desalinated water for reclaimed water is currently costing AED 205.52 million (USD 56 million) a year in Al Ain alone.

In **Dubai Emirate**, more than 165 m^3/year of reclaimed water is used for irrigation purposes predominantly for landscape irrigation. Reclaimed water is used to irrigate golf courses (recreational use) and also used for industrial purposes in the form of cooling water for the cooling towers. In addition, artificial recharge of groundwater has been initiated and about 16 Mm^3 of reclaimed water has been used for this purpose in 2005.

In **Sharjah Emirate**, about 75 m^3/year or 65% of the reclaimed water is distributed to the Municipality for irrigating the landscapes, parks and gardens. The remaining 35% of reclaimed water is discharged to the sea.

In **Ajman Emirate**, the distribution network is currently under construction by the Government of Ajman. Pumping stations will distribute some of the reclaimed water toward the farms area to be used in landscape irrigation within the farms and to irrigate a tree belt surrounding industrial areas as part of environmental protection measures. The remaining reclaimed water will be pumped to a newly installed microfiltration unit and RO plant for further treatment and will be then sold for industrial purposes (ASPCL, 2009).

In **Fujairah Emirate**, currently there are relatively small quantities used for irrigation purposes at WWTP site landscaping until the effluent distribution network (EDN) is completed in 24 months. The rest of the reclaimed water is discharged into the sea. The EDN once completed will distribute the reclaimed water to various user groups (Tanqia, 2009).

In **Ras Al Khaimah**, the reclaimed water is taken by tanker to the municipal area for irrigating the golf courses and landscape areas near the Corniche. The surplus is discharged in ponds to recharge the groundwater aquifer (EarthCAD, 2009).

Umm Al Quwain has no operational treatment plants yet.

Environmental and safety concerns

Wastewater and sludge disposal

While most of UAE's municipalities have developed master plans for sewage management this has focused on water and sludge treatment, but not sludge disposal.

Sludge is a major by-product of wastewater treatment. In 2007 wastewater treatment produced about 65,000 tons of sludge that was dried and composted with household solid wastes or green wastes and used as a soil conditioner and fertilizer. A significant proportion, however, is dumped in the desert. Rather than being seen as a problem, however, sludge should be seen as a valuable source of plant nutrients and as a soil conditioner, particularly for dry sandy loams that typically have poor water retention characteristics.

Use of reclaimed water

The success of water reuse depends in part on public approval of the practice. International experience suggests that the public often accepts the use of reclaimed water to irrigate recreational areas or to recharge groundwater. However, reuse in agriculture tends to raise concerns.

Wastewater can be reclaimed or reused for different purposes. As such, it should be protected from various sources of pollution in order to maintain its quality. One way of doing so is to prevent the discharge of major pollutants into public sewers. These compounds – persistent trace organics, trace minerals; and radioactive compounds – can enter public spaces, or in the worst case, the food chain, and adversely impact human health. Moreover, some industrial or commercial pollutants are toxic to biological systems that are commonly used for municipal wastewater treatment. Pollutants should be removed at their source, and to the extent feasible, retained in closed-loops and reused by the emitting industry (Goodland and Rockefeller, 1996). Indeed, many industrial pollutants can be extracted more easily in a concentrated form at their sources, rather than a diluted form in municipal sewage. In sum, wastewater management should shift from an end-of-pipe approach to a source approach. In addition, clean production and energy- and water-saving processes and technologies must be promoted.

Treatment at the source can minimize risks to human health; reduce environmental exposure to hazardous material; protect the integrity of municipal wastewater treatment systems; and decrease costs of treatment. Regulations for the discharge of industrial wastewaters have been drawn for Abu Dhabi but there are no national guidelines. There is also the need for an independent national regulatory agency to see that regulations are effectively enforced. Treated waste material will then be of a quality that allows for reuse. Reclaimed water is a significant source of fertilizing nutrients, Table 13, and this accounts for the lush vegetation seen in most of UAE's cities and landscaped areas.

Table 13: Reclaimed water contains lots of fertilizer

Nutrient	Fertilizer Contribution from Irrigation (kg per ha)	
	Irrigation rate 3,000 m³/ha	Irrigation rate 5,000 m³/ha
Nitrogen	48-186	80-310
Phosphorous	12-72	20-130
Potassium	6-207	10-345
Calcium	54-624	90-1040
Magnesium	27-330	45-550
Sodium	81-564	135-901

Source: Qadir *et al*,. 2010.

Health risks

Public concerns often focus on the health and hygiene aspects of water reclamation and reuse in agriculture. Many people also express aversion to the use of products derived from the treatment of human excreta to grow food. Further apprehension is reported to have been caused by the costs of water reclamation, as well as its indirect effects, including land development. If left unaddressed, these perceptions may negatively impact the marketability of produce that otherwise fulfills food quality criteria. This, in turn, would diminish the use of reclaimed water and biosolids.

Part of the challenge lies in the fact that farmers are unaware of the contents of the reclaimed water that they use for irrigation, and of its potential health and environmental impacts. They simply seek a reliable source of water. Consumers, in turn, may not be aware that the products that they purchase have been irrigated with reclaimed water.

Religious beliefs influence acceptance of water reclamation and reuse. Following the introduction of reuse programs, scholars in the Islamic world have set water quality requirements. The Council of Leading Islamic Scholars in Saudi Arabia, for instance, carried out extensive consultations with experts prior to issuing a fatwa in 1978 that approved the use of properly treated water for all purposes. The fatwa postulated that:

> *"Impure wastewater can be considered as pure water and similar to the original pure water, if its treatment using advanced technical procedures is capable of removing its impurities with regard to taste, color and smell, as witnessed by honest, specialized and knowledgeable experts. Then it can be used to remove body impurities and for purifying, even for drinking. If there are negative impacts from its direct use on the human health, then it is better to avoid its use, not because it is impure but to avoid harming the human beings" (CLIS,1978).*

The fatwa paved the way for allowing reuse of reclaimed water for different purposes depending on their degree of treatment, including ablution, removal of impurities, restricted and non-restricted irrigation, and ultimately, potable use. Similarly, religious scholars in the United Arab Emirates have issued a fatwa sanctioning the use of reclaimed water of particular quality for particular purposes.

Public awareness and education is necessary

Comprehensive and transparent information campaigns have been used in many parts of the world to raise awareness of water reclamation and reuse. These often aim to educate farmers on the precautions that must be taken when using reclaimed water; and to inform consumers about the safety of agricultural products irrigated with reclaimed water. Such campaigns must openly address the public's questions concerning the quality of reclaimed water and how it is applied. The public must also have confidence in the adequacy of health regulations and their enforcement (Asano, *et al*., 2007).

The planners of early water reclamation and reuse projects, such as those carried out in the 1960s in the United States, rarely consulted the public. This spurred subsequent civic activism to oppose reuse schemes. The emergence of such movements highlights the importance of acknowledging public concerns and seeking means of alleviating them.

Public education programs often utilize brochures, website and media advertising to convey information. Their key messages include:

- The current status of water supplies and the contribution of water recycling for future water resources;
- On-going and planned water reuse programs, and opportunities for the public – including businesses – to participate in them;
- Approved uses of reclaimed water; and
- Wastewater treatment processes, and procedures for ensuring the quality of treated water.

Importantly, communications must be tailored to different groups of water users. Industrial water users, for instance, may benefit from more specialized information in the form of technical manuals.

There is, therefore, a need for more transparency, information sharing and involvement of the farmers and local communities in decision-making process around water reuse projects. Water quality data must be widely available, understandable and freely shared. Extension services should also be well-equipped to provide advice on water reuse. Where these conditions are met, the use of reclaimed water produces significant benefits, as the example from Tunisia illustrates (Box 3).

Capacity-building is needed

A pool of technical support personnel is a pre-requisite for the safe and sustainable implementation of water reclamation and reuse schemes. Extension services must be qualified to address not only technical issues related to the operations and maintenance of reclamation or reuse facilities; they must also be conversant in the environmental, health and socio-economic aspects of reuse.

Extension services, in cooperation with other relevant agencies, should design comprehensive training programs that are tailored to the particular needs of different reuse stakeholders. Training for irrigators, for instance, should address the precautions that must be taken to ensure the safe delivery and use of reclaimed water; control of potential pollution to the potable water supply system; and protection of long-term soil productivity. Given the high levels of sodium and other compounds in reclaimed water training will also be needed on proper management practices and crop production under these circumstances. Outreach activities, including training, should set reuse within the broader context of good water resources management. This should encompass water conservation practices.

Box 3: Integrated wastewater treatment and irrigation reuse in Tunisia

Tunisia launched a national water reuse program in the early 1980s to increase usable water resources. In 2003 about 30-43% of the 0.19 km^3 produced by Tunisia's wastewater treatment plants was used for agriculture and landscape irrigation. Reusing wastewater for irrigation is viewed as a way to increase water resources, provide supplemental nutrients, and protect coastal areas, water resources and sensitive wetlands and lakes. Reclaimed water is used on 8,000 ha to irrigate industrial and fodder crops, cereals, vineyards, citrus and other fruit trees. Regulations do not allow the use of secondary-treated water on any vegetable crops whether eaten or not. Regional agricultural departments supervise the Water Law and Water Reuse decrees and collect charges (about AED .037/m^3 (USD 0.01/m^3) for large schemes. Water use associations charge the same for small schemes. Golf courses are also irrigated with reclaimed water. Other reuse opportunities including industrial processes and cooling, environmental and no-potable urban reuse are under consideration. Interdepartmental and follow-up commissions have been established to bridge the gap between different ministries and their agencies, the municipalities and representatives of users at regional and national levels to preserve the human and natural environment.

Source: M. Qadir *et al*,. 2010.

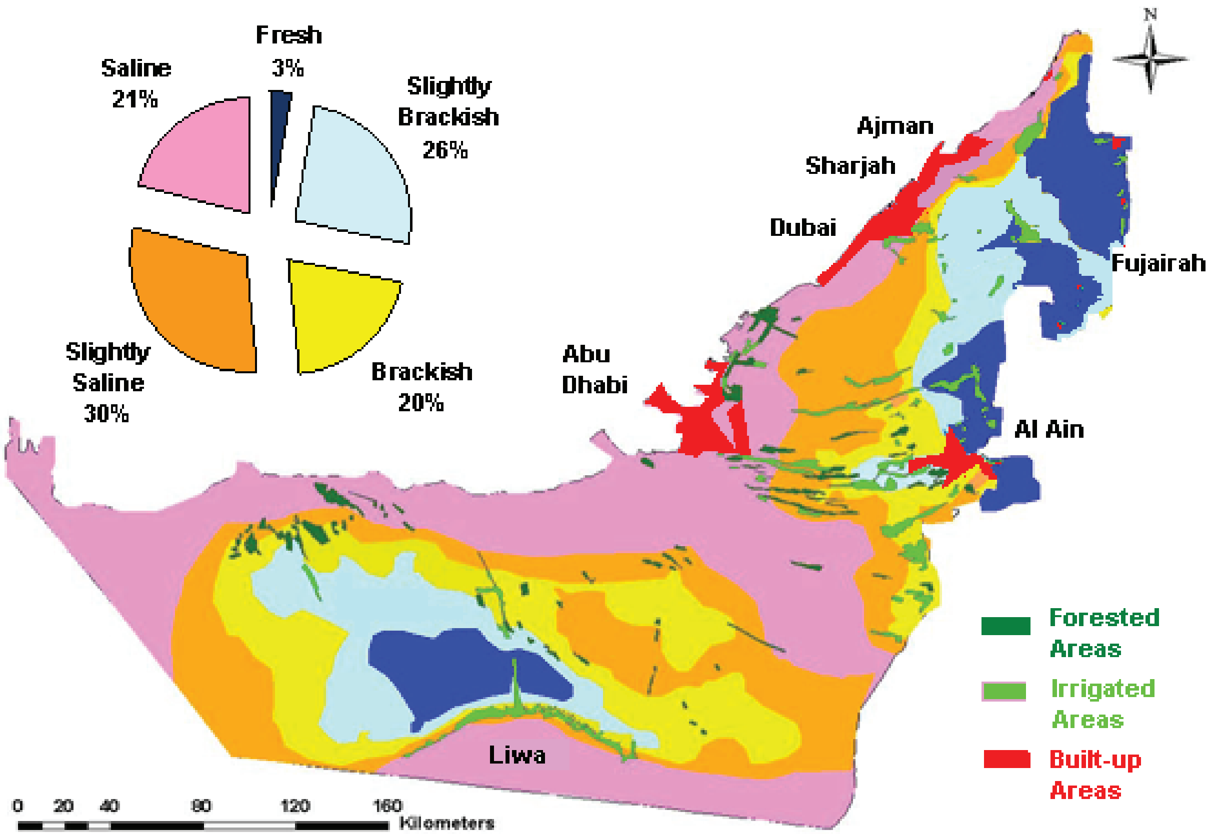
Chapter 5
Groundwater

CHAPTER 5
GROUNDWATER

OVERVIEW

Groundwater is UAE's only reliable natural water resource. Access and use tend to be local and primarily for agriculture or forestry. The national volume of groundwater is very large but only 3% of the water available, about 20 km^3, is fresh, Figure 16.

Figure 16: Groundwater resources are large but mostly of a poor quality and irrigation is concentrated in a few areas



Sources: Modified after Ebraheem and Al Mulla 2009, EAD 2009 by ICBA 2010.

Since mid 1960s demand for groundwater has increased in response to Federal government and Emirate incentives to expand agriculture and 'greening of the desert.' But because of limited rainfall recharge, demand has greatly exceeded natural replenishment and mining of groundwater reserves steadily increased. At the present rate of use it is expected that most fresh groundwater reserves will be completely used in the next 10 to 20 years. While Emirate-level governments have introduced measures to curtail further drilling for groundwater, these have proved to be too little too late, and are ineffective. Regulation and enforcement are very difficult to implement because landowners believe that land ownership also gives them ownership of underlying groundwater.

Groundwater Availability

While the largest geographical occurrence of fresh groundwater is in the northeastern part of the UAE, the largest fresh water volume – 73% – lies beneath the Liwa Crescent area of Abu Dhabi Emirate. This is for two reasons. The aquifer at Al Liwa has a much higher ability to transmit water (transmissivity) and has a high storage capacity. In contrast the excellent unconsolidated gravel aquifers in northern and northeastern areas that cloak the eastern and western mountain slopes are only partially saturated while the underlying limestone aquifers are more cemented, have poorer storage and a generally lower transmissivity except where fractured by faults. In addition the northern areas were the first to exploit their fresh groundwater and most of it has been used. Estimates of groundwater reserves by Emirate and water quality class are summarized in Table 14.

Table 14: UAE's usable groundwater reserves in 2005 (km³)

Water Quality	Salinity range TDS (mg/l)	Abu Dhabi	Ras Al Khaimah	Dubai	Sharjah	Fujairah	Umm Al Quwain	Ajman	Total
Fresh	<1,500	18.5	0.55	0.03	0.53	0.26	0.03	0.00	20
Slightly Brackish	1,501-5,000	188	0.92	0.54	0.46	0.15	0.12	0.00	190
Brackish	5,001-10,000	147	0.19	0.50	0.05	0.04	0.10	0.01	148
Total	**-**	**353.50**	**1.66**	**1.07**	**1.04**	**0.45**	**0.25**	**0.01**	**358**
Share	**-**	**98.8%**	**0.5%**	**0.3%**	**0.3%**	**0.1%**	**0.1%**	**0.00%**	**100%**

Source: Modified after Ebraheem and Al Mulla, 2009 by ICBA 2010. See Annex 1.

Al Ain and northwards

As shown in Figure 16, groundwater quality deteriorates westwards away from the areas of natural rainfall recharge in the mountainous east and north. In these areas the easily utilizable fresh and brackish groundwater occurs below 60m depth as a relatively thin lens that overlies deeper and more saline groundwater. Generally this fresh-brackish water lens is less than 100 m thick and its average thickness is seldom more than 30 m except locally. Annual recharge from rainfall is very small.

Liwa Crescent

This is the UAE's single biggest fresh groundwater resources. It is the residual water left behind from the wetter periods that are associated with the glaciations of the Northern Hemisphere 6,000 to 10,000 years ago.[37] In that sense it is a mineral resource similar to petroleum – it can be mined but not renewed.[38] The lens-shaped aquifer composed of wind-blown sand is located in a depression in the underlying Fars Formation. The useable water is composed of an upper layer of fresh water about 30 m thick that overlies about 35 m of brackish water. The shallowest fresh water is about 5 m in the centre and this falls away radially to about 20 m depth 30 km north of Liwa. Fresh water comprises 14% of the Liwa resource or 15.8 km³. Brackish water volume is estimated to be about 116 km³.

The USGS and NDC 1996 study determined that the lens of fresh water is naturally losing water to the surrounding desert. However, the annual rate is very low – some 9 Mm³ – primarily because the very low groundwater gradients induce minimal groundwater flow. USGS calculated it would take about 6,000 years for a particle of water to move 20 km from the centre of the lens. In consequence, the fresh water at Liwa can be considered as an independent reservoir (with minimal baseflow from Oman Mountains) which can be beneficially mined.

Groundwater Use

Groundwater is used primarily for agriculture and forestry. A very small volume – 3% or 115 Mm³– is used for domestic and industrial water supplies in the Northern Emirates. As shown in Figure 17 irrigated areas are scattered across the UAE with three areas of concentration: Liwa in the south, west of Al Ain in the centre and a few scattered areas in the north. Generally fresh and slightly brackish groundwater is used directly and the vegetation and crop type is matched to the salinity levels of the local groundwater. But as the irrigated area expanded west of Al Ain, many farmers have resorted to localized desalination of brackish groundwater using small RO plants. In the northern part of the southwestern region most of the irrigated area shown uses desalinated groundwater or seawater courtesy of the NDC's oil exploitation operations. The irrigated areas embracing the eastern areas of Abu Dhabi city are primarily using desalinated water because the local groundwater is too saline – although some fresh groundwater is imported from the east through an especially constructed pipeline.[39]

Agricultural Use

The distribution of UAE's cropped area among the Emirates is given in Table 15. As noted earlier, the total cultivated area is contracting by 4,200 ha per year.

Table 15: UAE cropped area in 2008 (ha)

	Fruits	Green Fodder	Vegetables	Other crops	Total
Distribution	45.9%	38.6%	13.6%	1.9%	100%

Source: ICBA, 2010.

Agricultural Water Requirements

A number of studies have estimated crop water requirements in the UAE and there is an abundance of data from the UAE/FAO experimental stations established in the 1970s. The research data emanating from these are derived from highly-managed irrigation systems designed and operated by specialists. Field inspection indicates a different reality. Many on-farm irrigation systems are operated by unskilled expatriate labour who bring with them highly water-inefficient traditional practices. Although most farms have irrigation hardware that is potentially very efficient at delivering water to the plants, the management skills are low-technology accustomed and frequently workers by-pass the modern equipment to flood water around the plants or trees. Education of farm workers is thus a high priority as is the introduction of incentives for farm owners to practice water conservation.

Apart from the managerial issues affecting on-farm water use, some of the basic assumptions used in the past to derive gross irrigation demand are not standard; most important being the area actually irrigated. It is normally assumed that the whole field is irrigated, but both the USGS and the Japanese Technical Assistance (JICA) (under UAE's Ministry of Agriculture and Fisheries in the 1990s) applied correction factors for non-irrigated areas within irrigated fields, orchards and forests. As a result of these differing assumptions, estimates of unit area gross water demand differ among previous studies by as much as 50%. Typically they ranged between 6,300 m^3/ha and 20,290 m^3/ha. Additional groundwater to leach salts from the soil was used and this varies between 10 and 50%.

To resolve this problem we have examined field experimental data on net crop water demand produced in UAE by JICA for 23 crops. These have been split into three main categories: tree crops; field crops and vegetables (Table 16). These are grown in the climate experienced in Liwa and Al Ain and account for 95% of all UAE's agricultural water use. After correcting for water use efficiency, assuming high-tech irrigation and two levels of management, gross unit area water demand by crop group is found to range from 3,900 m^3/ha under the best conditions and crops to 19, 890 m^3/ha under the worst. Additional water would have to be added to the estimated gross water demand to provide adequate flow through the soil profile to leach out any salts accumulated via evapotranspiration. Depending on water quality and soil type this may range between zero and 50% of the net water demand. Thus, the annual gross demand for Rhodes grass under modest efficiency and allowing an additional 30% more water for leaching will be about 26,000 m^3/ha. While it may mitigate the salt build-up in the soil, it significantly increases the energy demand for irrigated agriculture in brackish water areas.

Estimates of Agricultural Groundwater Demand

Actual gross water consumption will be determined by the mix of crops, cropping calendar and the locality. In the traditional oases with date palms under traditional management water demand will be highest; in more modern areas with mixed cropping and plastic tunnel horticulture, water demand will be the lowest as evapotranspiration is reduced. Much also depends on the cropping calendar and cropping intensity: two or three annual crops in rotation may use as much water as perennial tree crops.

Table 16: Estimates of crop water demand considering location and management efficiency but excluding leaching requirements

Crop	Net Water Demand m³/ha		Gross Water Demand by Crop Type (m³/ha)			
			High Efficiency (90%)		Modest Efficiency (70%)	
	Al Ain	Liwa	Al Ain	Liwa	Al Ain	Liwa
Trees						
Date Palm	13,200	13,500	14,670	15,000	18,860	19,290
Fruit Trees	8,430	8,780	9,370	9,760	12,040	12,540
Field Crops						
Rhodes Grass	13,800	14,200	15,330	15,780	19,710	20,290
Wheat	3,500	3,600	3,890	4,000	5,000	5,140
Vegetables						
Average of 16	4,330	4,690	4,810	5,210	6,190	6,700

Source: ICBA based on MAF/JICA water use data, 1996.

Using present cropping patterns (Table 15), and assuming overall modest water use efficiency (Table 16), the weighted annual average gross crop consumptive is estimated to be 1.56 km³ in 2008, Table 17. More recent data are not available. The volume of water required for leaching is not included as it is not consumed because it typically finds its way back to the shallow groundwater reservoir for reuse. Gross water demand – the amount of groundwater that has to be pumped – could increase this by 25% to about 1.95 km³ in 2008 to meet leaching requirements.

Total crop water demand is dominated by date palms and Rhodes Grass. Together these account for 94% of groundwater use for agriculture.

Table 17: Crop water consumptive use in 2008 (Mm³)

Emirate	Date palms	Green fodder	Vegetables	Fruits	Other crops	Total	Share
Abu Dhabi	320	600	65	4	2	991	63%
Sharjah	164	26	3	0.8	0.2	194	12%
RAK	127	40	9	0.5	0.5	177	11%
Fujairah	77	12	2	1.3	0.1	92	6%
Dubai	51	21	1	0.3	0.1	74	5%
Ajman	17	2	0.3	0.2	0	20	1%
UAQ	12	5	0.4	0.1	0	17	1%
Total	**768**	**706**	**81**	**7**	**3**	**1,565**	**100%**
Distribution	**49%**	**45%**	**5%**	**0.5%**	**0.2%**	**100%**	

Source: ICBA from MOEW 2010 crop data.

As discussed in the previous section, there is high uncertainty and wide range in estimating agricultural groundwater use in UAE. For example, the USGS independently calculated groundwater use for agriculture in Abu Dhabi Emirate to be only 0.426 km³ a year using 2004 data.[40] A further study by Mott MacDonald in 2004 estimated gross agricultural demand in Abu Dhabi to be 1,253 km³ a year (fivefold the USGS estimates).[41] EAD had earlier estimated gross demand to be 1.95 km³ a year using 2003 data (EAD, 2009). The difference in total agricultural consumption estimates is excessively large. Given that agriculture is the largest consumer of groundwater, determining the correct quantity of water consumption is critically important. It significantly affects the medium- to long-term viability of the agricultural sector. More research is needed to finalize agricultural water demand. A national agricultural inventory using ground-truthed satellite imagery is required, as is better data on actual crop water use – the data presented in Table 16 is based on well managed research station information and probably does not accurately represent actual water practices practiced by UAE's mostly expatriate farmers.

Forestry Use

Forested areas covering 347,000 ha and they are predominantly located in Abu Dhabi. The forestry sector is heavily dependent on groundwater, competing with agriculture and other uses. The trickle irrigation network is about 430,000 km in length.[42] Current criteria used in Abu Dhabi by EAD and USGS for forestry water use is 1,900-2,500 m^3/ha per year when trees are spaced at 6 to 7 meter intervals. EAD used an average value of 2,000 m^3/ha per year from investigations in the Western Region where 80% of the Emirate's forests are located (Brook 2004). This rate of water demand is similar to research results conducted by EAD in the Western Region, and from the literature.[43] Within some areas, forest water use is four times higher but these cover only a relatively small proportion of all forests.[44] Because almost all forested area in Abu Dhabi is supplied by high efficiency drip irrigation, gross water demand is equivalent to net water consumption and there are no return flows to the groundwater reservoir. In 2008 the water demand for forestry is estimated to be about 0.69 km^3 a year, where about 0.09 km^3 a year are in Dubai Emirate and 0.6 km^3 are in Abu Dhabi Emirate. This agrees well with independent estimates for Abu Dhabi Emirate. EAD's estimate was 0.69 km^3 a year, and the USGS's estimate was 0.65 km^3 a year.[45]

Total water demand for afforested areas may be overestimated as not all plants reach maturity. Unless the trees receive adequate irrigation and water quality they may be stunted and/or die. Most trees are fed with brackish water; however, trickle irrigation with poor quality water also creates problems because the removal of chemical deposition that clogs the drip orifice requires regular maintenance. Recent research by EAD (Brook 2004) indicates that "the majority of trees receive under-irrigation… [that] will lead to the development of reduced canopies: no forests have been observed which have a full canopy, which indicates that they are young stands or that they have been under-irrigated and their growth restricted." Given that forests were started four decades ago this is surprising.

Determination of the actual area of forest and its water use need considerably more research. Use of the remote sensing Landsat Thematic Mapper found 162,100 ha of total vegetated area, including forest, in 2000 and 152,000 ha in 2004.[46] In comparison EAD (2006) estimated it to be 376,000 ha. While remote sensing is clearly the way forward to gain data for the whole of the UAE, the biggest problem indentified in the image analysis was the mapping of scattered Acacia trees against background noise – accuracy was in the range 50-64%. This could be improved upon data from DubaiSat1 or other up-to-date US, French or Russian satellite imagery whose resolution is much finer.

Improving knowledge on the coverage, health and density of the UAE's forests is essential. It would reveal their ecological advantages and allow assessment of their development effectiveness against their design objectives: providing protected areas for wildlife sanctuaries; protecting roads from sand incursions and anchoring dune areas. Only thus can the cost-effectiveness of desert greening and groundwater mining for forests be evaluated.

Environmental Impact of Current Groundwater use Policies

Fresh and brackish groundwater resources will eventually be fully depleted at current rates of use. Agriculture and forestry are effectively mining the groundwater resource because the rate of replenishment is very low: less than 0.2 km^3 a year compared with total withdrawal on 2.3 km^3 a year.

Horizontal flow within and between aquifers is generally poor. This is particularly true in the mountainous areas of the east and north where a faulting system acts as a barrier by changing flow direction, and in the areas away from the mountains the groundwater gradients are too small to induce large volumes of horizontal flow from east to west.

Table 18: Fresh groundwater use - some estimates of the life of the aquifer underlying currently irrigated areas at present rates of annual groundwater use

Water Quality	Abu Dhabi	Ras Al Khaimah	Dubai	Sharjah	Fujairah	Umm Al Quwain	Ajman	Total
Fresh Water[47] Volume, km^3	2.79	0.24	0.17	0.10	0.10	0.03	0.03	**3.4**
Agricultural Demand, km^3	0.22	0.014	0.11	0.065	0.063	0.002	0.001	**0.26**
Life of Fresh Aquifer, years	13	17	2	2	2	15	30	**13**

Source: ICBA, 2010. Agricultural demand assumes that the mix of crops shown in Table 17 is present over the fresh water aquifer. A different crop mix would change the projections.

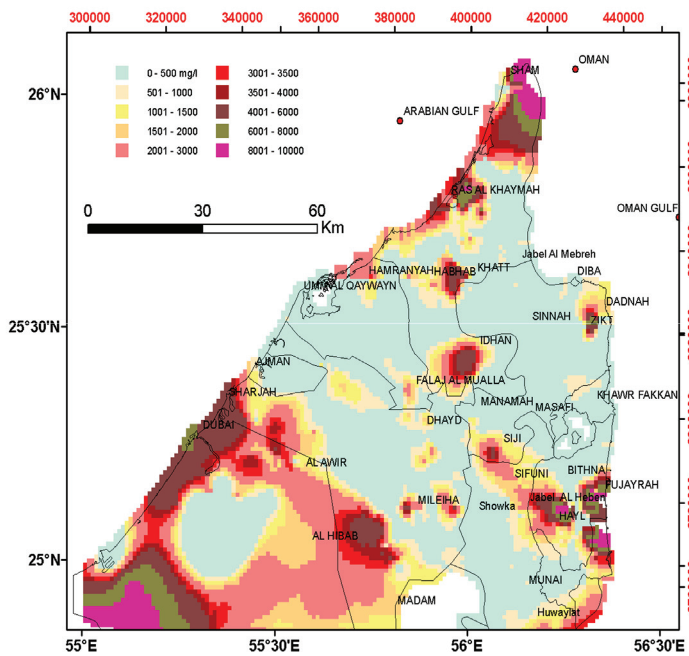
There is horizontal flow but it is very slow – the NDC/USGS estimate that the flow rate in Abu Dhabi is about 0.03 km^3 a year. There are no published estimates for other emirates. In addition, assuming minimal migration of higher salinity water from underlying aquifer to substitute for withdrawn water as a consequence of these three conditions, groundwater withdrawal has generally emptied the aquifer around the wells much faster than horizontal inflow can fill the hole created and well yields decline.

As a result of this situation agricultural areas effectively only have access to the groundwater within a radius of two kilometers around each well. Groundwater outside this area of influence is effectively beyond utilization. Accordingly we have roughly calculated the area and volume of groundwater available to the present irrigated areas. Agriculture developed over fresh water areas covers only 14,000 ha or 21% of the total agricultural area that has a water demand of 0.26 km^3 a year. This area overlies 7.5% of the fresh groundwater area. If we assumed that wells could induce inflow from the equivalent area around the agricultural zone, about 15% of the fresh groundwater reserves are being accessed. This is equal to a volume of 3.4 km^3. At the current rate of groundwater use the very preliminary estimate of time it will take to fully deplete fresh groundwater resources is given in Table 18.

In many respects brackish groundwater resources are even more fragile than fresh groundwater. Agriculture developed over brackish groundwater covers an area of about 34,500 ha and, on the two-to-one ratio of accessible groundwater, the volume of available slightly brackish to brackish water underlying this area is 5.5 km^3. Annual demand from agriculture is estimated to be 0.65 km^3. Using the same method of calculation as for fresh groundwater, all brackish groundwater reserves could be exhausted in about 8 years.

In practice, however, the aquifers will not just dry up. First, groundwater levels will start falling and well yields will decline. To overcome this problem most well owners initially deepen their wells and/or install a bigger pump. This only makes matter worse; groundwater levels drop further and pumping costs increase dramatically. In addition to declining well yields the common experience has been that groundwater quality also deteriorates. Eventually, farmers realize they are engaged in a losing battle and abandon the well and, in many cases, the farm too. This has certainly occurred in many areas where groundwater has been heavily drawn down, particularly in the northern Emirates, Figure 17.

Figure 17: Saline groundwater intrusion into the fresh aquifers of the Northern UAE



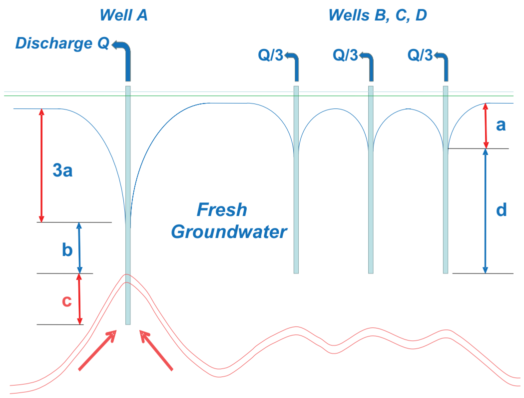
Source: Ebraheem and Al Mulla, 2009.

In Abu Dhabi 47% of the fresh groundwater reserves have been mined according to the USGS. Groundwater levels declined at a rate of about 10 m a year until the mid 1990s, and have declined up to 70 m since then. Natural falaj flows have dried up and those that do flow are augmented by pumped groundwater. The requirement to lift water over a much greater elevation requires more energy, and this has the indirect impact of increasing the greenhouse gas emissions of the power plants needed to produce the extra energy. Depending on local conditions, electrical costs increase about 3.2 times for each 10m of pumping depth and this may cause abandonment of farming.[48]

Despite these local problems there will be considerable volumes of slightly brackish groundwater in the areas that have not been exploited for agriculture. These could provide for either a future groundwater strategic reserve or with less priority for new areas of irrigated agriculture. However, if new irrigated areas are proposed groundwater resources would need to be managed far better than in the past. There would be two requirements. First, a more systematic assessment of the groundwater occurrence would need to be made as a basis for licensing withdrawal to ensure sustainable use. Second, much greater attention would have to be given to the design of wells and well fields.

The groundwater system is fragile and great care has to be taken that deeper saline groundwater is not drawn into the fresher overlying aquifer as now happens. Under current practice wells are made as deep as possible to maximize yield, and this is what causes water quality deterioration as the deeper poorer quality water is sucked up into the well, Figure 18. If instead a number of smaller and shallower wells were installed they could, with careful management, remain viable for a much longer period of time. Clearly considerable regulation of the groundwater resource is required for sustainable future use. In Abu Dhabi regulations exist as to the spacing between wells in any one area.

Figure 18: Better well design could reduce the incidence of drawing brackish deep groundwater into freshwater aquifers



Source: ICBA 2010.

Groundwater Pollution

The groundwater underlying currently irrigated areas show signs of pollution from use of excess fertilizers. In 1996 over 41% of all sources that were monitored by NDC/USGS in some selected areas of Abu Dhabi exceeded WHO guidelines for nitrate (10 mg/l), the highest recorded being 650 mg/l (Robins et al., 2006). Inland reverse osmosis desalination plants using brackish or saline groundwater discharge their brine effluent to desert depressions. The amount discharged is not known nor is the impact on underlying groundwater quality.

Deep Aquifer System

In addition to the regional Quaternary aquifer, there are two important aquifers that have high to medium groundwater potential; the Northern Limestone Aquifer (Wadi Al Bih Aquifer) in Ras Al Khaimah and Eastern Limestone Aquifer (Jabal Hafit Aquifer) south of Al Ain city in Abu Dhabi Emirate.

The outlook

The groundwater management problem is confounded by the lack of a coherent agricultural policy and the modest role that agriculture plays in the economy - it contributes less than 2% of GNP. Current policies support highly technical agricultural production at one extreme (greenhouse, hydroponics) and hobby farming at the other. Food security is frequently invoked in support of increased agricultural production but a comprehensive assessment of total agricultural potential within the severe constraints imposed by the UAE’s climate and soils and high costs of essential inputs (energy and water) has not been made. In addition, significant additional work needs to be undertaken to fully understand the socio-economic complexity of Abu Dhabi’s agricultural sector. Only thus can we determine the economic and social tradeoffs for current agricultural production models and determine if the financial and environmental costs of groundwater mining make economic sense.

Chapter 6
Strategic Options for Water Conservation

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There are ample opportunities for water conservation in the UAE in all sectors of water production and use and this chapter reviews them and makes recommendations for change. Until the present there has been no attempt to manage demand for water. Instead the response has been to increase water supplies with almost no concern that financial and environmental costs may in some cases significantly exceed benefits. As a result per capita domestic water consumption is among the highest in the world and UAE's only natural resource, groundwater, has been extensively mined. It is clear that this state of affairs cannot continue. Not only it is inefficient; it is also very costly to the state that has to provide heavy subsidies and to the environment that is degraded by waste disposal to the sea and land and through avoidable greenhouse gas emissions.

Why Conserve?

Environmental issues aside it makes financial and economic sense. Currently water use in the UAE costs the economy about AED 18.2 billion (USD 4.96 billion) a year. Water users currently may pay a maximum of about 28% of the total cost, and the Emirate governments subsidize the difference of almost AED 13.1 billion (USD 3.57 billion). In addition there are other less tangible environmental costs that have local and global impacts – many of these have already been discussed. Without conservation, groundwater resources will soon be exhausted and the UAE would be totally reliant on desalination and reclaimed water.

Water is priced below cost and value

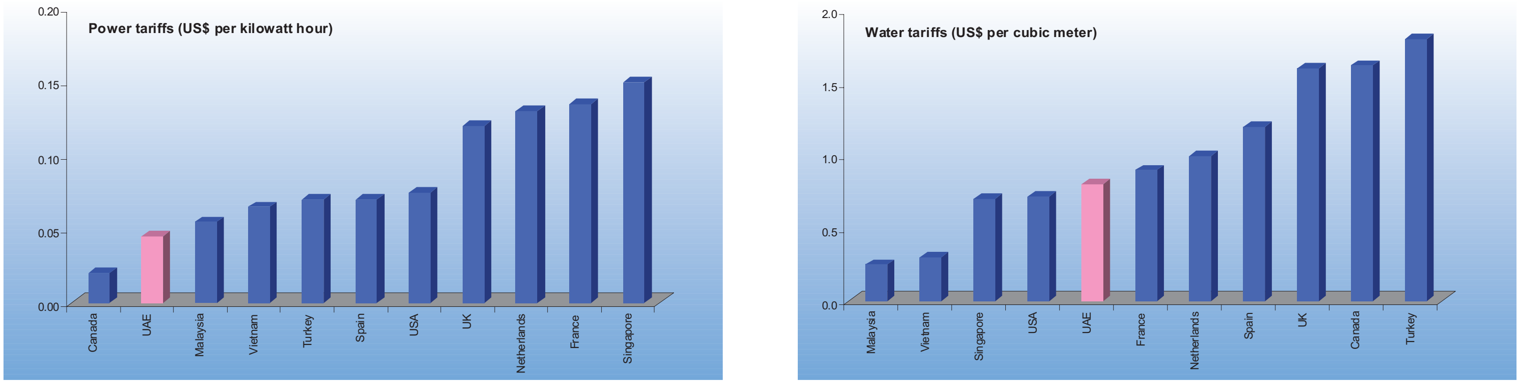
Currently of the 4.6 km^3 of water used in the UAE each year only 22% is paid for by consumers. The reason is that groundwater and reclaimed water that account for 2.9 km^3 or 63% of all water supplies are provided free. Desalinated water tariff is highly subsidized to nationals particularly in Abu Dhabi Emirate. Water tariffs for non-nationals ranges from AED 2.2 (USD 0.6) per m^3 in Abu Dhabi that is served by ADWEA to as much as AED 8.8 per m^3 in the other Emirates served by FEWA, DEWA and SEWA.[49] In addition commercial and industrial consumers who account for 0.7 km^3 or 40% of desalinated water consumption pay a similar tariff to non-nationals. The cost of producing desalinated water, however, is much higher than the tariffs charged and because many consumers pay less than the full cost, the implicit subsidy is about AED 6 (USD 1.64) per m^3. Annually this amounts to about AED 9.5 billion (USD 2.59 billion).

Reclaimed water is provided free but on average costs AED 4.8 (USD 1.31) per m^3 to produce. Consequently the implicit subsidy is about AED 4.2 billion (USD 1.14 billion) for the 0.86 km^3 produced each year.

Groundwater is far more difficult to cost and value. Groundwater is free but users have to bear the production cost. Almost all the production is private and until recently most of the initial capital investment in agricultural wells and pumping equipment was heavily subsidized by Emirates and Federal governments. The best estimates of the real production costs range from AED 0.85 (USD 0.23) to AED 1.60 (USD 0.44)/ m^3 depending on location and specification. Even then, most agricultural users receive highly subsidized electricity so the operating costs tend to be very low. If electricity were priced at the levels paid in the advanced world economies this would not be the case, Figure 19. Currently a typical farmer pays AED 0.03 per kWh (USD .008 per kWh) whilst the typical electricity cost is AED 0.25 kWh (USD 0.68per kWh), a subsidy of almost 90%. On all groundwater pumped for agriculture the electricity subsidy alone is AED 271 million (USD 73.8 million) a year.

The cost of groundwater production does not, however, represent its value to the economy. As shown in Chapter 5 fresh groundwater is a finite resource that is being mined and it is irreplaceable once gone. When farmers run out of fresh or moderately brackish groundwater they typically have two choices: stop using or use an alternative

Figure 19: Cheap electricity does not encourage conservation of groundwater



Source: Al Farra, 2007.

resource. The only viable alternative sources of water are desalinated water. Generally this means installing a small RO plant, a well that produces salty water or tapping a desalinated water supply from one of the commercial producers. The preferred choice, particularly in the major agricultural producing area of Al Ain, is to switch to desalinated water and pay the highly subsidized tariff (if billed). Thus at the margin the alternative to fresh groundwater is desalinated water. In economic terms this means that the opportunity cost of groundwater is the same as its substitute, desalinated water. Consequently the economic value of fresh or moderately brackish groundwater is AED 8.8/m^3 (USD 2.4 /m^3) cost to the UAE if they had to replace it. The implied government subsidy to farmers is thus AED 4.5 billion (USD 1.23 billion) a year.

Encouraging Water Conservation

Water consumption in the UAE is by international standards high; however, it is important that policies to manage demand are developed over time and after careful consideration of likely reaction by the consumer. It is also useful to consider various approaches to water conservation that have been used in other areas and research will be needed to develop policies that best fit the social, economic and natural environments of the UAE. These approaches available may be categorized as price and non-price and described below.

Price-based Approaches

Price-based approaches to water conservation use tariffs to transmit information about water scarcity to encourage changes in behavior that lead to reductions. From an economic perspective, water resources can be viewed as a form of natural asset that provides service flows used by people in the production of goods and services such as agricultural output, human health, recreation, environmental quality etc. Providing or protecting water resources involve active employment of capital, labour, energy and other scarce resources. Using these resources to provide water supplies means that they are not available to be used for other purposes. The economic concept of the 'value' of water is thus couched in terms of society's willingness to make trade-offs between competing uses of limited resources.

An economist's task of estimating the benefits and loss of benefits resulting from resource use is perhaps easiest when markets are established and consumers' willingness to pay certain prices can be examined. Water is considered to be a natural monopoly, and moving from traditionally held views that it should be universally available to introducing economics and pricing is difficult. With non-market environmental goods such as water, it is necessary to infer willingness to trade off money for the use of the resources and any additional benefits associated with its management. The sum of the derived economic benefits is essentially captured by people's total willingness to pay including use value, that is, the value of water in its many uses include drinking, irrigation, species habitat and non-use value. For example some people derive value from watching the water flow in the falaj systems, as well as using it to produce flowers in their gardens or cooking their food. Others, such as farmers, see it as a production input and may not be willing to pay much more for it as doing so lowers their profit margins.

From the cost side of the equation, the task of estimating values would seem more straightforward. Obviously in the UAE, the details of capital expenditure and operating costs of producing potable water are well known by the operators of the desalination plants. There are, however, other costs that should also be taken into account, such as the opportunity costs of using energy to produce water when it could be used in other economic activities. There is also the difficulty of what the future costs of supply will be. If growth of demand is small, future costs are probably well known. However, where demand grows rapidly, as is the case in the UAE, future costs may be higher as new capacity will need to be installed more frequently.

Introducing pricing which reflects these various benefits and costs is difficult and various approaches may be used. It is also reliant on the installation of metering. Flat-rate water fees are not linked to the quantity consumed and a fixed rate per time period, often a month, is levied. This sort of tariff is applied by ADWEA for those that do not have water meters. Flat-rate water fees are the norm of farmers using groundwater – the only difference being that the tariff is zero. To whomever it is applied, flat-rate tariffs provide almost no incentive for conservation.

In other approaches there is a direct link between volume consumed and prices charged – a prerequisite for households is that all consumers are metered. Where metering is not feasible for non-household use, volumes consumed could be linked to particular activities such as irrigating a particular crop at a certain time of the year, or a unit of production.

In most countries there is a welfare element built into the pricing to protect the poor who may have difficulty paying. Thus the first defined volume is free and then any consumption above that pattern is charged. This might further be developed with block-price or seasonal-price structures, such as those recently introduced to Dubai in which where at various ranges of consumption differential pricing is applied, a higher price being paid for higher levels of water consumption (an increasing block tariff). This results in a large number of users of water paying substantially higher rates than more conservative consumers who are normally assumed to be poor. In figures published for the US showing the share of US residential water price structures (Raftelis Financial Consulting 2002) the following percentages were found:

- Decreasing price Block Structure 30%
- Uniform Price 36%
- Increasing Price Block Structure 30%

More recently a leading water supply economist has made a strong case for a uniform water tariff with a rebate that targets only the poorest consumers.[50] Under this tariff scheme, all consumers have the same price signal that could be set at the marginal cost of water new supply thus ensuring the water they use will be replaced. Determining the best system for the UAE requires careful consideration of many variables.

An important consideration is how people and industry react to any increases in prices. Do they absorb the increased costs without changing their habits, or do they respond by reducing their water consumption and so the price they pay? Various analyses on the reaction to changes in pricing have found a range of responses by water consumers.[51] Consumers' reactions are measured using the notion of elasticity where a relatively elastic demand is where a small change in water price, brings a large change in water demand (values more negative than -1). Inelastic demand is where a small change in prices brings a small change in demand (values between 0 and -1). In the USA a 10% increase in water price will reduce household's outdoor water demand by between 3 and 7%. Indoor demand is less responsive – a 10% increase typically reduces demand by only less than 2%. Thus, providing indoor plumbing fittings are efficient, there is little room for indoor water saving whatever the cost of water.

Water demand for industry and agriculture require different modeling because changes in price affect costs of production and profits. Often this type of data is deemed to be commercially sensitive and so not made available for analysis. In work by Griffin (2006) in the US and Reynaud in France, the demand elasticity for industry varied widely (between -0.15 and -0.98) and was much linked to the type of industry – those with heavy water consumption were more responsive to price changes. In similar work, recent analysis of 24 US agriculture water demand studies suggest a mean price elasticity of around -0.48.[52] These values highlight that water demand is a relative inelastic to pricing but is variable. There are also important social, economic and political considerations in any discussions on water pricing that need to be taken into account. There has been almost no published research on the elasticity of tariffs in the UAE on consumers' willingness to pay.

Non-price Based Approaches

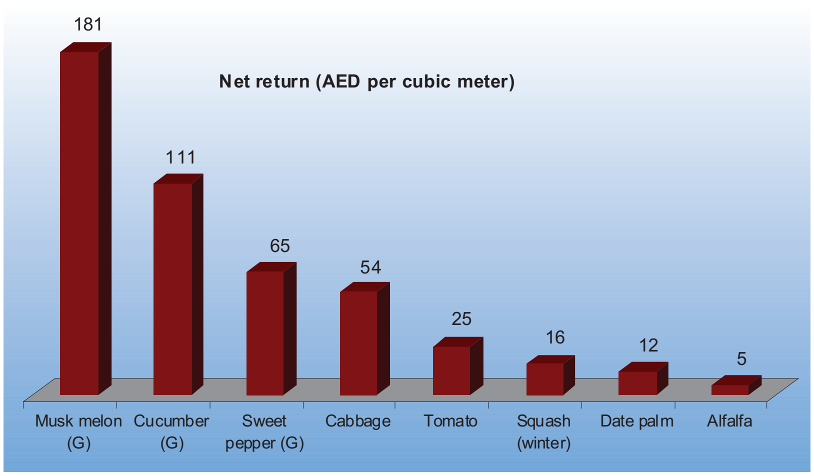
The non-price based approaches encourage water conservation through the adoption of new technologies or practices, such as low-flow showerheads, restrictions on the time/length of irrigation of gardens, or administrative allocation based on a rationing approach. These might equally be applied to industry and agriculture as to domestic customers and again the aim is to encourage the adoption of processes which use reduced amounts of water used. The changes in technology or practices are encouraged through a range of regulatory and economic policy instruments including subsidies. The recent move in Abu Dhabi Emirate to introduce water-efficient technologies is an important step in this direction. There are, however, no guarantees of success. Introducing a low-flow showerhead policy might just mean that users stay longer under the water. The same can be found with irrigation. Introducing drip-irrigation does not necessarily mean this will always be used and operators can unplug the hoses and return to flood irrigation when they want to.

It is useful to look at empirical evidence from policies introduced in other areas and the evidence is mixed on the aggregate effects of these programs (Olmstead and Stavins, 2007). For example, in the summer of 1996, water consumption restrictions in Corpus Christi Texas, which included prohibiting landscape irrigation and car-washing, did not yield statistically significant water savings in the residential sector. However, a longer term program in Pasadena California did result in aggregate water savings (Kiefer, 1993), while mandatory water use restrictions in Santa Barbara California induced a demand reduction of 29% (Renwick, and Green, 2000).

Water utilities typically implement a variety of non-price conservation programs simultaneously, making it difficult to determine the effects of individual policies. One analysis of the effect of conservation programs on aggregate water district consumption in California found small but significant reductions in total use following landscape education programs and watering restrictions, but no effect from education programs away from landscaping, low-flow fixture distribution, or the presentation of drought and conservation information on customer bills (Corral, 1997).

With non-price approaches which involve restrictions on use through regulation, there is a need for enforcement and this can often be difficult if human resources are not available for monitoring. The most obvious application in the UAE of regulated water supply is for the agricultural sector. In this case the government regulator would determine the most economically efficient allocation of water. Typically this would be targeting the crops that maximize value to the economy and produce the highest return for the volume of water used. Earlier research in the UAE provides such information for policy-makers, Figure 20. There is clearly a very large range of values and thus the policy choice to encourage conservation would be tend to favor greenhouse crops over field crops.

Figure 20: Net financial returns from groundwater irrigation in the Al Dhaid area in 1996



Source: MAF and JICA, 1996.

There is a need for awareness-raising of the potential for conservation in the various sectors targeted in tandem with the introduction of any measures to bring any chance of success. Currently in the UAE awareness-raising is increasingly being led by municipalities such as Dubai, organizations such as the Emirates Wildlife Society in association with the World Wide Fund for Nature, Al Basama Al Beeiya, and underpinned by the principles of Estidama (sustainability).[53] Information instruments can be useful in water conservation policy as they help to inform consumers about why and how they should conserve water. They also help to perceive the problem partly as their responsibility and not just that of the government.

In the following sections potential water conservation is considered for both demand and supply management. We first examine desalinated water use where potential savings and instruments to achieve them can be well defined. Next we examine the driver of groundwater use – agriculture – and estimate its cost effectiveness and possible water savings. We then briefly examine the efficiency of reclaimed water use. On supply management we look at alternatives to present desalination systems, leakage prevention and finally we examine conservation of rainfall.

Desalinated Water – Demand Management

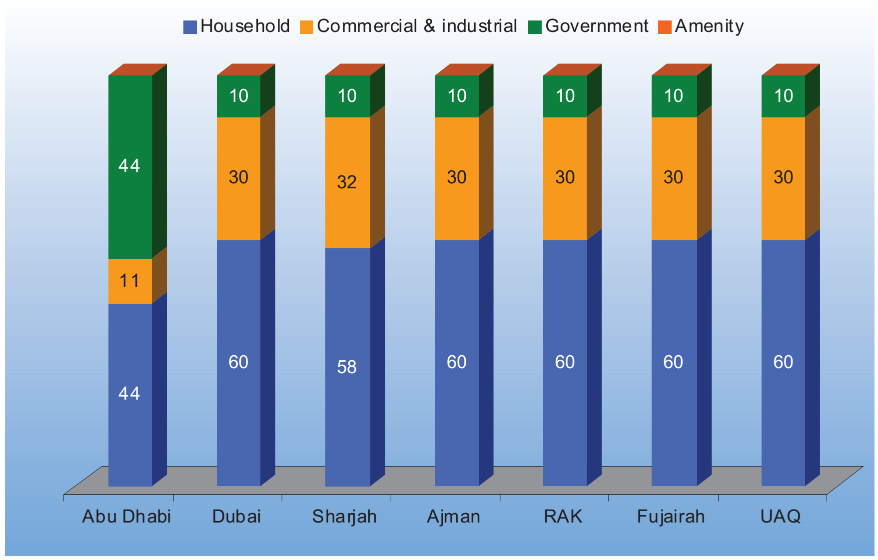
Desalinated water supplies have grown rapidly over the last four decades and most is allocated for household water use, Figure 21. Abu Dhabi is the exception because 44% of desalinated water is allocated by the government and this goes mainly to private estates. As with other Emirates, there is little information about the volumes of water allocated to commercial and industry, amenity and government or what the water is used for. Consequently it is almost impossible to determine criteria for water use efficiency and thus potential conservation opportunities. In contrast there is sufficient information to determine how efficiently desalinated water allocated to households is used.

Per capita residential water use has grown steadily over the last four decades in line with national policy that all reasonable household demand for water should be supplied. Even so, household demand continues to grow, Table 19.

A breakdown of consumption by household type indicates a marked difference between flats (apartments) and households that have gardens. Typically flats consume between 165 to 220 lpcpd whilst villas with gardens consume between 400 and 1,760 lpcpd.[54] By implication the difference in consumption between flats and villas is used outside the house for washing cars, garden irrigation and similar activities.

UAE's overall average residential daily water consumption is very high in comparison to the experience of other countries, Figure 22. The

Figure 21: Most desalinated water is used in households, 2008 (lpcpd)



Source: ICBA, 2010.

Table 19: Growth of household water consumption in UAE (lpcpd)

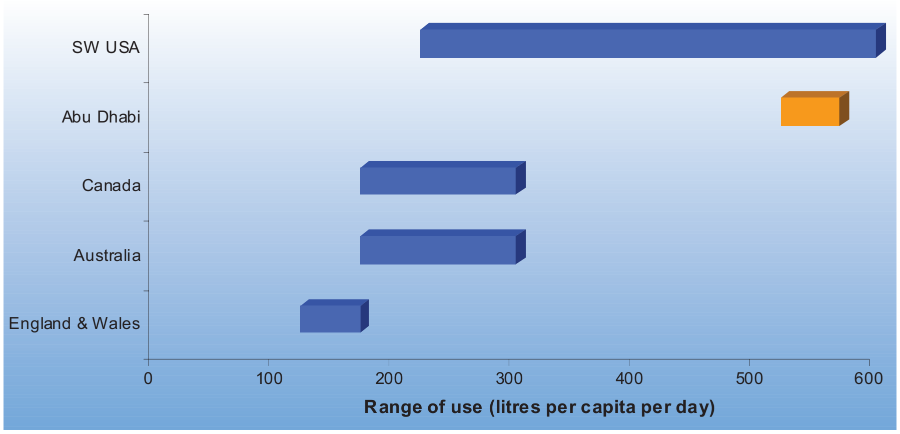
	2004	2006	2008
Abu Dhabi	405	505	526
Dubai	303	354	377
Sharjah	124	146	158
Ajman	227	247	295
Umm Al Quwain	194	220	225
Ras Al Khaimah	234	256	266
Fujairah	104	112	136

Source: ICBA 2010 compiled from ADWEA, DEWA, SEWA, and FEWA.

large range of residential water use in the USA data is because the minimum value is that for indoor water use whilst the maximum includes external and garden use. There is close agreement between RSB's data on expatriates and UAE nationals and the USA data in terms of household consumption where there is no garden or external use. In the USA indoor water use was 226 lpcpd; in Abu Dhabi it was 165 to 220 lpcpd.

What is a realistic figure for per capita water consumption? The average domestic consumption of 16 advanced economies ranging from the USA to the UK and Australia is 197 lpcpd. Consequently we could take 200 lpcpd as a target figure for the UAE. Current average domestic consumption is 364 lpcpd. Therefore household desalinated water use could be reduced by almost 50% and still meet all human needs with no adverse public health impacts. In addition reclaimed water could be substituted for toilet flushing that accounts almost half of all household fresh water use – but this would require dual water supply systems that could only be economic to install in new buildings and the public's acceptance of using reclaimed water.

Figure 22: Total household water use - some international comparisons



Source: Ofwat.gov.uk. 2009; and Heaney and others. 1999. Nature Of Residential Water Use And Effectiveness Of Conservation Programs. University of Colorado

Per capita consumption of desalinated water could be substantially reduced if the correct incentive structures were introduced. Many are already being introduced to the UAE, Box 4. The international experience is that after physical improvements (such as leakage reduction and installation of more efficient plumbing appliances), administrative and pricing instruments are the most effective means to reduce wasteful household consumption.[55]

Increasing Water Tariffs

The simplest pricing instrument is to raise the water tariff to cover costs. The international experience, as stated earlier, is that increasing water price reduces water demand. Singapore implemented a wide-scale water conservation in 1997 including raising water tariffs from USD .67 to USD 1.52 per m^3. By 2007 this had reduced per capita indoor water demand by 11%. Overall per capita household water consumption was reduced from 172 lpcpd to 157 lpcpd between 1995 and 2007. Even though consumption fell, revenue from household increased from USD14.5 to USD29.4 or by 103%. Thus properly managed, raising water tariffs can be a win-win situation.

If a policy choice was made to increase UAE's tariffs on desalinated water to reduce per capita household water consumption to international levels in conjunction with awareness-raising programs, there could be substantial savings. The effect of reaching a target of 200 lpcpd over a period of 5 years is shown in Figure 23 that depicts the growth of desalination capacity and the demands on it according to the UAE's population projections. Under current water consumption the demand exceeds desalination capacity.

Box 4: Water conservation in Dubai

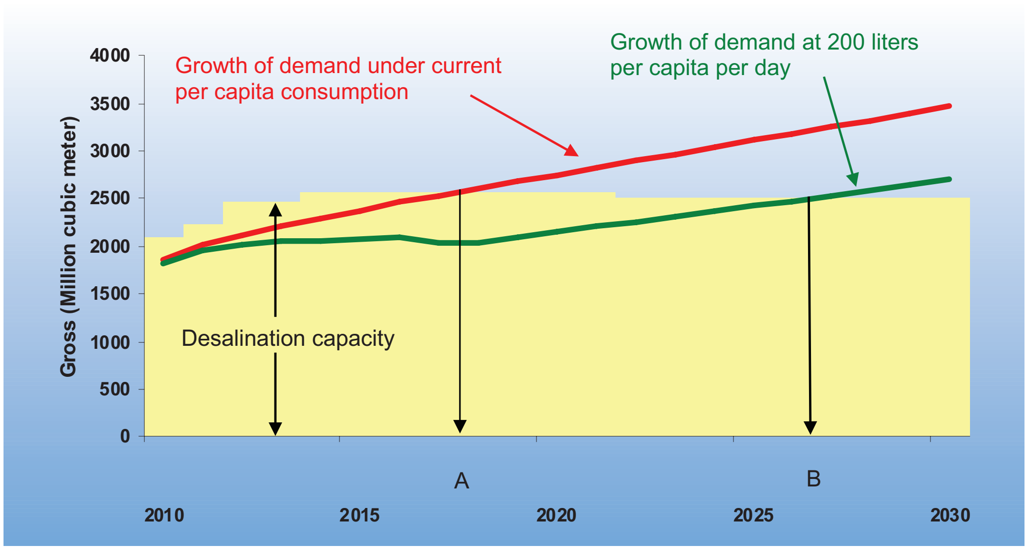
DEWA started a competition in 2009 to save energy. The top 10 contestants that answered the questions "How do you save water?" and "How can DEWA encourage water and energy conservation?" were awarded AED 1,000.

These initiatives are not only confined to competitions. According to the Director of Irrigation and Drainage in Dubai Municipality, replacing the tap filter with a water flow would reduce consumption from 10 to 15 litres to only 2 litres. Another innovation is to place especially made plastic bags in the water cistern and this reduces flushed water by 35%. Mr Peter White said "I have installed all these water-saving devices in my villa. It has cut my water consumption by half."

Source: Asia Water Wire, 9 August 2009.

in 2017 and thereafter there will be a shortfall in supply with additional new investment required. With a phased reduction in per capita demand there would be a surplus supply until 2026. Annual water savings would increase from 310 Mm^3 in 2015 to over 760 Mm^3 in 2030. Cumulatively, the saving over the whole period would be 10.97 km^3; this has a current value of AED 92 billion (USD 25.07). If the environmental benefits from reducing brine disposal by 40 km^3 and the reduction in greenhouse gas emissions by about 44 million tonnes could be monetized, the economic savings would be very much greater.

Figure 23: Reducing per capita water consumption would delay the need for new investment and reduce operational costs



Source: ICBA, 2010.

Desalinated Water – Supply Management

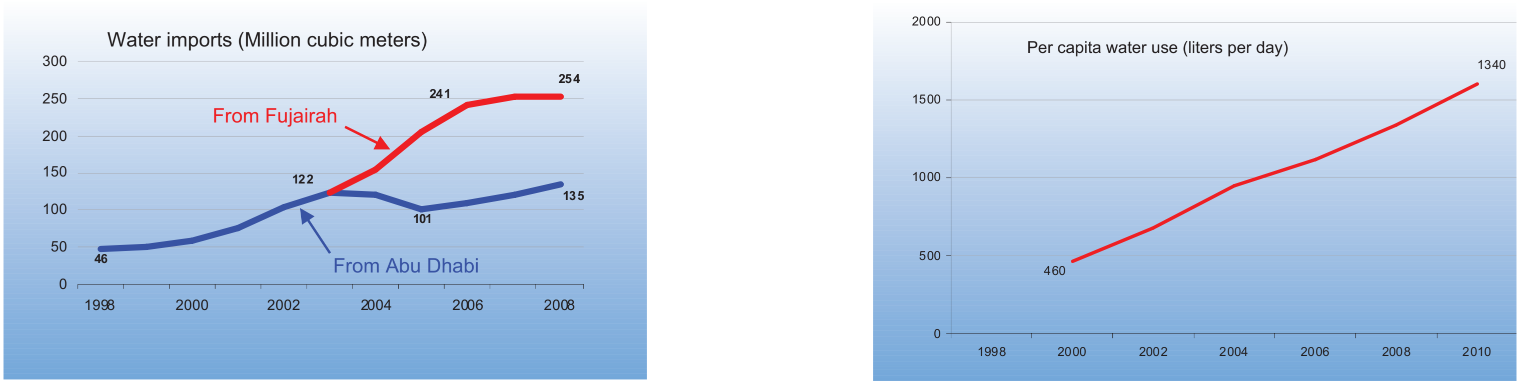
The first place to look for water conservation is to reduce unaccounted-for-water (UfW). UfW comprises physical losses from leaking pipes and valves and unlicensed connections, and administrative losses that covers non-billed customers and defective water meters. Data on leakage has been difficult to obtain from some of the Emirates but from that available it would suggest that the UAE's transmission and distribution systems for desalinated water are relatively new and well managed by international standards. The sector currently assumes total network losses to be approximately 10% - around 2% from transmission and 8% from distribution.[56] Recent information from Abu Dhabi Distribution Company (ADDC) suggests higher distribution system losses – about 16%. By international performance standards this is an excellent performance given the age, construction and materials used in the distribution system.

Leakage of desalinated water from the water company's distribution network is small. In 2007, ADDC retailed 69% of the Emirate's water supply. The Al Ain Distribution Company (AADC) that serves 57,000 customers did not respond to requests for information. The ADDC manages an extensive distribution system that connects more than 226,000 customers through a pipe network of more than 6,100 km covering 86 zones. The ADDC 2005 Annual Report highlights that network coverage is increasing at 10% a year. Breakage of pipes accounted for over half (54%) of customer complaints. Even so, on the basis of international comparators, supply outages from breaks in the supply network were only two-thirds of international norms (0.03 breaks/km). Despite this ADDC management acknowledges that leakage remains a problem and a leakage management strategy initiated in 2006 in response to RSB's requirements is ongoing.

Physical leakage accounted for 16% and technical and administrative losses accounted for another 19%. Thus overall UfW in 2007 was 35% of the supply.[57] Administrative losses include unregistered connections and illegal connections and are primarily a billing and financial accounting issue. In comparison with Singapore where unaccounted for water was 5.1% in 2004, there is room for improvement. Rigorous follow up and the ability to disconnect delinquent consumers are essential to get administrative losses under control.

Supply management also includes efficient allocation of desalinated water. Al Ain's demand for desalinated water was initially met by pumping water from the coastal desalination plants north of Abu Dhabi. More recently it has

Figure 24: Uncontrolled water imports may lead to wastage



Source: ICBA, 2010.

also been supplied from the new MSF-RO facility at Fujairah that pumps its water over the mountains to Al Ain. As a result of the improved water supply per capita water consumption in the municipal area has skyrocketed, Figure 24. Surveys commissioned by RSB/EAD indicate that much of the additional desalinated water is being used for irrigation. This, in addition to the disposal of reclaimed water into basins nearby, and the wadi running through the city has caused a sharp rise to the local water table that now causes localized waterlogging and flooding.

Groundwater

Agriculture is the biggest user of water in the UAE and thus the prime target for water conservation efforts. All farms are owned by nationals and thus water is free.

Demand management using non-price instruments has been tried but has not been very effective. The instrument chosen – well licensing in Abu Dhabi Emirate – has proved to be difficult to enforce particularly when many new wells are replacements of ones that have either suffered from yield reduction or water quality problems. Indeed, even monitoring water use using water meters has proved to be difficult and farmers have been reluctant to cooperate.[58]

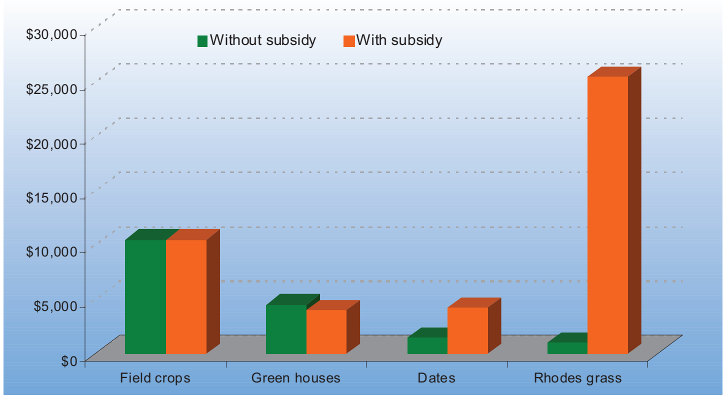
Demand management using water pricing has not been attempted because of fundamental philosophical differences about ownership of groundwater. Farmers see the water beneath their land as their property and they have strong views about government's attempts to charge for their use of this resource. This view is universal in both developing and developed economies. Consequently other ways to reduce groundwater use have to be found. To understand farmers' perspectives on irrigated agriculture ICBA undertook farm surveys over the period November –December 2009 (Annex III). The findings from these surveys show that price incentives and subsidies severely distort agricultural production systems.

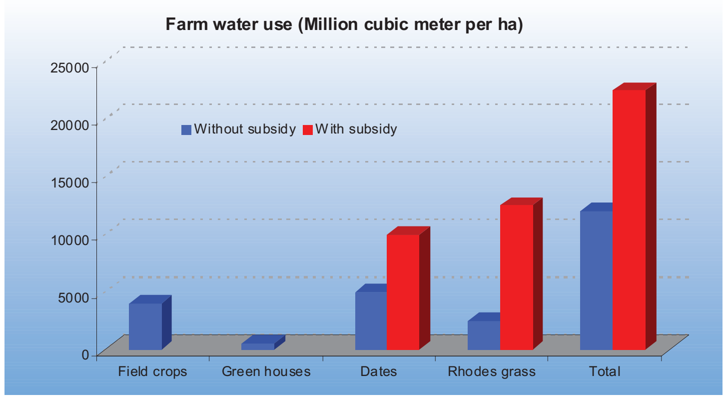
Survey Findings

Under the current system of farm subsidies farmers can make good returns from most crops and exceptional returns from fodder crops, Rhodes Grass in particular, Figure 25.

As shown farmers make profits of AED 93,000 (USD 25,340) per ha on subsidized Rhodes Grass but only AED 2,910 (USD 790) per ha in its absence. Crop subsidies are given in terms of purchase support prices. In the case of Rhodes Grass, the government purchases it at AED 1,650 (USD 450) /tonne. Because it take 3 tonnes of fresh grass to make one tonne of dry fodder the government pays AED 4,950 (USD 1,350) a tonne for dry fodder. Government then sells the dry fodder back to farmers at AED 300 a ton. Thus the net subsidy is AED 4,650 (USD 1,270) a tonne. Not surprisingly this gives farmers a huge incentive to grow Rhodes Grass. There are also price support systems for other crops, but at a much lower level, and these range from AED 2.00 (USD 0.55)/kg for cucumber to AED 1.00 (USD 0.27)/kg for cabbage.

Figure 25: The effects of agricultural subsidies on farm profitability and groundwater use





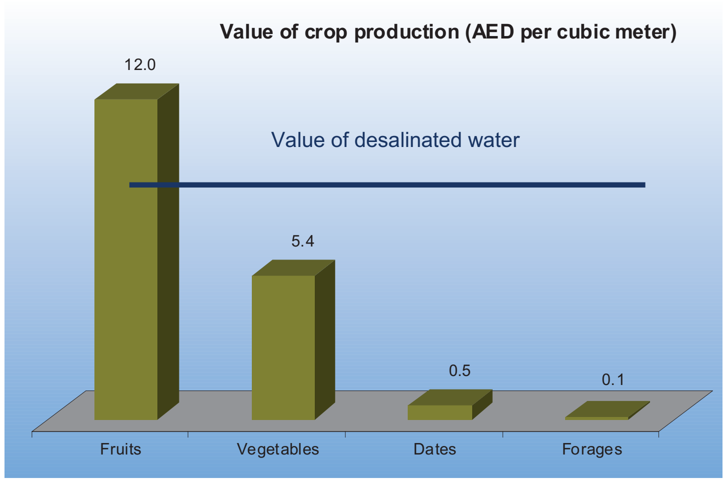
Source: ICBA, 2010.

From the conservation perspective the most important finding was that agricultural subsidies doubled overall on-farm water consumption as shown above on the right. Dates and Rhodes Grass were the principal crops involved. The total subsidy, taking the marginal cost of groundwater at AED 8.8 (USD 2.4)/m^3 and the subsidy on electricity costs, amounts to AED 135,500 (USD 36,900)/ha. The cost to the national economy for 22,740 ha of Rhodes Grass is about AED 3 (USD 0.82) billion a year. If Rhodes Grass were not grown the water conservation saving would be 0.46 km^3 a year. Both are considerable savings in Abu Dhabi Emirate.

Reducing water use in agriculture is not an easy policy to implement. The advantages and disadvantages of policy choices are summarized in Box 5.

The second question to answer is which crops add value to the economy? The results, Figure 26, show that only fruit justifies the use of groundwater irrigation if the full economic price is charged. However, if only the cost of supply excluding subsidies – AED 1.6 (USD 0.44)/m^3 - is considered then vegetables also become profitable. Neither dates nor forage are profitable if the full cost of using groundwater is considered.

Figure 26: Only fruits justify use of groundwater at it economic price



Source: ICBA, 2010.

Restructuring the agricultural sector to use less fresh groundwater may result also in many farmers abandoning agriculture. The introduction of instruments to regulate agricultural demand for groundwater, (specifically more realistic energy pricing, water pricing and licensing), and water use zoning, is difficult. This is more so given substantial agricultural production subsidies for high water use plants such as Rhodes grass. Similarly, while there is plenty of brackish groundwater, its application to agriculture requires significantly higher energy use and cost in order to ensure adequate leaching of the soil profile to manage salt accumulation or alternatively to remove the salts before using small-scale RO plants. In consequence, until the government resolves to rationalize agricultural subsidies and social policy objectives, and to tackle the difficult groundwater pricing, allocation and zoning issues, progress on the conserving fresh groundwater resources is likely to be very limited.

Box 5: The advantages and disadvantages of policy options for agriculture

POLICY OPTION A – TARGET REDUCTION IN THE USE OF DESALINATED WATER IN AGRICULTURE

Positive outcomes

- Reduced or banned agricultural use of desalinated water would significantly reduce the demand for energy and water production.
- There would be a one-off reduction in desalinated water demand of at least 11% of present demand. This is equivalent to about 11 Mm^3 a year or 3% of the 2030 supply gap.
- Pollution of groundwater from return irrigation flows may decrease.

Adverse outcomes

- Agricultural productivity would decrease in some areas
- Some farmers may need income support subsidies
- Farmers may respond by pumping brackish groundwater. Energy costs and related CO_2 and brine production may increase because of the need to pump additional water for leaching.
- More brackish water may induce increased subsidies for tolerant crops like Rhodes Grass and this may lead to further expansion of livestock numbers.
- Farmers may install small RO increasing energy use over the existing situation. But the net effect may be small as leachate volumes would be much lower.

Discussion

Given the small contribution to meeting the long-term desalinated supply shortfall and the likely socio-economic reaction from well placed farmers the political costs may be too high. Thus this policy option could be dropped as a constraint. A similar argument may apply to the forestry sector unless it is strategically down-sized to the most economically and environmentally efficient areas.

POLICY OPTION B – REDUCE THE AGRICULTURAL SUBSIDY FOR WATER-THIRSTY FORAGE CROPS

Positive outcomes

- Reduced mining of the brackish groundwater resource that could become a viable water supply source if nuclear energy became available.
- Reduction in water and energy use – perhaps by 50% of present agricultural use. The primary benefit would be to the energy sector and reduced gaseous emissions because water for Rhodes Grass is not a substitute for desalinated water.
- Reduction in livestock herds. Significant gains to rangeland ecosystems and groundwater protection.
- Significant gain to the treasury as subsidies are phased out – maybe more money for environmental management?

Adverse outcomes

- Reduced income for farmers.
- There may be an influx of farmers to urban areas as they become under- or unemployed. Income subsidies may be required to stem this flow.
- The livestock sector would decline affecting the livelihoods of those depending on it for a living.
- Farmers may invest in small-scale RO for other types of agriculture, thereby lowering the environmental benefits of the policy.
- Biodiversity would decrease as would sequestration benefits.

Discussion

This is an easy choice from the energy perspective but a difficult one for the water sector. Water security may require that the moderately brackish groundwater areas be put into a strategic reserve. The costs and benefits from an agricultural and social perspective are unclear because of the paucity of socio-economic data. Almost nothing is known about the environmental flows associated with the major forage crops and this would need to be clarified as the eventual solution would be a trade-off against global benefits.

Source: Adapted from Abu Dhabi Water Resources Master Plan, 2009.

Reclaimed Water

About 30% of all reclaimed water is currently disposed of to either the Gulf or the desert. This is mainly the result of distribution constraints in municipal systems rather than any decision to preclude its use. Any adverse impacts on the quality of the Gulf waters, or on groundwater from inland disposal have not been adequately researched. In the case of Al Ain there have been unforeseen consequences: waterlogging.

In some areas, amenity and landscaping projects have been planned on the basis of reclaimed water but demand in many areas has now outgrown supply. This is particularly marked in the summer months when reclaimed water supplies fall noticeably with an absent population and reduced tourist numbers. The resulting supply limitations have led to desalinated water being used in some areas as a substitute.

In some areas this “temporary” top-up facility has now become permanent. In 2008, the Abu Dhabi Municipality used 197 million m^3 of water for amenity and landscaping projects. Of this, 46% was desalinated water; 34% was reclaimed water; and 20% was groundwater. Thus slightly over half the supply was from the environmentally friendly sources of reclaimed water and shallow groundwater. The continued use of expensive desalinated water has occurred because it is free and has no cost to municipalities. However, in the last year Abu Dhabi Municipality has begun replanting highway medians with dry landscaping and desert plants to conserve water. With field trials suitable plants can be identified and important means of savings in water usage can be recommended to all landscaping sectors.

The policy response for reclaimed water is thus simple. First, move towards less water demanding landscapes. Second, invest in large and more efficient municipal irrigation systems. Third, put a premium on desalinated water so that is not used as a costless substitute for cheaper sources of water.

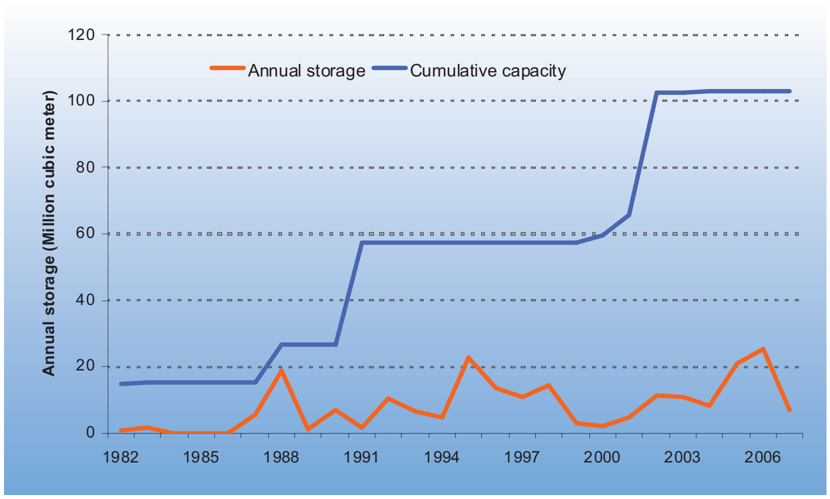
Rainfall

The Federal government has invested considerable sums to build dams in the Northern Emirates to capture flood flows, Figure 27. In the northern wadis of the UAE intense winter rainfall occasionally causes flash floods that sometimes reach the sea. To avoid wasting this valuable fresh water since the early 1980s the Federal government embarked on a national dam-building program to capture flood discharges. More than 114 structures capable of storing 118 m^3 have been constructed to date, the majority in the Northern Emirates. Another 68 are in the planning stage. The main aim has been to augment local aquifer recharge, but the stored water has also been extracted directly from the reservoir and used in agriculture.

To 2007 this policy has encouraged total investment in the major dams of AED 857 (USD234) million, and this has captured 105 Mm^3. Any evaporative loss of stored water will increase water costs. Its potential contribution to gross agricultural demand by Emirate is shown in Figure 28. Apart from Fujairah the contributions would be very small if it were all used.

However, there have been disputes among potential water users on the release of water downstream. In most situations this would not be a major issue if such disputes could be quickly settled. Each day that the water cannot be slowly released or directly injected to recharge underlying aquifer, it is lost due to the very high evaporation rate and this becomes a serious supply efficiency

Figure 27: The growth of dam capacity in the Northern Emirates

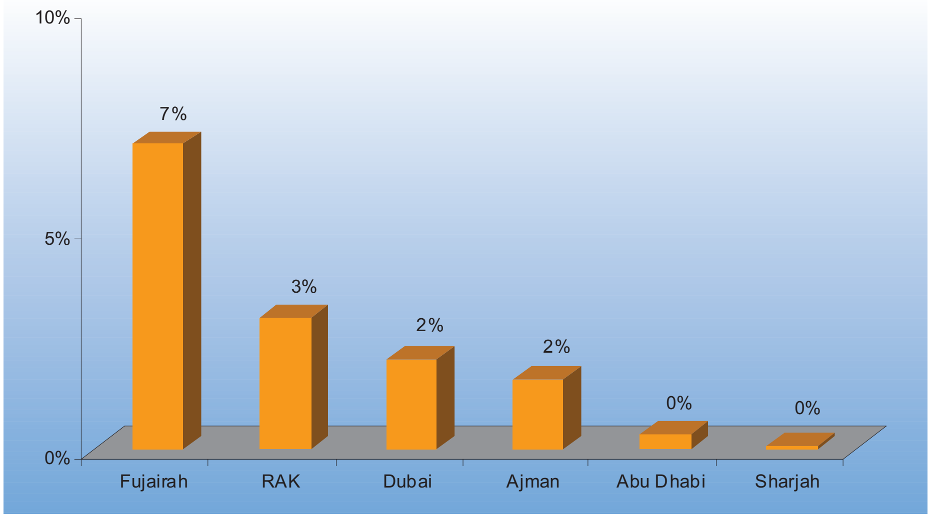


Source: ICBA, 2010.

issue. Once stored below ground it is almost immune to evaporative losses and can be tapped by farmers both in upstream and downstream zones.

The main conservation role for dams is that they should be actively managed to encourage maximum infiltration to the aquifer and there is a need to develop local institutions for the joint uses of the stored water.

Figure 28: The contribution of dam storage to agricultural water demand



Source: ICBA, 2010.

Improving Planning and Next Steps

Conservation cannot be achieved without improved planning and a better understanding of the forces driving water demand. Generally planning involves substantial cross-sectoral policy, institutional, infrastructure, economic and environmental analysis of all water and water related activities to determine complementarities and externalities and likely trade-offs needed to maximize benefits and reduce costs. Only then are the priority areas for detailed conservation targeted.

Adopting such a centralized approach in the UAE is fraught with difficulty. This is because of the multiplicity of organizations dealing with water, the lack of national standards and criteria for water production and use. Until these can be harmonized and common standards agreed water conservation will be difficult. Essential planning information is either partial or non-existent and substantial work is required to bring the information base into alignment with planning and conservation needs. One of the major issues is that each Emirate plans independently and there is little coordination to maximize potential synergies, or agree on approaches to conservation.

Water is a unitary resource and it needs to be managed and planned comprehensively to minimize investment and maximize benefits. Demand management is needed and adoption of water conservation measures will bring huge savings in economic investment and operational costs. To achieve this will require improved institutions to ensure cooperation to harmonize policy and planning efforts, and agree on common standards. This will not be easy. The Federal Government is the only institution able to engage with the Emirate's Governments to harmonize policies, legislation, planning standards and regulation. A National Water Council could provide the necessary leadership and coordination to get this done. The next chapter explores the institutional challenges and makes recommendations for the changes needed if UAE's water conservation efforts are to be successful.

Chapter 7
Institutions

Chapter 7
Institutions

The governance, legal and regulatory frameworks systems are the foundations on which policy and management decisions are developed and implemented. They determine the authority, roles and responsibilities of the various organizations involved and are the framework within which further ideas are considered. It is therefore important to understand the current systems in place in the UAE in the area of water as any developments in strategic conservation policy will be framed by, and impact, them.

The governance framework for water management in UAE

The starting point for an analysis of the governance system in the UAE is its Constitution, and the division of powers between the Federal and the Emirate levels of authority is clearly demarcated within. Whilst water is not mentioned explicitly, by implication of some of its provisions (Articles 23, 120, 121, 122 reproduced in Appendix 4.1) natural (water) resources are the public property of the Emirates. This provides a solid legal backdrop to the current system of the Emirates' exercise of regulatory authority over water resources abstraction, use and protection from pollution. This is further confirmed in laws in effect in the different Emirates such as Abu Dhabi Law No. (6) 2006 on Regulation of Drilling of Water Wells. As a result, institutions, legislation and regulations governing natural water resources are engaged mostly at the Emirate level, with the Federal legislature and executive retaining authority for national policy/strategy overview. There are thus seven Emirate organizations with direct responsibilities for managing the natural water resources and the MOEW is primarily responsible for strategic level decision-making.

By contrast, the legal status of non-conventional water resources, like desalinated water and reclaimed water, is not explicitly defined in the Constitution (unlike electricity). They therefore become in effect the property of the relevant producer, and are for it to dispose of and allocate for further use. The operations and management of these non-conventional water sources take places at the Emirate level with a variety of organizations involved ranging from municipalities to private companies. At the Federal level the Ministry of Energy is responsible for strategic decision-making in the area of water desalination but no clear mandate is given to any ministry for reclaimed water management. Prior to the recent ministerial re-organization wastewater was managed at the Federal level by the General Secretariat of Municipalities whose responsibilities have now been absorbed within MOEW. Indirectly this ministry also has responsibilities in non-conventional water under its duties to protect the marine, terrestrial and groundwater environments from any pollution resulting from their operations.

Under the Constitution, there is no clear indication as to responsibilities for water conservation/ demand management although under Article 23 "Society" is '…responsible for the protection and proper exploitation of such natural resources and wealth for the benefit of the national economy'. This onus to protect water resources and to ensure sustainable use has been taken on board by the Federal legislature and executive through Federal Law (24) 1999 with responsibility for this being given to MOEW. In terms of operations though, Emirate-level organizations are the most active in this area.

Thus, the constitutional emphasis on devolution means that most organizations involved in water governance are found at the Emirate level. The resulting institutional systems in the seven Emirates have developed relatively independently of each other and there is little commonality between them. Article 118 of the Constitution does call for the Emirates to 'coordinate their legislations in various fields with the intention of unifying such legislations as possible'. There seems little evidence of directly addressing this Article in the various laws that have been developed although there has been a transfer of ideas between the Emirate organizations in the area of natural water resources law in the last few years.

The balance between the roles and responsibilities of the Emirate and Federal governments are further affected by agreements made at the GCC level. There is an increasing number of agreements on legal and regulatory standards and operations for various aspects of water, particularly desalinated water, that are then to be translated into action at the Federal and then Emirate level.

The legal Frameworks and laws affecting water in UAE

Laws, regulations, standards and their enforcement are an important part of any governance system ensuring the protection of human and environmental health as well as economic efficiency. They give direction, transparency and clarity in many areas such as in responsibilities, roles, and standards for a particular environment or sector.

From the Federal and Emirate laws makers, as well as from various international agreements, the various organizations involved in the water governance in the UAE are bound by a number of water and environmental laws, regulations and standards summarized in Table 20.

Table 20: Some of the agreements and laws affecting the environment and water in the UAE

Legal Jurisdiction	Date of ratification and legal instruments in place	
International agreements	1990	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989)
	1995	United Nations Framework Convention on Climate Change (1992)
	1998	United Nations Convention to Combat Desertification (1994)
	1999	Convention on Biological Diversity (1992)
	2002	Convention on Persistent Organic Pollutants (2001)
	2002	Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC Convention) (1998)
	2005	Kyoto Protocol (1997)
	2007	Ramsar Convention (1971)
Implementing Regional Agreements	1979	Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978)
	2003	Convention on Conservation of Wildlife and its Natural Habitats in the GCC countries
Federal Level		Federal Decree No. (77) of 2005 regarding Protocol of Control of Marine Cross-Border Transport and Disposal of Hazardous and Other Wastes
		Federal Law No. (23) of 1999 on Exploitation, Protection & Development of Living Aquatic Resources in Waters of the State of UAE
		Federal Law No. (24) of 1999 regarding the Protection and Development of Environment
		Ministerial Declaration No. (24) of 1999 System for Assessment of Environmental Impacts
		Cabinet Resolution/Decision No. (37) of 2001 regulating Federal Law No. (24) of 1999 Concerning Protection and Development of the Environment
		Cabinet Resolution No. (3) of 2002 concerning National Environmental Strategy and Environmental Action Plan for UAE
		Federal Law No. (11) of 2006 amending certain provisions of Federal Law No. (24) of 1999 concerning the Protection and Development of the Environment
		Cabinet Resolution No. (12) of 2006 concerning Air Pollution System
		Federal Decree No. (9) of 2007 regarding the Law (regulations) on Fertilizers and Agricultural Conditioners of the GCC Member States
		Federal Decree No. (10) of 2007 regarding the GCC Pesticides Law (Regulations)

Arguably the most influential law is Federal Law No. (24) of 1999 Protection and Development of the Environment which covers various areas that affect water management including:

- the requirements for Environmental Assessments of developments;
- various aspects of environmental protection;
- environmental monitoring;
- emergency and disaster planning;
- protection of the marine environment from oil industries, transport;
- polluted water discharges;
- protection of drinking water quality from storage tanks;
- control of air emissions such as from vehicles, the burning of soil and liquid wastes, as well as from the oil extractive industries;
- handling dangerous substances; and
- natural reserves.

Following the passing of this law, numerous regulations have been established through decrees that cover specific areas of the environment or give more details of the various articles. For example, the Federal Environment Agency (now abolished) developed various guideline limits and some of these are directly relevant to the water sector in the UAE such as for air quality from stationary sources and water quality discharges into the sea from industrial sources. These standards have subsequently been adopted to varying extents in the different Emirates.

Institutions, laws and regulations of the water supply systems

The three main sources of water in the UAE - natural resources, desalinated and reclaimed water - and their subsequent use are managed predominantly at the Emirate level under differing institutional arrangements. Until recently these organizations were all in the public sector but in the last few years, in some of the Emirates, there has been an increased involvement of the private sector particularly in water services. Such moves were designed to expand infrastructure and to increase effectiveness and efficiency in various aspects of water delivery, particularly with regards to costs and service. The result is a range of specialist institutions with different setups and ownership ranging from full government through public/private partnerships to concessions. For example, Tanqia in Fujairah is a wholly private owned company with a 33 year concession, whilst SEWA is completely government-owned with private sector input only in the area of technical expertise.

There are also differences in the mandate and coverage of the various organizations and laws. Some Emirates regulate and manage separately the different supply systems whilst others combine or link them to other sectors. Desalination is understandably managed within the same organizations as electricity production, whilst wastewater is sometimes managed alone (Fujairah, Ajman and Abu Dhabi) or as departments within larger, usually municipal structures. With the exception of Sharjah, natural resources are managed by organizations separate to water services.

Natural water resources

Groundwater continues to be the most widely used resource but as it is also the strategic reserve there is a need to protect the various aquifers to ensure water security during times of need. Surface water contributes little to the overall resource base but is locally important during the winter season especially where check dams are present.

At the Federal Level, the MOEW's Water Resources and Nature Conservation section is responsible for developing strategic policies and plans for water, establishing national standards in certain areas, and for coordinating activities with the Emirates and with other Federal organizations.

The vision of the MOEW is "conserving environment and the natural resources for sustainable development" and this reflects the functions and organizational structure given under Ministerial Resolution No. (21) of 2009. The Ministry of Environment and Water in 2009 assumed the various roles of the Federal Environment Agency (set up under Federal Law No. (7) 2003 and abolished with Federal Law No. (7) 2009) and the General Secretariat of the Municipalities (whose remit included managing wastewater).

Whilst water is a part of many aspects of Resolution No. (21), a number of the specific functions under Article (3) are particularly relevant:

- Developing plans, strategies and policies in the field of water;
- Developing programmes that ensure output in various sectors including water to secure food security;
- Ensuring environmental protection in economic and social plans for the country;
- Evaluating water resources and determining programmes and means that ensure good management and conservation; and
- Proposing legislation to support the Ministry's functions.

The day-to-day operations and management of natural water resources takes places at the Emirate level. These competent organizations, usually a department within the municipality, are responsible for managing the natural water resources including the implementation of articles of Federal laws. The various competent authorities are:

- Abu Dhabi – Environment Agency Abu Dhabi (EAD);
- Dubai – Dubai Municipality (DM), Dept of Environment;
- Sharjah – Sharjah Electricity and Water Authority (SEWA) and Sharjah Environment and Protected Areas Authority (SEPA);
- Umm Al Quwain - Umm Al Quwain Water Authority (UAQWA);
- Ajman – Ajman Municipality, Department of Public Health and Environment (ADPHE);
- Ras Al Khaimah – Ras Al Khaimah Municipality Authority of Environment and Nature (RAKMAEN); and
- Fujairah – Fujairah Municipality, (FM).

The development of protection measures, controls and management practices for the natural water resources varies markedly between the competent authorities.

Groundwater Legal and Regulatory Controls

By implication of Articles 120, 121 and 122 of the Constitution, there is little doubt that the protection of groundwater resources from over-abstraction or pollution comes under the scope of authority of the Emirates, and that the Federation has limited authority in the matter. As a result, it comes as no surprise that there is no direct Federal regulation. However, the existing Federal environmental protection regulation i.e. Federal Law No. 24 of 1999 on the Protection and Development of the Environment does address the protection of groundwater resources directly (Article 39) as well as indirectly such as through the need for facilities for the disposal and treatment of waste, including wastewater, of municipal and industrial origin, and from desalination plants, are subject to the prior environmental clearance requirements of that Law [59]. As a result of this Federal regulation, all relevant projects must undergo an environmental impact screening prior to undergoing any separate licensing process under Federal or Emirate law.

With the exception of Fujairah, laws have been passed for controlling and managing groundwater, with Abu Dhabi and Ras Al Khaimah passing the first comprehensive measures in 2006:

- Abu Dhabi Law No. (6), 2006 on Regulation of Well Drilling followed by Executive Rules no 6, 2007;
- Dubai Law No. (15) of 2008 on Protection of Groundwater in the Emirate of Dubai;
- Proposed Sharjah Law, 2007 Protection of Water in Sharjah Emirate;
- Umm Al Quwain, Law No. (2) 2008 Protection of groundwater and regulation of well drilling in Umm Al Quwain Emirate;
- Ajman Law No. (4) 2009 Regulation of Well Drilling and Consumption of Groundwater; and
- Ras Al Khaimah Law No. (5) 2006, Regulation of Well Drilling.

Table 21 Natural water resource legal and regulatory provision

	EAD	DM	SEWA	SM	UAQWA	ADPHE	RAKMAEN	FM
Information gathering/inventorying	**	*	**		*	*	*	
Licensing of wells and their further development	***	*	**		*	*	*	
Regulating drilling	***	*	**		*	*	*	
Regulating abstraction and rates	*	*	**		*	*	*	
Regulating use		*	**		*	*	*	
Monitoring and Enforcement	*	*	**	*	*	*	*	
Pollution Protection	**[60]		**		*	*	*	
Explicit link to Federal environmental clearance requirement								
Integration with other water sources				**	*			

* = legal and/or regulatory provision present
** = legal and/or regulatory provisions present and setup
*** = legal and/or regulatory provisions present, setup and monitored and enforced

Most of these laws establish provisions for new wells or those that are to be further developed. In a number of the laws there is the provision to establish protection zones for groundwater. Some include details on the actual control measures (metering, pumps etc), and on the data to be provided by well-owners such as the use of the water and estimated rate of abstraction (Dubai).

The most difficult area is in regulating existing wells. These wells, and traditional groundwater rights (aflaj), which pre-date regulatory legislation, play a significant role in much of the country's rural areas. Their use is grounded on the deep and diffuse conviction of the owners that, regardless of what the Constitution says about all natural resources in general being the property of the Emirates, groundwater is the property of the landowner, for him to extract and dispose of as he sees fit. As a result, managing their rights (and convictions) in the context of a new law introducing regulation of water resources abstraction and use, raises delicate "expropriation" issues.[61]

A further difficult area is the actual implementation, administration and enforcement by the different competent authorities for their water legislation. In the light of the clear-cut constitutional division of powers and responsibilities between the Federal and the Emirate governments in relation to water resources in general, there is no doubt that the matter of enforcement falls under the exclusive remit of the Emirates. This tends to be problematic in any jurisdiction, and the Emirates of the UAE are no exception, with large variations in actions. A number of reasons may be put forward to explain this including a lack of both numbers and adequately trained law enforcement capacity of the regulatory authorities. Inspectors do exist but their numbers and mandate varies greatly across the different Emirates.

Thus groundwater is regulated and managed by seven different organizations at the Emirate level and one at the Federal level. Different laws, regulations and practices have resulted for managing this resource and this is sub-optimal given the importance of this as the strategic water reserve of the country. There is a need to agree at the national level various standards and regulations for management and information collection and these should then be implemented by the competent authority within the Emirates. This harmonization would bring a greater understanding and protection of the resource. An annotated proposal for this harmonized regulatory body for the different Emirates is given in Appendix 4.2.

Surface Water Legal and Regulatory Controls. Surface water during certain times of the year and in specific areas can become a locally important input to the water balance equation. However, there has been little development of laws or regulations for surface waters.

The main regulations refer to the many dams built by the MOEW. These are constructed in cooperation with the competent authority of the Emirate where it is sited and follow prescribed international design and construction regulations and standards from international organizations such as the World Dam Commission. The MOEW, local authority and relevant sector representatives cooperate to agree access to this reservoir waters. The quality of the water behind the dams is also managed through the cooperation of the MOEW, the local authority and local people.

One exception to the general lack of control over surface water is Wadi Wurayah in Fujairah which in 2009 was established as the first protected mountain area of the UAE. This protection zone, situated wholly within Fujairah Emirate, was established to safeguard fresh water springs, pools and streams that provide its unique wildlife with a renewable and safe drinking resource.

As with groundwater, surface water is managed by seven different authorities and there has been little development or enforcement of measures to protect the wadis and waters. There is a need again to develop national protection and technical standards which should be coordinated with those for groundwater. The MOEW should oversee such developments and work with the competent authorities in the Emirates on establishing monitoring and enforcement measures.

Non-conventional resources

The manufacture of water from either seawater or wastewater has grown rapidly in importance in the water balance of the UAE over the last decade. Desalinated water is the primary source of potable water and reclaimed water is being explored in further detail to enhance the contribution it can make in certain use sectors.

Desalinated Water

Many different specialist organizations are involved in the production, transmission, distribution and control of this water source. At the Federal level the Ministry of Energy is responsible for developing strategic policies and plans for desalinated water, establishing national standards in certain areas, and for coordinating activities with the Emirates, with other Federal organizations as well as with GCC counterparts. There are currently no Federal laws concerning desalinated water although of course Federal Law No. (24) 1999 affects the abstraction and discharge of water from the sea.

An important recent development at the Federal level has been the passing of Cabinet Decree No. (37) 2009 which will lead to even greater coordination of activities in the production of desalinated water. Under this decree a Council for Electricity and Water is in the process of being formed, to be headed by the Minister of Energy, to coordinate and enhance activities between the major authorities and organizations involved in the production and distribution of desalinated water. This is an important move to coordinate activities across the growing number of organizations.

The four large organizations directly responsible for the production and distribution of desalinated of water at the Emirate level are ADWEA[62], DEWA[63], SEWA and FEWA[64]. The last, FEWA, is responsible for serving the needs of the four Northern Emirates. With the exception of Abu Dhabi these authorities are government owned although the private sector is involved to various degrees in design, construction and operation. In Abu Dhabi a system of highly specialized organizations has been established and the private sector is involved to a much greater extent here, particularly in the area of water production.

In addition to these large Emirate based authorities, there are an increasing number of smaller organizations, often associated with large developments, which are licensed to produce and desalinate their own water. Some, such as Dubai's Palm Water, are licensed for extended periods, whilst others such as the Tourism Development and Investment Company in Abu Dhabi have a fixed period of operation.

A small but important part of the desalinated water supply system to both consumers and commercial enterprises is bottled desalinated water. There are many companies involved in this business and their activities are controlled at the Federal level by the Emirates Standards and Metrology Authority (established under Federal Law (28) 2001). These companies are a mixture of government and private sector organizations.

A final group involved desalinating water are individual landowners, usually involved in agriculture. They have small reverse osmosis systems installed to provide water of a suitable quality for their activities. Their use tends not to be licensed or regulated with their activities based on groundwater. There is thus an overlap of organizational control between natural resource and desalinated water management.

The production of desalinated water is both technically complex and expensive, and is predominantly mixed with that of electricity. These factors, in tandem with the potential for environmental impact, ensure that desalinated water is the most regulated source of water in the UAE. To control the activities of this ever-increasing group of organizations, regulators have been established in many of the Emirates. They have introduced technical, health, safety, economic and environmental regulations and standards to varying extents to ensure adequate protection is in place for many aspects of the desalination process, transmission and use. The regulations have evolved under a number of influences with the regulators often adopting international standards from organizations such as the World Health Authority (WHO), International Desalination Association (IDA), International Organization for Standardization (ISO) and the International Water Association (IWA). Each Emirate has different standards and different monitoring and enforcement systems in place.

In recent years there have been various standards and regulations introduced through GCC level agreements. Ministers responsible for electricity and desalinated water meet to discuss and agree standards for various aspects of this sector. This committee meets twice a year and following approval, the standards are then sent to the national ministries, and in the case of the UAE, the Emirate-level organizations for approval and adjusted for plant to plant specifications. Whilst these have been highly technical to date, there are moves to introduce more explicit standards for environmental protection such as for brine discharge. The level of adoption by operations is difficult to assess at present.

The regulations and standards that have been developed affect the design, engineering, building and operations of the plants. The current environmental standards for different desalination plants in Abu Dhabi are given in Appendix 4.1 and show the development of increasingly stringent values.

Implementation of Regulations

The Abu Dhabi regulator, the RSB, is transparent and is perceived to be a model to follow. It is a wholly independent organization that reports directly to the Executive Council and its role and responsibilities are clearly defined under various Abu Dhabi laws[65]. Its activities cover desalinated and reclaimed water, and electricity and its website gives details on all licences issued, and regulations established. The regulator regularly holds open consultations with key stakeholders on future areas of regulation (eg price control reviews, water supply regulations). Dubai has now taken the first steps to develop a similar regulatory organization under Executive Decision No (2) of 2010, which RSB attached to the Dubai Supreme Energy Council. This model should be followed by other regulators.

Looking forward, the number of organizations in the UAE involved in desalinating water is likely to increase in the near future with a greater role being played by the private sector And this coupled with the increasing transfers of desalinated water across the different Emirates (ADWEA supplying water to FEWA) and moves to develop a national (and even GCC) water grid require the setting of clear national standards that are adopted by all. Whilst water production is obviously a local activity, increased efficiency and effectiveness and agreed levels of environmental protection could be achieved if national standards are coordinated. The standards currently used by the different regulators differ little but should be rationalized and agreed on for different receiving bodies. These set limits should be backed up with common guidelines and standards for monitoring and enforcement such as for sampling frequency, online vs. grab samples, baseline surveys, and laboratory analysis methods and standards.

The coordination of such activities is one of the functions defined for the recently created Council of Water and Electricity. There is a need to define environmental as well as technical specifications so the MOEW should be part of the various discussions. Recent moves in this direction by committees at the GCC level should also be reflected in any deliberations.

Reclaimed Water

In all the Emirates, except Umm Al Quwain, there is a mixture of network and tanker wastewater collection and various levels of treatment and technologies are in use. Given the potential risks involved in this sector a range of institutional provisions, legal and regulatory frameworks and standards have evolved.

Until recently the Federal level organization responsible for reclaimed water was the General Secretariat of UAE Municipalities. However, this was abolished in the middle of 2009 and its jurisdiction and services were transferred to the MOEW. At the moment this is not an active area of legislative or regulatory development with responsibilities still to be finalized. Hence, as with all other aspects of water management in the UAE, the organizations primarily responsible are based at the Emirates level.

In some of the Emirates one principal organization is involved in collecting treating and disposing of wastewater. In Sharjah, for example, the Drainage Department within Sharjah Municipality is managing the whole wastewater industry through the supervision, operation and maintenance of the sewerage system, pumping stations, irrigation trunks, surface water network and the treatment plants. Similarly the ADSSC is licensed and regulated by the RSB. Contrarily Dubai Municipality is responsible for managing the wastewater projects execution, operation and maintenance through 3 of its departments:

1. The Drainage and Irrigation Department (responsible for the supervision of sewerage, Irrigation and treatment plants infrastructure designing and execution).
2. The Sewage Treatment Plants Department (responsible for the operation and maintenance of the sewage treatment plants).
3. The Sewerage and Irrigation Network Department (responsible for the op eration and maintenance of the sewerage and irrigation network).

In recent years the private sector has become increasingly involved in managing sewage services through public/private partnerships with the first concession granted in Ajman through the establishment of Ajman Sewerage Private Company Limited (ASPCL).

In addition to the principal Emirates-level organizations there are an increasing number of smaller organizations involved in the reclaimed water sector. Recent moves by mega-developers and other organizations to manage their own decentralized provisions have meant further private sector involvement. Companies such as Nakheel, Emaar, Dubai Holding and Sports City are constructing the wastewater infrastructure for their projects, including sewage treatment plants, sewerage network, pumping stations and reclaimed water distribution networks to serve these communities. In addition in some municipalities the application and use-management of reclaimed water is outsourced to various private sector companies; whilst In some of the Emirates the actual operations are outsourced to other companies and their activities are little regulated or controlled.

Given the potential health, economic and environmental impacts of poor wastewater management various laws, regulations and standards have been developed which control its input, collection, treatment, disposal and re-use. The Federal Law No. (24) of 1999 sets a framework for the protection and development of the environment in the UAE (Articles 35, 37 and 38).

However, it is the area of regulations and standards that is most crucial to managing effectively and safely reclaimed water. An effective regulatory framework must cover the three main parts of the system:

1. Control on matter entering the sewerage network;
2. Control over the collection, treatment and disposal sewage system; and
3. Control over the subsequent use of reclaimed water.

The regulations in place in the Emirates controlling the input of material into a sewerage network are variable (see Appendix 4.2). Sharjah already have controls in place for various activities, and in 2007 the RSB of Abu Dhabi released new regulations for public consultation that address trade and industrial effluent control. These are comprehensive are being put into action in 2010. Where the reuse standards exist they tend to be based on international best practice as little research has taken place in the UAE to ascertain the relevant values for this environment. The most difficult part of controlling this part of the wastewater system is monitoring and enforcement given the spatial spread and localized nature of sewer inputs. This has yet to be addressed adequately in any of the Emirates.

Various standards are in place to control aspects of wastewater collection, treatment and transfer (Annex 4.2), although many are site specific. Whilst there is little public discussion in the development of many of these regulations, the general trend amongst the various organizations is to adopt international practices and standards. In addition the contractors brought in to design, build or operate the various plants and systems will often bring their own standards which become the basis for the activities.

The key to effective standard setting in the 'use' part of the reclaimed water cycle is that they are linked to actual types of application. Varying specifications have been developed in some of the Emirates based on this. For example, Sharjah already has in place standards for restricted and unrestricted agriculture. And by far the most transparent, comprehensive and potentially effective standards are those recently introduced by the RSB in Abu Dhabi which have been developed within an institutional and regulatory framework of effective monitoring and enforcement. The regulations, which became effective in the middle of 2010, aim to ensure that the use of reclaimed water (and biosolids) is safe, economical and environmentally beneficial.

In many of the Emirates however, there is a lack of clarity as to the regulation and control mechanisms in place. There is a need to develop appropriate standards for 'approved reuse activities' that might include irrigation of urban areas, restricted and unrestricted irrigation of agricultural and forestry areas, irrigation of domestic gardens, toilet flushing, fountains and water features, air conditioning processes, street cleaning and dust suppression, vehicle washing, concrete manufacture and fire fighting.

Institutional Development

From the review of the institutional, legal and regulatory frameworks for water supply systems, it becomes obvious that fragmentation exists that is likely to cause inefficiencies and ineffectiveness. It is suggested that Article 23 of the Constitution is re-interpreted in the area of water resources. There is a great need for national coordination in natural water management to protect the strategic reserve, as well as in non-conventional water development to bring greater returns on investments. This coordination needs to come in many different areas ranging from standards setting to future strategic planning.

In the specific area of national standards, agreement between the different Emirates would help to overcome many of the problems now found. From international experience best-practice should follow this structure:

- Government sets the standards (often on the advice of the regulator);
- The construction and operations organizations achieve the standards; and
- Regulators monitor and enforce the standards.

In the case of the Emirates, the setting of regulations standards should be coordinated at the Federal level, across ministries and Emirate level authorities/agencies. The agreed terms would then be implemented by the competent authority within each Emirate. The benefits would be to:

- Provide a cogent system of regulation and control throughout the Emirates;
- Avoid the use of standards with lists of unimportant parameters;
- Avoid potential problems arising from the private sector involvement with standard setting;
- Provide a transparent system that would satisfy the needs of consultants and contractors in design; and
- Provide the government at all levels with the assurance that the system is fair and that it protects both public health and the environment.

Water use

Institutional, legal and regulatory frameworks in the area of water use are more complicated than in the supply side of the system and usually straddle many different variables. Use management initiatives are often in direct conflict with the objectives of individual sectors such as increasing agricultural production or increasing tourist visits. To date institutional, legal and regulatory frameworks for water use management have been developed to only a limited extent in the UAE.

The general approaches to direct water use regulation may be classified under three headings:

1. Regulation through administrative allocation where a central government bodies determines how much water is available for use in various sectors/areas;
2. Regulation through authorized tariffs (generally responsibility of central government) on natural water resources to protect the public good, and might involve economic measures such as a water mining fees or a depletion allowance. These should be set by an independent national organization; and
3. Regulation through the levying of charges by producers of water for their services. In this context water is a private good and any levies need to be highly regulated in themselves to stop excessive profit taking from natural monopolies over which private operators have control. Without an independent regulator, then the global experience shows that the setting of tariffs becomes politically dominated by the vested land owners or by social activists who are concerned that water pricing will adversely affect the welfare of the poor.

Economic-based approaches (above points 1 and 2) to water use management transmit information about water scarcity to encourage changes in behaviour so hopefully will lead to reductions.

In the UAE there are no Federal level organizations directly involved in water use management and responsibilities for this falls to the various Emirates. There are, however, indirect Federal controls on water use within the various sectors that result from their strategic policies.

At the Emirate level, there are various initiatives from different organizations to manage water use and encourage water conservation. For natural resources management, there are no authorized tariffs (regulation area 2 above) and to date any controls on groundwater use have been an indirect result of changing agricultural policies and subsidy regimes rather than actual legal or regulatory frameworks.

In the sectors using desalinated water, most of the Emirates are actively managing water use through levying charges by the producing authorities (regulation 3 above) such as the slab tariffs of DEWA, SEWA and FEWA. Whilst these are not universally applied, they are important steps in reducing demand and there has been a harmonization of tariffs between the three authorities.

There have been other regulation initiatives through the Emirate level organizations such the departments of municipalities to encourage water use efficiencies through the adoption of smarter designs or technology or use. For example, in Dubai[66] there is a drive for ‘green buildings’ which adopt designs and technologies which save water (and energy) and the new phase of guidelines and specifications, Green Building Regulations – Stage II, to regulate building standards for achieving efficiency in the use of electricity, water and renewable energy has been launched in March 2010. Similar initiatives are found in the some of the other Emirates.

The need for greater sectoral coordination in water use management is being increasingly recognized. In Abu Dhabi, for example, the Economic Affairs Unit of the Economic Affairs Authority (EAA) is currently working with other government and non-government entities to develop a comprehensive Demand Side Management (DSM) strategy for electricity and water consumption within the Emirate. The objective of the EAA in coordinating this activity will be to develop an integrated overall DSM strategy to assist the Emirate in meeting its short and long term water (and energy) needs. The partners in this include members of the ADWEA group of companies, the RSB, EAD, the Urban Planning Council, Emirates Wildlife Society and others.

Importance of Institutional Development

The institutional framework for water in the UAE is relatively fragmented and disparate with many different authorities/agencies involved. Following the articles in the Constitution, water has been predominantly managed at the Emirate level and this has not been without its own success. However, given the increasingly water stressed situation and rapidly developing economies it is now important to think more strategically and across Emirate boundaries. The present setup is a series of separate agencies, many of whom overlap in their roles, whilst gaps in key areas also exist. There is very limited strategic or operational planning between the various water sources and/or water uses.

In terms of laws and regulations there are large variations in the formulation and passing of measures, as well as in their implementation. Standards for many aspects of water supply vary between areas that are authorities that neighbour each other and share the same sea. There is limited access to information held by the individual organizations meaning that planning, and decision-making is not always based on current and comprehensive information.

There is an urgent need for a coordinating body to be established, that can bring together authorities in the Emirates and Federal government level. The first steps towards this would be an organization that takes onboard and expands the remit of the current Council for Water and Electricity and the proposed National Water Council of the MOEW to cover all water sources and uses. This should be cross-ministerial and should answer to the Cabinet. Annex 4.4 outlines a possible framework for such a body.

There is an urgent need for increased coordination and coherence that can bring together authorities in the emirates and Federal government. The first step towards this would be to reinterpret Article 23 of the constitution to enable the Federal Government to develop strategic integrated and coordinate water resources planning with the Emirates' competent authorities. In a country as arid as the UAE, water supply and use should be planned and regulated at the highest level but implemented or operationalized at the local level (see Box 6).

Given the future demands for water in the UAE, strong institutional, legal and policy leadership will be needed to ensure economic development is supported and the environment and society is protected.

Box 6: Multi-level governance responsibiltities – the case of the German Federal Republic

Federations often experience overlaps and gaps in water responsibilities and roles resulting from their multi-levels of governance - Federal, State and Municipal authorities. The starting point for any analysis is the constitution which determines where these lie and define the important property/legal rights to the resource. In most but not all federal countries, water is the property of the state/province. With growing complexity in water management, there have been increasing moves in many advanced federal countries towards national-level strategies, policies, laws and regulations and locally-run implementation and operations. This brings greater coordination across the boundaries and helps diffuse any tensions between neighbors in key areas such as resource use and pollution control. This also supports increasing input from private sector and special interest groups in water governance.

A good example is the Federal Republic of Germany. There are no provisions in the German Constitution that directly regulate the use or protection of water, but recent legal decisions acknowledge groundwater as a public good so allowing Federal restrictions on its use. The fundamental legal framework in Germany is the Basic Law which allocates responsibility and authority between Federal and State governments (states are known as Länder). Under the Basic Law it states that the Federal government is responsible for setting up regulatory and legal framework for water. However, the Länder are responsible for implementing and supplementing the Federal Regulations, and enforcing statutory provisions.

Chapter 8
The Strategy

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Key initiatives

This Strategy provides a framework to sustainably manage the UAE's water resources over the period to 2021. As such it highlights the challenges and opportunities to better manage scarce and expensive water resources and provides a range of options to do so. Some of the options will be easy to implement, others less so. It also has to be recognized that because water management is devolved among the seven Emirates the type and quality of information about water resources and use varies widely – this is particularly so for the agricultural sector – and the availability of better information may favour some policy options more than others. Institutions to monitor and regulate water resources management will also evolve over time and may require policy responses different to those suggested in the Strategy. Consequently the findings in this Strategy should be reviewed every five years to keep it relevant and up-to-date. In order to implement the Strategy, the following eight initiatives should be implemented:

Initiative 1: Develop legislation, standards and Federal mechanisms for integrated water resources management

To preserve, protect and enhance water resources management in UAE, and to appropriately allocate and effectively use water resources for the benefit of current and future generations:

- Coordinate the development of common regulations, standards, and specifications for economic, technical and environmental controls;
- Support stakeholder coordination and understanding;
- Integrate anticipated consequences of climate and environmental change;
- Monitor and evaluate progress towards achievement of national objectives;
- Ban water export; and
- Etablish a national council to coordinate water and a forum for dialogue and coordination among stakeholders on water resources.

Initiative 2: Better manage natural water resources and enhance strategic reserve

- Introduce water budgeting at the national, regional and local levels that takes account of all water supplies and uses;
- Facilitate formation of a national water quantity and quality monitoring system;
- Guide and oversee the creation of a national water database;
- Improve the design and operation of dams in the Northern Emirates to improve retention of floodwater and groundwater recharge; and
- Promote zoning and artificial groundwater recharge.

Initiative 3: Develop national agricultural policy aimed at water conservation and increasing value to the economy

- Promote a new agricultural development model that is water conservative, environmentally benign, and commercially viable;
- Initiate research to deepen knowledge on UAE's agricultural economy and its use of water;
- Conduct a study with farmers to agree which parts of UAE's traditional agriculture should be retained as part of its cultural heritage;
- Agriculture and forestry compete for the same scarce water resources – a plan to assess the trade-offs and where they should be applied should be prepared; and
- Build on this knowledge to initiate an agricultural plan to better conserve scarce water resources.

Initiative 4: Manage efficiently desalinated water from a comprehensive and national perspective

- Introduce and apply economic optimization principles to design future desalination capacity;
- Reduce losses in water distribution and main lines;
- Create a national water grid system to enhance water security and cost efficiencies; and
- Further develop Aquifer Storage and Recovery (ASR) using surplus desalinated water where economically feasible.

Initiative 5: Rationalize water consumption to be within the global daily per capita water consumption rate

- Develop strategies to reduce the daily per capita consumption of water to the global average of 200 litres per capita per day (lpcpd);
- Review and adopt as suitable water efficient systems and technologies;
- Develop strategies to match water quality and different uses; and
- Design awareness programs and campaigns.

Initiative 6: Review and develop clear water pricing and subsidy policies

- Review and adjust water tariffs of all water sources for all customers to reflect more the water production and distribution costs; and
- Review and adjust government subsidies for all water resources and uses.

Initiative 7: Better manage effluent and reclaimed water

- Develop wastewater effluent discharge standards for UAE's marine and terrestrial environments and monitor their enforcement by the Emirate level authorities;
- Coordinate the development of common standards for wastewater collection, treatment, and reuse in different sectors;
- Monitor the enforcement of environmental standards by the individual Emirates;
- Assess network integrity to minimize leakage and inflows;
- Coordinate measures to increase use of reclaimed water; and
- Coordinate awareness raising campaigns to overcome public fears.

Initiative 8: Capacity building and strengthening of local expertise on the concepts of integrated water resources management

- Develop a body of expert knowledge and training to support national capacity in water resources technologies and management, particularly in non-conventional water resources; and
- Encourage greater participation of private water sector organizations in capacity building.

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Endnotes

Endnotes

1. Constitution of the UAE Article 23.
2. Federal Law 24/1999.
3. Constitution of the UAE, Articles 23, 120, 121 and 122.
4. Constitution of the UAE, Article 118.
5. For example, Abu Dhabi Law No. 6 of (2006) on the Regulation of Drilling of Water Wells.
6. The Ministry of Environment and Water in 2009 assumed the various roles of the Federal Environment Agency (set up under Federal Law No.7 /2003 and abolished with Federal Law No. 7/2009) and the General Secretariat of the Municipalities (whose remit included managing wastewater).
7. Detailed information is given in Annex 1.
8. It should be noted that farmed area is not the same as cultivated or irrigated area because most farms include some uncultivated land. In 2008 there were 34,535 farms of which 91,558 ha (91%) was cultivated.
9. In 2007 there were 1.7 million goats, 1.2 million sheep, 0.4 million camels and 0.06 million cows. MOEW Agricultural Statistics 1998-2007.
10. In the Eastern Region of Abu Dhabi Emirate, native species such as ghaf and arak are most commonly grown, while in the western forestry area, salam, damas, sidr and ghawawiaf dominate the stands.
11. Brook, M.C., H. Al Houqani, T. Darawsha, M. Al Alawneh and S. Achary (2006). Groundwater Resources: Development & Management in the Emirate of Abu Dhabi, United Arab Emirates. In: Arid Land Hydrology: In Search of a Solution to a Threatened Resource. Proceedings of the 3rd UAE-Japan Symposium on Sustainable GCC Environment and Water Resources. Abu Dhabi, UAE, 28-30 January, 2006. In this paper Brook and others reported that average forestry water use under drip irrigation in the Eastern Region of Abu Dhabi was 2,161 m3/ha and in the Western Region it was 1,990 m3/ha. The relatively low water use compared to the evapotranspiration requirements of about 2,300 mm/year/ha is because the trees only cover about 10% of the ground area.
12. Realistic Scenario is based on constant groundwater supply at current levels, double desalinated water supply and 180 litres per day that can be reclaimed and water conservation practices assumed.
13. See Annex 2 for the data sources and assumptions used to make these projections.
14. Regulation and Supervision Bureau was established in 1998.
15. Distribution costs to consumers would raise this cost by about 50 %.
16. In 2008 the UAE Gross Domestic Product was AED 934 billion (USD 254.5 billion), of which the no-oil sectors was AED 590 (USD 160.76) billion.
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34. The Dolphin natural gas pipeline project linking Qatar, the UAE, and Oman is the first cross border natural gas pipeline in the Gulf Arab region. Natural gas is imported from Qatar's North Field to Abu Dhabi, Dubai, and Fujairah in the UAE, and then on to Oman. The managing company, UAE's Mubadala Development Company, holds a 51-% stake in Dolphin Energy, with France's Total and U.S. Occidental Petroleum at 24.5 % each. The project will carry about 2 Bcf/d of natural gas from Qatar to the UAE and Oman. The project consists of a 48-inch subsea export pipeline running 226 miles from Qatar to Dolphin's facilities at Taweelah, Abu Dhabi, where the first natural gas imports were received in July 2007. From Taweelah, a 152-mile pipeline runs to the Qidfa Water and Electricity Station in Fujairah. Construction on this line will be completed by third-quarter 2010.
35. See Annex 1 for assumptions.
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39. Md. Dawoud of EAD (2010) Personal communication. This pipeline provides irrigation water to forestry plantation.

40. See Moreland *et al*. (2007) page 132. USGS sate that the net water consumption (presumably after percolation return flow has been subtracted) is 600 mm per unit area per year.

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42. At 7 m spacing a one ha block would require 14.2 rows of irrigation pipe. As 305,000 ha are under irrigation the total length is 14.2 x 305,000 = 433,100 km.

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45. The EAD value for forestry use of water is taken from Water Resources of Abu Dhabi Emirate, UAE (2006), page 55. 607 Mm3/year of water was used to irrigate 305,243 ha of forest. This is equivalent to 200 mm per unit area per year. While this may appear small compared with evapotanspiration rates there are 210 trees planted her ha at approximately 7 m spacing. The USGS estimated is taken from Moreland et al.., 2007. The total groundwater use over the period 1970-2005 was 6,800 Mm3. Over this period the cumulative area irrigated was about 3.2 million ha. By calculation water use was 200 mm per unit area per year.

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48. David Pimental, *et al*. (2004) Water Resources: Agricultural and Environmental Issues. BioScience, Vol. 54, No. 10, October 2004.

49. Non-nationals comprise 80% of the UAE’s population of 4.1 million (2008) but this varies from 90% in Dubai to 55% in Fujairah. By Water Authority non-national consumers are DEWA (90%); SEWA (83%); ADWEA (75%) and FEWA (66%).

50. Bowling, J.J. (2008) The Role of tariffs in managing urban water supply and sanitation. John Hopkins University.

51. This section is summarized from Olmstead *et. al.* (2006) and Dalhuisen *et. al.* (2003).

52. Schierling *et. al*. (2006)

53. ‘Heroes of the UAE’ launch Water Conservation Campaign to combat Water Wastage. 12 January 2010.

54. RSB (2008) Water and electricity consumption by residential consumers.

55. The EPA reported that toilet flushing can account for up to 45 % of indoor residential water demand (EPA, 2004). The use of reclaimed water for toilet flushing in commercial and residential buildings can reduce potable water demand and do not require potable water quality. The feasibility depends primarily on plumbing and related infrastructure cost. In California, tertiary treated reclaimed water is deemed safe for toilet flushing. Dual plumbing for potable and reclaimed water is necessary for the use of reclaimed water in buildings (Asano, 2007). The Irvine Ranch Water District in California researched the economic feasibility of expanding its urban dual distribution system to provide reclaimed water to high-rise buildings for toilet and urinal flushing. The study concluded that the use of reclaimed water was feasible for flushing toilets in buildings of 6 stories and higher. Following this study, an ordinance was enacted requiring all new buildings over 55 feet (17 meters) high to install a dual distribution system for flushing in areas where reclaimed water is available (EPA, 2004). In 1991, the Irvine Ranch Water District began using reclaimed water for toilet flushing in high-rise office buildings. Potable water demands in these buildings have decreased by as much as 75 % due to the reclaimed water use (EPA, 2004).
56. RSB (2008) Annual Work Plan for 2009.
57. ADDC (2008) Letter from Ahmad Saeid Al Mareikhi, General Manager.
58. Dr Md Dawood. EAD. Personal communication (2009).
59. By virtue of the List of projects subject to environmental clearance requirements, featured in the Executive Order No. 37 of 2001.
60. Water quality protection outsourced to Rochester Institute of Technology, Abu Dhabi campus.
61. The aborted Federal Water Act Regarding Protection and Development of Water Resources prepared in 2008 acknowledges the existence of such rights, in the relevant Definitions clause (Article 1.24) and, indirectly, in the transitional clause making a generous allowance for the owners of existing wells (Article 49).
62. Abu Dhabi Water & Electricity Authority was set up under Abu Dhabi Law No. (2) of 1998, and amended by Law No. (19) of 2007.
63. Dubai Electricity and Water Authority was set up under Dubai Decree No. (1) of 1992 The Establishment of Dubai Electricity and Water Authority with certain provisions amended under Dubai Decree No. (13) of 1999.
64. FEWA was set up under Federal Law No 31 for 1999 regarding the establishment of FEWA. Also note UAE Federal Law No. (9) of 2008 Amending Some of the Provisions of Federal Law No. (31) of 1999 Establishing the Federal Electricity and Water Authority.
65. Law No. (2) 1998 Concerning the Regulation of the Water and Electricity Sector in the Emirate of Abu Dhabi and amended under Law No. (19) of 2007, Law No (9) of 2009.
66. Dubai Circular No. (161) of 2007 on the Implementation of Green Building Criteria in the Emirate of Dubai.

Annex 1
Overview of Water Resources

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Overview of Water Resources

This annex gives an overview of the four major sources of water in the UAE. Naturally occurring water (surface and groundwater) is variable in quantity and quality throughout the country and is the most important source of water supply for agricultural activities and rural communities. Non-conventional resources, desalinated and reclaimed water, are the major sources of supply for the domestic, commercial and industrial sectors, and for urban amenity greening and plantations. Some non-conventional water resources are used for agriculture as a replacement for poor quality groundwater.

Surface Water

Introduction

The main renewable fresh water resource in the United Arab Emirates (UAE) is wadi runoff which is determined by rainfall characteristics and the nature of the terrain. Other sources, such as sabkhas and ponds, are generally too saline to be used as a source of water for human activities. Whilst limited in terms of total contribution to UAE water sources, surface water may be locally important.

Rainfall Characteristics

The UAE has an arid to hyper-arid climate with low rainfall, high temperatures and high evaporation rates. The rainfall distribution is variable across the country and is characterized by intense short duration rainstorms. Evaporation rates are high and exceed 3000 mm/yr in the Western Region of Abu Dhabi where temperatures reach over 45 C^{o} in the summer season.

Rainfall occurs in winter, mostly in the period from December to April. The average annual rainfall for the last forty years is about 120 mm/year (MOEW, 2009), with the highest average monthly rainfall (16 mm) found in January and the lowest in May (1 mm), Figure 1.1. Across the country, the average annual rainfall ranges from 80 mm to 140 mm, with the highest values found in the mountain and east coast regions, and the lowest in the desert foreland. The mountain region rainfall was about 120% of the average annual rainfall, with the east coast about 110%, the gravel plains 97%, and the desert foreland 69%. The highest recorded annual rainfall occurred in 1995/1996 with over 420 mm/year while the lowest value of 2 mm/year occurred in 1999/2000. In more general terms recent figures show that the climate has been drier than usual during the period 1999 to 2006 (MOEW, 2009).

Wadi flows

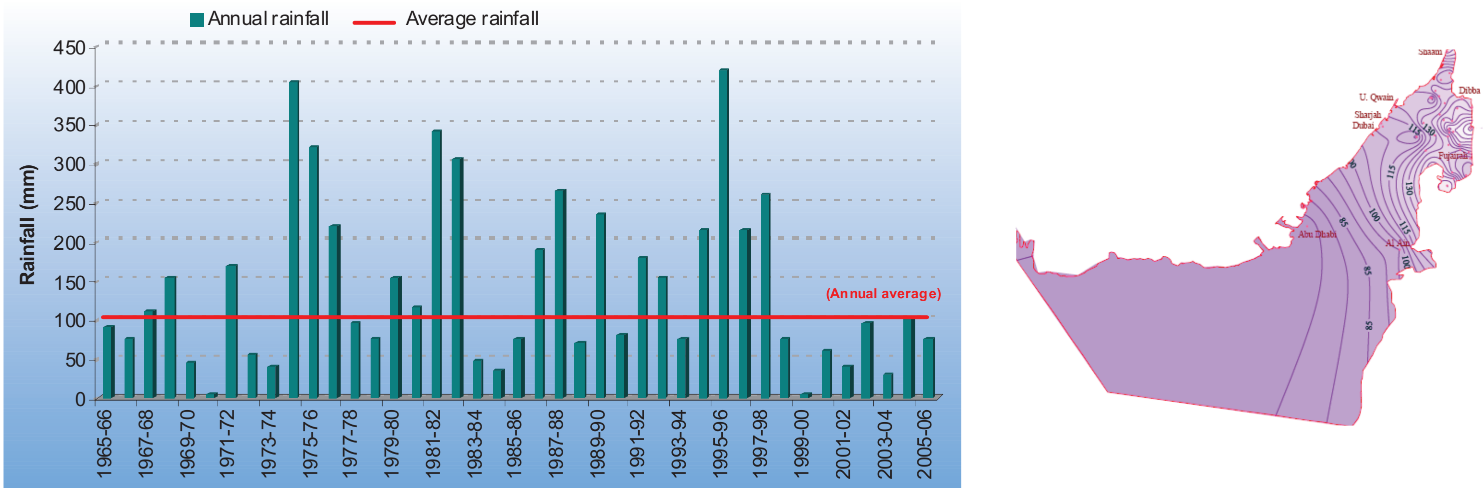
There are 60 surface water catchments defined in the UAE, of which 48 are located in the Northern Emirates and 12 in Abu Dhabi Emirate. The areas of these catchments range from 3 km^2 at Khat to 1362 km^2 at Idayah, Table 1.1. The Al Hajar Mountain group in the Eastern Region divides the surface catchments into two main orientations – those draining towards the Gulf of Oman in the east, and those draining to the desert and Arabian Gulf in the west.

The wadi flow patterns found reflect the characteristic of rainfall storms and the nature of the catchments. Generally the minimum rainfall required to produce runoff was 75 mm in the Oman basin and 90 mm in the Jabel Hafit basin (Rizk and Al Sharhan, 2003). In the Eastern Region intense or prolonged storms over the mountainous and impermeable terrain produce seasonal flash floods. In contrast in the Western Region flow is limited by the low rainfall of 40 mm/year, high evaporation rate of 3,360 mm/year, and relatively flat and permeable terrain.

Several studies have estimated the average annual surface water flow in the Eastern Region. Rizk and Al Sharhan (2003) estimated the percentage of rainfall as runoff to range from 3% in Jabal Hafit basin to 18% in the Northern Oman Mountains. Based on these percentages, the potential average annual surface water flow can range between 23 million cubic meters (Mm^3) to 138 Mm^3 per year (MOEW, 2009), Table 1.1. According to Rizk and Al

Sharhan (2003), the highest flood potential was in the Wadi Sidr (Northern Oman Mountains) and Wadi Al Faydah (Jabal Hafit), with the highest risks of flash flooding occur in wadis Shik, Sidr and Ayn Al Faydah.

Figure 1.1: Average Annual Rainfall and Rainfall Distribution in United Arab Emirates



Source: MOEW, 2009.

Table 1.1: Estimated potential surface water flow in the UAE

Catchment	Area km²	Average Annual Rainfall, mm	Surface Water Flow, Mm³	
			At 3% of Rainfall	At 18 % of Rainfall
May	61	130	0.24	1.42
Ghalilah	76	136	0.31	1.86
Madah	95	130	0.37	2.22
Zikt	100	148	0.44	2.66
Naqab	107	137	0.44	2.63
Wurrayah	137	145	0.60	3.58
Hatta	164	145	0.71	4.28
Wahala	195	121	0.71	4.25
Al Maksar	214	140	0.90	5.39
Ham	291	140	1.22	7.33
Al Ghoure	340	150	1.53	9.18
Al Bih	476	121	1.72	10.35
Tawiyean	503	133	2.01	12.04
Limhah	1,236	125	4.64	27.81
Idayah	1,362	120	4.90	29.42
Sub-total			**20.74**	**124.41**
Remaining 45 catchments			2.26	13.59
UAE Total			**23.00**	**138.00**

Sources: ICBA compiled from MOEW, 2009.

Dams and diversion structures

To manage the wadi flows and flash floods, a series of 114 multi-purpose dams were constructed from the early 1980s. Benefits include increasing groundwater recharge; protecting people and farmland from flood damages; storing water to meet local agricultural water demand; conserving downstream areas from erosion; reducing water losses to the ocean; and limiting seawater intrusion in coastal areas. The MOEW directly manages 66 of the 114 dams, Figure 1.2.

Figure 1.2: Photo of Ghalilia Dam

Source: MOEW, 2009.

Dams and barrier have been constructed along the main wadis in all seven Emirates; the majority being in the north where significant flash floods occur. In Abu Dhabi Emirate, where flash flooding is less of a problem, only one recharge dam and series of recharge basins have been in Wadi Sumeni with a combined storage capacity of 31.5 Mm^3.

The total storage capacity of the dams in the UAE is about 118 Mm^3, of which the total design capacity of the largest 16 dams is about 100 Mm^3 (Table 1.2). Water retained by the largest nine dams over the period 1982 to 2000 was 178 Mm^3 and this had increased to 211 Mm^3 by 2007, Figure 1.3.

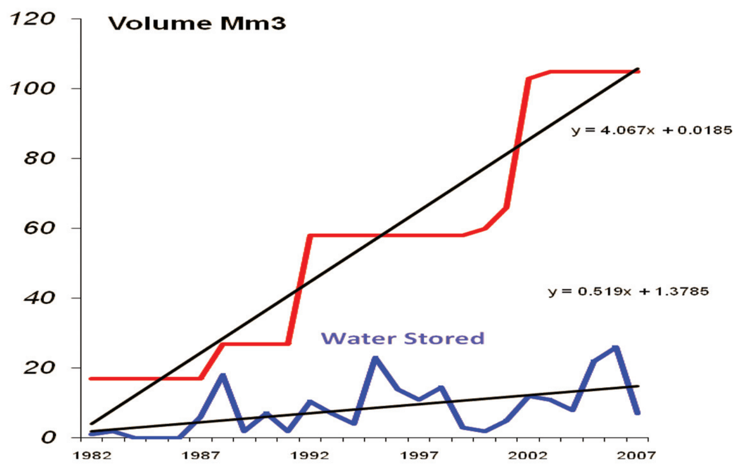
Table 1.2: Main reservoir capacities by Emirate

Emirate	Dam Name	Design Capacity (Mm^3)	Area Benefitted
Abu Dhabi	Shwaib	31.500	Shwaib farm areas
Dubai	Hatta	11.200	Hatta
Fujairah	Tawiyeen	18.500	Tawiyeen-Hamraneyah-Khat
Ras Al Khaimah	Albeeh	9.742	Berairat-Nakheel
Fujairah	Ham	7.800	Fujairah-Kalba
Fujairah	Wuraya	5.200	Bidya-Khorfakkan
Fujairah	Alowais	3.500	Dhadnah
Ajman	Hadhaf	3.000	Muzera-Masfut
Fujairah	Baseerah	1.600	Baseerah-Dibba
Fujairah	Ham 16 D	1.500	Fujairah
Fujairah	Alseeji Main Dam	1.000	Alseeji-Dhaid Plain
Ras Al Khaimah	Alqasah	0.720	Alkasa-Kadra
Fujairah	Marbah-Qidfa	0.600	Marbah-Qidfa
Ras Al Khaimah	Sufini	0.600	Sufini-Kadra-Dhaid Plain
Ras Al Khaimah	Alqor	0.584	Almunaye-Alhawelat
Ras Al Khaimah	Rabqa	0.542	Rabqa-Almunaye
Fujairah	Fay	0.500	Baseerah-Dibba
Ras Al Khaimah	Buraq	0.500	Buraq-Saeh Fili
Total		**98.600**	

Source: MOEW, 2009.

Analysis of the relationship shown in Figure 1.3 between the reservoir capacity created and the volume of water stored indicates that for every 4.01 m^3 of storage created about 0.52 m^3 of water is captured, a ratio of 13%.

Figure 1.3: Annual storage versus cumulative capacity storage behind dams



Source: MOEW, Dubai Municipality, 2009.

Dam Recharge Efficiency

An important objective of the dam construction is to increase the recharge of the aquifers. This can be affected by many variables such as porosity of the reservoir floor, rate of releases and subsequent infiltration through the downstream wadi bed, and rate of evaporation from the lake. As case studies in other countries have shown, dams and their reservoirs need to be managed actively to maximize their efficiency.

An assessment study on dam recharge efficiency was conducted on three main dams in the UAE: Ham, Bih, and Tuween where the percentage of water that had percolated from the reservoir into the groundwater was measured using isotope hydrology. The recharge efficiency for Ham Dam was 47%, Tween Dam 22%, and Bih Dam 31%. The balance was lost to evaporation or was retained in the unsaturated/soil zone. These findings suggested that recharge efficiency could be further enhanced if the 10-15 cm of accumulated silt on the wadi floors was removed to expose the predominantly gravel top layer, thus increasing percolation.

Investment in dams

The construction of dams represents a significant investment; typical costs for completed projects are shown in Table 1.3.

Table 1.3: Cost of dams constructed 2001-2004

Year Constructed	Dam Group	Number of Dams	Storage Capacity Mm^3	Cost	
				AED million	USD million
2001	Zaid Phase 1	27	5.9	210	56.8
2002	Zaid Phase 2	28	7.1	320	86.5
2003	Zaid Phase 3	2	0.4	28	7.6
2004	Zaid Phase 4	1	0.1	6	1.5
Total		**58**	**13.4**	**564**	**152.4**
Average Cost per m^3				42	11

Sources: ICBA based on MOEW database, 2009.

Future Dam Development

The Federal government is planning to extend its flashflood dam construction program and build 68 new dams in the coming years (H2O, 2008), to bring the total number to 182. It is anticipated that this will go some way to achieving the objectives of increasing the availability of fresh surface water supplies, and increasing groundwater recharge to prevent further deterioration in groundwater resources. About 54 dams are proposed for the Northern Emirates with a total storage capacity of 2.7 Mm^3. There will be 29 in Fujairah, 19 in Ras Al Khaimah, 5 in Sharjah and 1 in Umm Al Quwain. This planned increase in storage of 2.8 Mm^3 from the 54 dams will cost an estimated investment about 228 million AED (MOEW, 2009). The costs of the proposed dams are more expensive than those built to date because the most economical sites have already been developed and more will be built from concrete, Table 1.4.

Table 1.4: Capital Cost of Proposed Dams

Dam Construction Material	Number of Dams	Storage Capacity Mm^3	Cost	
			AED million	USD million
Concrete	15	0.31	51	14
Earth	36	2.28	163	44
Gabion	3	0.21	14	4

Sources: ICBA based on MOEW database, 2009.

Cost of Water Stored in Dams

The historic hydrologic data shows that given 13% capture efficiency, it requires an average about 8 m^3 of reservoir storage to capture 1 m^3 of water. When groundwater recharge efficiency is taken into account, between 2-5 times this volume is required to ensure 1 m^3 of groundwater recharge. Therefore groundwater recharge of 1 m^3 will require between 16 and 40 m^3 of reservoir storage.

Using the capital cost data above, and assuming that dams have an effective lifespan of 30 years and that annual operation and maintenance is 5% of capital investment, the present cost of capturing rainfall and converting it to groundwater storage is as shown in Table 1.5.

Table 1.5: Cost of water from Dams

	Old Dams Table 1.3	New Gabions	New Earth	New Concrete
Capital Cost per m^3	11.00	18.00	20.00	58.00
Annual O&M cost	0.55	0.80	1.00	2.60
Net Present Cost per USD/m^3 over 30 years	0.51	0.84	0.93	2.43
Cost of Recharged Groundwater USD/m^3				
At 50% recharge efficiency	1.02	1.68	1.86	5.86
At 20% recharge efficiency	2.55	4.20	4.65	29.30

Sources: ICBA based on MOEW database, 2009.

Several conclusions emerge from this analysis. First, water capture by dams is not cheap even at high (50%) conversion efficiencies to groundwater recharge. Second, at lower recharge efficiencies the cost of conserved rainwater becomes more expensive than desalinated water. And third, there is no economic justification for concrete dams.

Other surface water bodies

In addition to the wadi flows, water is potentially available from artificial lakes and ponds.

Artificial Lakes and Ponds

Artificial wetlands, lakes and ponds were mostly created for recreation, beautification, conservation and biodiversity protection purposes. Most of these lakes and ponds are supplied from springs, groundwater or desalinated water. There are many lakes and ponds forming the Al Wathba Wetland Reserve which is the largest wetland and the first protected area declared by Royal Decree in the Emirate of Abu Dhabi (ERWDA, 2001). Other significant lakes and ponds include: Mubazzarah, Ruwais Town Centre Lakes, Abu Dhabi Golf Club and Ain Al Fayda in Abu Dhabi Emirate. These are locally important for the environment.

Main findings and recommendations

1. While there has been significant capital investment to build dams in main wadis more attention is needed to maximize water conservation. Under present operational policies less than half the flood water captured and stored is beneficially used for groundwater recharge. Research is needed to determine the best way of increasing recharge efficiency from dams, including determining recommendations for dam location vis-à-vis groundwater recharge and improved policies for reservoir management and water release to downstream riparian zones.
2. Integrated watershed management of both quantity and quality of surface water should be implemented. This will require expanding hydrological monitoring in wadis of high potential to capture runoff.

GROUNDWATER

Introduction

Traditionally, groundwater was the main source of water for all uses in UAE. UAE civilization started close to springs, but due to aridity, small number of springs were found and used. The main springs were found in the eastern and northern regions. Table 1.6 describes the main springs, the volume of discharge, the quality and region.

Table 1.6: Main Existing Springs

Spring Name	Discharge (m^3/day)	Salinity (ppm)	Region	Notes
Mudab	80	1200	Eastern	Active
Al Warea'	933	450	Eastern	Active
Al Ghumor	750	1400	Eastern	Active
Khat	4320[1]	1450	Northern	Active

Source: Water Statistics Book for GCC, 2008.

The UAE people used the falaj system, which is the traditional groundwater management system involving a shallow lateral tunnel dug uphill to intersect the water table. Aflaj (plural of falaj) are still found in a number of areas in the UAE, Table 1.7. The water allocation system of the aflaj ensured sustainability over thousands of years.

Table 1.7: Main Existing Aflaj Systems

Falaj Name	Type	Length (m)	Salinity (ppm)	Region	Notes
Al Raheb	Gheli	500	450	Eastern	Active
Sakamkam	Gheli	500	525	Eastern	Active
Madok	Gheli	3000	450	Eastern	Active
Al Farfar	Gheli	2000	650	Eastern	Seasonal
Al Hewelat	Gheli	3200	1200	Central	Seasonal
Hatta	Gheli	1150	720	Central	Seasonal
Nusla	Gheli	1200	1000	Central	Seasonal
Northern Khat	Gheli	1000	1400	Northern	Seasonal
Southern Khat	Gheli	1000	1400	Northern	Seasonal
Almoured	Gheli	3000	1000	Northern	Active
Habhab	Dawodi	500	700	Northern	Water flow from nearby well

Source: Water Statistics Book for GCC, 2008.

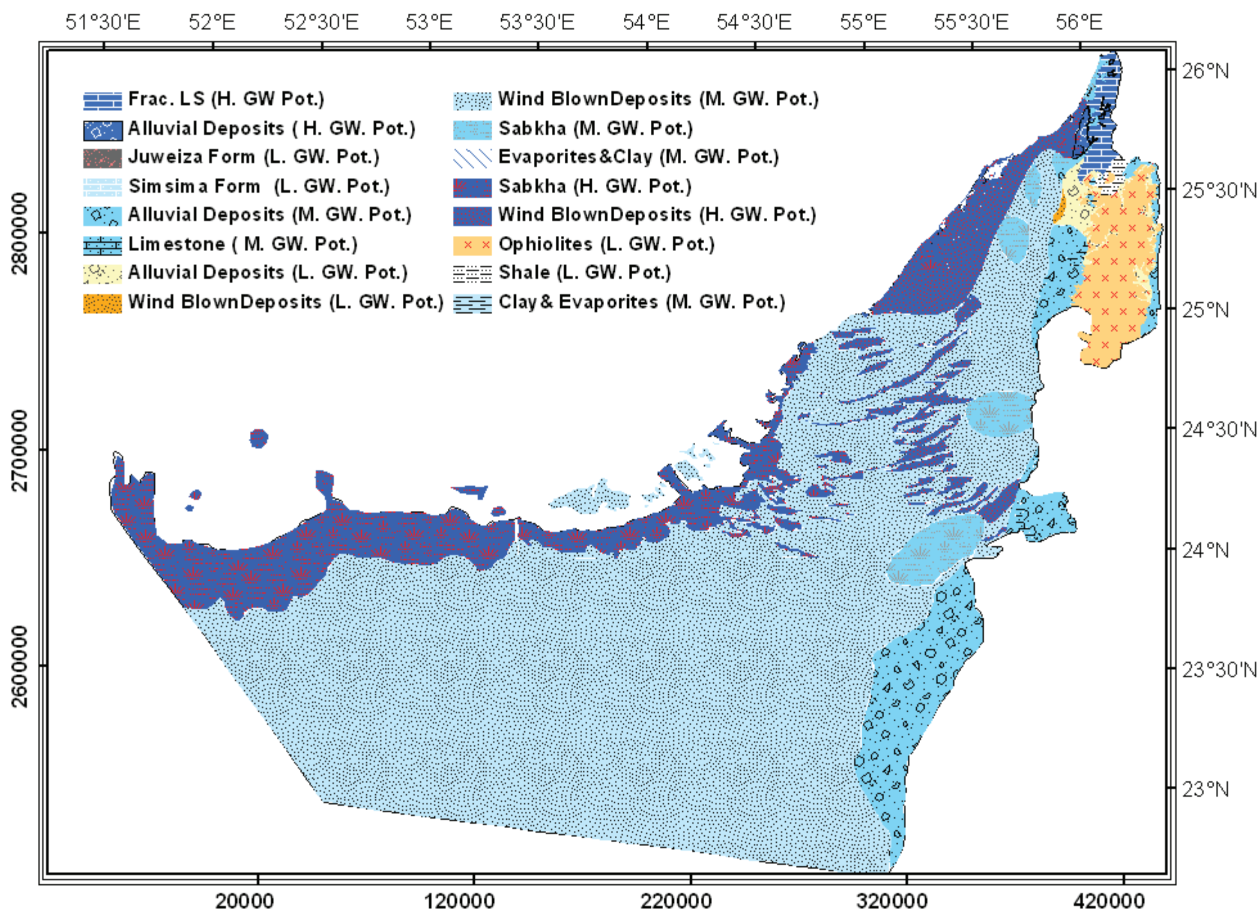
As a result of the country's fast economic development since the 1960's, a huge number of wells have been drilled. Most of these wells were drilled close to agricultural and forest areas as in Al Ain and in the Northern Emirates near fresh groundwater sources. Fresh groundwater became insufficient to meet the increasing demand for water and so the reliance on brackish groundwater gradually increased to substitute for the shortage of fresh groundwater for agricultural and forestry purposes. These human activities have caused over-exploitation of the groundwater resource, thus depleting the reserve to more than half that of the pre-development storage. Brackish groundwater was depleted at a steeper rate than the freshwater depletion rate.

At the national level, there is a reliable quantity of potential groundwater that could be kept as a future strategic reserve, but at the local level and particularly under existing agricultural and forestry areas it is found that groundwater reserves are very limited. Their fast depletion can be directly linked to over-exploitation for agricultural and forestry irrigation. This will be explained more in the following sections. Description of the hydrogeological setting and aquifer occurrences are discussed first, followed by highlights on water balance and groundwater potential.

Hydrogeology

The hydrogeology of aquifer system in UAE can be classified into two main aquifer systems: the Shallow Aquifer and the Deep Aquifer. The Shallow Aquifer is mostly of Quaternary age and consists of alluvial deposits, wind blown deposits, and evaporates. The Deep Aquifer occurs mainly in fractured limestone rocks, igneous rocks (Ophiolite), and carbonate rocks (Figure 1.4). Carbonate aquifer occurs at significant depths and it has been less explored and used. Each aquifer system is explained in the following sections.

Figure 1.4: Hydro geological map of United Arab Emirates



Source: Ebraheem and Al Mulla, 2009.

Groundwater storage (productivity) and quality varies spatially and in depth in both the Shallow and Deep Aquifer systems. For example, in the Shallow Aquifer, alluvial deposits water quality is fresh with high, moderate, and low groundwater potential as shown in Figure 1.4, while the Simsima Aquifer (Deep Aquifer) water quality is brackish with low groundwater potential (Table 1.8). A detail of water quality and groundwater potential is presented in Table 1.8.

Table 1.8: Groundwater potential in main aquifers

Aquifer System	Aquifer Name	Emirate / Region	Groundwater Type	Groundwater Potential
Shallow Aquifer	Alluvial Deposits	Northern Emirates	Fresh	High
			Fresh	Moderate
			Fresh	Low
	Wind Blown Deposits	Northern Emirates	Brackish	High
		Northern Emirates and Abu Dhabi Emirate	Brackish	Moderate
		Northern Emirates	Brackish	Low
	Sabkha	Coastal Area of Northern Emirates and Abu Dhabi Emirate	Highly Saline	High
		Inland Areas of Northern Emirates and Abu Dhabi	Highly Saline	Moderate
	Evaporates and Clay	Northern Emirates	Brackish	Moderate
	Clay and Evaporates	Northern Emirates	Brackish	Moderate
Deep Aquifer	Juweiza Aquifer	Northern Emirates	Brackish	Low
	Ophiolites Aquifer	Northern Emirates	Brackish	Low
	Fractured Limestone Aquifer	Northern Emirates	Fresh- Slightly Brackish	High
	Limestone Aquifer	Abu Dhabi (South Al Ain)	Brackish-Slightly Saline	Moderate
	Shale Aquifer	Fujairah	Brackish	Low
	Simsima Aquifer	Abu Dhabi	Brackish	Low

Sources: ICBA, 2010 after Ebraheem and Al Mulla, 2009, and IWACO, 1986

Occurrence of aquifers in Northern Emirates

The aquifer system in Northern Emirates consists of the following aquifers:

1. The Shallow (Quaternary) Aquifer
2. The Deep Aquifer, which consists of the following aquifers:
    1. Juweiza Aquifer
    2. Northern Limestone Aquifer (Carbonate (Hajar) Aquifer)
    3. Ophiolite Aquifer.

The importance of each aquifer, aquifer characteristics, hydraulic properties, and groundwater quality are described below:

1. The Shallow Aquifer (Quaternary Aquifer)

This aquifer is composed of shallow unconsolidated Alluvial/Eolian deposits and is considered the main water source for all uses. The aquifer is hydrogeologically unconfined, while the lower part is considered a semi-confined aquifer. This aquifer system consists of two aquifers:

a. Eastern Gravel Aquifer:
Composed of alluvial and contains fresh groundwater, recharged from rainfall.

b. Western Gravel Aquifer:
Composed of sand and gravel with thin interbeds of silt and clay, recharged from rainfall near the eastern mountains. Groundwater salinity ranges from 1000 to 3500 mg/l in Al Ain, Dibba, Hatta, Khatt and Fujairah areas. Salinity of 3500 to 6500 mg/l exists near Ras Al Khaimah, Madinat Zayed, Liwa and Dubai. Salinity greater than 10000 mg/l exists in Dhaid, west and south of Al Ain, and Kalba areas.

The dominant quality of water in this aquifer is brackish to saline water except in areas along the structural ridge particularly in the vicinity of Bajada where there is high potential of fresh groundwater as in the area close to Meleihah. Most of domestic production wells of SEWA are located in this area (Meleihah) (Ebraheem and Al Mulla, 2009).

Aquifer productivity varies within the Quaternary Aquifer, where moderate productivity was noticed in areas adjacent to the Structural Plain, and low productivity north of Al Dhaid area. High specific yield values were noticed in this aquifer particularly in areas dominated with faults and structures. The average Transmissivity value was about 776 m^2 / day, while storage coefficient was about 0.024, Table 1.9. These values were noticed in such places as close to the fault zone near the Jabal Meleihah, near the Dibba Line and the fault zone at the margin of Oman Mountains.

Regional groundwater flow in Quaternary Aquifer is from southeast to northwest. This regional flow is disturbed by major cones of depressions under agricultural areas that heavily abstract groundwater in these areas (Al Dhaid area). The estimated drawdown in the middle of Al Dhaid for the period 1969-2008 exceeded 110 meters (IWACO, 1986).

Table 1.9: Transmissivity and storage coefficient of the Quaternary Aquifer of Northern Emirates

Well Name	Transmissivity (m^2/ day)	Storage Coefficient
GP-12	213	0.003
GP-4	320	0.003
GP-1	520	0.006
GP-2	437	0.003
GP-3	185	0.024
GP-6	307	0.024
GP-7	200	0.004
GP-10	50	0.001
GP-11	60	0.001
GP-14	87	0.003
GP-15	413	0.001
GP-16	120	0.003
GP-17	110	0.002
GP-19	500	0.010
MF-1	175	0.010

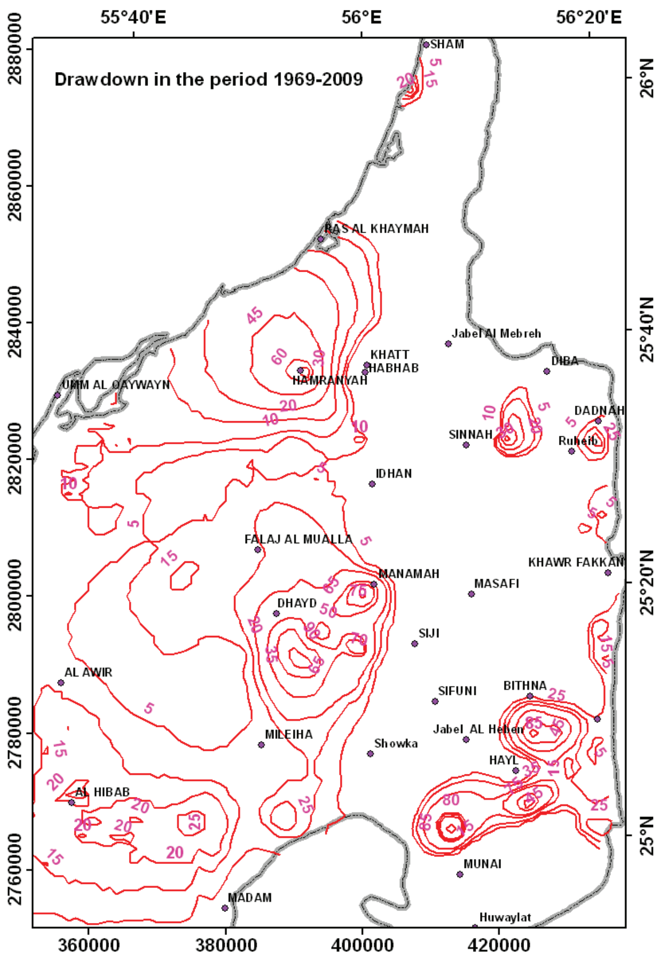
Source: after IWACO, 1986.

The depth to water table ranges from less than 20 m close to coastal areas to 200 m in mountain areas of the Northern Emirates close to the Dhaid area. The saturated thickness of the Quaternary Aquifer varies spatially. However, some aquifers are thin and their potential to store water is very limited (less than 10 m) in the Sand Aquifer of the Eastern Region.

The decline of groundwater level is great in the Quaternary Aquifer and reaches 60 m to 80 m as in Al Hamranyah and Jabal Al Heben, Figure 1.5. These high decline zones are close to the intensive agricultural areas of the Northern Emirates.

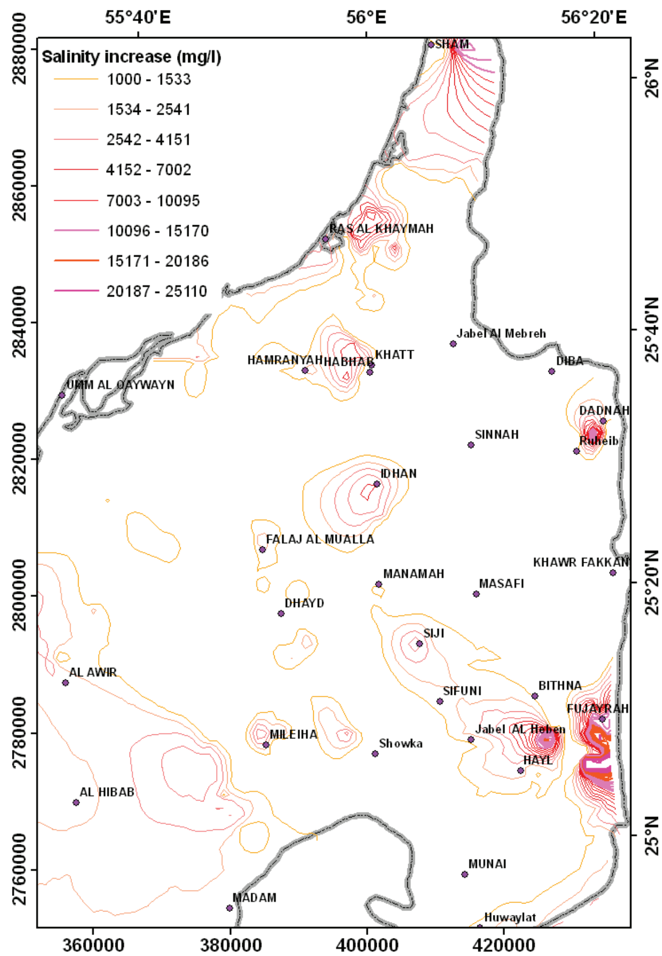
The impact of intensive irrigation in addition to causing cones of depressions that changes groundwater flow direction is increasing salinity levels. This increase in groundwater salinity ranged from 500 mg/l to 8000 mg/l during the period 1969-2008 as noticed in several areas (Hamranyah, Digdaga, Dhaid, Idhn) (Figure 1.6).

Figure 1.5: Groundwater level decline in the Quaternary Aquifer of the Northern Emirates for the period 1969-2009



Source: Ebraheem and Al Mulla, 2009.

Figure 1.6: Increase in groundwater salinity levels of the Quaternary Aquifer of the Northern Emirates in the period 1969-2008



Source: Ebraheem and Al Mulla, 2009.

2. Deep Aquifer

2.1 Juweiza Aquifer (called also Lower Aquifer)

Juweiza aquifer is a semi-confined low permeable aquifer of Upper Cretaceous age, composed of clay and gravel. Low permeable deposits composed of chalky limestones exists near Dhaid area. Water bearing potential exists close to karstic limestones near Meleihah, and in the conglomerate layer. This layer consists of assorted gravels interbedded with limestone and dolomite, and is considered the most productive layer in the Lower Aquifer (Meleihah area). Aquifer productivity and potential depend on the existence of this conglomerate layer (IWACO, 1986).

Aquifer hydraulic characteristics vary along the aquifer. For example, transmissivity ranged from 2.7 to 1166 m^2/day, with weighted average of 50 m^2/day. Storage Coefficient (s) ranged between 0.001 and 0.02 with an average value of 0.0028 (JICA, 1996). Table 1.10 summarizes transmissivity and storage coefficient values in Juweiza Aquifer.

2.2 The Northern Limestone (Carbonate (Hajar) Aquifer

The Northern Limestone aquifer (Wadi Bih Aquifer) is composed of fractured limestone and dolomite is dominant in Wadi Bih of Permian to Triassic age (Rizk and Alsharhan, 2003). The Limestone (Fractured Rock) Aquifer is found in the fracture zones of Oman Mountains. Groundwater flow occurs in fractures and faults, for example, karstic springs.

The Carbonate Aquifer is composed of well jointed, karst weathered, thin bedded, nodular, fragmental and porcellanous dolomitic limestones and also limestones interbedded with calcareous shales.

Fractured limestone has high groundwater potential and high transmissivity values, while limestone with less fracture has medium groundwater potential and less transmissivity values. Table 1.11 summarizes the Hajar Aquifer transmissivity and storage coefficient values (IWACO, 1986).

2.3 Ophiolite Aquifer

The Ophiolite aquifer is composed of fine to medium-grained igneous rocks, characterized by joints and fractures. Hawasina and Semail Ophiolite rocks are hydrogeologically considered hard rocks with limited permeability. However, fracturing and weathering from regional tectonics in these hard rocks have caused higher porosity and permeability. The frequency of occurrence of fractures has generally been found to decrease with depth. The Ophiolite aquifer has good freshwater resources.

The Hawasina and Semail Ophiolite rocks are classified as having limited groundwater resources. Semail Ophiolite rocks are often higher productive than Hawasina rocks. Generally, agricultural wells tapping this aquifer have a yield of less than 10 m^3/hr (IWACO, 1986).

Table 1.10: Transmissivity and storage coefficient of Juweiza Aquifer of Northern Emirates

Well Name	Transmissivity (m^2/day)	Storage Coefficient
GP-1A	7.6	0.006
GP-2	2.7	-
GP-3	6.1	0.001
GP-6	1166	0.020
GP-10	264	0.001
GP-11	480	-
GP-14	230	-
GP-15	156	-
GP-16/16A	120	0.003
GP-17	110	-

Source: after IWACO, 1986.

Table 1.11: Transmissivity and storage coefficient of Hajar Aquifer of Northern Emirates

Well Name	Transmissivity (m^2/day)	Storage Coefficient
RK-11	580	0.1
RK-14	2800	0.1
RK-15	140	0.1
RK-16	66	0.1

Source: after IWACO, 1986.

Occurrence of aquifers in Abu Dhabi Emirate

The aquifer system in Abu Dhabi Emirate can be classified into two main aquifers:

1. The Shallow Aquifer (Surficial Aquifer)

The surficial aquifer is unconfined and consists of shallow, unconsolidated alluvial and eolian deposits mostly of the Quaternary period. The sand dunes and alluvial deposits are the most productive aquifers in the Emirate. These deposits extend over 80% of Abu Dhabi Emirate (about three-quarters of the UAE area), from the sea to the desert near Liwa. In the Eastern Region the main aquifers are Quaternary sand and gravel aquifers, while in the Western Region, the main aquifer is Quaternary sand aquifer (EAD, 2009).

Groundwater quality varies within the shallow aquifer. Fresh to slightly brackish groundwater exists in Quaternary sand dunes between Liwa and Madinat Zayed (Moreland, 2007), while brackish to slightly saline water occurs farther to the north and east of Liwa crescent vicinity. The highest salinity occurs in the narrow highly saline coastal strip (sabkhas). Sabkha salinity ranges from 10,000 mg/l to 250,000 mg/l.

The depth of the water table in the surficial aquifer ranges from less than 20 m close to coastal areas and in the sand dune aquifer in the Liwa Region to 100 m in the Eastern Region (close to the Al Ain part of the sand and gravel aquifer).

The sand dune aquifer in the Western Region is the main groundwater reserve for the Emirate. This aquifer has the highest saturated thickness in that region (Liwa vicinity, particularly along the western border with Saudi Arabia) the saturated thickness ranges between 75 m to 150 m and the highest specific yield of about 26%.

2. Deep Aquifer

2.1 Eastern Limestone Aquifer (Jabal Hafit Aquifer)

Composed of interbedded limestone and marl of Middle Eocene Dammam Formation. Water is slightly alkaline and Total Dissolved Solids (TDS) ranges between 3900 and 6900 mg/l. Three water bearing zones exist: fresh water zone, a mixing zone of fresh and brackish water, and deep saline zone.

2.2 Bedrock Aquifer

The bedrock aquifers are found in carbon rock formations. Bedrock aquifers occur generally throughout the Emirate at significant depths and have not been explored or exploited like the shallow unconsolidated aquifers. The main bedrock aquifers are found in the following formations (EAD, 2009):

1. The Asmari Formation;
2. The Karstic Limestone Formations;
3. The Dammam and Rus Formation;
4. The Rus Formation;
5. The Umm er Radhuma Formation; and
6. The Simsima Formation.

Groundwater recharge

The main recharge episodes of the aquifers took place many thousands of years ago. Researchers have shown that there were important recharge events 9,000-6,000 years Before Present (BP) and 32,000-26,000 years BP (Neff *et al*. 2001; Woods and Imes, 2003; Woods et al. 2003). Today, the direct recharge from rainfall to aquifers is minimal, meaning that any water withdrawals are essentially mining the resource. The annual recharge to groundwater for the whole UAE is estimated to range from 22 to 32 Mm^3 (Rizk, 2003), while Khalifa (1995) gives value to be around 109 Mm^3. Further estimates by the MOEW showed a higher recharge range of 140 to 190 Mm^3 (MOEW, 2009).

The recharge to groundwater occurs primarily through sub-wadi flows from the mountains (the Jaww Plain and around Jabel Hafit) with further contributions from infiltration from surface wadis during periods of intense rainfall, and irrigation returns in agricultural areas. The shallow-alluvial aquifers are most rapidly recharged by rainfall events. The fan deposits are the main recharge zone for the desert aquifers to the west and the coastal alluvial plain to the east of the mountains. No rainfall-recharge occurs through the dune sands. About 15% of rainfall that drains the wadi surface percolates into the wadi floor and infiltrates to groundwater. This causes groundwater baseflow to discharge to the wadi floors. Estimates of lateral inflow from the 24 largest wadis amounts to 0.8 Mm^3 per year, with an additional 0.063 Mm^3 per year from surface flow (Robins *et al*., 2006).

In the Al Ain area, estimates for the 17 wadis emerging onto fan deposits showed that the cumulative sub-wadi interflow through the wadi gravel is 0.13 Mm^3/day, and the cumulative average annual surface water runoff is 10,370 Mm^3/day, with the six largest wadis accounting for nearly 70% of the total runoff (Imes *et al*., 1993; Robins et al., 2006).

Groundwater reserve

Carbonate aquifer. The total volume of groundwater reserve in the Carbonate aquifer is estimated to be about 374 km^3. This estimation was based on aquifer area, saturated thickness, and specific yield for each aquifer Table 1.12 (Ebraheem and Al Mulla, 2009).

Table 1.12: Groundwater reserve in the Carbonate Aquifer in UAE

Aquifer	Region	Saturated Thickness (m)	Area (km^2)	Specific Yield (%)	Water Quality / Category	Groundwater Reserve (km^3)	Recharge (Mm^3)
Hajar	North Wadi Bih (RAK)	130	370	0.1	Fresh to Slightly Brackish	4.8	7
Hajar	South Wadi Bih (RAK)	250	270	0.1	Fresh to Slightly Brackish	6.8	3
Hajar	Sharjah (near RAK-15)	170	30	0.1	Fresh to Slightly Brackish	0.5	0.4
Carbonate	Abu Dhabi (West)		57,000		Saline	326.7	
Carbonate	Abu Dhabi (East)				Saline	35.2	
Total						**374**	

Sources: Ebraheem and Al Mulla, 2009 after IWACO, 1986, and GTZ, 2005.

superficial aquifer. The volume of fresh and brackish groundwater reserve (< 10,000 mg/l) in the superficial aquifer was estimated to be about 470 km^3 as a product of area, saturated thickness, and specific yield for each region. These estimates were compiled from previous studies of Abu Dhabi Emirate by USGS and GTZ, and extrapolated to cover the remaining Northern Emirates based on the MOEW database (USGS, 1996; GTZ, 2005; MOEW, 2009) (Table 1.13). It is important to note that more than 50 km^3 of slightly saline groundwater (15,000 mg/l to 20,000 mg/l) could be considered as an additional potential groundwater reserve (Figure 1.7).

Table 1.13: Groundwater Reserves per Groundwater Quality (2005)

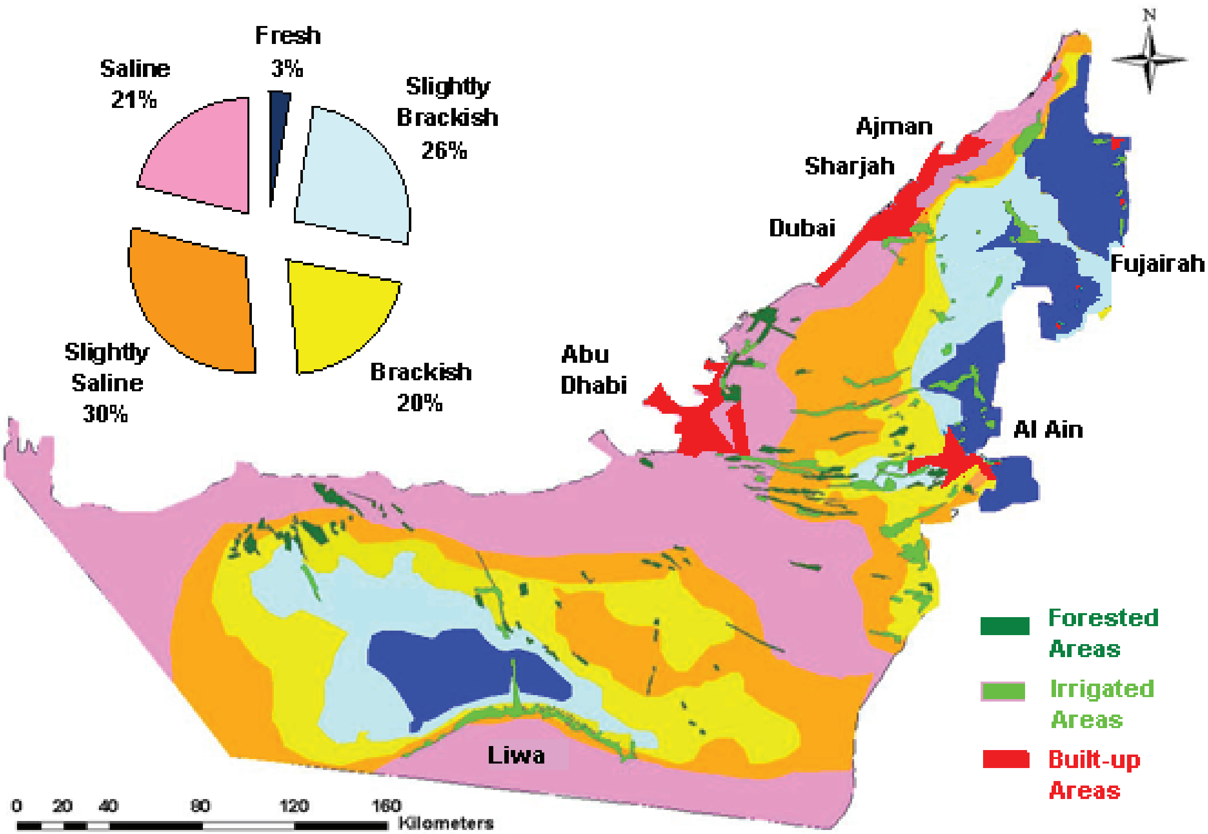
Salinity Zone	Abu Dhabi (Km^3)	Dubai (Km^3)	Sharjah (Km^3)	Ajman (Km^3)	Umm Al Quwain (Km^3)	Ras Al Khaimah (Km^3)	Fujairah (Km^3)	Total (Km^3)
Fresh (<1500 mg/l)	18.5	0.03	0.53	0.00	0.03	0.55	0.26	20
Slightly Brackish (1501-5000 mg/l)	188	0.54	0.46	0.00	0.12	0.92	0.15	190
Brackish (5001-10000 mg/l)	147	0.50	0.05	0.01	0.10	0.19	0.04	148
High Brackish (10001-15000 mg/l)	114	0.40	0.05	0.05	0.06	0.01	0.02	115
Total Fresh and Brackish	**468**	**1.47**	**1.09**	**0.07**	**0.31**	**1.66**	**0.47**	**473**
Slightly Saline (15001-20000 mg/l)	56	0.02	0.05	0.01	0.03	0.01	0.01	56
Total Including Slightly Saline	**524**	**1.49**	**1.14**	**0.08**	**0.34**	**1.66**	**0.48**	**529**
Saline (20001-25000 mg/l)	54	0.04	0.04	0.01	0.02	0.00	0.01	54
Total Including Saline	**578**	**1.53**	**1.18**	**0.09**	**0.36**	**1.66**	**0.49**	**583**
Highly Saline (25001-40000 mg/l)	67	0.04	0.05	0.06	0.04	0.01	0.01	67
Brine (> 40001 mg/l)	90	0.08	0.03	0.02	0.01	0.01	0.00	90
Total (km^3)	**734**	**1.64**	**1.26**	**0.17**	**0.42**	**1.68**	**0.49**	**740**

Source: Ebraheem and Al Mulla, 2009.

The fresh groundwater reserve in the shallow aquifer is about 3% (20 km^3) of available groundwater (fresh and brackish groundwater). Abu Dhabi Emirate has the highest potential of fresh groundwater reserve with more than 73% of fresh groundwater (18.5 km^3) mostly in the Liwa area, 15 km^3 in the Western Region and 3.5 km^3 in the Eastern Region (USGS, 1996; GTZ, 2005; MOEW, 2009). By comparison the remaining emirates have limited fresh groundwater reserves. The breakdown of groundwater reserve per emirate is presented in Table 1.13.

When considering the entire UAE, these quantities reveals that there is a huge potential of groundwater reserve with differing water quality levels. Even after investigating what percentage can be technically and feasibly utilized; a reliable potential groundwater reserve still can be expected. However, looking locally at these reserves under the existing agricultural and forestry areas, Figure 1.7, and assuming minimal lateral flow to these areas, it is clear that limited groundwater reserves are available in these areas. If the demand pattern would continue in the future, then both fresh and brackish local groundwater would be depleted within 10 to 20 years with a faster brackish groundwater depletion rate than fresh water rate as most agricultural and forestry areas are irrigated with brackish groundwater, Figure 1.7.

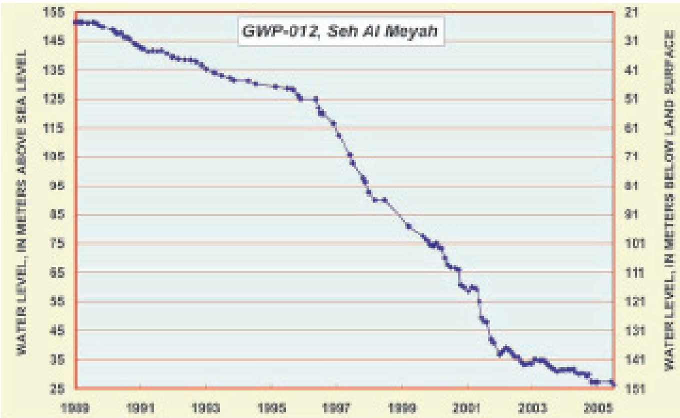
Figure 1.7: Location of Agriculture and Forestry areas versus Groundwater Quality



Source: ICBA 2010, based on data from EAD, MOEW, 2009.

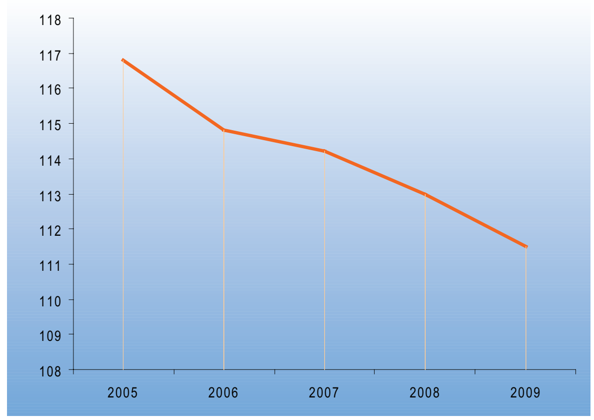
Currently, agricultural land shrinks by 4,200 ha per year due to declining groundwater levels in these areas. The evidence of such high depletion rates is clear in some areas as in Al Sad, Al Ain and Liwa areas (Figure 1.8). In the Al Sad area, for example, there is a steep drop in water level – 125m from the pre-development level over 16 years. This drop is due to the extensive use of groundwater for agricultural purposes; similar water level declines were observed in the Northern Emirates as well (Figure 1.9).

Figure 1.8 Drop of Water level in Abu Dhabi Emirate (GWP-012, She Al Meyah)



Source: EAD, 2009.

Figure 1.9 Drop of Water level in Northern Emirates (Washah Well – OWJ-3)



Source: MOEW Annual Report, 2009.

The potential groundwater reserve estimates for each groundwater salinity zone under agricultural and forestry areas are presented in Table 1.14.The results obtained showed that about 14,000 ha of cultivated areas are underlain by fresh groundwater reserve that accounts for 7.5 % of the available groundwater, while about 35,000 ha of cultivated areas are underlain by brackish groundwater reserve of about 12% of available groundwater.

Table 1.14: Groundwater Reserve per Water Salinity Zone and Use (2005)

Classification	Salinity Level	Agriculture		Forestry	
		Cultivated Area (ha)	Volume (Km^3)	Area (ha)	Volume (Km^3)
Fresh	<1500	14000	1.70		
Low Brackish	1500-7000	8672	1.15	224	0.05
Brackish	7000-10000	25846	1.58	9184	1.04
Slightly Saline	10000-25000	142767	15.08	21772	3.57
Saline	25000-100000	31335	3.26	24429	1.96
Brine	100000-125000	407	0.02	805	0.01
Total		**223,033**	**22.79**	**56414**	**6.63**

Source: ICBA, 2010.

Note: These areas were based on previous available irrigated areas published by MOEW, and did not include the new numbers from MOEW as the spatial locations are not available.

About 140,000 ha of the cultivated areas are underlain by slightly saline groundwater (< 25,000 mg/l) that is about 15 km^3 of potential groundwater. Most probably, these irrigated areas, in addition to areas underlain by saline and brine groundwater, are where desalinated groundwater or other water sources are being used. This also indicates an important potential groundwater reserve for future inland RO desalination.

Water Quality

Water quality reflects the age of the water and the reactions with the surrounding geology. There are a range of salinity levels found in the aquifers and as well there are some naturally occurring concentrations of elements that may be harmful to humans or the environment. Abstraction levels have brought about a decline in the water quality in many aquifers:

- Groundwater of the Liwa Crescent has high chromium concentrations and salinity increases with depth;
- Fluoride has concentrations above the WHO guidelines in parts of the Liwa area and is high to the west of the Liwa area; and
- Chromium - 80% of wells exceeded the WHO guideline (50 µg/l), particularly the fresh waters in the east.

Environmental Impact of Groundwater Use

Due to the rapid expansion in the agricultural area several environmental problems have occurred:

- Over-abstraction of groundwater without wise management and control has caused a sharp drop in water levels in the fresh groundwater region. About 47% of fresh groundwater volume has been depleted in the north-eastern part of Abu Dhabi Emirate (USGS, 2005), and a similar rate was observed in the remaining emirates particularly in the mountainous region. Most of the exploited fresh groundwater was for agricultural purposes.
- Groundwater levels declined at a rate of 10 m per ten years up to the mid-1990s, and have since declined by up to 70 m. Falaj flows have declined continuously since the 1960s (Robins *et al*., 2006).
- Ground-water contamination from land-use practice particularly the widespread growth of agricultural farms in areas underlain by high quality groundwater. Extensive use of pesticides and fertilizers has caused the degradation of groundwater quality in these agricultural and forestry areas. Protection of these fresh groundwater zones could be accomplished by proper land-use planning.
- Over-abstraction has not only affected the quantity removed from storage reserve, but also caused the groundwater quality to be more saline. The water level decline due to abstraction has induced inflow of poorer quality water from deeper aquifers; particularly where wells are open to multiple aquifers and where mixing of groundwater from different zones has increased the water salinity. Most of the groundwater aquifers in the UAE are affected by saltwater intrusion, except the central part of the Ophiolite aquifer. Saltwater intrusion problems exist in Ras Al Khaimah, Al Dhaid, Dibba, Kalba, Dubai (Jebel Dhanna), Madinat Zayed, Liwa and the Al Ain areas (Shiref *et al*., 2005 and Rizk, 2003). In addition, poor well installation practices can allow upward migration of poor quality water through improperly sealed boreholes.
- Rising nitrate concentrations are a problem in many areas due to the over-use of fertilizer and over-irrigation. High nitrate concentrations occurred in Wadi Bih, south of Dubai, Al Ain, Al Khaznah, Madinat Zayed and Liwa. By 1996 41% of all sources that were monitored exceeded the WHO guidelines of 10 mg/l and the highest concentration was 650 mg/l (Robin *et al*., 2006).
- The high rate of groundwater exploitation has caused groundwater decline and prevented natural flows in the desert aquifer towards both the coastal sabkhas and the Gulf and springs discharging in the east.

Recommendations

- Fresh groundwater reserves should be considered as a strategic reserve for the benefit of the public as a whole to meet emergency needs such as a failure in desalinization facilities. Fresh groundwater should be used in an optimal way and prioritized for drinking water purposes.
- Protection of available water resources from any harm or pollution that causes serious degradation to its high quality should be ensured. This could be accomplished through appropriate land-use planning that can serve to protect groundwater resources by limiting activities and industrial operations that are known to pose threats to aquifers, and the initiation of groundwater protection zones around fresh groundwater regions to minimize adverse effects and the risk of pollution.
- Abstraction of groundwater should be planned carefully to ensure sustainable development in the long term, and gradually reduce groundwater abstraction to be within the safe yield of the aquifers. This reduction in groundwater abstraction can also reduce water quality problems by minimizing migration of poor quality water from underlying aquifers.
- Standards to ensure that all wells are designed and installed in accordance with sound engineering standards in a way to prevent cross-flow from deep saline aquifers should be enforced.

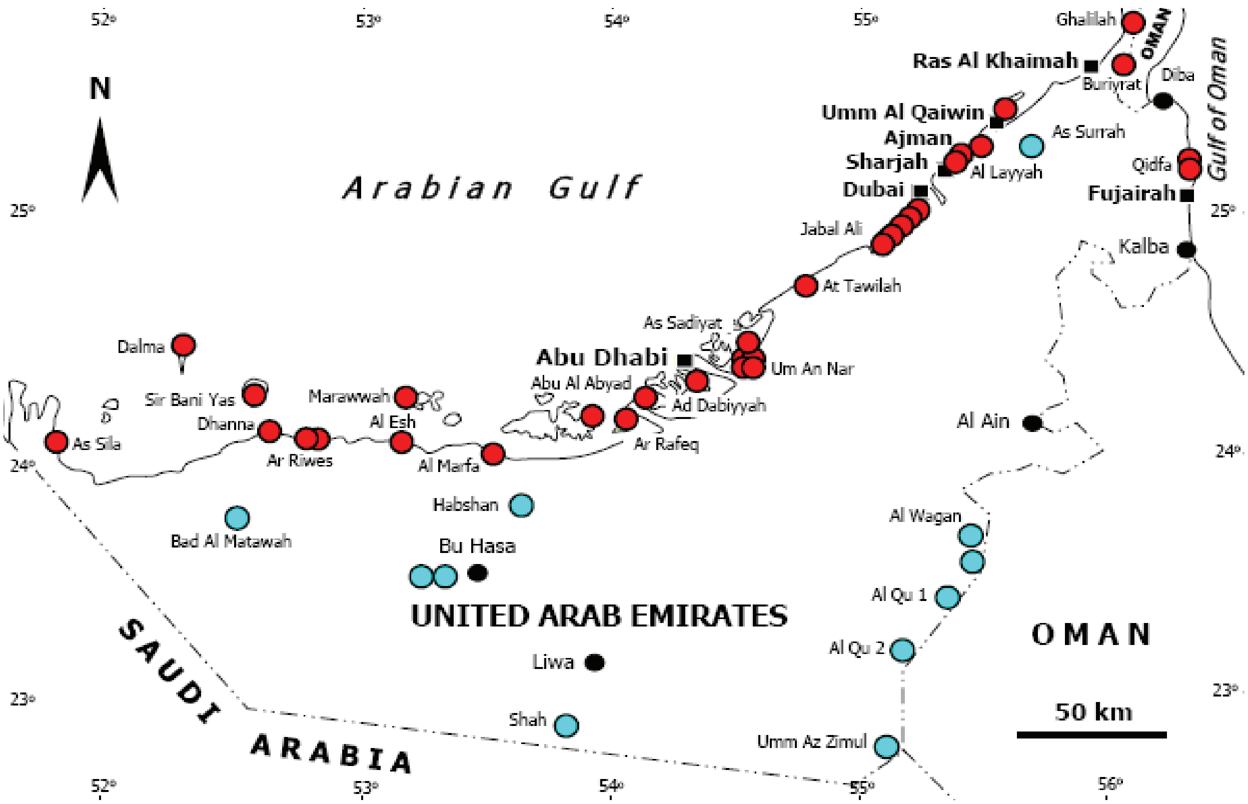
- Standards for using brackish water for irrigation that help protect groundwater resources from possible damage should be developed.
- The greater use of artificial storage and recovery projects to increase water resource potential and storing desalinated water during off-peak night time periods should be investigated and probably expanded (possible locations could be in areas of water level depression).

Desalination

Introduction

Desalinated water is the primary source for potable water use in the UAE. Both seawater and inland water desalination are practised in the country (Figure 1.10).

Figure 1.10: Main coastal and inland desalination plants in United Arab Emirates



Source: Al Asam and Rizk, 2009.

Water desalination capacity and production

Desalination has increased threefold since 2000 in a response to increasing water demand from economic development and population growth. Current national desalination capacity is about 1,700 Mm^3 per year. Abu Dhabi Emirate has the highest share (67%), followed by Dubai Emirate (18%), Sharjah Emirate (10%), while the Northern Emirates account for around 5%. Some desalinated water supplies are transferred between emirates. About 1% of Abu Dhabi's capacity (25 Mm^3) is sold to the Northern Emirates on an annual contract to cover the current shortage of fresh potable water. A new desalination plant in Fujairah Emirate exports 168 Mm^3/year of supplies for consumption in Abu Dhabi Emirate.

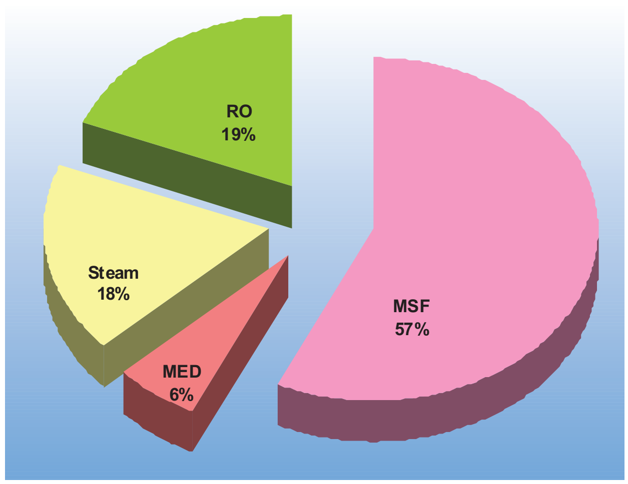
Currently, 70 desalination plants use both use thermal distillation and membrane technologies. Thermal distillation, including multistage flash distillation (MSF) and multi effect distillation (MED), takes place almost predominantly in cogeneration plants where water is distilled from the thermal energy used to produce electricity. Membrane technology is limited to Reverse Osmosis (RO) that uses electrical energy to pump brackish water or seawater through the membranes. Each technology differs in the volume of water required to produce a cubic meter of desalinated water and energy use efficiency, Table 1.15.

Table 1.15: Water and energy requirements for alternative desalination technologies

Environmental requirement or impact	Distillation		RO	
	MSF	MED	Salt	Brackish
Volume of saline feed water per m3 of fresh water	4	3	2 to 2.5	1.3 to 1.4
Volume of brine effluent per m3 of fresh water	3	2	1 to 1.5	0.3 to 0.4
Energy Consumption Mj/m^3	186	162	24	29

Source: EAD, 2009.

Figure 1.11: Desalination technology share of capacity



Source: ICBA, 2010.

High oil prices in 1973 sparked the growth in seawater desalination in the Middle East. The inflow of funds allowed the Gulf States to invest in the development of their infrastructure on a grand scale. This included investments in power and water. For desalination the only viable technology available was MSF invented in 1958 and this has continued to be the mainstay of desalination in the UAE, Figure 1.11. The MSF process today is much as it was then but the units are larger – up to 60,000 m^3/day – and reliability has been improved through the use of better materials and an improved understanding of the process. To be cost-effective, the MSF process is coupled to a fossil fuel power plant which can supply low grade steam. This is often referred to as waste heat. This is a misnomer. The steam used by an MSF plant could be used to generate more electrical power. By tapping this steam at a higher temperature than necessary, the power output of the power station is reduced. Even so, capital costs have fallen; the process is well understood and reliable. Most importantly it has security of supply.

Reverse Osmosis is the next most important desalination technology in the UAE accounting for about a fifth of current production. RO is now the preferred technology outside the Gulf States and accounted for 56% of worldwide online capacity in 2006. The slow uptake of RO in the UAE was because MSF manufacturers could deliver the large scale of production required and RO membranes were expensive, pre-treatment not well understood and energy consumption of RO was high. A particular difficulty for early RO was coping with the high salinity and seawater temperatures prevalent in the Arabian Gulf. More recently membrane prices have fallen, their performance improved, pre-treatment is better understood and energy consumption has dropped dramatically, Table 1.16.

Table 1.16: Costs of Desalinated Water

		MSF	MED	RO
Investment Cost	USD/m^3/day	1,200-1,500	900 – 1,000	700-900
Total Water Cost	USD/m^3	1.10 – 1.25	0.75 – 0.85	0.68 -0.82

Source: World Bank, 2004 ibid.

Assumptions: Plant capacity 30,000 m3/day; plant life 20 years, interest rates 7% and labor at USD45,000/year.

Combining MSF and RO enables more efficient use of energy and the UAE commissioned the largest desalination hybrid plant in the world at Fujairah in 2003. It can potentially produce 624,000 m^3/day. The plant was situated on the Gulf of Oman to mitigate the high salinity and temperature problems in the Arabian Gulf. Almost two-thirds of the water is produced by five MSF units coupled with the power plant and over a third is from seawater RO. This is a more flexible system as RO helps to reduce the electricity demand when there is a mismatch between the water and electricity demand in the summer. Singapore has similarly recently completed the world's largest diameter seawater RO plant (10,000 m^3/day) as part of its "Renewables Strategy' and has reduced energy use by 30% compared with MSF.

Reverse osmosis is the preferred alternative for desalination outside the Gulf Region primarily for environmental and cost considerations, Table 1.16. These costs are based on typical medium-sized installations. There are economies of scale with larger MSF plants and water productions are given as USD 0.84/m^3 for the Taweelah A2 MSF distiller. It is not known if subsidized or global market prices are used for the cost estimate so actual economic costs could be higher. The main reason for the lower costs for the RO process is that it does not require energy to heat the water and the energy cost for pumping and power is about USD 0.13/m^3. In comparison, MSF distillation total energy costs are USD 0.35 of which USD 0.24 are used for heating.

If RO is used to desalinate brackish water, energy costs will be significantly reduced as will the environmental impacts. Using Abu Dhabi's substantial brackish groundwater resources has also several advantages, particularly in terms of dispersing and securing potable water supplies.

The MSF plants on the coast are vulnerable to oil and other spills in the Gulf and to possible terrorist or regional conflict. There is thus an argument for locating these plants inland from the coast – subject to a full environmental impact assessment and approval - and feeding and discharging cooling water via pipelines even if poor water quality compromises desalination. It would also have very positive environmental impacts visually as the power plants could be set within forest plantations thus beautifying the coastline.

The following sections describe desalination faculties by emirate.

Abu Dhabi Emirate

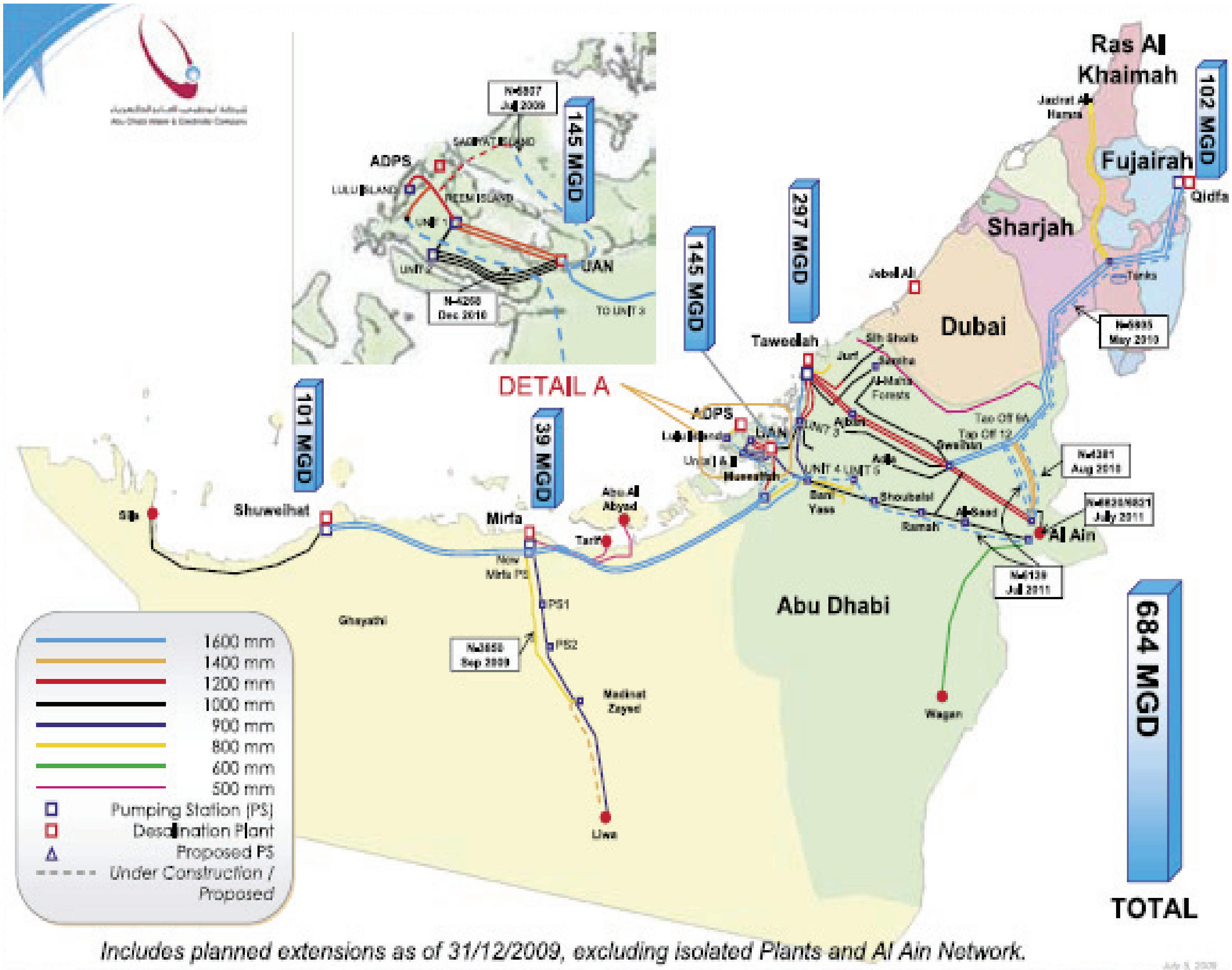
Abu Dhabi Water and Electricity Authority (ADWEA) is a government authority responsible for generating power and producing water for Abu Dhabi Emirate. ADWEA has facilitated a long-term privatization joint stock program for water and electricity sector. This partnership with 8 independent producers of water and power known as Independent Water and Power Producers (IWPPs) enables them to build, operate and own power and desalination plants. ADWEA holds the majority share (60%) and under the partnership agreement IWPPs are committed to sell their production to Abu Dhabi Water and Electricity Company (ADWEC). The water produced is distributed through an extensive distribution network that includes over 2,000 km of pipeline (ranging in diameter from 500 to 1600 mm) at quite high pressure. This network is managed and operated by TRANSCO, Figure 1.12. Bulk water sold by ADWEC is retailed to local water distribution companies that provide water services to the main municipalities and industries. Details of the IWPPs are described in Table 1.17.

Future Desalination Plans

ADWEC evaluated the expansion potential of existing desalination plants in 2008 and found the following:

- Al Mirfa is the only coastal generation/desalination location that could be further developed without site constraints. Al Mirfa station would require some reconfiguration in order to make it better approximate the other cogeneration stations power-to-water ratio.
- Fujairah and Taweelah are considered likely sites for additional capacity expansion. Further large capacity expansions at Taweelah are not considered by ADWEC. Taweelah C has some environmental constraints that limit further expansion. The possible site extension could be 164 Mm^3 (100 MIGD).
- FEWA Fujairah (F3) site should have transferred to ADEWA by 2009. This transferred site may be

Figure 1.12: Abu Dhabi's Water Desalination and Transmission System



Source: ADWEC, 2008.

considered as suitable for further development. The potential capacity might not exceed 117 Mm^3 (70 MIGD) due to the limited size of the site and water transmission constraints.

- The existing Um Al Nar sites current water capacity temporarily exceeds its maximum long-term potential because of the deferred retirement of some older capacity. Due to its location close to mega projects and existing transmission and infrastructure, Umm Al Nar has high potential for future expansion.
- If Shuweihat S3 will be constructed in 2012/2013 with a capacity of 164 Mm^3 (100 MIGD), future expansion will be very limited at this site.
- There is an additional new site that has potential capacity - the Northern Emirates station which would have a capacity of not less than 250 Mm^3 (150 MIGD).
- ADWEA is presently constructing a new power plant, the Shuweihat S2, with anticipated production of 1600 MW of power and 164 Mm^3 (100 MIGD) of potable water.

If implemented, ADWEC expects desalination potential to expand to 1608 Mm^3/ year by 2013, Table 1.18.

Table 1.17: Existing desalination plants, their capacity, and technology used in Abu Dhabi Emirate

Company	Plant Name	Plant Capacity (Thousand m³/day)	Treatment Technology	Annual Water Production (Mm7 pt/year) 2007	Annual Water Production (Mm7 pt/year) 2008	Notes
GTTPC	Taweelah A1 (old)	146	MSF	117.4	118.3	
	Taweelah A1 (new)	240	MED	0.0	58.9	
ECPC	Taweelah A2	232	MSF	76.7	77.7	
TAPCO	Taweelah B1	318	MSF	108.5	107.4	
	Taweelah B2	105	MSF	30.2	25.0	
	Taweelah B2 Extension	314				
APC	Um Nar East A	86	MSF	9.6	retired	retired
	Um Nar East B	105	MSF	25.4	26.4	retired
	Um Nar West 1-6	109	MSF	29.5	31.1	
	Um Nar West 7-8	105	MSF	12.6	4.3	retired
	Um Nar West 9-10	32	MED	0.4	0.0	
	Um Nar West B	286	MSF			
	Sas Al Nakheel	95	MSF	123.0	137.5	
	Al Mahatah	68	MSF			
	ADPS	68	Steam			
AMPC	Al Marfa'	73	MSF			
	Al Marfa' expansion	104	MSF	31.9	47.9	
SCIPCO	Al Shuweihat S1	459	MSF	143.2	150.0	
ESWPC	Qadfa'- Fujairah	169	MSF			
FAPCO	Qadfa'- Fujairah	450	MSF/RO			
Total		**3,117,473**		**708.4**	**784.5**	

Source: ADWEC, 2008.

Gulf Total Tractebel Power Company (GTTPC): Emirates CMS Power Company (ECPC); Taweelah Asia Power Company (TAPCO); Arabian Power Company (APC); Al Mirfa Power Company (AMPC); Shuweihat CMS International Power Company (SCIPCO); Emirates SembCorp Water & Power Company (ESWPC); Fujairah Asia Power Company (FAPCO).

Table 1.18: Existing sites estimated gross potential in Abu Dhabi Emirate

Water MGD	Taweelah	Umm Al Nar	Mirfa	Fujairah	Shuweihat	Total
Maximum Potential	400	95	150	330	300	**1,275**
Utilized Capacity	298	95	39	234	300	**966**
Unused	102	0	111	96	0	**309**

Source: ADWEC, 2008.

Utilized Capacity = Existing + Under Construction + Committed + Planned

Currently, Abu Dhabi (ADWEA) provides bulk water supplies under contract to the Northern Emirates to meet their increased water demand resulting from the booming economy during the 2004-2008 period. Contracted exports of desalinated water are summarized in Table 1.19.

Table 1.19: Abu Dhabi Desalinated Water Exports to the Northern Emirates

Year	2008	2009	2010	2011	2012	2013	2014	2015
MIGD	20	20	30	30	30	30	30	30
Mm^3/year	33	33	50	50	50	50	50	50

Source: ADWEC, 2008.

Dubai Emirate

Dubai Electrical and Water Authority (DEWA), a governmental institution, is solely responsible for producing and managing desalinated water and power generation in the Emirate. Currently, most of the desalination plants are located in Jebel Ali. The main desalination treatment technology used is MSF, while the most recent and planned desalination plants are using RO. The total current installed desalination capacity was about 460 Mm^3 in the year 2008. A new desalination plant (Jabal Ali M Plant), scheduled to start operations in 2010, will add a desalination capacity of 174 Mm^3 per year.

Future Desalination Plans

DEWA is working on development of public-private partnerships for desalination following the Abu Dhabi IWPP business model. Nine new desalination plants were planned and some are under construction to meet the increasing water demand. Involvement of the private sector is expected to double existing capacity by the year 2015 to 950 Mm^3, Table 1.20.

Table 1.20: Current installed desalination capacity and technology used in Dubai Emirate (2007)

Plant Name	Treatment Technology	Plant Capacity (000 m^3/day)	Plant Capacity (Mm^3/year)	Plant Capacity (Mm^3/year)
Jabal Ali D	MSF	159	58	58
Jabal Ali E	MSF	114	42	42
Jabal Ali G	MSF	286	104	104
Jabal Ali K	MSF	273	100	100
Jabal Ali L	MSF	318	116	116
Jabal Ali M*	MSF	477	174	174
Jabal Ali	RO	114	42	42
Total		**1,741**	**635**	**635**

Source: DEWA, GWI.

Some desalination plants are privately managed in co-ownership government such as Palm Water and Jafza companies. Palm Water plans to develop desalination water projects in Jebel Ali Free Zone Area (Jafza) to supply Jafza's industrial and commercial demand including Jafza’s expansion plans covering the developments in Jafza North, Jafza South, Techno Park and Jebel Ali municipal area, Table 1.21.

Table 1.21: Under Construction and Planned Desalination Projects in Dubai Emirate

Planned Plants	Plant Capacity (thousand m^3/day)	Treatment Technology	Plant Capacity (Mm^3/Year)
Jebel Ali SWRO	22.7	SWRO	8
Jafza	100	RO	37
Mina Rashid	100	RO	37
N Station	182	SWRO	66
Palm Jebel Ali and Madinat Al Arab (two Plants)	150	SWRO	55
P Station (Hassyan) Phase I	550		201
P Station (Hassyan) Phase II	550		201
Q Station- Phase I	320		117
Q Station- Phase II	240		88
Q Station- Phase III	240		88
Q Station- Phase IV	159		58
Total			**954**

Sources: ICBA, 2010 based on data from DEWA, GWI.

Sharjah Emirate

Total desalination capacity for Sharjah Emirate is about 115 Mm^3 per year. Actual desalinated water produced was about 100 Mm^3 in 2008 (SEWA, 2008). The largest desalination plant is Al Layyah which has a capacity of 84 Mm^3, and uses MSF and MED treatment technology. MSF and MED accounts for 89% of water production, and the remainder is from RO, Table 1.22.

Table 1.22: Existing desalination plants, their capacity, and technology used in Sharjah Emirate (2008)

Plant Name	Plant Capacity (m^3/day)	Treatment Technology	Water Production (Mm^3/year)
Al Layyah	147,747	MSF	82.09
Al Layyah	81,829	MED	
Al Sa'jah	28,049	RO	8.86
Al Humreh	4,819	RO	1.68
Kalba'	9,092	MED	5.76
Kalba'	14,775	RO	
Abu Musa Island	91	MED	1.29
Al Zubeer	409	RO	
Seer Bun'ear	68	RO	0.20
Total	**309,609**		**99.87**

Sources: ICBA, 2010 based on data from SEWA.

Future Desalination Plans

Seven desalination plants will be built for Sharjah Emirates. Some are either in the planning phase or under construction. These plants will add a total desalination capacity of 168 Mm^3 per year. The largest desalination plant is Al Humreh with a desalination capacity of 133 Mm^3 a year and will start in operation in the year 2014, Table 1.23.

Table 1.23: Planned desalination capacity for Sharjah Emirate (2008)

Plant Name	Plant Capacity (m^3/day)	Treatment Technology	Plant Capacity (Mm^3/year)	In Operation
Al Layyah	36,369	Stream	13.3	2009
Al Layyah	22,730	RO	8.3	2009
Al Humreh	363,686	RO	132.7	2014
Sear Bunear	682	RO	0.2	2009
KhorFakkan	22,730	RO	8.3	2009
Kalba	13,638	RO	5.0	2009
Abu Musa Island	682	RO	0.2	2009
Total	**460,507**		**168.1**	

Source: ICBA, 2010 based on data from SEWA 2008.

Water supply to the Northern Emirates which include Ajman, Ras Al Khaimah, and Fujairah is planned and managed by the Federal Energy and Water Authority (FEWA).

Ras Al Khaimah Emirate

Installed desalination capacity for Ras Al Khaimah Emirate is about 33.5 Mm^3 per year and in 2008 this produced 29.6 Mm^3 (FEWA, 2009), Table 1.24. Almost all water production is from the Al Nakheel MED desalination plant which has a capacity of 26.5 Mm^3. The plant has been in operation since the year 1998. The remaining desalination plants use RO. Only the Al Burairat plant uses brackish groundwater as a source for desalination, while all remaining desalination plants use seawater.

Ras Al Khaimah Emirate imports under yearly contact about 8.3 Mm^3 per year from ADWEC in Abu Dhabi Emirate. This import is expected to continue until all the planned desalination plants are commissioned.

Table 1.24: Existing desalination plants, their capacity, and technology used in Ras Al Khaimah Emirate

Plant Name	Plant Capacity (m3/day)	Plant Capacity (Mm3/y)	Treatment Technology	Water Production (Mm3/year) 2008
Al Burairat	5,455	1.7	RO	2
Al Humraniah	682	0.25	RO	0.25
Rafaq	341	0.12	RO	0.12
Ghalilah	13,638	5	RO	3.56
Al Nakheel	72,737	26.5	MED (Steam)	23.7
Total	**92,853**	**33.57**		**29.63**

Sources: ICBA 2010 based on data from FEWA for the year 2008.

Future Desalination Plans

A new desalination plant at Al Maareed with total desalination capacity of 25 Mm^3 per year (FEWA, 2009) is under construction.

Ajman Emirate

The total desalination capacity is about 33.4 Mm^3 per year, while the actual desalinated water produced for the year 2008 was about 23.58 Mm^3 per year. Ajman desalination plant has the largest desalination capacity and uses MED treatment technology for desalination. The main water source for desalination is seawater. In addition the Helew plant abstracts groundwater through an array of wells.

Future Desalination Plans

Future plans to increase the desalination capacity in the Emirate include installing additional desalination capacity at Al Zawra plant to increase its desalination capacity to 16.6 Mm^3 per year (FEWA, 2009). The proposed plant will use RO desalination treatment technology, Table 1.25.

Table 1.25: Existing desalination plants, their capacity, and technology used in Ajman Emirate

Plant Name	Plant Capacity (m^3/day)	Plant Capacity (Mm^3/y)	Treatment Technology	Water Production (Mm^3/year) 2008
Al Zawra'	4,546	10	RO	7.34
Ajman	15,457	5	RO	4.71
Ajman	50,007	18.3	MED (Stream)	11.47
Al Helew	341	0.12	RO	0.06
Total	**70,351**	**33.4**		**23.58**

Sources: ICBA 2010 based on data from FEWA for the year 2010.

Fujairah Emirate

The total desalinated water capacity for Fujairah Emirate is about 6.66 Mm^3 excluding Qadfa' 2 desalination plant which was removed from service. The actual desalinated water produced in the year 2008 was 3.09 Mm^3. According to the new plans, the Qadfa' 3 desalination plant will be shifted to Al Zawra desalination plant in Ajman

Fujairah Emirate imports about 8.3 Mm^3 per year (5 MIGD) from ADWEC on an annual bases contract to supplement the current deficit which the Emirate faces. These imported quantities will continue until all plants planned and under construction become operational, Table 1.26.

Table 1.26: Existing desalination plants, their capacity, and technology used in Fujairah Emirate

Plant Name	Plant Capacity (m^3/day)	Plant Capacity (Mm^3/y)	Treatment Technology	Water Production (Mm^3/year)
Qadfa' 1	4,546	1.66	RO	0.82
Qadfa' 2*	9,092	3.32	RO	2.62
Qadfa' 3	13,638	5.00	RO	2.27
Total	**468,245**	**6.66**		**3.09**

Sources: ICBA 2010 based on data from FEWA for the year 2008.

* Qadfa' 2 is removed from service and was not included in the calculations.

Umm Al Quwain Emirate

Umm Al Quwain has an independent water authority that manages and controls water resources in the Emirate. Desalinated brackish ground water using RO is the main source of water for all uses. The total quantity of desalinated water was about 8 Mm^3 per year in 2008.

Environmental Impact

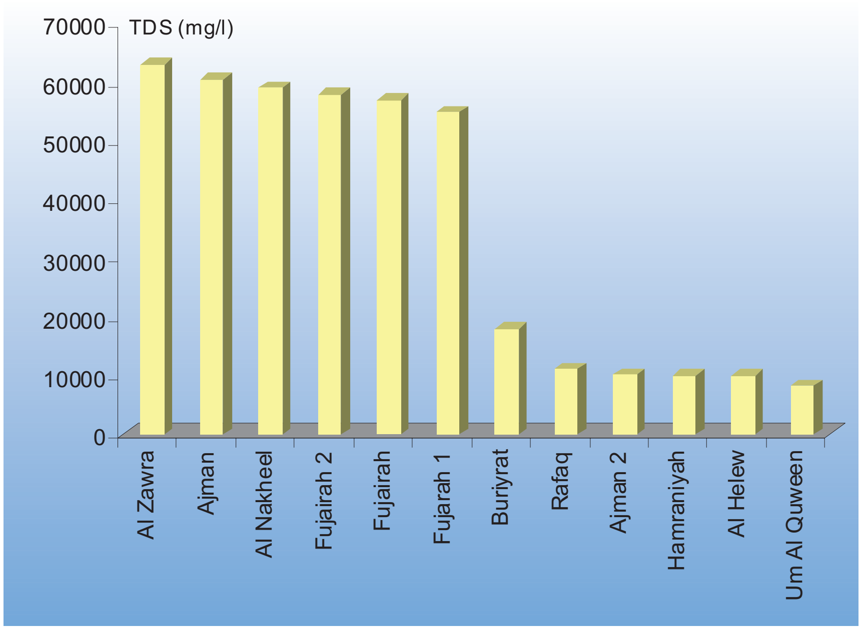
The Arabian Gulf countries flush about 24 tons of chlorine, 65 tons of chemicals used to clean pipes, and about 300 kg of copper into the Gulf Sea daily. Because the Gulf can is effectively a closed sea with a low rate of turnover, chemicals dumped in it accumulate over time. Consequently sound management is required to ensure that the UAE meets its obligations under international treaties it has signed.

The main environmental impacts from desalination are:

- the brine concentrate and associated chemicals discharged residuals produced from desalination pre-treatment process;
- heavy metals from corrosion or cleaning agents;
- rising seawater temperature from hot brine discharge to the Arabian Gulf; and
- greenhouse gas emissions from using energy to produce electricity for desalination process.

Brine produced from seawater desalination process is highly saline, Figure 1.13. In UAE, the brine reaches up to 65,000 mg/l as total dissolved solids (TDS) (Al Asam and Rizk, 2009). This high salinity brine can harm marine life and cause a change in species composition in the Gulf region (EAD, 2009). One way of reducing environmental pollution is to phase out MED and MSF desalination technology and gradually replace it with RO.

Figure 1.13: Brine disposal in some selected desalination plants



Source: ICBA based on data from Al Asam and Rizk, 2009.

Brine Disposal

Disposal of brine effluent is a major problem. The only alternative is inland disposal. Fortunately some land in the UAE is of relatively low value and much of it is underlain by highly saline groundwater. There are several options for inland disposal and Table 1.27 lists some of the management and environmental challenges that could be considered.

Inland brine disposal using evaporation ponds has potential commercial value as well as specific environmental concerns. Many of the factors considered in brine evaporation are also applicable to collection and evaporation of agricultural drainage although the waters have far lower concentrations of total dissolved solids.

Brine waste is an asset that may be used to offset the cost of desalination. In Australia, for example, brine water value-added enterprises are active in reducing costs and meeting environmental performance criteria (Box 1.1). However, there are sometimes adverse environmental consequences that need careful assessment as examples from the San Jaoquin Valley in California illustrate (Box 1.2).

Table 1.27: The Challenges of Inland Brine Disposal

Method of Disposal	Capital Cost*	O&M Costs*	Land Required	Env Impact	Energy	Public Concerns	Geology**
Deep Wells	L	M	L	L	M	M	H
Evaporation Ponds	M-H	H	H	M	L	H	H
Land Spreading	M	L	H	M-H	L	H	H
Thermal Evaporation	H	H	L	L	H	L	L
Sewers	L	L	-	M	L	L	L

Source: Modified after National Academy of Sciences (USA). 2008. Desalination - A National Perspective.

Notes: Magnitude of challenge: L = low; M = medium; H = High.

* Costs are site-specific and vary greatly

** Geologic requirements are concerned with risks of contaminating freshwater aquifers

Box 1.1: Cutting the Costs of Environmental Management – Brine Harvesting

The Pyramid Salt Company of Northern Victoria in Australia harvest salt evaporated from saline groundwater. The product is sold for stock feed, medical and chemical uses. In a proprietary process, specific dissolved minerals and compounds are extracted individually using multiple evaporation processes and/or cooling, supplemented by chemical processing. Industries using these compounds include, for example, wallboard manufacturers, soil remediation and reclamation and waste water treatment. Enterprises are typically medium- to large-scale. Set-up costs are about USD10, 000 per ha and good quality salts can be sold for USD12 to USD150 a ton.

Source: Australian Department of Agriculture, Fisheries and Forests. 2002. Introduction to Desalination Technologies in Australia.

Box 1.2: Evaporation Ponds – The California Experience

Saline agricultural drainage (producing 400,000 tons of salt annually) was not allowed to be discharged to the San Joaquin River and over the period 1972-1985. Instead the water was directed to 28 evaporation ponds covering 2,900 ha. In addition to concentrating salts, the ponds also provided seasonal resting, foraging and nesting habitat for waterfowl and shore birds. An Environmental Impact Report (EIR) in 1979 identified seepage, spillage from flooding, accumulation of toxic or noxious wastes (pesticide, nutrients and sewage), adverse effects of wildlife and mosquitoes as adverse environmental impacts. Many of these impacts were mitigated through better management and engineering measures. Specific attention was paid, however, to impacts on wildlife. It was found that selenium occurred at elevated levels in the concentrated water (more than 0.2 ppm) and its bioaccumulation in the aquatic food chain reduced reproduction rates, caused birth defects and killed water birds. The worst-affected ponds had their operating permits withdrawn by the Central Valley Regional Water Control Board until mitigation was successful and the CVRWCB entered into memoranda of understanding with three operators to select consultants for further EIRs ever three years. As a result design and management practices of evaporation ponds were significantly improved.

Source: San Joaquin Valley Drainage Implementation Program. 1999. Final Report Evaporation Ponds.

Energy Conservation and Greenhouse Gas Reduction

New water supply production plants have been very large and very costly, typically more than USD2 billion. These lumpy investments take up to six years to come on-line considering design, contracting and construction. In the absence of demand management there is no choice but to build new capacity. Global best practice indicates that RO plants have significant cost and environmental advantages over the current multi-stage flash distillation processes when not used in cogeneration. Power plants alone are more efficient than power and water plants. So the suggested strategy is to fill the demand-supply gap in relatively small increments. Brackish groundwater RO could be run at half the cost of seawater. They have the additional advantage of producing between half and three-quarters less concentrated brine and significantly lower greenhouse gas emissions when power supply is factored in.

Uniform information on greenhouse gas emissions associated with desalination is not available for the UAE. However, EAD (2006) state that total emissions in Abu Dhabi from power and desalinization plants produce 13.5 million tonnes of gases and particulates per year, and carbon dioxide forms 99.65% of these emissions.[2] The next largest emission is nitrous oxide and nitrogen dioxide which total 34,000 tonnes per year. While the volume of nitrous oxide is relatively small it is 200 times more effective as a greenhouse gas than CO_2 and is thus equivalent to 6.8 million tons of CO_2. The emission hazard in Abu Dhabi is exacerbated by increasing shortages of offshore gas and several power plants burn high sulphide oil in times of shortfall.

In terms of direct CO_2 emissions Abu Dhabi's power plants fit well within the expected range of international efficiency standards for gas-fired facilities – about 380 grams equivalent per kWh (EAD, 2009). In the UK for example, the range is 362 to 575 grams.[3] Determination of the share of total energy used that goes to water production in MSF plants is complex. Theoretical and empirical studies indicate that Saudi Arabia's MSF plants at Al Jubail utilizes between 24 and 46 percent of energy for water production depending on the accounting method used and the power to water ratio.[4] Earlier studies in Abu Dhabi yielded similar results.[5] Clearly, reducing the demand for desalinated water produced by MSF would significantly lower the carbon footprint of the UAE.

Other considerations – How secure is the seawater supply?

Other important considerations that might affect desalination industry in the future in UAE include the regular oil spill into the Gulf. The Gulf is vulnerable to these regular spills which can affect the desalination plants' performance. In addition, the red tide can also limit utilizing seawater as the extent, causes, timing and frequency of occurrence of red tide are unknown. The incident at Fujairah in 2009 is an example of its effect on desalination industry.

Main Findings and Recommendations

1. Desalination should be managed in an overall planning framework that takes into account all socio-economic and environmental aspects, and integrates desalination with other alternative water resources to meet demand.
2. Incorporate Strategic Environmental Assessment procedures into project planning to ensure environmental consequences are identified and that programs put in place to mitigate adverse human, social and environmental consequences.
3. The Multi-stage Flash method causes the most effluents, toxic material, air pollution, and the most industrial risk, while RO technology has the least impact on the environment. Therefore, RO technology is recommended for the future.
4. The emphases on renewable energy sources and nuclear energy will influence the technologies used in desalination as cogeneration will no longer be possible. There is likely to be an increased adoption of RO treatment which uses less energy.
5. Inland brine from RO treatment could be disposed of in solar ponds for evaporation and used for producing energy – a process still needing to improve its efficiency. This technology and process need to be monitored to ensure adoption when and where cost-effective.

Reclaimed Water

Introduction

The UAE population exceeded five million by end of 2009 and is growing at an annual rate of 6.2%. As a result, increasing amounts of wastewater are produced each year from domestic consumers and the wide range of municipal, industrial, and recreational premises. Wastewater is recognized globally as a valuable non-conventional resource upon appropriate treatment.

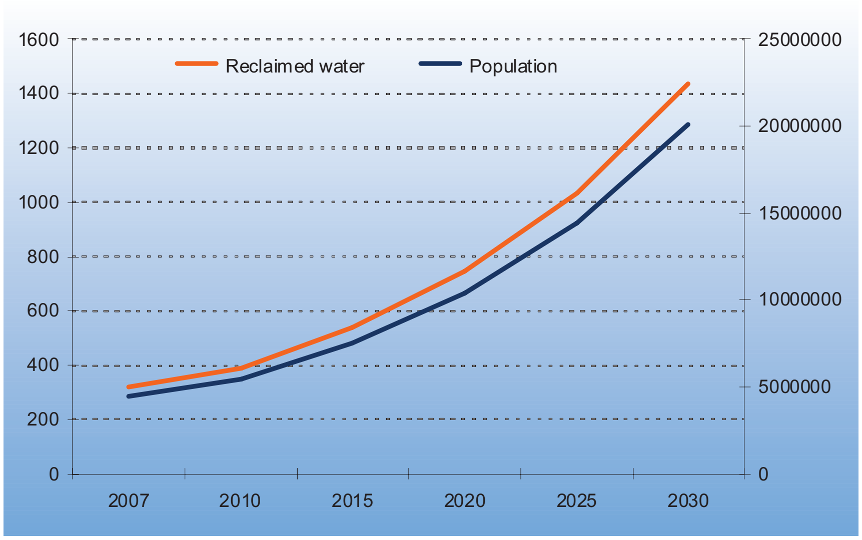
For some time, the UAE Government has been concerned with promoting the treatment and reuse of wastewater, especially for amenity and restricted agricultural purposes. The reuse of treated wastewater has many benefits, most of which are (i) conserving and reusing polluted desalinated water half of which is currently wasted, and (ii) substituting for freshwater, especially that used in the amenity and agricultural sectors.

Existing wastewater treatment plants (WWTPs) have relatively good technical efficacy with their treated effluent complying with international standards, despite problems of inflow exceeding design capacity at many of the plants. Treated effluent from the existing WWTPs also generally complies with standards and regulations for reuse in restricted irrigation, and thus can be used for irrigation of fodders, trees, and crops that are not eaten raw or uncooked (see Annex 4 for more details). The existence of micro organisms such as faecal coliforms and intestinal nematodes in the treated effluents from some UAE plants is one of the main obstacles for effective reuse on leafy vegetables because of the associated health risks.

Current and future projections of wastewater quantities

The production of wastewater in the UAE amounted to about 559 Mm^3 in 2009. This figure is over-estimated as will be explained later, and the actual quantity of generated wastewater is believed to be about 364 Mm^3. If population continues to expand at current rates, future projections show that this figure could reach around 1,400 Mm^3 by 2030 (Figure 1.14). It is unlikely, however, that this volume will be achieved.

Figure 1.14: Produced wastewater projections in UAE



Source: ICBA based on data from Al Asam and Rizk, 2009.

Part of the generated wastewater cannot be collected because of the lack of a centralized sewerage collection system. In addition some potential wastewater (grey water) is used for domestic garden irrigation, and some water is lost from cracks in the sewer pipes. There are also losses during the treatment phases; and losses during storage and conveyance of treated wastewater to end users. The major indicators are summarized in table 1.28. This table shows that currently more than 559 Mm^3 are being treated and 352 Mm^3 are being reused for irrigation of trees and green areas; most of which is concentrated in Abu Dhabi and Dubai. More than 207 Mm^3 or 37% of treated wastewater is wasted and most of it is discharged to the sea.

The projections of wastewater production in the UAE for the period (2007-2030) are shown in Table 1.29 below. The main assumptions for projecting reclaimed water quantities are:

- Only residential and governmental water consumptions are considered for generating wastewater that has potential for future reuse;

Table 1.28: Wastewater treatment and reuse in the UAE, 2009

Indicator	Abu Dhabi	Dubai	Sharjah	Ajman	Ras Al Khaimah	Fujairah	Umm Al Quwain	Entire UAE
Population (2007) *1,000	1,493	1,478	882	224	222	137	52	**4,488**
Population with Sewerage systems	93%	75%	60%	50%	0%	85%	0%	**50-98%**
Treated effluent (Mm3/year)	192	200	110	22	20	15	0	**559**
Reused effluent (Mm3/year)	96	165	75	4	7	5	0	**352**
Amount Reused	50%	83%	68%	18%	35%	33%	0%	**63%**

Projected quantities were based on 300 l/c/d, 90% reaches sewers, and 75% after treatment.

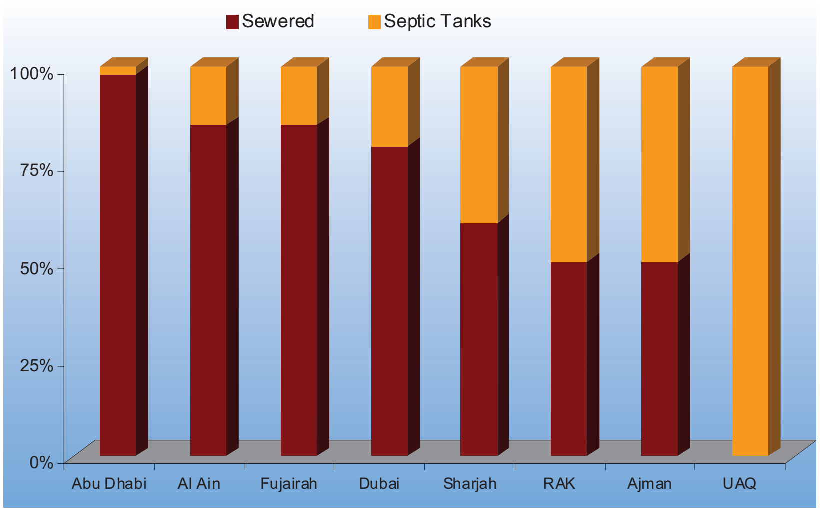
- Industrial wastewater will be treated and reused within the industrial zones (these quantities were not taken into account in the projections); and
- The average daily per capita generated wastewater is realistically180 liters (ICBA, 2010). Alternative projections were developed as possible scenarios to show the range of potential generated wastewater quantities. These scenarios were based on the assumption that the average specific water consumption would be about 300 lpcpd, of which 90% would reach the sewer system, and only about 75% would be available after treatment. The realistic quantities of produced wastewater in year 2030 are projected to reach about 1,400 Mm^3.

It is uncertain whether current high population growth rates will continue in the future. At least these projections give a range of generated wastewater for the next few years. The major question that arises is what percentage of this potential available amount will be collected and treated and thus become possible for potential reuse. Some proportion will be lost through leakage and evaporation during collection and treatment. Moreover, some of these quantities will be collected and managed onsite, especially in rural and remote areas as well as in recreational and mega-investment projects. In addition, these amounts do not include the wastewater produced from industries. The realistic quantities have been estimated to take into account these uncertainties.

Sewerage and collection system

Over the years, all of citizens of the UAE have access to sanitary wastewater disposal either through sewerage systems or septic tanks. Those areas which are not connected to the public sewerage system use on-site sanitation system or individual treatment units. Septic tanks are the most common method utilized, particularly in the rural areas. Special tankers are available to empty and transport wastewater to treatment plants or receiving points. Figure 1.15 shows the coverage rate of public sewerage systems and onsite units in the different emirates of the UAE. Generally, only wastewater that is collected by sewerage systems can be processed and reused.

Figure 1.15: Sewerage and onsite coverage in the UAE, 2008



Source: ICBA, 2010.

Table 1.29: Projected quantities of produced wastewater in UAE and Per Emirate, 2007-203 (Mm^3)

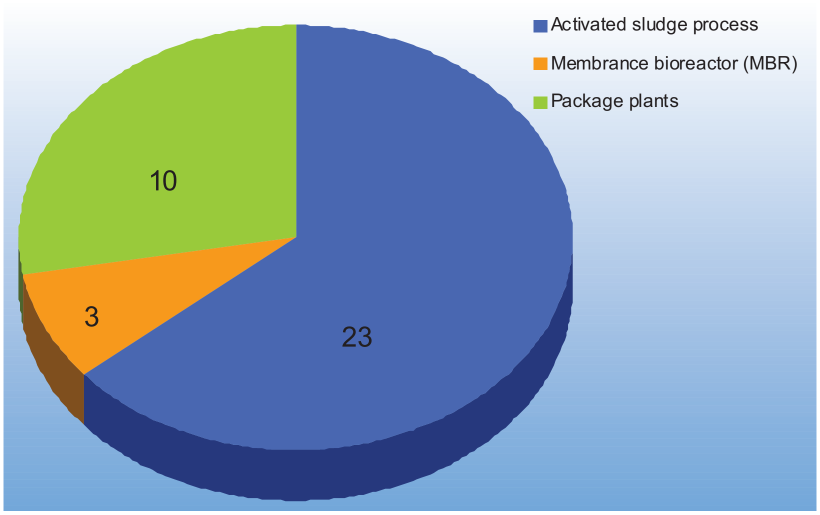
		2007	2010	2015	2020	2025	2030
Abu Dhabi	Population projections I	1493000	1664930	1996594	2394328	2871292	3443271
	Population projections II	1493000	1768141	2343933	3107231	4119095	5460472
	Population projections III	1493000	1875531	2743035	4011794	5867402	8581299
	Realistic produced wastewater quantities	106	119	142	171	205	246
	Produced wastewater projections	147.14	164.08	196.76	235.96	282.97	339.33
	Produced wastewater projections	147.14	174.25	230.99	306.22	405.94	538.13
	Produced wastewater projections	147.14	184.83	270.33	395.36	578.23	845.69
Dubai	Population projections	1478000	1847925	2681438	3890908	5645915	8192522
	Realistic produced wastewater quantities	105	132	191	277	403	584
	Produced wastewater projections	145.66	162.43	194.79	233.59	280.12	335.93
Sharjah	Population projections	882000	1093567	1564852	2239242	3204269	4585185
	Realistic produced wastewater quantities	63	78	112	160	228	327
	Produced wastewater projections	86.92	96.93	116.24	139.4	167.16	200.46
Ajman	Population projections	224000	264229	347963	458233	603447	794679
	Realistic produced wastewater quantities	16	19	25	33	43	57
	Produced wastewater projections	22.08	24.62	29.52	35.4	42.45	50.91
Fujairah	Population projections	137000	160323	208346	270755	351859	457256
	Realistic produced wastewater quantities	10	11	15	19	25	33
	Produced wastewater projections	13.5	15.06	18.06	21.65	25.97	31.14
Ras Al Khaimah	Population projections	222000	248067	298488	359159	432161	520002
	Realistic produced wastewater quantities	16	18	21	26	31	37
	Produced wastewater projections	21.88	24.4	29.26	35.09	42.08	50.46
Umm Al Quwain	Population projections	52000	58493	71166	86584	105342	128165
	Realistic produced wastewater quantities	4	4	5	6	8	9
	Produced wastewater projections	5.12	5.71	6.85	8.22	9.86	11.82
Entire UAE	**Population projections**	**4488000**	**5440744**	**7516186**	**10412112**	**14462088**	**20138280**
	Realistic produced wastewater quantities	**320**	**388**	**536**	**742**	**1031**	**1436**
	Produced wastewater projections	**442.3**	**503.4**	**625.7**	**779.6**	**973.6**	**1218.8**

Annual Growth rates: Abu Dhabi (3.7,5.8,7.9%), Dubai 7.73%, Sharjah 7.43%, Ajman 5.66%, Fujairah 5.38%, Ras Al Khaimah 3.77%, Um Al Quwain 4%(Ministry of Economy, 2005).

Wastewater treatment systems

Modern technologies for the collection and treatment of wastewater for reuse had been introduced in the UAE in the seventies. The first sewage treatment plant using activated sludge process was commissioned in Abu Dhabi in 1973. It was designed to serve a population of 30,000 with a treatment capacity of 6,810 m^3/day. There are more than 60 medium and large wastewater treatment plants in the UAE, of which 36 in Abu Dhabi and Al Ain, 4 in Dubai, and 18 in Sharjah, while the rest are distributed in the other emirates, except for Umm Al Quwain that lacks any treatment plant. Two of the largest wastewater treatment plants in UAE are located in Abu Dhabi (Mafraq WWTP) and in Dubai (Al Aweer WWTP) with design capacities of 260,625 m^3/day and 260,000 m^3/day respectively. As well there are plans for establishing new treatment plants and the rehabilitation of old ones in all the emirates. The main technologies used for wastewater treatment in the UAE are: activated sludge, aerated lagoons, trickling filters, membrane bio-reactors and anaerobic treatment, in addition to package plants (Figure 1.16).

Figure 1.16: The existing treatment processes in Abu Dhabi and Al Ain



Source: ADSSC, 2009.

Most of the UAE WWTPs are activated sludge plants with tertiary treatment that consists of sand filtration and chlorination. The following conventional treatment methods are used in the treatment plants:

- Activated sludge using surface aerators or fine bubble diffusers;
- Aerated lagoons;
- Sequential batch reactors;
- Trickling filters;
- Aerated submerged media;
- Package plants (based on activated sludge); and
- UASB (upflow anaerobic sludge blanket) technology.

Many projects have been planned or underway either to construct new treatment plants or to expand the capacities of the existing facilities to cope with current and future flows. For example, the wastewater treatment technologies in the Emirate of Abu Dhabi vary between the traditional activated sludge process with or without sludge stabilization, the membrane bioreactor process and the Package plants. Recently, there are 36 operational WWTPs distributed between Abu Dhabi and Al Ain districts. The activated sludge process represents the major applied technology with almost 64% of the total treatment plants (that is, 23 plants out of the total 36).

Treated effluent quality

Most of the major treatment plants in the UAE use conventional treatment methods including tertiary treatment, thus producing high quality effluent. Table A1.2 of annex 4.1 shows the quality of the effluent from major treatment plants in the country.

The treated effluent from Mafraq and Zakher WWTPs represents more than 90% of the total produced water from the entire existing 36 plants in Abu Dhabi Emirate. Therefore, the quality of the treated water produced from these two plants is analyzed and discussed. Tables A1.1 and A1.2 present quality parameter data for raw sewage, treated effluent and dried sludge for a range of parameters for Mafraq and Zakher WWTPs in 2008. The quality of selected other treatment plants is highlighted in Table A1.1 and Table A1.2. The final effluent quality produced from most WWTPs shows a high quality standard with regard to the Biochemical Oxygen Demand (BOD), the Total Suspended Solids (TSS) and the Ammonia (NH3) content. The removal efficiency of the BOD, TSS, and NH3 at Mafraq was 99%, 98.4% and 93.6% respectively. At Zakher, the removal efficiency for the BOD, TSS and NH3 is 98.9%, 98% and 94.8% respectively. The other treatment plants in Abu Dhabi and Al Ain are achieving above 90% removal efficiency of the previously mentioned parameters in general.

The flows of treated wastewater effluent that are potentially available for application in irrigation of high value crops or for unrestricted irrigation are limited due to the following constraints:

High effluent salinity. Electrical conductivity (EC) is a reliable indicator of the total dissolved solids (salts) content of the water. The addition of irrigation water to soils adds to the concentration of salt in the soil. Concentration of these salts will result in an increase in osmotic potential in the soil solution interfering with extraction of water by the plants. Toxic effects may also result with an increase in salinity. Most fresh drinking water will have less than 100 μS/cm conductivity. Some slightly salty drainage water found on salt-affected farms will be around 1,800 μS/cm; very brackish water could be around 27,000 μS/cm. While seawater has conductivity of around 54,000 μS/cm. Salinity is the major limiting factor for application of treated wastewater in the irrigation of high value crops and growing salt sensitive crops requires conductivity of less than 700 μS/cm. Some examples of crops and their tolerance to salinity are shown in Table A1.3. The specific values on acceptable EC levels in waters used for irrigation are:

- <1,000 μS/cm for unrestricted use;
- 1,000 – 2,500 μS/cm for restricted use;
- >2,500 μS/cm unacceptable.

Health risks. The available data shows that most WWTPs have treated effluents with sufficiently low fecal coliforms which is acceptable for restricted irrigation; irrigation of crops that are not eaten raw or uncooked. According to the WHO (2006) guidelines (see Table A1.2), all existing WWTPs can be used for restricted irrigation. Many smaller WWTPs have lower faecal coliform values, making their treated effluents safe and suitable for unrestricted irrigation: crops that are eaten raw such as vegetables. Improving the disinfection systems at the existing WWTPs will produce treated effluents that can be used for irrigation of all types of crops without endangering public health in accordance with the strictest standards. However, this should not compromise the suitability of the other quality parameters. The low detention time and the high concentration of TSS in many WWTPs explain largely the relatively poor effluent quality in terms of faecal coliforms. Tertiary treatment is supposed to improve the pathogens removal. This calls for performance assessment of the existing tertiary treatment units, especially if the treated effluent is to be used for unrestricted irrigation.

BOD. The BOD content is substantially reduced in most existing WWTPs. Although the BOD content in treated effluents in few WWTPs exceeds the RSB guideline limits (BOD 20), the reported values are still within global guidelines – such as the USEPA – for application of treated wastewater in agricultural irrigation of food crops not commercially processed (see Table A1.2).

- TSS: The existing WWTPs have good performance pertaining removal of TSS. Only a few WWTPs have treated effluents with high TSS concentrations.
- In a reuse context, using such effluent for irrigation causes malfunctions to the irrigation systems and hinders the effective disinfection. TSS can lead to the development of sludge deposits and anaerobic conditions when poorly treated wastewater is discharged in the aquatic environment.
- Ammonia: The ammonical nitrogen typically covers a quarter to all of the reduced nitrogen in sewage. The concentration of ammonia in most existing WWTPs is far below the local guidelines. In the case of the few WWTPs that exceed the limits, nitrification is needed to reduce the concentration of ammonia, especially when the treated effluent is to be discharged into the aquatic environment.

The existing WWTPs in the UAE in general have good performance in the removal of major contaminants that endanger public health and the environment. However, high salinity and the existence of faecal coliforms in most WWTPs remain a major concern for application of treated effluents in unrestricted irrigation or irrigation of high value crops. Membrane processes such as RO are capable of solving this problem and produce a high quality effluent suitable for applications without any risks to the public health and the environment.

Recently, a project had been initiated and started in Ajman for constructing a WWTP to reduce the salinity in the final treated effluent from the existing plant and thus improve its quality. The plant has a microfiltration unit followed by a reverse osmosis unit. The effluent quality from this plant will be of a very high quality and the treated product will be sold to the end consumers for reuse in different applications.

Sewage sludge

The quantity of sludge (bio-solids) generated by the wastewater treatment plants in the UAE is estimated to be more than 90,000 tons of wet sludge per year. All the major treatment plants in the country employ advanced treatment methods for sludge processing such as: aerobic or anaerobic digestion, sludge thickening units, mechanical dewatering or thermal dryers and drying beds. The smaller treatment plants in the rural areas make use of aerobic digesters to stabilize the sludge and drying beds for dewatering.

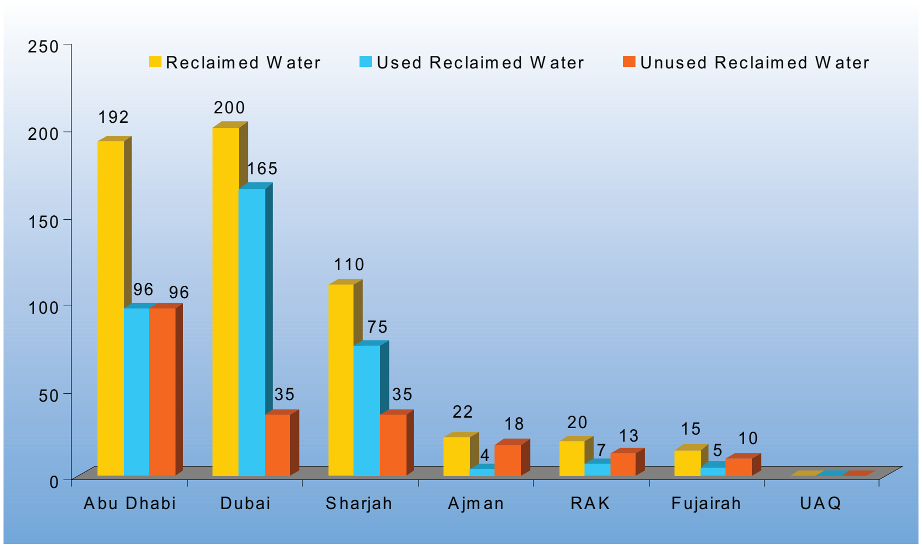
At present most of the processed sludge in the Emirates of Abu Dhabi and Sharjah is mixed with the municipal green waste and is further treated at the composting plants and used as fertilizer. The thermally dried sludge produced at the Dubai WWTP is used as fertilizer for greenery and public parks and also part of it is used as landfill. The cost of treatment of sludge varies according to the type and level of treatment, which makes it difficult to accurately estimate cost.

Reuse of the treated effluent

Water reclamation and non-potable reuse typically require wastewater treatment technologies that are already widely practiced and readily available in many countries throughout the world. When discussing treatment for a reuse system, the overriding concern is suitability of the reclaimed water for the intended use. Higher level uses, such as irrigation of public-access lands or vegetables to be consumed raw without processing (unrestricted irrigation), require a higher level of wastewater treatment and reliability prior to reuse than will lower level uses, such as irrigation of forage crops and pasture (restricted irrigation). For example, in urban settings, where there is a high potential for human exposure to reclaimed water used for landscape irrigation, industrial purposes, and toilet flushing, the reclaimed water must be clear, colorless and odorless to ensure that it is aesthetically acceptable to the users and the public at large, as well as to assure minimum health risk. Experience has shown that facilities producing secondary effluent can become water reclamation plants with the addition of filtration and enhanced disinfection processes.

In the UAE more than 350 km^3 of reclaimed water from wastewater treatment plants is reused annually mainly for irrigation purposes, Figure 1.17. The quality of the treated effluent produced by the treatment plants is high and suitable for irrigation purposes, as most of these treatment plants incorporate advanced tertiary treatment in the process scheme. The quality of the effluent produced by the

Figure 1.17: Reclaimed water, reused, and losses in UAE



Source: ICBA, 2010.

major treatment plants complies with the recommended standards for restricted irrigation. The effluent quality compliance percentage archived for the important parameters such as BOD, TSS, heavy metals and E. coli is as high as 100% most of the time. For ammonia the compliance percentage reported ranges from 70 to 80%.

For health and aesthetic reasons the use of reclaimed water for food crops is not implemented in the UAE. Reuse of treated sewage effluent is presently limited to the irrigation of non-food crops and the landscaping of the parklands, urban roads, forestry and highways. The quality of the effluent and efficiency of the process are assessed by a selected number of commonly used parameters.

There is considerable scope to reduce the negative effects of wastewater use in irrigation through the selection of appropriate irrigation methods. In the UAE, an advanced distribution network comprising of underground pipes, reservoirs and pumping stations exists for the conveyance of treated effluent to the different parts of the cities to be used for irrigation. Automatic sprinklers and drip irrigation are the methods that are widely used for irrigation and also advanced automatic irrigation controllers are used in many places to improve the efficiency of the irrigation system.

The water demand for landscape irrigation generally varies considerably during summer and winter seasons. Presently there are no seasonal storage facilities to manage the excess treated wastewater available during the winter months. There is no provision for the discharge of untreated wastewater to the water courses. However, in emergency situations, it becomes necessary to discharge the wastewater overflows to open channels or wadis as a temporary measure.

Abu Dhabi. In the Emirate of Abu Dhabi, the treated effluent has been used to irrigate landscapes, parks and gardens since 1976 and currently around 96 Mm^3/year of treated wastewater are used for this purpose. More than 45 Mm^3 of treated wastewater is used in Al Ain City annually for irrigation purposes, mainly for landscapes, gardens, parks, forestry, urban roads and highways.

Dubai. In the Emirate of Dubai, more than 165 Mm^3/year of treated wastewater is used for irrigation purposes predominantly for landscape irrigation. Treated effluent is used to irrigate golf courses (recreational use) and also used for industrial purposes in the form of cooling water for the cooling towers. In addition, the artificial recharge of groundwater has been initiated and about 16 Mm^3 of treated wastewater has been used for this purpose in 2005.

Sharjah. In Sharjah, about 65 Mm^3 which accounts for 65% of the treated effluent water is distributed to the municipality for the irrigation of the landscapes, parks and gardens. The remaining 35% of the water is discharged to the sea.

Ajman. The distribution network is currently under construction by the Government of Ajman. Pumping stations will distribute some of the treated effluent water to the farming areas to be used in landscape irrigation within the farms and to irrigate tree belts surrounding industrial areas as part of environmental protection measures. The remaining treated effluent water will be pumped to a newly installed microfiltration unit and reverse osmosis plant for further treatment and will be then sold for industrial purposes.

Fujairah. Currently there are relatively small quantities used for irrigation purposes at WWTP site landscaping until the effluent distribution network (EDN) is completed in 24 months. The rest of the effluent is discharged into the sea. The effluent distribution network once completed will supply the following amounts of various user groups, Table 1.30.

Ras Al Khaimah. The treated sewage effluent (TSE) is taken by tanker to the municipal area for the irrigation of some golf courses and landscape areas near the Corniche. The surplus of the TSE is discharged in ponds, where some recharging for the ground water recharge takes place.

Onsite systems for wastewater treatment and reuse

Growing residential, industrial, and recreational construction on unsewered areas face many challenges in providing reliable and cost-effective strategy for managing the future wastewater flow. Projects are often delayed or even cancelled if a community does not have the means to link a new development to a central WWTP, or to expand the existing conventional plant to accommodate the projected flow. However, expansion of an existing municipal WWTP may not provide the best solution. The existing plant processes may not be able to handle the variable flow rate or harsh composition of the new wastewater flow and the resultant effluent may endanger the environment or residents with poor quality discharge.

Table 1.30: The committed end users of the treated effluent water in Fujairah

End User	Initial volume of effluent required (m^3/day)	Ultimate volume of effluent required (m^3/day)
Municipality of Fujairah	6,019	6,764
Refinery	100	100
Fujairah Steel Plant	0	500
Stone Crushers	400	400
Fujairah Free Zone	100	500
Golf Course	6,000	7,000
UAE Naval Base	1,000	1,000
Future Ind. Consumers	500	2,000
Al Hilal City	500	2,600
Total	**14,619**	**20,864**

As effluent discharge requirements become increasingly stringent, many communities are considering advanced wastewater treatment technologies to ensure regulatory compliance and to preserve environmental health. There is also a growing need to conserve dwindling potable water supplies with progressive water reuse programs. By restoring wastewater to reuse standards, communities and industries can produce high quality reuse water for non-potable applications such as irrigation or industrial processes.

Decentralized, onsite treatment and reuse at household and small community levels is believed to be very practical in the case of the UAE where great amounts of the freshwater consumption is used for the irrigation of home gardens. This option might lead to a substantial drop in the municipal water consumption on one hand, and on the other replace some of the freshwater used for irrigation. Onsite treatment and reuse of wastewater might be more influential than other measures or initiatives that aim to improve water availability in the UAE.

Since February 2003, the city of Al Dhaid in Sharjah Municipality has been using a Z-MOD™ Packaged Plant to restore wastewater to high quality irrigation water for public parks, promenades and afforestation projects. The entire turnkey system was designed, constructed and commissioned in less than one year. Skid-mounted modular components simplified the installation process and provide for rapid expansion as the community grows and requires additional wastewater treatment facilities. With an average daily flow of 275 m^3/day, the single-train MBR system treats wastewater from approximately 3,000 people. Tanker trucks are used to deliver raw wastewater to the facility and again to transport the treated water from the reservoir to various sites throughout the city. An expansion of the plant is planned for the near future for one additional process train to bring the average daily flow rate up to 550 m^3/day (GE, 2009).

Public perception towards onsite reuse is a major factor that can undermine all efforts. Sometimes it is difficult to implement such a program and to enforce compliance with guidelines regarding appropriate uses of the wastewater. Additionally it can be challenging to operate and maintain the onsite treatment and reuse systems. Nevertheless, public awareness programs and campaigns are needed before, during, and after starting the application of onsite treatment and reuse.

Health aspects and environmental impacts

The possibility of contamination with bacteria or viruses when domestic sewage is used is extremely important. However, even with industrial wastewater pathogens can occur. Thus, analysis should be undertaken at least once. Usually the coliform bacteria are used as an indicator organism. In 1998, the World Bank, UNEP, UNDP and WHO released a study giving recommendations for irrigation water used for raw consumable crops: Coliform bacteria ≤ 1,000/100 ml; Helminths eggs: ≤1 (Note: European rivers, for example, have a count of coliform bacteria around 100/100 ml). UNEP (1998) considers the protection of public health especially that of workers and consumers to be one of the most critical steps in any reuse program. To this end, it is most important to neutralize or eliminate any infectious agents or pathogenic organisms that may be present in the wastewater. For some reuse applications, such as irrigation of non-food crop plants, secondary treatment may be acceptable. For other applications, further disinfection, by such methods as chlorination or ozonation, may be necessary. Table 1.31 presents a range of typical survival times for potential pathogens in water and other media.

Table 1.31: Typical pathogen survival times at 20 - 30°C (in days)

Soil	Crops	Freshwater and sewage	Pathogen
< 100 but usually < 20	< 60 but usually < 15	< 120 but usually < 50	Viruses
< 70 but usually < 20	< 30 but usually < 15	< 60 but usually < 30	Bacteria
< 70 but usually < 20	< 10 but usually < 2	< 30 but usually < 15	Protozoa
many months	< 60 but usually < 30	many months	Helminth

Source: USEPA, 1992.

Presently treated wastewater is not used for the irrigation of food crops and as such there are no special arrangements for the periodic inspection and monitoring of the farm workers. However, medical examinations of the employees of sewage treatment plants are sometimes conducted to identify any health problems prevalent among those exposed to sewage.

Main Findings and recommendations

- There is an urgent need to establish a unified/centralized database or system for gathering the different data on the quantities and quality of wastewater before and after treatment. The database should include data from all essential parameters tested at all functioning treatment plants in the United Arab Emirates.
- Each Emirate has adopted its own specifications and standards for discharge of raw wastewater in the sewerage system as well as for discharge and reuse of treated wastewater and sludge. However, there are decimal differences between the standards of the different emirates, thuse there is a critical need to establish a national standard to be adopted by all UAE emirates.
- There is high potential for reuse of treated wastewater in the UAE, especially for some agricultural irrigation. Currently less than two thirds (352 Mm^3/year) of the treated wastewater is being reused, while about 207 Mm^3/year is lost through wastage. The quantities of used reclaimed water and wastewater collection and treatment should be maximised.
- Wastewater collection in the UAE is reasonably high. However, it is obvious that a large proportion of the desalinated water produced does not end up in the sewer systems and sewage treatment plants. This is mainly attributed to the excess use of desalinated water for the irrigation of vegetation in home gardens, amenity landscaping and farms.
- Raw sewage includes industrial discharges that contain major chemical constituents. Therefore, it is recommended that the wastewater of small industries within the industrial zones be collected in a separate sewage system and then treated in special treatment plants. The effluent of these plants should be used

onsite, for forest irrigation or for sand dune fixation. Industries must install pretreatment facilities to reduce pollution to domestic wastewater level. The big industries should have their own treatment facilities and reuse systems.

- High salinity is a major obstacle for different applications of the treated effluents. Salt content should be minimized at source through prohibition of industrial waste discharges, avoidance of infiltration of rainwater into the sewer system, and detection and repair of sewer leaks that allow intrusion of brackish groundwater into the sewer systems. Nanofiltration or Reverse Osmosis processes might be used to reduce salinity of the reclaimed water but also bring economic and energy costs-benefits.
- Wastewater reclamation and reuse systems should contain both design and operational requirements necessary to ensure reliability of treatment. Reliability features such as alarm systems, standby power supplies, treatment process duplications, emergency storage or disposal of inadequately treated wastewater, monitoring devices, and automatic controllers are important. From a public health standpoint, provisions for adequate and reliable disinfection are the most essential features of the advanced wastewater treatment process. Where disinfection is required, several reliability features must be incorporated into the system to ensure uninterrupted chlorine feed.
- A storage facility is, in most cases, a critical link between the sewage treatment plant and the irrigation system. Storage is needed for the following reasons: i) to equalize daily variations in flow from the treatment plant and to store excess when average wastewater flow exceeds irrigation demands (includes winter storage); ii) to meet peak irrigation demands in excess of the average wastewater flow; and iii) to minimize the effects of disruptions in the operations of the treatment plant and irrigation system. Storage is used to provide insurance against the possibility of unsuitable reclaimed wastewater entering the irrigation system and to provide additional time to resolve temporary water quality problems. Taking into consideration the local specific conditions of the UAE, underground or covered storage reservoirs are more appropriate than maturation ponds or surface reservoirs that are often used in other countries.
- Onsite treatment and reuse at household and small community levels is believed to be very practical in the case of the UAE where great amounts of the freshwater consumption go to irrigation of home gardens. This option might lead to a substantial drop in the household water consumption and reduce the quantities of sewage that needs to be collected and treated. The UAE needs to develop a strategy for onsite management of wastewater from small and remote residential areas. The separation of grey and black wastewater at house/building level is worth considering in order to utilize grey water after proper treatment for irrigation of home gardens and landscape and amenities within the surroundings of these premises.
- The government institutions should cooperate to develop a user-friendly manual for construction of onsite treatment and reuse facilities at individual households in rural and remote areas. Meanwhile, strict regulations and monitoring policies are needed to regulate this type of systems in order to safeguard public health and the environment.
- Composting of dried sewage sludge is highly recommended because of its high economic value to the agricultural sector. The Biosolids Management Strategy prepared recently by ADSSC is a good initiative towards utilization of sewage sludge safely and economically.
- There is an urgent need to further investigate the quantities and quality of dried sewage sludge that are mixed with green waste and solid waste composting plants. Similarly, investigation is needed on the amounts of dried sludge that are being stored onsite at the different WWTPs.
- The wastewater from mega projects needs to be collected, treated, and reused onsite within these projects.
- A comprehensive economic cost-benefit analysis is needed on the different treatment and reuse alternatives, as well as on the different tradeoffs associated with plant size, technology, and proximity to served community and reuse site. One should find an answer to the questions: Do economic benefits from the intended reuse outweigh the economic costs associated with improved effluent quality?

Annex 1.1

Table A1.1: Typical characteristics of raw wastewater in the UAE

Parameter	Unit	Abu Dhabi (2008)	Al Ain (2008)	Dubai	Sharjah	Ajman (2009)	Fujairah (2009)	Ras Al Khaimah (2009)
pH	S. Units	7.2	7.4	7.3	7.2	7.8		7.1
Electrical Conductivity	ìS/cm	5,050	2,108	1,847	4,580	5,600		
Total Suspended Solids	mg/l	170	193	226	599	270	300	254
Total Dissolved Solids	mg/l	2,602	1,402	931	3,020	3,376	900	5,151
Ammonia	mg/l	27	23.2	35	40.1	43	30	
Biochemical Oxygen Demand (BOD)	mg/l	235	185	274	335	276	250	213
Chemical Oxygen Demand (COD)	mg/l	376	383	572	1,146	723	550	838
Dissolved Sulphide	mg/l	18.4	2.5	26		30		
Total Alkalinity as $CaCO_3$	mg/l	238	248	280	292			
Total Hardness as $CaCO_3$	mg/l	408	238	200				
Oil & Grease	mg/l	32	40.3					
Chlorides	mg/l	1,512	375	400	1,322	1,511	360	
Sulphates	mg/l	69	353	151	420	486		538
Total Phosphorus	mg/l	12	10.8	9.2	11.1	8.5	8	
Calcium	mg/l	51	37.4	28				
Magnesium	mg/l	68	32	31.2				
Potassium	mg/l	34	21					
Sodium	mg/l	579	207					
Copper	mg/l	0.12	0.03	0.12				
Iron	mg/l	1.7	0.68	1.29				
Nickel	mg/l	0.33	0.01	0.05				
Chromium	mg/l	0.04	N/D	<0.006				
Zinc	mg/l	0.43	0.28	0.22				
Manganese	mg/l			0.05				
Lead	mg/l			0.01				

Sources: ADSSC (2008, 2009).

Table A1.2: Treated effluent quality from major treatment plants in the UAE

Parameter	Unit	Abu Dhabi (2008)	Al Ain (2008)	Dubai (2005)	Sharjah (2005)	Ajman (2009)	RAK (2009)	Fujairah (2009)
pH	value	7.0	7.2	7.1	7.1	7.8	7.2	7.1
Electrical Conductivity	ìS/cm	4,700	1,759	1,524	4,589	5,896		
TSS	mg/l	2.8	3.8	2.2	11	14	10	1.5
TDS	mg/l			919	3,028		5,014	940
Ammonia - N	mg/l	0.8	1.2	11.2	6.4	49		0.06
Nitrite (NO_2)	mg/l				0.07			
Nitrate (NO_3)	mg/l					0.6		
BOD	mg/l	1	1.9	1.0	6.0	46	4.5	5
COD	mg/l	10	20.6	76	22	128	73	15
Turbidity	NTU							
Total Alkalinity as $CaCO_3$	mg/l	53	100	80	139			
Oil & Grease	mg/l				5.8			
Total Coliforms	MPN/100 ml	0-2,419	5-1,491					
Chloride	mg/l	1,466	339	300	1,341			380
Suphate	mg/l	169	331		378	352		
Total Phosphorous	mg/l	6	5.2		6.9	6.2		1.1
Calcium	mg/l			76				
Magnesium	mg/l			14.4	86			
Potassium	mg/l				35.2			
Sodium	mg/l				857			
Copper	mg/l			0.027	Nil			
Iron	mg/l			0.155	0.022			
Nickel	mg/l			0.044	Nil			
Chromium	mg/l			Nil	Nil			
Zinc	mg/l			0.021	Nil			
Manganese	mg/l			0.031	0.041			
Lead	mg/l			0.01	0.08			

Table A1.3: Example of crops tolerant to salinity

Electrical conductivity of irrigation water (dS/m and mg/l)*					
<2 <1,280	**2-3 1,280-1,920**	**3-4 1,920-2,560**	**4-5 2,560-3,200**	**5-7 3,200-4,480**	**>7 >4,480**
Citrus	Fig	Sorghum	Soybean	Safflower	Cotton
Apples	Olives	Groundnut	Date palm	Wheat	Barley
Peach	Broccoli	Rice	Harding grass	Sugar beet	Wheat grass
Grapes	Tomato	Beets	Trefoil	Rye grass	
Strawberry	Cucumber	Tall fescue	Artichokes	Barley grass	
Potato	Cantaloupe			Bermuda grass	
Pepper	Watermelon			Sudax	
Carrot	Spinach				
Onion	Vetch				
Beans	Sudan grass				
Corn	Alfalfa				

*1dS/m = 640 mg/l; ***Source:*** FAO, 2000.

Table A1.4: Sludge characteristics (2005)

Parameter	Unit	Abu Dhabi	Al Ain	Dubai	Sharjah
Dry Solids	%	86.3	75 - 85	98	17.8
Moisture Content	%	13.0	15 - 25	2	82.2
Volatile Matter	%	68.3	60 - 70	71	81.5
Total Nitrogen	%	3.1	3 - 4	5.67	N/A
Ash	%	N/A	N/A	29	N/A
Grease	%	11.9	N/A	5.56	N/A
Total Phosphorous	%	0.85	N/A	2.07	N/A
Total Potassium	%	N/A	N/A	0.14	N/A
Chlorides	%	4.0	N/A	0.05	N/A
Arsenic	mg/kg	N/A	N/A	3.43	N/A
Beryllium	mg/kg	N/A	N/A	< 5	N/A
Chromium	mg/kg	104	N/A	61	275
Cobalt	mg/kg	177	N/A	13	11
Cadmium	mg/kg	4.9	N/A	2.4	9.5
Mercury	mg/kg	N/A	N/A	4.76	N/A
Manganese	mg/kg	N/A	N/A	171	175
Selenium	mg/kg	N/A	N/A	0.512	N/A
Iron	mg/kg	5,600	8,489	N/A	N/A
Nickel	mg/kg	126	158	N/A	164
Copper	mg/kg	468	186	N/A	964
Lead	mg/kg	N/A	80	137	234
Zinc	mg/kg	1,132	1,038	3,183	2,420
Ova and Cysts	No./25g	N/A	N/A	< 1	N/A
Entero Virus	PFU/100g	N/A	N/A	< 4	N/A

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Annex 2
Overview of Water Use

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Overview of Water Use

Introduction

The United Arab Emirate is the third largest per capita water consumer after the United States and Canada, and the second largest desalinated water producer after Saudi Arabia. Most of the desalinated water is used to meet the potable or urban water demand: domestic, industrial, and amenity water demands. A significant portion of the desalinated water is used for amenity and gardening within urban areas. In addition, in some areas desalinated water is also used in agriculture as in the Al Ain area. Agricultural and forestry water use is mainly met from groundwater resources and particularly brackish groundwater resources. Amenity is supplied mainly from reclaimed water resources.

Water Supplies

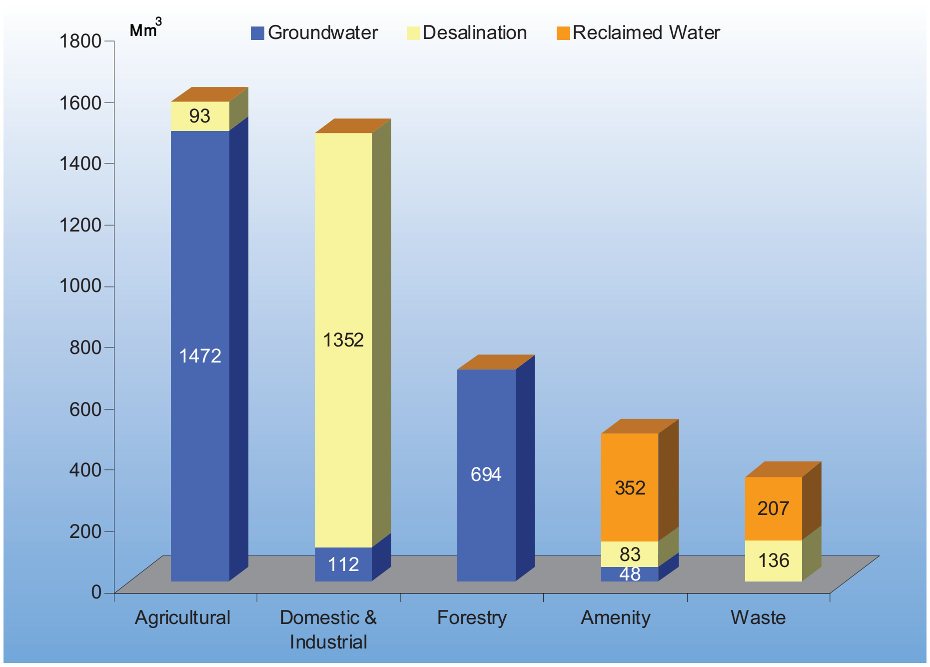
Three main water supply sources are used to meet the water needs in the United Arab Emirates: 1. groundwater supply which accounts for 51% of total water supply (49% of this quantity is used for greenery); 2. desalinated water accounts for 37% of total water supply and is used mainly for potable water use; in addition, small quantities of fresh and desalinated groundwater are used for domestic and industrial purposes particularly in Northern Emirates; and 3. reclaimed water supply which accounts for 12% of water supply and is used mainly for amenity and landscaping within the urban areas.

The total renewable and non-renewable annual water supplies are about 4.6 Km^3. The total non-renewable water supply, mainly groundwater, is about 2.15 km^3. The total renewable water supply is about 2.45 km^3 which includes: about 1.66 km^3 desalinated water, about 559 Mm^3 reclaimed water, and 150 Mm^3 of renewable groundwater (11 Mm^3 from dam recharge and 139 Mm^3 from direct rainfall recharge).

Water Use

The ways in which water resources are used in the different water-using sectors are shown in Figure 2.1.

Figure 2.1: The utilization of UAE's water resources by water using sectors in 2008



Source: ICBA, 2010.

Groundwater use

The total fresh and brackish groundwater use was about 2.3 Km^3 per year in 2008 and most was used for irrigation. Agriculture used about 1.47 km^3 (63%) and forestry used about 0.69 km^3 (30%), Only about 5% or 0.12 km^3 of mainly fresh and desalinated groundwater was utilized by domestic consumers. The remaining about 50 Mm^3 (2%) was used within urban areas for amenity plantations and landscaping (Figure 2.2).

Desalinated water use

Desalinated water is used mostly for potable water supplies. The total desalinated water for all uses is about 1.66

km³. About 1.35 km³ (81%) is used for urban water supplies (domestic and industrial), while about 93 Mm³ is used for agricultural purposes, 83 Mm³ is used for amenity and landscaping uses, and 136 Mm³ are physical losses in the network (Figure 2.3).

Reclaimed Water Use

Reclaimed water is only used for amenity and landscaping supplies within urban areas. The total reclaimed water used in the year 2008 was about 0.56 km³ (Figure 2.1) (ICBA, 2010).

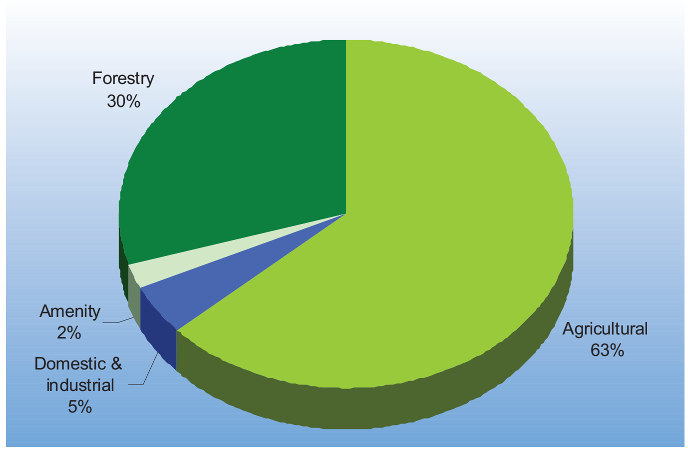
Sectoral Distribution of Water Use

Agricultural is the largest water user in the UAE as it accounted for 34% of total water use (about 1.56 km³) in 2008. About 92% of the agricultural water supply is from groundwater resources (Figure 2.4). Agricultural also used desalinated water and this use was about 93 Mm³ in 2008. The majority of this (85 Mm³) consumption was in the Al Ain region of Abu Dhabi while limited volume (8 Mm³) was used in Dubai Emirate.

The domestic and industrial water sector accounts for 34% of total water use, that is, 1.46 km³. About 92% of domestic and industrial water supply is from desalinated water. Forestry, which is fully supplied from brackish groundwater of about 694 Mm³, accounts for about 17% of total water use. Amenity and landscaping use accounts for about 11% of total water use (about 0. 5 km³). Amenity is mainly supplied from reclaimed water which accounts for 71% of total amenity supply.

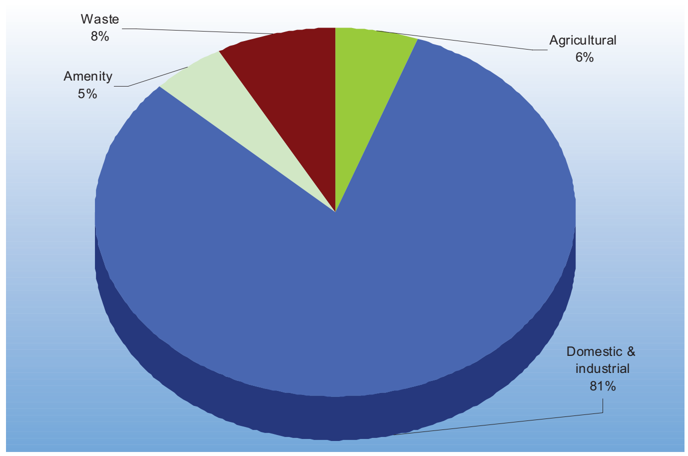
Sectoral water demand varies among the different emirates with Abu Dhabi Emirate producing and using the most - 61% of UAE's total water demand (Figure 2.5). In Abu Dhabi Emirate, irrigation (agriculture, amenity and landscaping)

Figure 2.2: Sectoral Distribution of Groundwater Uses in UAE (2008)



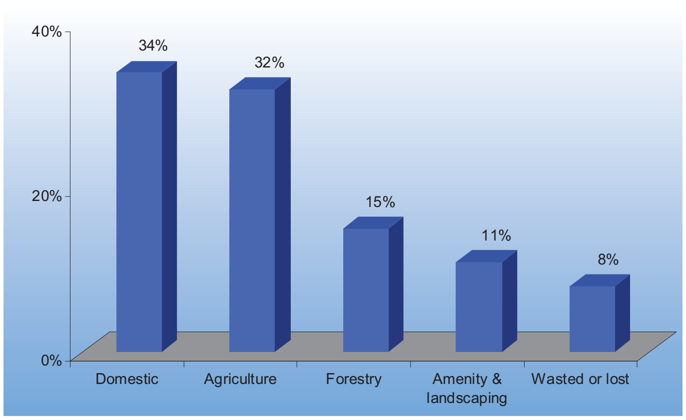
Source: ICBA 2010 based on compiled data from MOEW, ADWEC, DEWA, SEWA, FEWA 2008.

Figure 2.3: Sectoral Distribution of Desalinated Water Uses in UAE (2008)



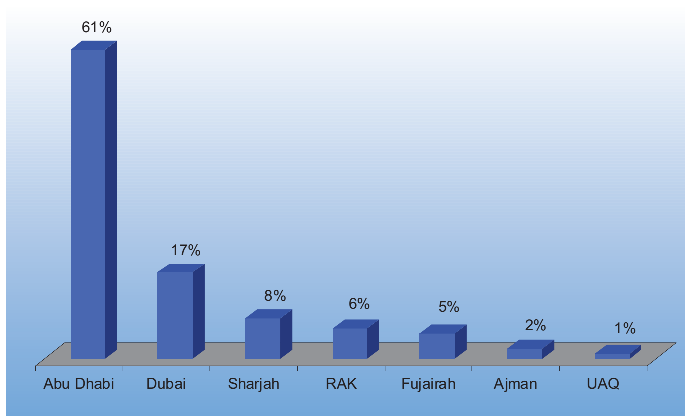
Source: ICBA 2010 based on data from MOEW, ADWEC, DEWA, SEWA, FEWA, 2008.

Figure 2.4: Sectoral distribution of water use in 2008



Source: ICBA, 2010.

Figure 2.5: Distribution of Water use by Emirate



Source: ICBA, 2010.

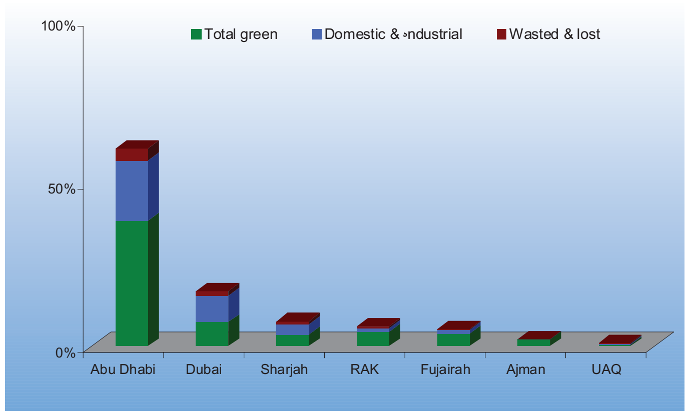
accounts for 64% of all water use. Potable water use is only 30% of the Emirate total water demand. In contrast, the potable water use for Dubai Emirate accounts for about 44% of total water demand which is close to its irrigation water demand (47%) (Figure 2.6).

The detailed sectoral distribution for Abu Dhabi and Dubai Emirates in 2008 are presented in figures 2.7 and 2.8.

Agricultural water demand for Abu Dhabi Emirate is estimated to be about 991 Mm^3 (36%), domestic and industrial water demand is about 840 Mm^3 (30%), amenity and landscaping is about 165 Mm^3 (6%), while forestry water demand is about 600 Mm^3 (22%).

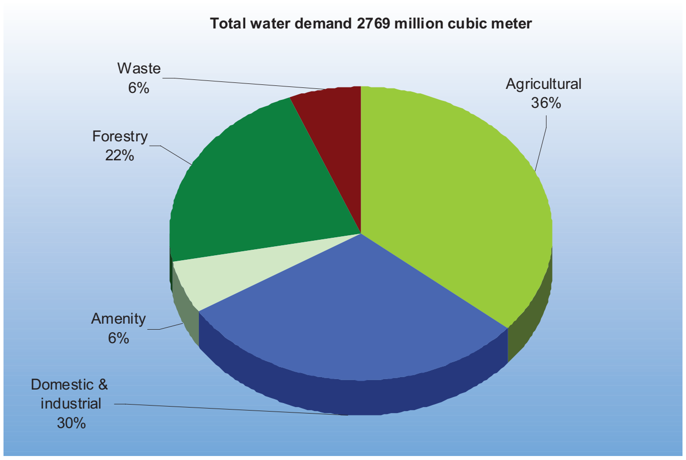
For Dubai Emirate, the 2008 total water demand including agricultural was about 832 Mm^3. Agricultural water use

Figure 2.6: Sectoral Water distribution by Emirate



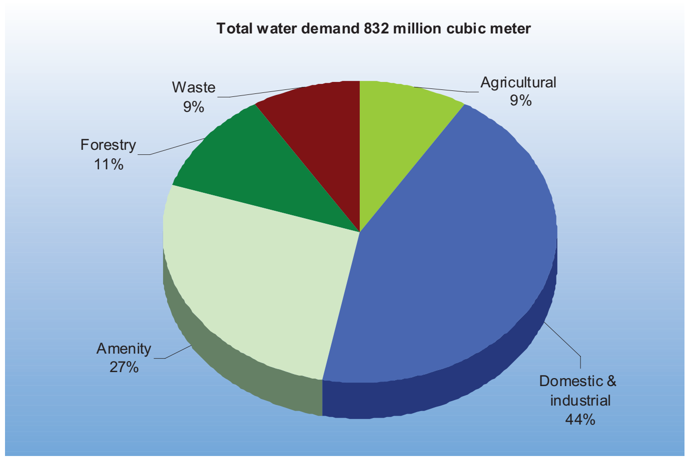
Source: ICBA, 2010.

Figure 2.7: Water demand per water sector for Abu Dhabi Emirate (2008)



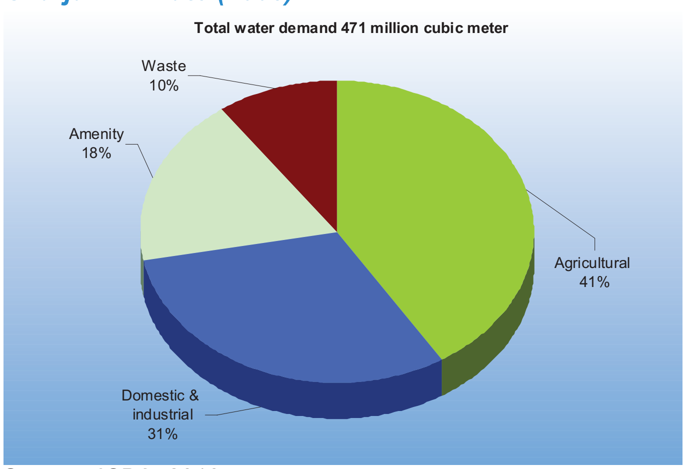
Source: ICBA, 2010.

Figure 2.8: Water demand per water sector for Dubai Emirate (2008)



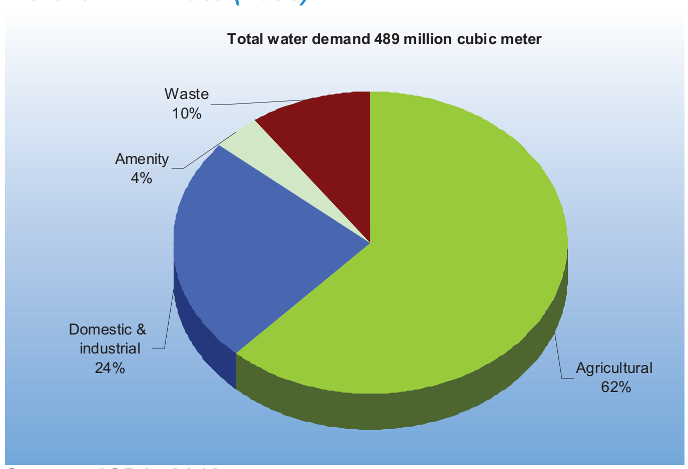
Source: ICBA, 2010.

Figure 2.9: Water demand per water sector for Sharjah Emirate (2008)



Source: ICBA, 2010.

Figure 2.10: Water demand per water sector for Northern Emirate (2008)



Source: ICBA, 2010.

accounts for only 9% of total water demand, while amenity, landscaping and agriculture together account for 47% of total water demand. Domestic and industrial water demand use accounts for 44% of total water demand (362 Mm^3).

For Sharjah Emirate, about 41% (194 Mm^3) total water use is for irrigation, and this is supplied from groundwater. Domestic and industrial water use is about 145 Mm^3 (31%), mostly supplied from desalinated water, while amenity water demand accounts for about 18% (85 Mm^3). Most amenity water is supplied from reclaimed water (Figure 2.9). In the Northern Emirates, irrigation accounts for 305 Mm^3 (62% of all demand) and is only supplied from groundwater. Domestic and industrial water demand, supplied from both groundwater and desalinated water, is about 24% (116 Mm^3) (Figure 2.10).

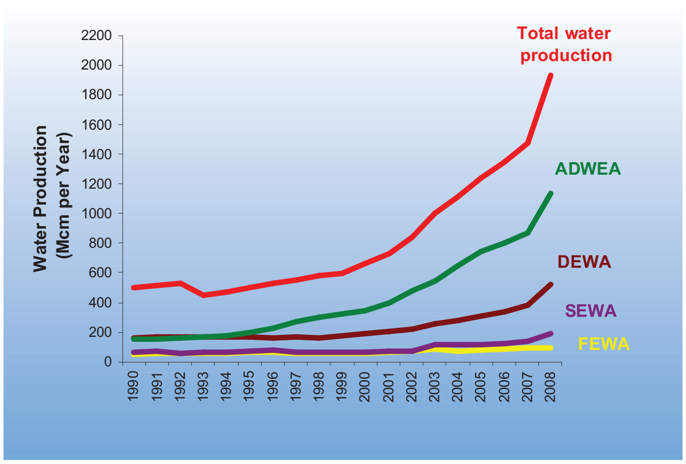
Desalinated Water

Five water institutions are responsible for producing desalinated water in UAE:

1. Abu Dhabi Water and Electricity Authority (ADWEA) serving Abu Dhabi Emirate;
2. Dubai Electricity and Water Authority (DEWA) serving Dubai Emirate;
3. Sharjah Electricity and Water Authority (SEWA) serving Sharjah Emirate ;
4. Federal Electricity and Water Authority (FEWA) serving Ajman, Ras Al Khaimah, and Fujairah; and
5. Um Al Quwain has its own water utility.

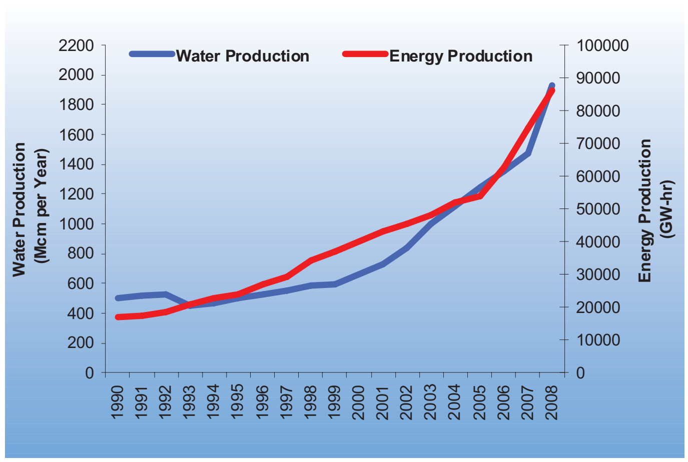
The total water production was 1.93 km^3 in 2008 (Ministry of Energy, 2009). Most of this was produced by desalination powered by fossil fuels. The historical growth of water production compiled from the Ministry of Energy database is presented in Figure 2.11. Desalinated water production increased by 93% between 2003 and 2008 at a similar rate to electricity generation, Figure 2.12.

Figure 2.11: Historical water production per production authority



Source: ICBA 2010 as compiled from the Ministry of Energy, 2008.

Figure 2. 12: Historical water production vs energy consumption



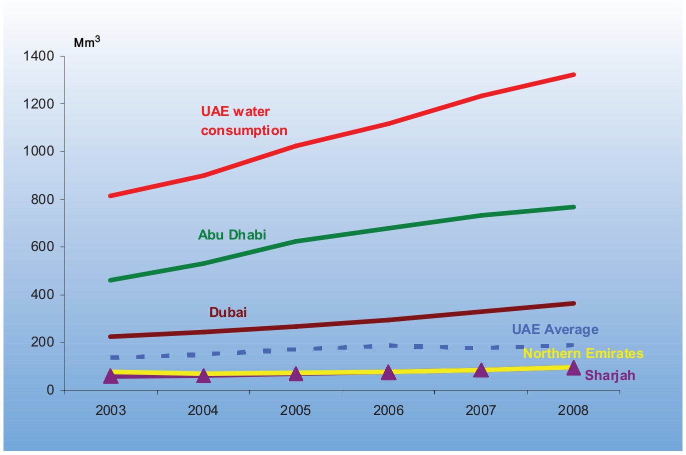
Source: ICBA 2010 as compiled from the Ministry of Energy, 2008.

Per Capita Water Consumption

Water consumption in the UAE has grown steadily in response to population growth and urban and industrial expansion. Total urban water consumption was about 1.3 km^3 for the year 2008 (Figure 2.13).

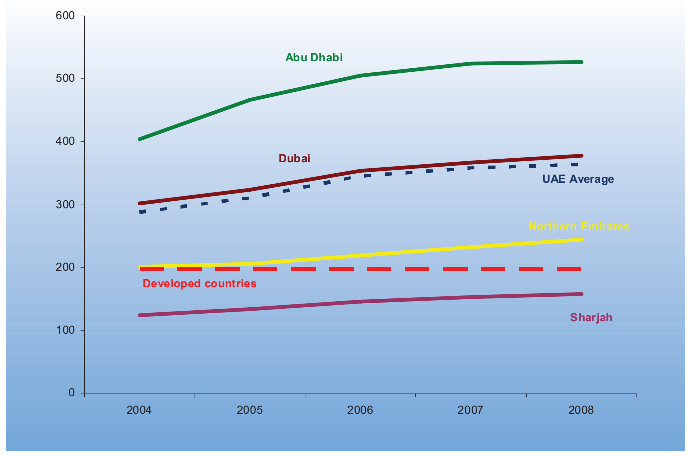
Current per capita urban water consumption (domestic, industrial & commercial, amenity, and governmental uses) was about 753 liter per capita per day (lpcpd) which is one of the highest rates over the world. The overall weighted average household domestic per capita water consumption accounted for about half (364 lpcpd) of all desalinated water use.

Figure 2.13: Growth of Water Consumption in the United Arab Emirates



Source: ICBA 2010 based on data from ADWEC, DEWA, SEWA, FEWA, and Ministry of Energy, 2008.

Figure 2.14: Average household domestic water consumption (litres per capita per day)



Source: ICBA, 2010.

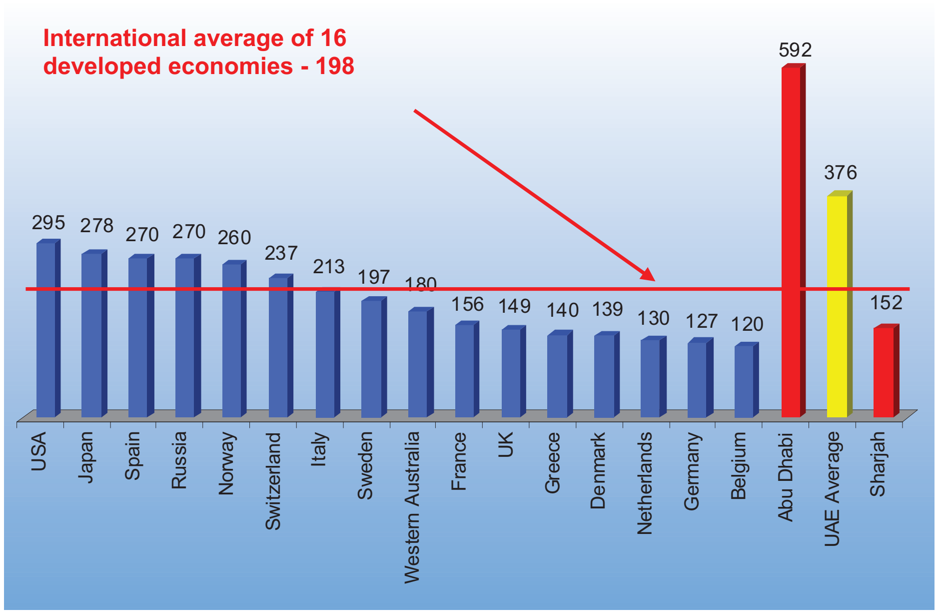
Consumption of potable water varies considerably by Emirate. Abu Dhabi Emirate has the highest per capita water consumption followed by Dubai Emirate as shown in Figure 2.14. Consumption is lower in the Northern Emirates (Ajman, Ras Al Khaimah, Um Al Quwain, and Fujairah) and lowest for Sharjah Emirate (158 lcpd).

The UAE per capita household domestic water consumption of 364 lpcpd is higher than the average international water consumption of 198 lpcpd, the United States and countries with dry climates such as Spain, Western Australia and Greece (Figure 2.15).

The distribution of desalinated water consumption varies considerably within the emirates but data are only available for Abu Dhabi. There, for example, only 24% of desalinated water consumption is for human, commercial, industrial and mega-project use (Figure 2.16). The balance goes to irrigation of gardens, landscaping and other non-potable uses.

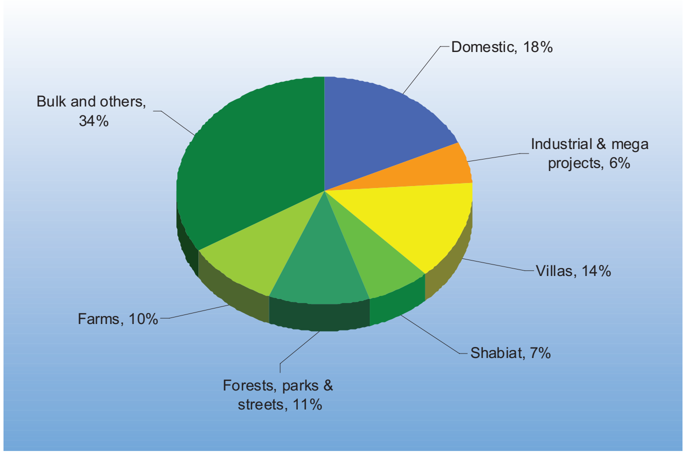
Domestic water consumption differs significantly between the UAE national and expatriate populations, and also in the residential type. The evidence for the large share of household desalinated water use that is not used for human consumption derives from surveys undertaken by the Regulation and Supervision Bureau of Abu Dhabi, Table 2.1. Water consumption of both expatriates and nationals living in flats or apartments varies between 160 and 220 lpcpd – within the range expected in developed economies. Once a garden is added, however, water consumption increases significantly. Villas owned by nationals show the highest rates of use whilst expatriates have the lowest – but it is still at least three times greater than those without gardens.

Figure 2.15: International benchmark for water use efficiency



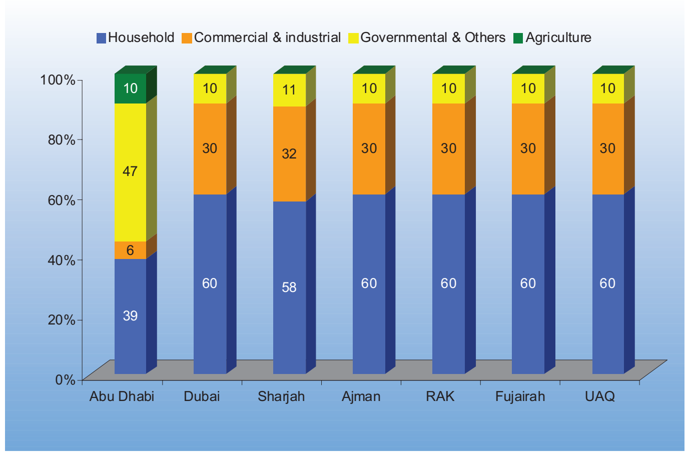
Source: ICBA 2010 based on data from ADWEC, DEWA, SEWA, FEWA, and Ministry of Energy, 2008.

Figure 2.16: Sectoral distribution of desalinated water in Abu Dhabi Emirate (2008)



Source: ICBA, 2010.

Figure 2.17: Sectoral distribution of desalinated water consumption in 2008



Source: ICBA, 2010.

The primary reason for the high consumption of desalinated water in households is the low or negligible cost of water from most consumers – there are few financial incentives to economize and conserve water, the exception being expatriates resident in Dubai. Annex 3 discusses the costs and subsidies in more detail.

Future Water Demand

This section discusses demand projections for the three major water sources: desalinated water, recycled water and groundwater.

Table 2.1: Household water consumption by property type and nationality for Abu Dhabi Emirate

Nationality	Property type	Liters per capita/day
Expatriates	Flats	160-220
	Villas	270-730
UAE nationals	Flats	165
	Villas	460-1760
	Shabiyat	610-1010
Overall average	-	**525-600**

Source: RSB, PB Power surveys (2005-2007).

Desalinated Water

Water demand forecasting is difficult and complex. Basic drivers of demand for desalinated fresh water are per capita water consumption, population growth, urbanization, the effectiveness of economic policies to promote industrialization and competitive access to world markets. The recent global economic crisis 2008-2009 has severely affected economic growth – and thus water demand – in most countries, and the UAE has been no exception. Demand management policies such as conservation-driven water tariffs, effective water charging and collection of bills, leakage and water loss reduction programs and public awareness raising activities also play a vital role.

Supply problems may also play a part – this was the case recently in Abu Dhabi where the capacity of the TRANSCO water transmission network constrained supply. Thus there are a large number of combinations of the variables affecting water demand, and to model them all would produce a large array of future demand forecasts, all of which have a high degree of uncertainty. To simplify the problem of demand forecasting the Strategy examined a range of likely population and industrial growth estimates.

Two scenarios were developed earlier by the Mackenzie Study (MOEW, 2004) and they provide a uniform, if somewhat dated, approach to projecting demand for the whole UAE.

Scenario 1. ***The Optimistic Growth*** assumed: domestic water demand growth of 10% annually until the year 2020, and 1.5% thereafter; industrial and commercial water demand growth of 13% annually until the year 2015 and then 10% until the year 2020; and 6.9% thereafter to 2030. In this scenario annual demand for desalinated water was projected to be 4.8 km^3 in 2030.

Scenario 2. ***Conservative Linear Growth*** assumed: domestic water demand growth of 8% annually until the year 2020, and 1.5% thereafter; industrial and commercial water demand growth was assumed to grow by 13% annually until the year 2015; 8% until the year 2020; and 6.9% thereafter until the year 2030. In Scenario 2 annual demand for desalinated water was projected to be 4.4 km^3 in 2030.

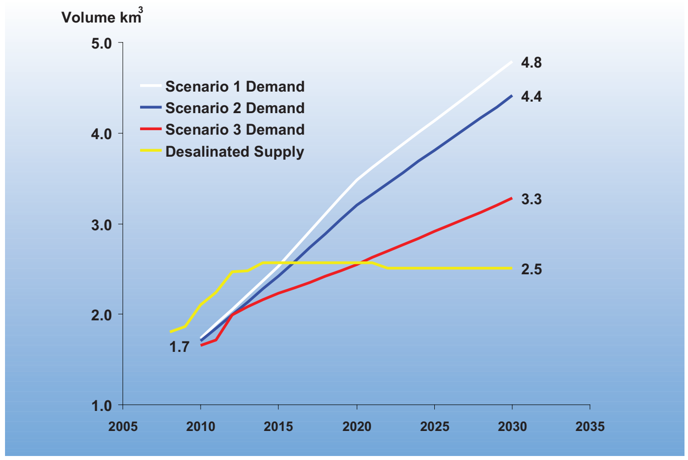
Scenario 3. ***Realistic Growth*** assumed: domestic water demand grows by 9% annually up to the year 2015, and 3.5% from the year 2015 up to the year 2020, 2.5% thereafter up to the year 2030. The industrial, commercial, and governmental water demand is assumed to grow by 9% up to the year 2015, and to grow by 3% thereafter until the year 2030. Under Scenario 3 annual demand for desalinated water in 2030 is estimated to be 3.3 km^3.

Scenario 4. ***Business-as-Usual (BAU)*** assumed: current growth rates of population and water demand continue until 2030 at which time the UAE population would be about 20 million. Under the BAU Scenario annual demand for desalinated water in 2030 would be 6.9 km^3 - or three times the present demand. As the future is unlikely to follow the extremely rapid growth of the last 5 years because of the global economic downturn. Scenario 4 is not considered further.

When the demand for desalinated water for Scenarios 1, 2 and 3 is compared with current and future prediction of desalinated capacity (Figure 2.18), it is clear that demand will greatly exceed supply in all likely demand projections. The only unknown is whether the demand deficit occurs sooner (2015, Scenario 1) or later 2020 (Scenario 3).

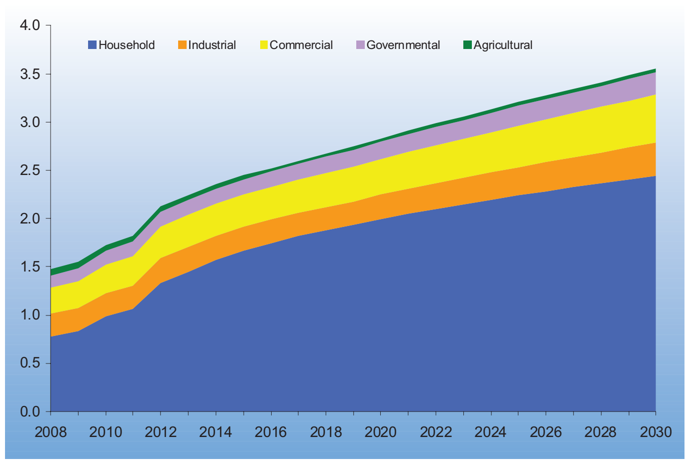
Examination of the composition of the demand for desalinated water shows that household demand is likely to remain the single largest component. On the basis of the detailed demand analysis from Abu Dhabi (ADWEC 2009), household consumption will continue to account for most of the demand, Figure 2.19.

Figure 2.18: Demand for desalinated water exceeds supply under all projections after 2020



Sources: ICBA based on ADWEC 2009 and MOEW 2004.

Figure 2.19: Realistic potable water demand scenario



Sources: ICBA 2010 based on compiled data from ADWEC, DEWA, SEWA, FEWA, and MOEW 2008.

Closing the demand gap

There are three choices:

a) Increasing the supply;
b) Reducing the demand; and
c) A combination of both (a) and (b).

Supply Augmentation

Historically, supply augmentation is the usual option that has been followed in the UAE to bridge the gap between supply and demand; in particular by increasing desalination capacity with the installation of new plants each year. Considering an increase in desalination capacity as the sole future option has some limitations. This option is costly as it relies upon very large-scale capital investment (AED billions) and significant additional fossil energy consumption. There will also be large costs with extending the bulk water transmission system and operating it. In addition there will be large and adverse environmental impacts resulting from brine disposal and CO_2 emissions.

Supply Substitution

Recycling of treated wastewater (reclaimed water) could substitute for desalinated water when water quality is not an issue. Currently considerable volumes of desalinated water are used for amenity, home gardens and landscaping, and for agriculture. Implementing policies to eliminate the wasteful use of expensive desalinated water and encouraging the use of reclaimed water would go a long way to closing the supply gap.

Demand Management

This would be implemented through physical interventions (loss reduction from the transmission system), financial incentives (metering and increased water tariffs) and education to raise the awareness of the need to conserve expensive desalinated water. However, reducing water losses in the main transmission and distribution system is a very limited option and considerably more costly than other options. This is because current water systems are well maintained and managed with water losses ranging from 13% at Dubai Emirate to 20% in Sharjah Emirate (the remaining emirates are within these two ranges). Adopting best international technologies could reduce the water losses to be about 10%, but the investment costs will be very high and the cost per cubic meter saved may be much higher than the desalination cost. In addition, the saved quantities will be very small and cannot bridge the gap alone.

Reducing daily per capita water demand can reduce the water demand dramatically. Currently, the national average per capita water consumption of 364 liters per capita per day is the third highest per capita water consumption in the world after USA and Canada. If the per capita water demand could be reduced to be within an acceptable international range of 200 litre per capita per day, then future water demand would be met solely by available desalination capacity, thus overcoming the future shortfall.

At the emirate level, this demand-supply balance for desalinated water differs between each Emirate. The following section presents this in more detail for each Emirate.

Abu Dhabi Emirate

Most of the emirates have limited information regarding the basis for desalinated water demand forecasts. Only Abu Dhabi Emirate has published its water demand forecast to 2030. In this Startegy average water demand forecast was estimated as 15% less than the peak water demand for the planning horizon 2030.

The water demand forecast for the planning time horizon 2009-2030 prepared by ADWEC were based on the following assumptions:

- 390 liter per capita per day water demand;
- Plan Abu Dhabi 2030 (Urban Structure Framework Plan);
- Population census 2005;

- Constrained demand forecast up to year 2012 and unconstrained thereafter (due to water network constraints);
- Included Khalifa Port Industrial Zone (KPIZ);
- Included changes in land ownership laws in 2005;
- Release of surplus oil revenues for major infrastructure where more investment in infrastructure is anticipated; and
- Significant additional exports to Northern Emirates.

The per capita water demand forecast was assumed to be 390 liter per capita per day (ADWEC 2008) which is less than the current per capita water demand of 525 liter per capita per day. The justification for this reduction in a short period is not clear. It is unknown whether ADWEC can achieve this target immediately without assuming a longer lead time to reduce demand gradually. According to this forecast, about 80% to 90% of increase in peak water demand comes from residential and commercial mega projects and bulk and other consumers.

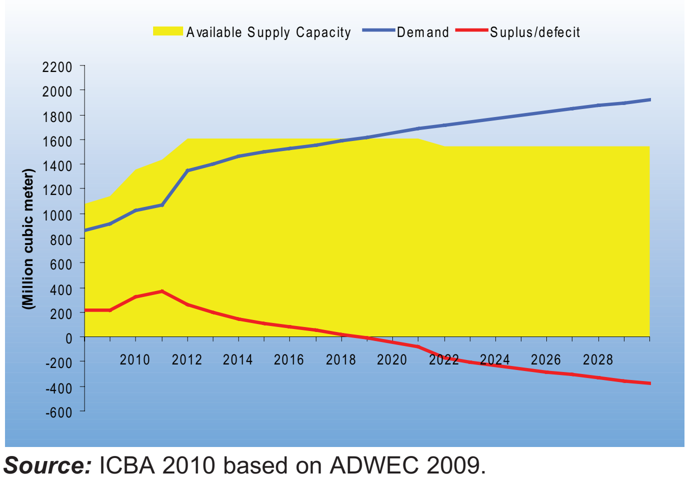
A constrained water demand forecast up to the year 2012 was assumed by ADWEC to account for the limited water network capacity to distribute the produced water demand. It was also assumed that unconstrained network capacity would be after the year 2012 when the network could work with full capacity to supply all water demand. For the period 2009-2011 water supply forecast takes account of water network constraints and is lower than water demand forecast.

Water demand forecast was based on the population census for the year 2005, and the future population projections according to Plan Abu Dhabi 2030 for Abu Dhabi Metropolitan area. The Abu Dhabi population is expected to triple by the end of the planning horizon to reach up to 3 million capita, while the number of visitors is expected to be fourfold (8 million) by the end of the same planning horizon 2030.

The anticipated average potable water demand (828 Mm^3 for the year 2008) is expected to double by the end of the year 2030 to reach about 1.8 km^3 (Figure 2.20).

Currently, the available desalination capacity meets the required water demand, and surplus capacity is expected in the short term (2012-2014) due to having the inline projects in operation up to the year 2014. A shortfall of water supply to meet the projected water demand might start after the year 2016 if no more desalination projects are constructed. This shortfall supply could increase to 380 Mm^3 by the end of the planning horizon 2030.

Figure 2.20: Available Desalination Capacity and Capacity requirements for Abu Dhabi Emirate



Source: ICBA 2010 based on ADWEC 2009.
Available Supply Capacity include existing plus under construction plus committed and planned desalination projects.

Power/Water Ratio Considerations

The ratio of power/water demand is expected to increase significantly and this may affect the economic cost of water production. According to ADWEC demand forecast the ratio of electricity to water demands will increase from around 10 in 2008 to approximately 22 by 2030, where electricity demand is forecast to grow much more rapidly than water demand. One important consequence of these differing growth rates is that only open cycle or combined cycle electricity stations will be required (unlike co-generation stations combining electricity and water generation) with no need to be located on the coast and possible nuclear and renewable capacity alternatives could also be used (ADWEC, 2008).

Dubai Emirate

For Dubai Emirate, the current available desalination capacity exceeds the required water demand, and surplus capacity is expected to continue in the short term (2010-2013) due to having the inline projects in operation up to the year 2013. A shortfall of water supply to meet the projected water demand might start after the year 2013 if no more desalination projects will be in place. This shortfall supply could increase to 400 Mm^3 by the end of planning horizon 2030 (Figure 2.21).

It is important to mention that there are many planned and committed desalination projects (see table 3.6 of Annex I) with total desalination capacity of 954 Mm^3 which will triple the existing desalination capacity by the year 2015. The status of these projects is not clear as some projects are on hold due to the economic recession. These projects are referred to in Figure 2.21 as potential capacity. This implies also a dramatic change to the projected water demand where the water demand will also be triple the current water demand.

Sharjah Emirate

Currently, Sharjah Emirate offsets its deficit or shortfall in water supply of about 5 Mm^3 by importing from ADWEC. This import of water will continue until the planned projects start in operation in the year 2014 (Al Humreh plant starts operation in 2014). A surplus of desalinated capacity is expected after the year 2014 until the year 2017 if no more projects are initiated. A shortfall of water is expected to occur after 2017 and this shortfall volume might reach about 270 Mm^3 in 2030 if no further actions are taken to cover this gap (Figure 2.22).

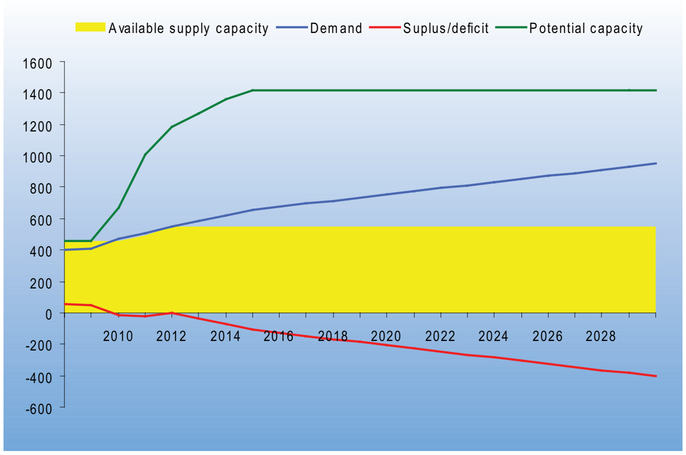
Ras Al Khaimah Emirate

Ras Al Khaimah Emirate imports the deficit quantity in water supply from ADWEC to meet its water needs. This import of water will continue until the planned projects start operation in the year 2011. A deficit of desalinated water capacity is expected after the year 2012 that will reach 40 Mm^3 by the end of the planning horizon in 2030 (Figure 2.23).

Ajman Emirate

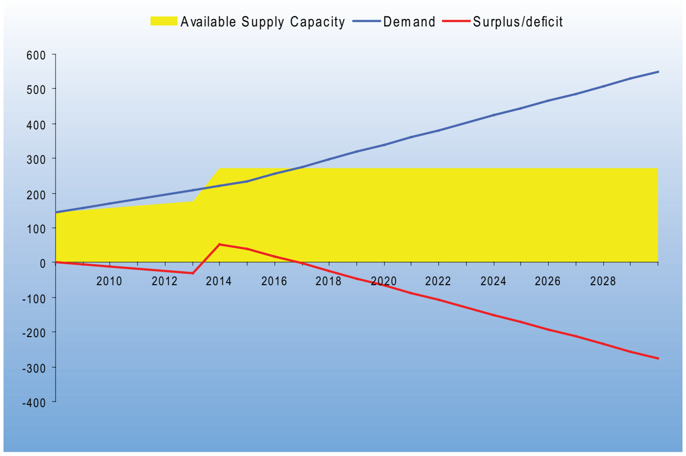
A similar water import situation is taking place in Ajman Emirate. Imports of shortfall quantity in water supply from ADWEC are contracted annually. For Ajman Emirate there are no clear future plans to meet the anticipated water demand. The water shortfall is expected to reach

Figure 2.21: Available Desalination Capacity and Capacity requirements for Dubai Emirate



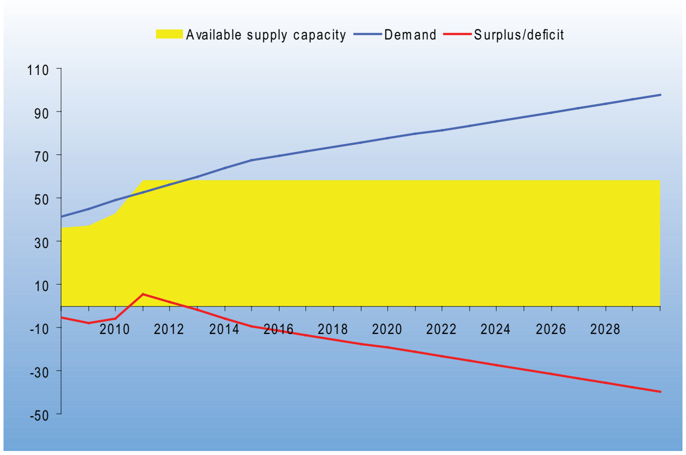
Source: ICBA 2010, based on data from DEWA, 2008.

Figure 2.22: Available Desalination Capacity and Capacity requirements for Sharjah Emirate



Source: ICBA 2010, based on data from SEWA, 2008.

Figure 2.23: Available Desalination Capacity and Capacity requirements for Ras Al Khaimah Emirate



Source: ICBA 2010, based on data from FEWA, 2008.

40 Mm3 by the end of 2030 if no more actions will be taken (Figure 2.24).

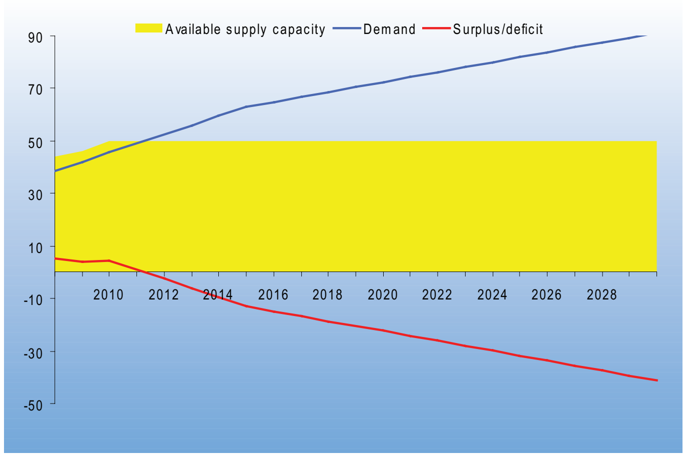
Fujairah Emirate

For Fujairah Emirate, the water shortfall is expected to increase annually to reach 4 Mm3 by the year 2030 if no further actions are taken to bridge the gap (Figure 2.25).

Um Al Quwain Emirate

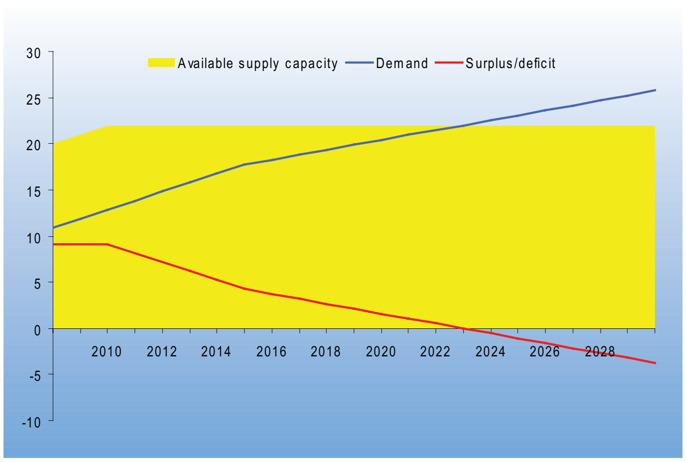
For Um Al Quwain Emirate, the water shortfall is expected to start after the year 2020 to reach 4 Mm3 by the year 2030 if no further actions are taken to bridge the gap (Figure 2.26).

Figure 2.24: Available Desalination Capacity and Capacity requirements for Ajman Emirate



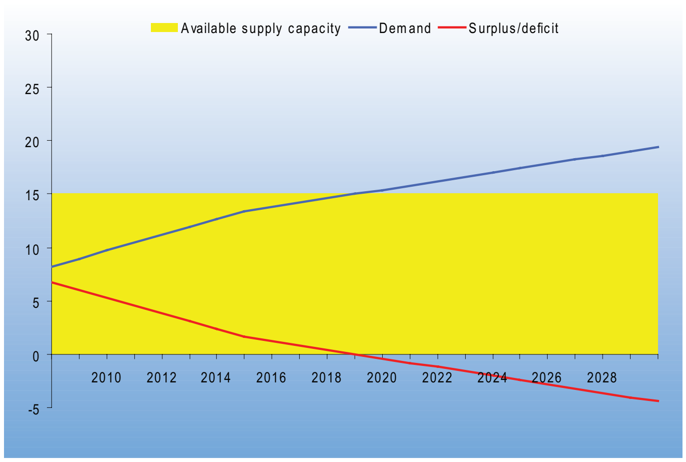
Source: ICBA 2010 based on data from FEWA, 2008.

Figure 2.25: Available Desalination Capacity and Capacity requirements for Fujairah Emirate



Source: ICBA 2010 based on data from FEWA, 2008.

Figure 2.26: Available Desalination Capacity and Capacity requirements for Um Al Quwain Emirate



Source: ICBA 2010 based on data from FEWA, 2008.

Non-Desalinated Water Demand

Agriculture

Due to the government policy of encouraging agricultural growth, the agricultural area has grown quickly since the1990s up to the year 2000. As most of the agricultural water resources were from groundwater, continuous unplanned groundwater abstraction affected the groundwater storage reserve, and caused a decline in groundwater level. This also caused water-scarcity on many farms, particularly after the year 2000. Some estimates of the reduction in agricultural areas are about 4200 ha annually. The share of actual irrigated areas according to crop type in UAE is presented in Figure 2.27.

The agricultural water use was about 1,565 Mm3 for the year 2008. Date palms are the major agricultural water user which uses about half of total agricultural water. Forage is the second largest agricultural water user after palm trees and account for about 39% of total agricultural water demand. Vegetables use about 13% of the total agricultural water (Figure 2.27).

The existing cropping pattern varies across the UAE. The UAE is divided into three agro-climatic zones: hyper-arid, arid and sub-humid. More than 80 percent of the area of the UAE is hyper-arid. Forages and date palms are the common field crops in the hyper-arid zone. Vegetables are the dominant crops in the northern, and fruit trees are prominent in the eastern zone.

Agriculture uses almost all of the groundwater abstracted and significant quantities of desalinated water. The sector, as a whole, consumes about 1.56 km^3 (i.e. 34 percent of total demand) of water that is provided to about 34,535 farms in 2008.

Water use data for agriculture, amenity and forestry for the different Emirates is given in Table 2.2. The three major groups of crop are vegetables, fodder (mainly Rhodes grass) and date palms. There is also limited cultivation of cereal and fruits.

Modern Irrigation

Overall, the area under modern mechanized irrigation has increased by more than 300% between 1998 to 2007. The area under drip irrigation has increased more than 3 fold between 1998 and 2007. In case of bubbler irrigation method, the increase was 500% over the same time period. In contrast, the area under sprinkler irrigation has decreased by about half.

Despite these advances, however, it is unclear how efficiently the potential of modern technology to save water is being used because most of the expatriate labour are unfamiliar with most of the systems installed. Thus training of farm laborers is essential for improving the efficient operation and maintenance of irrigation technologies.

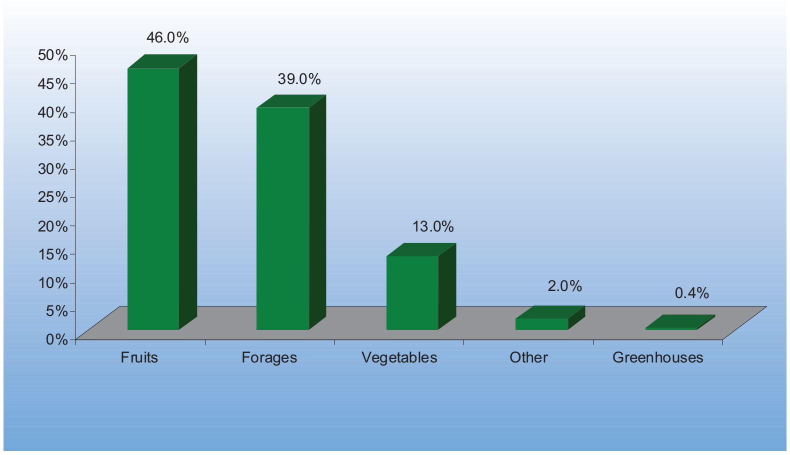
Protected Agriculture

The protected areas for growing vegetables have been increasing steadily over the years from 276 ha to 538 ha between 1998 and 2007 (Figure 2.28). A significant increase (76 percent) was recorded in 2007 against 2006. The number of greenhouses also increased from 7819 to 12,352 between 1998 and 2007. There remains great potential for greenhouse production system in UAE.

Forestry

Abu Dhabi and Dubai have forest areas of about 305,240 and 47,000 ha respectively. Other emirates have negligible forest areas. In Abu Dhabi, the forest

Figure 2.27: Share of Actual Irrigated Areas by crop type in 2008 (ha)



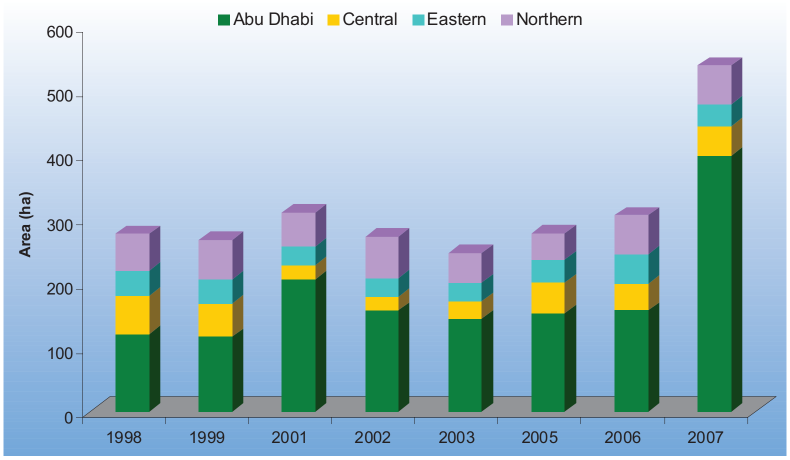
Source: MOEW Agricultural Statistics Data 2008.

Table 22: Annual water use in agriculture, amenity and forestry (Mm^3)

Emirate	Agricultural (Mm3)	Amenity (Mm3)	Forestry (Mm3)
Abu Dhabi	991	165	600
Dubai	74	227	94
Sharjah	194	85	Negligible
Ras Al Khaimah	177	7	Negligible
Ajman	20	4	Negligible
Umm Al Quwain	17	2	Negligible
Fujairah	92	5	Negligible
Total	1565	495	694

Source: ICBA, 2010.

Figure 2.28: Trend in greenhouse growth in UAE



Source: MOEW Agricultural Statistics Data 1998-2007.

area has expanded rapidly from 58,000 to 305,240 between 1989 and 2006. The average water use in the eastern region of Abu Dhabi was estimated as 2160 m^3/ha/year in 2006. In western region the estimated value was estimated to be 1990 m^3/ha/year (Moreland *et al.*, 2007). The total water use was presented in Table 2.2.

Amenity

Amenity irrigation has been increasing in UAE with the growth of urban development and highways/road. While these plantings have an ecosystem value, it is also important to consider their water quality and quantity implications. At present, the amenity area consumes about 11 percent of total consumption. Recycled wastewater contributes about 73 percent of total water used, with the remaining demand being met from desalination and groundwater.

Livestock

In UAE, the total livestock number has been increased from 1.84 million to 3.32 million between 1998 and 2007. The share of goats is of about 51%, followed by sheep of about 35 %, and camel of about 11%; the lowest share was for cows of only about 2%. The water use in this sector has increased from 17 Mm^3 in 1998 to about 27 Mm^3. The mean reason for livestock growth is due to the huge subsidy in Rhodes grass (60,100 AED/ha) which has influenced the expansion of livestock industry.

FUTURE DEMAND FOR NON-DESALINATED WATER

Agriculture

Agricultural water demand is estimated up to the year 2030. This scenario assumes that agricultural water demand will continue to decrease with the same current rate of 4,200 ha per year that has been the pattern since 2000. This assumption is based on current agricultural areas being limited to the existing areas, that no expansion to new soil-suitable areas will take place, and that the only source for water is local fresh and brackish groundwater, assuming minimal later inflow of groundwater. This scenario shows that all agricultural areas will diminish within 10 to 20 years. An alternative scenario is to assume that the agricultural demand will stay at the current level of 2.2 km^3 per year up to the year 2030.

Forestry water demand forecast

The forestry water demand from groundwater is assumed to grow at a constant current level of about 690 Mm^3 per year up to the year 2030.

Amenity water demand Forecast

The realistic scenario assumes the amenity water demand will grow at a constant rate equivalent to the annual population growth rate. As most of the amenity water is supplied from reclaimed water, the reclaimed water demand is estimated based on wastewater production rate that enters the sewer system which is assumed to be 180 lpcpd times the population.

Future water demand

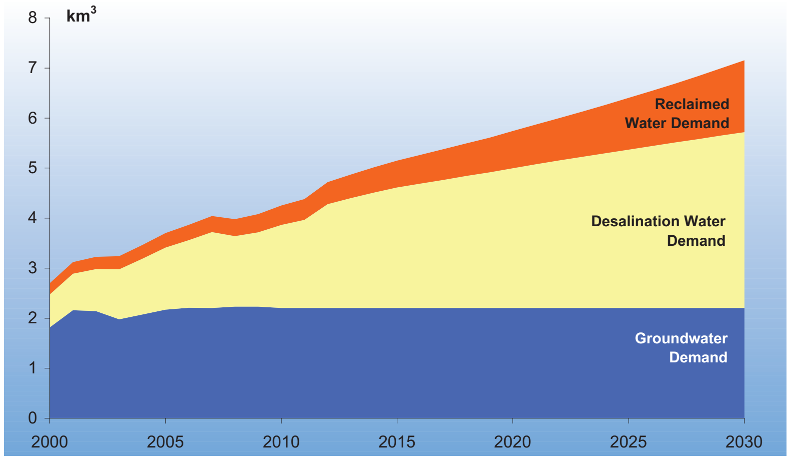
The UAE water demand will grow from 4.3 km^3 in 2008 (excluding current reclaimed water losses) to about 7.1 km^3 by the year 2030. Desalinated water demand is anticipated to almost double within the planning horizon from 1.7 km^3 in 2008 to about 3.5 km^3 by the year 2030. Reclaimed water demand is anticipated to grow from 320 Mm^3 (excluding current reclaimed water losses) in 2008 to 1.4 km^3 by the year 2030. Groundwater demand is assumed to be constant at 2.2 km^3 up to the year 2030 Figure 2.29.

If policy measures can be introduced to reduce per capita water demand from its current 364 lpcpd to 200 lpcpd, then total projected water demand could be reduced by 0.73 km^3 by the year 2030. The reclaimed water demand is anticipated to grow without reduction and will not be affected by the conservation measures or reducing the per capita water demand. Most of the reduction in per capita water demand is expected to be in the water resource that does not go to the sewer system, i.e. reducing the greenery water demand.

Recommendations

1. The current national per capita water consumption of 364 liter per capita per day is one of the highest per capita water consumption over the world. In a water-scarce country with such a harsh climate like the UAE, it is a must to reduce the average daily per capita water consumption to be within the international per capita water consumption of 200 liters per capita per day within five years. This will have major implications for bridging the gap between supply and demand, the economy, energy, and the environment.
2. The current water practices concentrate on meeting growing water demand by increasing supply, particularly through building more desalination plants. Managing the demand side of the water equation should be adopted to reduce the expected future water deficit.
3. Agriculture and forestry are competing on the same finite groundwater resource; priority of use should be decided based on economic and environmental considerations.
4. Groundwater is mostly a non-renewable resource. If the same current abstraction rate will continue, then fresh and slightly brackish groundwater resources will be depleted in 10 to 20 years. Therefore, groundwater abstraction should be managed sustainably for the benefit of the future generations. It is critical to secure a national strategic fresh groundwater reserve, which will also meet emergency needs as well.
5. The agricultural sector is the major water consumer in the country. The agricultural contribution to GDP is minimal, but the traditional cultural value of agriculture is high. Trade-offs between the economy and traditional values need to be made to decide which crops are of more value to UAE economy and consume less water at the same time.

Figure 2.29: Projection of UAE's water demand to 2030



Source: ICBA, 2010.

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Annex 3
Economic Analysis

Annex 3
Economic Analysis

Introduction

The development of water resources in any arid country is costly requiring both engineering technology and energy. In the United Arab Emirates (UAE), where natural levels of water resources are very limited, water production and distribution (particularly of a potable quality) is a costly business with much of this expense being borne by various levels of government. For example groundwater resource development (see Annex 1), still the main source of supply for agriculture, is heavily subsidized by the government through the provision of well-drilling, pumps and low-priced or free electricity. Desalination, wastewater treatment and groundwater developments all incur both capital infrastructure investments (CAPEX) and operational expenses (OPEX). This annex will review the macro economics of the current water systems to give insight on the costs and returns involved. It will also focus on the microeconomics of water in agriculture, the largest consumer of the resource.

Macro-economic analysis of water production and use

Costs of water production

The cost of producing water is a function of engineering, capital, labor and energy costs. The relative sums involved depend on the technology used, its efficiency and lifespan, the degree of financing needed and the amount and source of energy used.

Ground water extraction CAPEX, whether freshwater or brackish, involves the drilling of a well ~100m deep and compliant with set standards, which costs around AED 150,000 and an electrical pump that costs AED 7,400-18,350 (with a lifespan of around 10 years). The OPEX is dictated principally by electricity tariffs which at the moment are very low by world standards. Assuming the life of the well is 20 years with an approximate extraction rate of 25-30 m^3 per hour with the possibility of renovation, the CAPEX over the lifespan of the well is relatively negligible at approximately AED 11,000-14,700 a year (using straight-line depreciation and the OPEX is close to zero, reflecting current electricity tariffs). The costs are thus relatively small compared to the income that may be generated from the use of the water, and the potential for water abuse is large. Uninterrupted pumping for a whole year would typically yield 4.38 million m^3 of ground water per well and by virtue of scale, this would drive the cost per cubic meter down to less than one cent per cubic meter, thereby indicating that farming is an immediately profitable business. However, since pumps are not run twenty four hours, and farms are of limited size, groundwater is estimated to cost, at most, AED 1.65 per cubic meter.

The CAPEX and OPEX of desalination are of course substantially larger than groundwater and given the ever-increasing need to augment production of drinkable water, these costs will have a growing impact on government spending. The CAPEX is primarily determined by the technology used, the size of the plant, the financing need to raise the capital for the investment and the construction costs. In the UAE, Multiple Stage Flash (MSF) and Multiple Effect Distillation (MED) is primarily used which being co-generation technology brings construction and energy cost-efficiencies in both electrical and water production. The close-linking in MSF and MED technology does make it difficult to separate accurately the CAPEX costs of water generation from those of electricity without lengthy cost accounting separation methods.

In addition to actual physical assets, a typical calculation of the CAPEX of desalination takes into account, where applicable, the tenure of the independent water and power (IWPP) contract, the agreed Return on Capital (RoC), which in Abu Dhabi is set at 4.5%, and depreciation of the asset over its life. These classifications of cost apply to both the direct cost of water production as well as to the more indirect costs of transmission and distribution. Given the possible variations to factors involved in calculating the cost of desalination it is assumed by rule of thumb that CAPEX tends to fall over time due to improvements in technology scale and lowered production costs as well as lower interest rates on which the project is financed (often measured as a spread over LIBOR – London Interbank Offered Rate).

Whilst in many of the Emirates obtaining data on CAPEX and OPEX is difficult, there is some transparency, particularly in Abu Dhabi, allowing the following figures to be put forward for the UAE. Table 3.1 illustrates the point just made that over time there is a reduction in CAPEX and lowered production costs. Some alternative trends can also be observed: firstly, the cost per cubic meter of desalinated water has risen from USD 0.45 (AED 1.65) in 1998 to USD 0.63 (AED 2.31) in 2007; and secondly, that IWPP projects in Abu Dhabi are financed as approximately 70-80% debt and are subject to variations in the interest rates, which in turn are affected by sovereign ratings and the ability to issue new debt.

Table 3.1: Capital expenditure for desalinating water in Abu Dhabi Emirate

Project	Water Capacity (km^3/d)	Value (Billion USD)	Debt (Billion USD)	Year of financial close	Margin (bps over libor)	Cost per m^3 of water (USD)	% as debt
Taweelah A2	227	0.75	0.56	1998	80	0.45	74
Taweelah A1	385	1.50	1.02	2000	110	0.53	68
Shuweihat S1	454	1.80	1.28	2001	110	0.54	71
Umm al-Nar	430	2.00	1.39	2003	100	0.64	70
Taweelah B	750	3.10	2.17	2005	115	0.57	70
Fujairah F1	454	1.50	1.28	2006	65	0.45	85
Fujairah F2	590	2.70	2.14	2007	65	0.63	79

Source: Global Water Intelligence (GWI), 2010.

OPEX fluctates over time in the UAE reflecting changes in energy prices, as well as chemical and labor costs and other operations and maintenance overheads. Accurately estimating OPEX for the UAE is difficult as data are sparse with authorities unwilling to share actual costs because of, amongst a number of reasons, commercial confidentiality. Allowing for depreciation of the plant and for financing costs, the projects under the Regulation and Supervision Bureau's (RSB) supervision costs the Abu Dhabi government approximately AED 2,220 million for 2010 and with increases projected going forward (RSB, 2009). These calculations allow for the cost of the transmission and distribution. In terms of cost desalinated water across the value chain, production constitutes 57% of costs, while 37% is spent in transmission and distribution.

Wastewater treatment also comes with large CAPEX resulting from the infrastructure required for the collection, transmission and distribution networks as well as the treatment plant development. For example, for every AED 367m spent on distribution networks, CAPEX is around 77% of the project cost, a further 13% on financing charges and a remaining 10% on design and supervision costing. A large portion of the OPEX results from the chemicals used, operations and maintenance, and energy and labor costs. OPEX can rise depending on the quality of the wastewater. There is little official data for these costs although GWI (2010) has developed an overview for the country given in Table 3.3.

Given the existing technologies and their physical characteristics, the interest rate at which these projects are financed and delivered, CAPEX is expected to continue to grow at approximately AED 6.6bn a year, and OPEX is expected to rise from AED 4.4bn to AED 8.1bn by 2016. Cumulatively, this spending accounts for approximately AED 132bn between 2010 and 2016.

Table 3.2: Percentage of annual costs

Production	57
Transmission	17
Distribution	20
Wastewater	6

Source: RSB, 2009.

Table 3.3: Annual expenditure (million USD)

	2009	2010	2011	2012	2013	2014	2015	2016
Capital Expenditure								
Desalination	1870	1809	1196	1089	1470	1798	1668	2037
Water distribution network	101	117	133	148	162	173	181	186
Wastewater network	502	558	620	602	669	744	946	1052
Wastewater treatment	361	415	478	481	554	638	840	
Operational Expenditure								
Water	1175	1361	1474	1581	1687	1828	1995	2157
Wastewater	101	148	202	262	322	389	465	563
Total Expenditure	**4110**	**4408**	**4103**	**4163**	**4864**	**5570**	**6095**	**6962**
Cumulative Expenditure		**4408**	**8511**	**12674**	**17538**	**23108**	**29203**	**36165**

Source: GWI, 2010.

The economic cost of water use

The difference between the cost of water production and official tariffs is covered by government subsidies. As Annex 4 highlights, there has been little progress in introducing means of measuring, and so charging for, groundwater consumption. Whilst installing meters on wells has proven difficult, indirect methods such as through electricity tariffs could be used but are not feasible at present. For desalinated water, there are varying degrees of cost-recovery with DEWA, FEWA and SEWA operating a slab-tariff scheme with increasing cost per litre in the higher use bands. Expatriates are the principal group to pay these tariffs (see Table 3.4). In Abu Dhabi desalinated water costs are largely subsidized even for this group. In all the Emirates, the cost to nationals is negligible if not free. Similarly, reclaimed wastewater in most Emirates is principally offered for free to the various user groups, although in Abu Dhabi the passing of Law No. (12) of 2008 amending some provisions of Law No. (17) of 2005 concerning the Establishment of Abu Dhabi Sewerage Services Company has given the Abu Dhabi Sewage Services Company the authority to charge.

Estimating the water subsidy

Whilst CAPEX and OPEX give us insight as to the costs involved in establishing and running water production and distribution it is also important to consider factors beyond the development of physical assets. In understanding the full costs of water production and use in the UAE there is a need to consider the values of the subsidies that are in operation, especially those subsidies connected to groundwater use as currently there is no charge for this resource. To gain greater insight into these subsidies, two value boundaries have been estimated based on combinations and permutations of likely scenarios. In the maximum boundary, the market value of the produced water is considered and in the minimum, the cost of water production is used.

The size of the subsidy varies substantially with the valuation of groundwater. In reality, groundwater is extracted freely with no fees or tariffs. The most likely replacement for groundwater is desalinated water. In economic terms, therefore, the value of groundwater can be considered as the ‘substitution’ cost of groundwater by desalination water, that is, the cost of water production and distribution as discussed above in terms of CAPEX and OPEX.

The cost of electricity to farms is AED 0.11/kWh (compared to AED 0.73 for expatriates); a cost so low that it is almost negligible. The CAPEX and OPEX is estimated to be AED 8.26/m3 per cubic meter. The other valuation of groundwater - AED 8.80/m^3 - is based on its market value, which is the highest price water can be sold for in the UAE ‘water market’ should groundwater sources become depleted beyond usable extraction. Since nothing is paid toward groundwater resources, the estimated valuation of groundwater can be considered as a pure subsidy of the agriculture sector.

Table 3.4: Water tariffs by authority

Authority	Customer Type	Consumption (gallons) From	Consumption (gallons) To	Price (fils)	Cost per cubic meter (AED)
DEWA, FEWA, SEWA					
	Residential	-	6,000	3.00	6.60
	(expatriates)	6,001	12,000	3.50	7.70
		12,001	-	4.00	8.80
	nationals			0.00	0.00
	Commercial	-	10,000	3.00	6.60
	(incl. Govt &	10,001	20,000	3.50	7.70
	Industrial Est.)	20,001	-	4.00	8.80
ADWEA					
	Residential				
	nationals	1,000	-	0.00	0.00
	expatriates	1,000	-	1.00	2.20
	without meters*				50
	Commercial	1,000	-	1.00	2.20
	(incl. Farms, Govt				
	& Industrial Est.)				
	Tanker dist. remote)	1,000	-	1.00	2.20

Source: DEWA, FEWA, SEWA, ADWEA. * per month.

The value of desalinated water can also be based on its maximum market value, for example, in the scenario that there are shortages on competing uses, each additional cubic meter of water is likely to be obtained at the highest tariff of AED 8.8 m^3 (as per Table 3.4). Since the data is incomplete as to how much water is distributed between national and expatriate groupings in some of the emirates, the estimates below assume all users pay including nationals. In other words, the relative size of the subsidy will increase once we take into account water use by nationals that is not paid for.

At the time of the estimate, there is no market revenue for wastewater. The size of the subsidy for reclaimed water is therefore the production and distribution (CAPEX and OPEX) of wastewater only. Assuming the

Tables 3.5: Value of Subsidy by substitution (AED per cubic meter)

	Abu Dhabi	Other Emirates	UAE*
Groundwater	2.20	8.80	8.80
Desalination	0.00	2.20	8.80
Wastewater	0.00	0.00	0.00

Source: ICBA based on data from ADWEA, DEWA, SEWA, FEWA, *assumes perfect factor mobility.

Tables 3.6: Value of Subsidy by Factor Cost (AED per cubic meter)

	Nationals	Abu Dhabi	Other Emirates
Groundwater	0.84	0.84	0.84
Desalination*	8.26	6.10	1.65
Wastewater*	4.81	4.81	4.81

Source: ICBA based on data from ADSSC/Cardno 2009, World Bank 2004, GWI, 2010.

*distribution cost included for CAPEX and OPEX above discussed permutation of the value and cost of water, the maximum subsidy for water resources is estimated at AED 31.6 billion per year. The minimum subsidy of water resource is estimated at AED 24.2 billion per year.

Table 3.7: Maximum unrealized revenues (Implicit subsidy), million AED

Water source	Agriculture	Forestry	Amenity & Landscaping	Domestic & Industrial	Wasted & Lost	Total
Groundwater	12,950	6,107	423	987	0	20,467
Desalination	818	0	731	5,718	1,196	8,403
Wastewater	0	0	1,696	0	995	2,691
Total	**13,768**	**6,107**	**2,850**	**6,705**	**2,191**	**31,621**

Source: ICBA based on data from Water Demand, EAD 2009, subsidy estimated via ADWEA, DEWA, SEWA, FEWA, ADSSC/Cardno 2009, World Bank 2004, GWI, 2010.

Table 3.8: Minimum unrealized revenues (implicit subsidy), million AED

Water source	Agriculture	Forestry	Amenity & Landscaping	Domestic & Industrial	Wasted & Lost	Total
Groundwater	8, 911	4, 202	290	679	0	14, 082
Desalination	562	0	503	5, 718	822	7, 604
Wastewater	0	0	1, 696	0	995	2, 690
Total	**9, 473**	**4,202**	**2,489**	**6,397**	**1,817**	**24, 376**

Source: ICBA, based on data from Water Demand, EAD 2009, subsidy estimated via ADWEA, DEWA, SEWA, FEWA, ADSSC/Cardno 2009, World Bank 2004, GWI, 2010.

Note: The groundwater subsidy calculations are based on the size of the farms and not on their virtual water crop yields.

Analysis of water subsidy

A shift in the perception of the value and the cost of water can lead to very different outcomes. The implied subsidies presented above can be viewed as un-monetized use of limited resources and therefore partially reflect the unrealized revenues, or revenues foregone.

The maximum implied subsidy is AED 31.56 billion per year which consists of (a) desalinated water, approximately AED 8.4 billion per year; (b) ground water about AED 20.55 billion per year; and (c) reclaimed water of approximately AED 2.57 billion per year. The largest revenue stream forgone, in terms of use by sectors, is the implied subsidy to the agricultural sector. In the maximum case, the size of the subsidy is estimated at AED 13.76 billion per year. If landscaping and forestry was considered as one category the subsidy to this sector would also be as large, at approximately AED 8.95 billion. This is in contrast to the subsidy for other sectors, where the subsidy is relatively small at AED 6.6 billion per year, with this value assuming that everyone pays for water at the prevailing tariffs outlined above, which is not always the case.

The minimum implied subsidy is AED 24.2 billion per year which consists of (a) desalinated water, approximately AED 7.7 billion per year; (b) ground water about AED 13.9 billion per year; and (c) treated wastewater of approximately AED 2.6 billion per year. In the case that the implied subsidy is the least, agriculture accounts for a potential forgone revenue of approximately AED 9.5 billion while forestry and landscaping is approximately AED 6.6 billion. Domestic and industrial revenues foregone are approximately AED 6.2 billion; largely unchanged because the market for consumer and industrial water is omnipresent and tariffs are relatively close to production and distribution costs in all the emirates with the exception of Abu Dhabi where product costs exceed resale values. The value of the subsidy to the reclaimed water sector remains unchanged due to the non-existence of a formal market for this resource. The value merely reflects the subsidy at factor cost.

Should the population growth rates follow the trajectory of the 2030 vision, as the population increases, the volume of the subsidy is expected to increase with it. Since water resources are limited, policies must be oriented to conserve these resources.

The preliminary analysis concludes that the implied subsidy nexus:

- encourages the abundant use of groundwater resources;
- encourages the overuse of desalinated water resources; and
- does not accommodate for reclaimed water being a valuable resource if regarded as a commodity.

Whilst extracting groundwater and co-generating desalinated water is affordable in the context of oil windfalls, it does not guarantee water security. Should the combined effect of very low CAPEX and OPEX on groundwater extraction as well as the implied value of water pumped for farming use continue to be below the costs of alternative water sources, the water table (and the country's only strategic water resource) will continue to decline.

Future sources of water are likely to be needed from desalination sources to replace groundwater supplies for crops that contribute to food security, and keep up with population growth in the UAE. Reclaimed water management will also have to be initiated to take full advantage of grey water and come in line with population demands and the economic migration expected to the country.

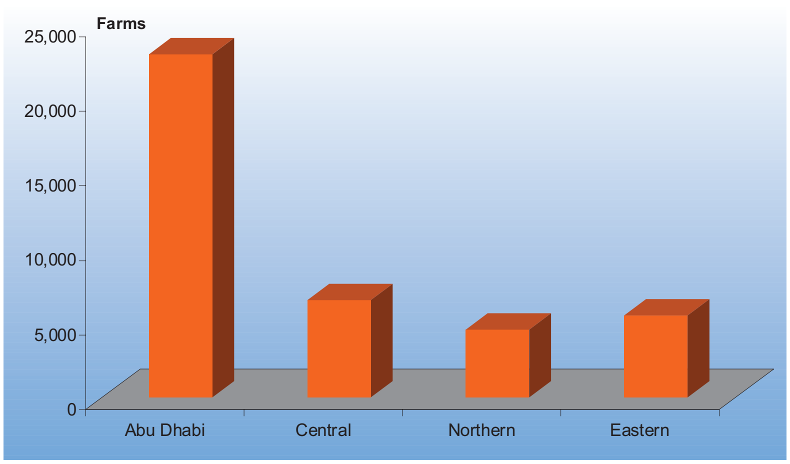
Micro-economic analysis of agricultural area and crop production

Given the large and highly-subsidized use of water by agriculture it is important that any conservation strategy considers this sector in depth. This sector has an importance to the UAE economy for cultural/historical reasons and to support food security. This section gives first an overview of agricultural activities and then an analysis of the water use.

The spread of farming activities is highly skewed within the country with nearly two thirds of agricultural activity concentrated in Abu Dhabi. Figure 3.1 represents the total cropped area in the UAE and per region as well as the number of farms. The total number of farms is 38,582 farms in 2007. The average cropped area per farm is 5.65 ha, while the average total area per farm is 6.64 ha.

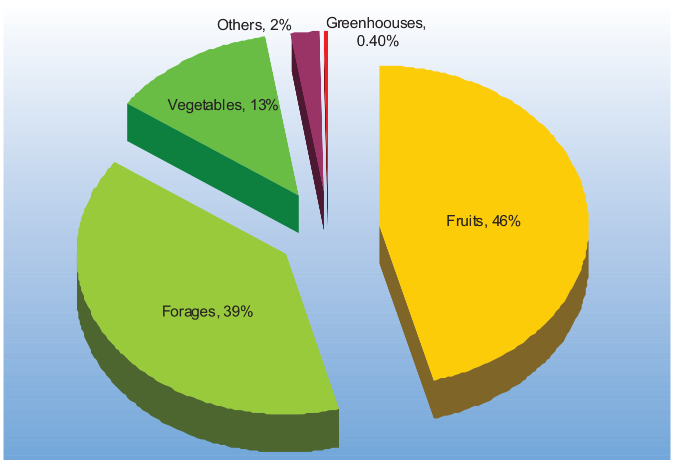
The crops grown on these farms are highlighted in Figure 3.2. The figure shows that 46% of the cropped area is allocated to fruit trees, where date palms represent the most important crop. Forage represent 39% of the cropped

Figure 3.1: Cropped area and number of farms per region in the UAE (2007)



Source: ICBA, 2010.

Figure 3.2: Major types of crops in the UAE



Source: ICBA, 2010.

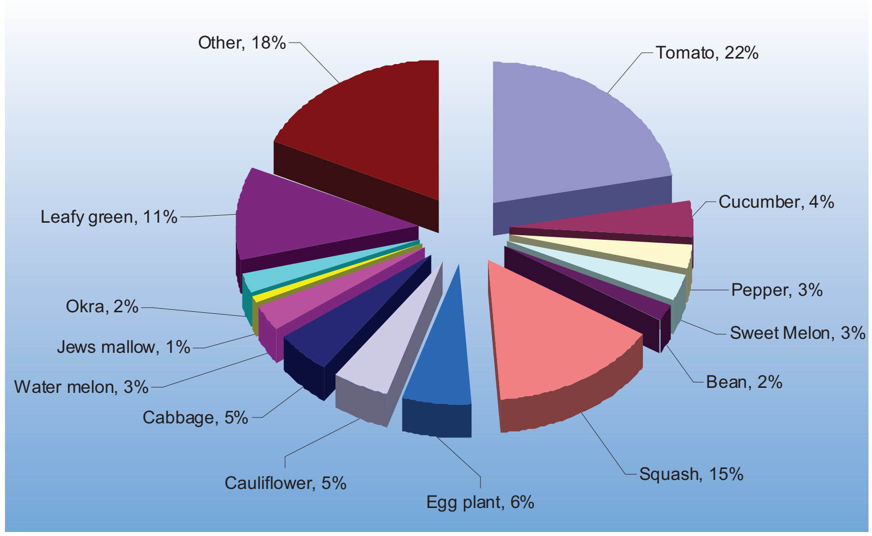
area with Rhodes grass representing the highest share of the field cropped area. Vegetables represent only 13% of the cropped area, however, with a great diversity of crops as shown in Figure 3.3. The most important vegetable crop is tomato which represents 22% of all area allocated to vegetables, followed by squash (15%), leafy green vegetables (11%) and eggplant (6%).

Figure 3.4 represents the changes in the number of farms during the period 2002-2007. The figure shows clearly the decline in the number of farms.

The fluctuation in the cropped area seems anecdotally to be a very quick response to incentives or subsidies. The number of farms increased while the cropped area decreased during the period 2002-2003 and continued to increase during 2003-2005. In 2007 the number of farms was slightly higher than the number of farms registered in 2002. In other terms, the cropped area decreased by 10% during the period 2002-2007 while the number of farms increased by 1% during the same period. Table 3.9 shows the average rates of changes in the cropped area and production of vegetables, fruit trees and field crops during the period 2002-2007. The table shows clearly that fruit trees' area and production did not change while the field crops' production decreased by 77% and vegetables' production decreased by 44%.

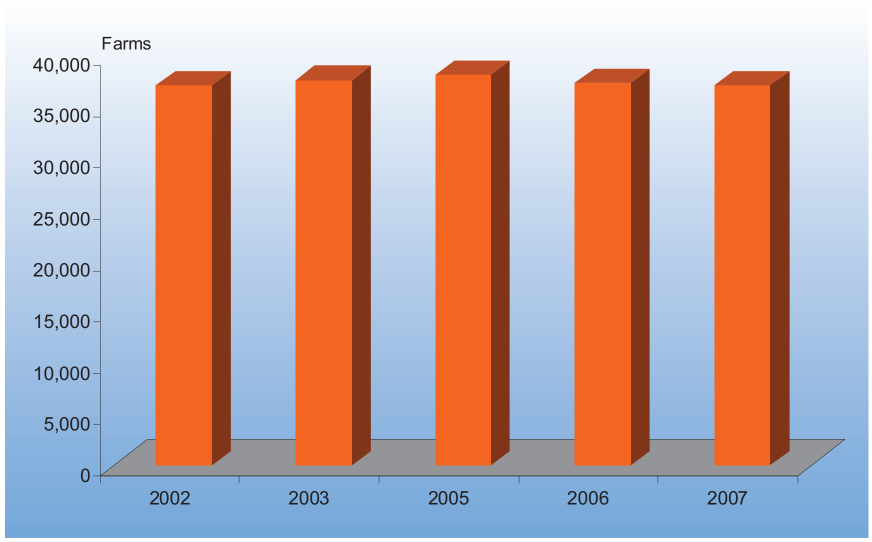
With both types of crops, the decrease in production was higher than the decrease in the cropped area, which indicates that traditional, less competitive farms continued farming while the most productive farms exited the market. This seems contradictory to economic theory. However, if the objective of farming is not the maximization of benefit but for hobby and recreation, then this could explain the result.

Figure 3.3: Different types of vegetables grown in UAE in percentage of vegetables cropped area



Source: ICBA, 2010.

Figure 3.4: Evolution of the number of farms during the period 2002-07 in the UAE



Source: ICBA, 2010.

Table 3.9: Rates of changes of the area and quantity during 2002-07

	Vegetables	Fruits	Field crops
Area	-43%	0%	-51%
Quantity	-44%	0%	-77%

The increase in livestock

Turning to livestock production, Table 3.10 shows the evolution of the number of animals during the period 2002-07. The figures indicate that the number of animals has been increasing constantly without being affected by the size of cropped fields and production which were on a decreasing trend. This could be explained by the import of animal feed including hay. The only type of animals which has had an average total decline for the period 2002-07 is cattle - the total number went from 107,444 heads in 2002 to 61,927 heads in 2007 - a decrease of 42%. This could be explained by the fact that imports of dairy products have had a strong bearing on the competitiveness of raising livestock.

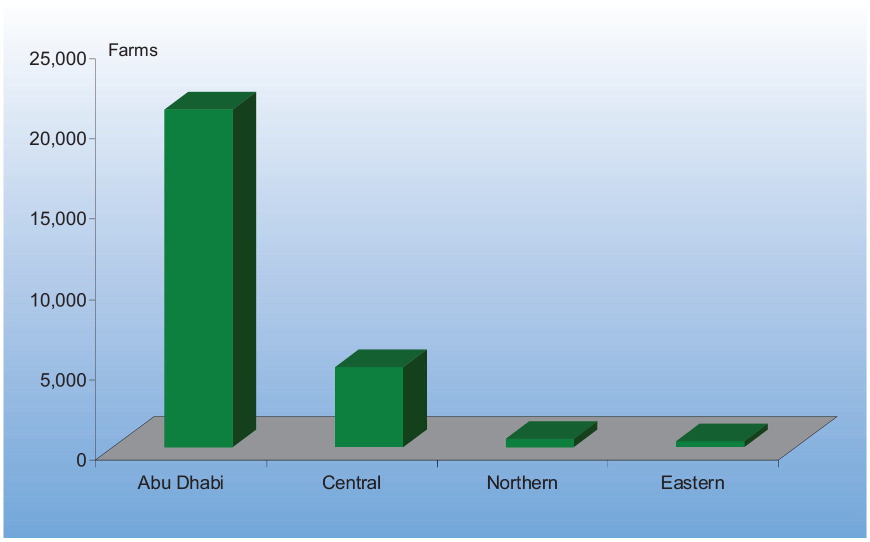
Table 3.10: Changes in absolute and relative terms of the number of animals during 2002-07

	2002	2003	2005	2006	2007
Sheep	553,614	582,717	1,058,146	1,113,775	1,172,325
Rate of change		5.0%	44.9%	5.0%	5.0%
Goats	1,430,176	1,495,283	1,546,206	1,626,087	1,707,837
Rate of change		4.4%	3.3%	4.9%	4.8%
Cattle	107,444	113,092	55,903	58,838	61,927
Rate of change		5.0%	-102.3%	5.0%	5.0%
Camels	245,766	258,684	341,395	359,340	378,227
Rate of change		5.0%	24.2%	5.0%	5.0%
Total	**2,337,000**	**2,449,776**	**3,001,650**	**3,158,040**	**3,320,316**
Rate of change		**4.6%**	**18.4%**	**5.0%**	**4.9%**

Irrigation Systems

Any form of agricultural activity is reliant on water addition through irrigation. The drip irrigation system is used in 21% of the total agricultural area; the sprinkler irrigation system is 2%; the bubbler irrigation in 72% and the remaining 5% is surface irrigation. The bubbler system is used on palm trees and fruit trees, which in turn represent the most important cropped area (87%). Figure 5 shows the total number of farms per region covered by MIS.

Figure 3.5: Use of Modern Irrigation Systems (MIS) per region



Sources: ICBA 2010 after Ministry of Environment and Water, 2007.

The efficiency of using water for each type of irrigation system is as follows:

1. Drip irrigation system - about 80-90%;
2. Sprinkler irrigation system - 70-85%;
3. Bubbler irrigation system - about 65%-75%; and
4. Surface irrigation system - not more than 60%.

The average weight of the efficiency of all irrigation systems is about 78%.

It is worth noting that given the relative efficiencies of each system, large savings could be achieved by subsidizing the use of particular types of irrigation systems with high efficiency as opposed to subsidizing the water consumption – potentially conserving 255 million m^3 per year. This is most effective when combined with farmer extension services which highlight good management practices to those involved.

Agricultural water use

As in many countries, agriculture output has a low economic value to the UAE economy and possible alternative uses of the water would likely be instantly more profitable. How productive is the use of water in the agriculture sector is an important question to be asked in any water conservation strategy. It is also important to consider how much it would take to render alternative uses of water inherently profitable. Food would need to be imported to meet any shortfall in the needs of the population, and so calculations of the virtual water inherent in imported products give a useful insight as to the water bound up.

Table 3.11 shows the water requirements for the main crops in UAE (as virtual water). Similar calculations for different animal products, and their virtual water content (as calculated by Chapagain and Hoekstra (2003)), are given in table 3.12. Table 3.11 indicates that dates and alfalfa as the highest water-consuming crop.

Table 3.11: Crop water requirements for some selected agricultural products

Products	Production (Thousand Tons)	Value (Thousand Dirham)	Water requirements (m^3/donum)
Vegetables	148.5	238,557	670
Dates	757.6	1,983,067	2000
Fruits	32.5	118,323	1020
Alfalfa	222.4	254,665	1570

Sources: Ministry of Environment and Water, 2008 and EAD, 2009.

Table 3.12: Production, value and virtual water of animals in UAE, 2007

Animal Production	Production (Thousand Tons)	Value (Thousand Dirham)	Virtual water (m^3/ton)
Meat	4.4	75,803	6342
Poultry Meat	29.4	307,268	1904
Milk & milk production	346.4	1,385,420	12149
Eggs	25.3	192,198	1968

Source: EAD, 2009.

Note: UAE's total meet production accounts for only 10% of the local market needs.

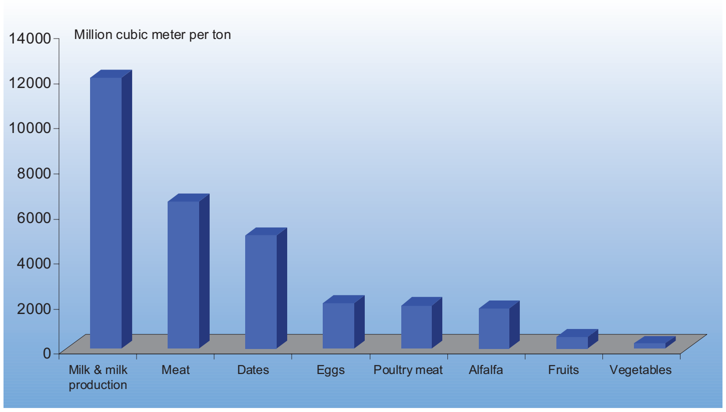
Figure 3.6 shows the virtual water of different crops and animal products. The data indicates that milk and meat production and the dates carry the highest content of virtual water. Countries exporting these products are effectively exporting high quantities of water; countries that do so are undermining their own food security. If reliable alternative sources exist for such products, then such products could be imported forgoing use of the UAE's water resources.

Farm business analysis

In order to gain a greater understanding of farming activities in the UAE, a socio-economic survey was undertaken on 74 farms as part of the development of this water conservation strategy (see Table 3.13 for geographical distribution).

Figure 3.7 highlights that the value of these products per unit of water is less than the average value of subsidy of water applied by the government which is estimated to be approximately AED 1.67. Producing these items is inherently a low-value task, consuming large amounts of water.

Figure 3.6: Virtual water of different crops and animals



Source: ICBA, 2010.

Figure 3.7: Value of production per cubic meter of water

Source: ICBA, 2010.

The farms were classified according to their water sources and price support for their agricultural output. Farms collect their water from several sources: the most common is groundwater; whilst some farms have their own on-site desalination plants; some use piped desalinated water; and a very limited number of farms also use reclaimed water. Likewise, farms collect their revenues from different sources – there are those that are under the price support scheme or those without subsidy scheme.

Table 3.13: Distribution of surveys per region

Dubai	4
Fujairah	4
Sharjah	5
Ajman	1
Um Al Quwain	1
Ras Al Khaimah	4
Abu Dhabi	52
Total	**71**

These farms under the survey were therefore grouped into five groups as follow, regardless of the region:

Group 1: Farms that use desalinated piped water at full cost **(DesFC)**

Group 2: Farms that use desalinated piped water at full cost, market their outputs in the private market and are not benefiting from the government price support scheme **(DesFC + NoS)**

Group 3: Farms using groundwater, not benefiting from government price support scheme **(NoS)**

Group 4: Farms using (tertiary) reclaimed water and benefiting from government Price support scheme **(RW)**

Group 5: Farms using groundwater and having on-site desalinated plants benefiting or not from government price support scheme **(DesPlant)**

The above grouping method was used to assess the profitability of farms using desalinated water, the profitability of farms using treated wastewater and calculate the effect of subsidy on farming.

Farm characteristics

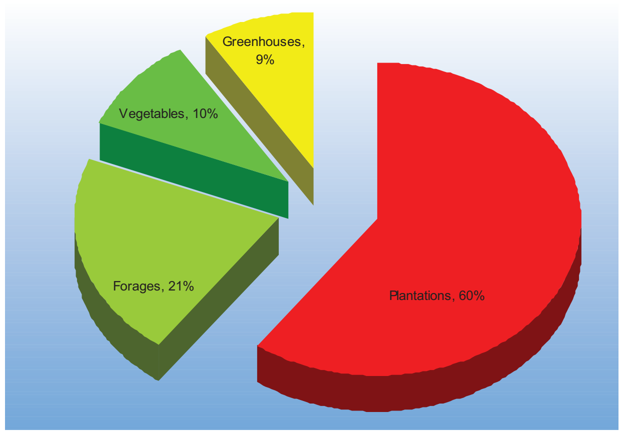
According to the survey results, bigger-than-average farms use desalinated water at full cost and do not benefit from any price support scheme. Those farms that are using desalinated water at full cost are the most frequently used for recreation with an average 194 days per year. Farms that use treated wastewater, however, are not used for recreation at all. This suggests that there may be an impediment to using reclaimed water for irrigation, such as a smell from treated wastewater, even though theoretically, tertiary treated wastewater should not generate any odor.

Figure 3.8 shows the crop mix of the total sample of farms considered in this study. The most important activity is represented by the plantations or tree crops. The most frequent tree crop is the date palm. Forages come in second order with 21% of the total cropped area. Open field vegetables represent 10% of the cropped area and greenhouses represent 9% of the cropped area.[1]

Table 3.14: Farm area and use of farm for recreation

Group	Average farm area in hectares	Recreation: average number of days/year
DesFC	3.66	194
DesFC + NoS	9.40	50
NoS	4.08	63
RW	3.35	0
DesPlant	3.35	18
Total farms	**4.01**	**95**

Figure 3.8: Crop mix of the farms sample



Source: ICBA, 2010.

Table 3.15 indicates the marketing channels for the main products. Most of the forages are sold to a public entity (89%). This is also true for dates where a semi-public company buys 89% of the product of the considered sample of farmers. By comparison vegetables growers sell most of the product to a private entity.

Table 3.15: Marketing channels for dates, vegetables and forage

Group	Vegetables	Dates	Forages
DesFC	Private entity (50%) Public entity (50%)	Semi-public entity (100%)	Public entity (100%)
DesFC + NoS	Private entity (100%)	Semi-public entity (100%)	Private entity (100%)
NoS	Private entity (58%) Local Market (42%)	Semi-public entity (80%)	Private entity (67%)
RW		Semi-public entity (100%)	Public entity (100%)
DesPlan	Private entity (75%)	Private entity (63%)	Private entity (100%)
Total farms	Private entity (73%)	Semi-public entity (89%)	Public entity (89%)

Source: ICBA, 2010.

In the Northern and Eastern Emirates farmers receive up to 50% of subsidy for agri-chemicals and 50% for investment in greenhouses. In some other Emirates (Abu Dhabi) farmers receive higher prices for their vegetables (table 3.16).

The results show that all farms rely extensively on expatriate workers. On average there are 1.5 employees per hectare with an average salary of 881 dirhams per month. Most often employees are offered basic accommodation in the farm and are allowed to produce the necessary crops for their own personal consumption.

On average there are 2 wells per farm, except those farms which depend on piped desalinated water (see table 3.18). The average well depth is 116 meters requiring an average water

Table 3.16: Vegetables under support price scheme in 2007-08 in Abu-Dhabi (AED/kg)

Cucumber	2
Tomato	1.5
Melon	1.5
Water melon	1.3
Cabbage	1
Eggplant	1
Courgette	2

Source: ICBA, 2010.

pump of 12 HP. The average pumping hours during summer is 11 hours/day while in winter it is only 9 hours/day. The electricity bill, consumption and subsidy are presented in Table 3.18. On average one hectare requires 316,822 kWh per year. The lowest electricity consumption is observed in farms using reclaimed water. Despite the use of RW, the electricity consumption per hectare is relatively high. The electricity subsidy, assuming a production cost of AED 0.25 per kWh, and given the very low price of electricity paid by farmers of AED 0.03 per kWh, is an approximately an average of AED 19,700 per hectare per year.

Table 3.17: Number of wells and pumping hours

Group	Number of wells per farm	Average Depth of the well (m)	Average HP of motor-pump	Average pumping hours in summer	Average pumping hours in winter
DesFC	0	135	7	5	
DesFC + NoS	2	107	9	13	12
NoS	3	117	13	12	11
RW	2	236	12	7	5
DesPlan	2	155	13	10	8
All farms	2	116	12	11	9

Sources: ICBA 2010 after MOEW, 2007.

Farm rent varies from a low AED 12,000 to AED 20,000 per hectare depending on the location and source of water for each farm.[2]

Table 3.18: Electricity consumption and electricity subsidy

Group	Volume of water extracted or used in m^3	Electricity bill in summer Dirhams every 2 months	Electricity bill in winter Dirhams every 2 months	Electricity consumption kWh/year
DesFC	7,609	853	1,393	224,571
DesFC + NoS	466,517	2,267	4,433	670,000
NoS	2,548,279	1543	2258	380,000
RW	47,083	767	1,033	180,000
DesPlan	50,774	1,967	1,169	313,556
Average total farms	**821,881**	**1,287**	**1,881**	**316,822**
Electricity bill Dirhams/month		644	940	
Electricity bill Dirhams/year		9,505		
Electricity Subsidy Dh/year/farm		79,205		
Electricity Subsidy Dh/year/hectare		19,736		

Table 3.19 shows the meter reading undertaken every two months for a group of 4 farms in Al Ain; electricity consumption varied from a low 9,417 kWh/month and per farm to a high 17,176 kWh/month and per farm. The average of the four farms considered is 10,911kWh/month, or an electricity bill of AED 327 per month, with an official tariff of AED 0.03 per kWh. The electricity subsidy is thus estimated at approximately AED 28,800 per year. The average farm size is 4.01 hectare, thus the electricity subsidy is 7,177 Dirhams/hectare/year.

Table 3.19: Electricity consumption in kWh for a group of 4 farms

Bi-month	Farm 1	Farm 2	Farm 3	Farm 4
1	17622	10030	51375	12897
2	20311	49780	42119	14079
3	15535	15970	21730	11761
4	16701	27440	65819	10736
5	8604	12570	29342	18859
6	15160	11410	27469	20511
7	22950	11090	24691	6347
8	25110	16790	22424	32164
9	22790	16230	23421	14250
10	20310	28980	28884	10257
11	19430	17000	30337	21642
12	14850	15940	16614	13004
13	15790	7020	65152	11833
14	22770	18110	36061	11823
15	28300	21150	20302	
16		21830	63384	
17			23681	
18			25643	
Total kWh for the whole period	**286233**	**301340**	**618448**	**210163**
kWh/month	9541	9417	17179	7506
Average kWh/month	**10,911**			
Dirhams/month	327			
Dirhams/year	3928			
Electricity subsidy/year/farm	28,804			
Electricity subsidy/year/hectare	7,177			

Crop profitability

The main crops - dates, Rhodes grass and vegetables - will now be considered in terms of their profitability.

Dates

Dates profitability is shown on Table 3.20. On average the total sales (revenue) per hectare of date palms is AED 10,768 per hectare. The average variable costs were AED 6,480 per hectare which resulted in an average gross margin (return to land and capital) of AED 4,287 per hectare. Farms that are based on piped desalinated water observed a negative gross margin despite selling the product to a semi-public date company. The anomaly is not related to salinity since these farmers are using desalinated water. The highest gross margin is obtained for the farms that use on-site desalinated plants. In this case the gross margin reached AED 14,901 per hectare. Farms based on recycled water achieved a gross margin of AED 1,608 per hectare.

Table 3.20: Financial profitability of dates among the five groups of farms

Group	Total Sales	Variable costs	Gross margins
DesFC	5,970	6,843	-873
DesFC + NoS	2,755	3,389	-634
NoS	7,622	5,391	2,231
TWW	1,791	183	1,608
DesPlan	37,438	22,536	14,902
All farms	**10,768**	**6,480**	**4,287**

Rhodes Grass

Most of the farms produce only Rhodes grass; only two farms are producing Alfalfa. Thus our analysis will be concentrated on Rhodes grass profitability.

Table 3.21 shows the figures related to the profitability of Rhodes grass. On average the gross margin per hectare is AED 45,723, although the gross margin varies widely among groups. The highest gross margin was observed in farms using piped desalinated water, with AED 93,543 per hectare, while the gross margin was negative on farms using groundwater and not benefiting from the subsidized price. Moreover, Rhodes grass would not be profitable if it were not subsidized. Table 3.21 shows the gross margin for Rhodes grass with and without subsidy, using data obtained from the agricultural extension service in Al Ain. The gross margin of Rhodes grass if the crop were not subsidized would be AED 2,910 per hectare while the gross margin would reach AED 63,010 if the crop is subsidized. The difference in price paid by the government compared to the market price is AED 1,200 per ton, which brings the average subsidy to AED 60,100 per hectare.

Assuming a water consumption of 25,000 cubic meters per hectare with production of 50 tons per hectare - the productivity approximates to 2 kg per cubic meter.

If Rhodes grass is irrigated using desalinated water and the same volumes of water, then the cost of irrigation water will be AED 82,500, costing AED 3.3 per cubic meter. Assuming the economic cost of water is AED 6.03 per

Table 3.21: Financial profitability of Rhodes grass among the five groups of farms

Group	Total sales	Total costs	Gross Margin
DesFC	110,231	16,688	93,543
DesFC + NoS	0	0	0
NoS	14,333	20,967	-6,633
RW	82,236	10,979	71,257
DesPlant	120,543	27,620	92,923
All farms	**68,524**	**22,801**	**45,723**

Table 3.22: Profitability of Rhodes grass with and without price support

	Without subsidy Dirhams/hectare	With subsidy Dirhams/hectare
Pesticides	1,040	940
Fertilizers	3,120	3,120
Seeds or plants	500	500
Labor	13,800	13,800
Machinery	1,130	1,130
Total Costs per year	19,590	19,490
Yield green in tons/hectare	50	50
Price/ton	450	1,650
Total sales	22,500	82,500
Water volume in m3	25,000	25,000
Gross margin	2,910	63,010
Amount of subsidy Dh/hectare	60,100	

Source: Agricultural Extension service, Al Ain (2009) cubic meter (McPhail, 1997), the subsidy of the irrigation water used to produce Rhodes grass is estimated at AED 68,250 per hectare for those who are using desalinated water for irrigation.

For a farmer using desalinated water the total subsidy per hectare is AED 128,350 per hectare. If we add the electricity subsidy (AED 7,177 per hectare) to this amount then we get a total subsidy of AED 135,527 per hectare. In other words, the cost to the government of 50 tons of green Rhodes grass is AED 2.71 per kilogram. This excludes the CAPEX subsidy which is assumed as a sunk cost. It is noticeable that the gross margin of the DesFC group, farmers using piped desalinated water, is AED 93,543 per hectare, which is lower than the government subsidy. This indicates that the subsidy is not fully transferred to farmers - only 69% of the subsidy is received by farmers.

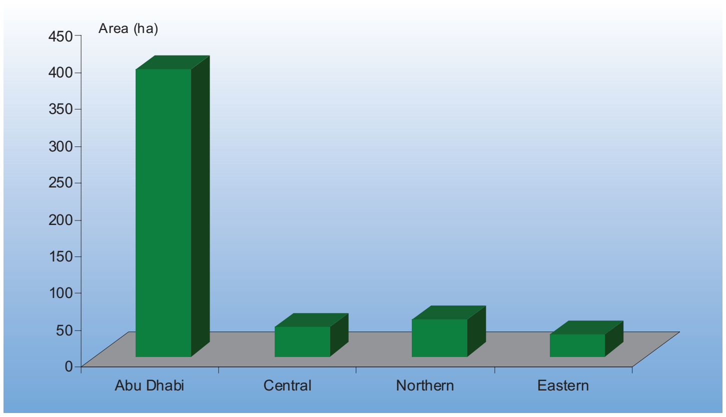
Vegetables production

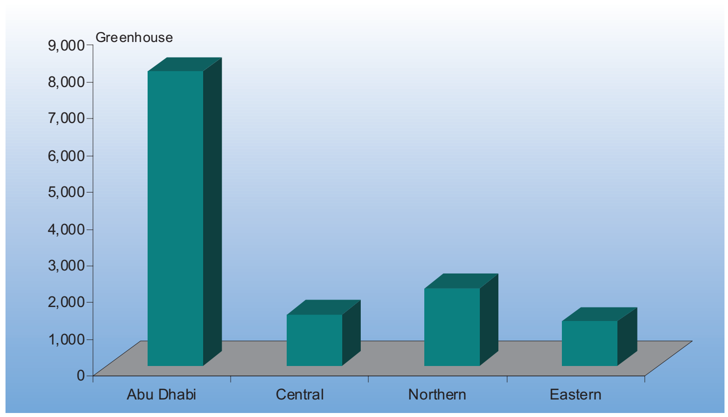
Vegetables are produced in greenhouses or in the open field and are examined below.

Greenhouses

In 2007 there were 12,352 greenhouses covering an area of 539 hectares with an average area per greenhouse of 436 square meters. (See Figure 3.13 and Table 3.23).

Figure 3.13: Distribution of greenhouses per region in 2007





Sources: ICBA 2010 after MOEW 2007.

Table 3.23: Number and area of greenhouses and crop cycles per greenhouse

Group	Average Number/farm	Average Total area/farm	Average number of cycles/year	Farmers with desalinated water	Farmers without desalinated water
DesFC	8	2,560	3	4%	4%
DesFC + NoS	47	14,933	3	4%	8%
NoS	17	5,034	2	16%	12%
RW	0	0	0		
DesPlan	22	6,784	2	24%	4%
All farms	**12**	**3,530**	**2**	**68%**	**32%**

These figures show that on average the area allocated to green houses is 3,530 square meters, representing 11% of the total farm area. The average farm has 12 greenhouses, each being 300 square meters cropped two to three times a year. The only crop observed is cucumber - the lack of diversity in production is mainly due to the lack of skills of personnel employed in the farms. The farms in UAE are not commercial but small-scale family managed unit and operated by low skill employees. The profitability of cucumber in greenhouses in one cycle is presented in Table 3.25. The figures show that farms that use piped desalinated water and those who have on-site desalination plants achieve the highest gross margins. It is notable that farms using desalinated water that have no access to support prices achieve better gross margin than those benefiting from support price scheme.

Table 3.24: Profitability of cucumber in greenhouses in one crop cycle

Group	Cucumber profitability per greenhouse (Dirham/cycle)		
	Average total sales	Average Total Costs	Average Gross Margin
DesFC	1,643	893	750
DesFC + NoS	6,400	3,583	2,817
NoS	2,521	1,402	1,119
RW	0	0	0
DesPlant	4,806	2,372	2,433
All farms	**2,766**	**1,178**	**1,588**

The profitability by greenhouse and year are presented in Table 3.25.

Cucumbers in comparison to Dates and Rhodes grass carry a lower margin. Rhodes grass earns AED 45,723 per hectare compared to AED 14,319 per hectare for cucumbers. This is based on the biased support price in favor of Rhodes grass.

When we compare non-subsidized Rhodes grass to greenhouses performance we can see that Rhodes grass has a gross margin of AED 2,910 hectare while cucumber has AED 16,319 hectare. Greenhouses also outperform dates profitability as the latter has an average gross margin of AED 4,287 hectare. However, caution should be taken when interpreting gross margins as expansion in greenhouses would bring down prices in the wake of new supplies. Thus the two major problems facing greenhouses profitability are the low skill of farm employees impeding diversification and marketing related challenges. The situation is also akin to Oman where most greenhouses are cropped with cucumber. Farmers note cucumber yield higher than any other crop produced in greenhouses. For example, the yield for cucumber is double the yield obtained for sweet melon. The cucumber's cycle is shorter than other crops' cycles and some farmers tested other crops such as tomato but competition from Middle-East countries (Syria, Lebanon and Turkey) is fierce and market prices are low. If this is the case, then quaternary reclaimed water is not likely to be profitable as farmers will most likely pay the full economic cost of the treatment.

Table 3.25: Profitability of cucumber in greenhouses per year

Group	Cucumber profitability per greenhouse and per year (Dirham/year)			
	Average total sales	Average Total Costs	Average Gross Margin	Average GM/hectare
DesFC	4,071	2,179	1,893	8,352
DesFC + NoS	17,533	9,750	7,783	5,165
NoS	6,243	3,350	2,893	3,831
TWW	0	0	0	0
DesPlan	12,417	5,783	6,633	17,761
All farms	**5,975**	**2,561**	**3,415**	**16,319**

The survey undertaken in the UAE did not allow for the capture of details of use of inputs per crop. Table 3.27 summarizes the results obtained from four farms and three cycles of cropping in Northern Oman that are using groundwater to produce cucumber. The crop net profitability accounting for both fixed and variable costs is AED 3.9

per square meter. Assuming that 80% of the area is cropped, we obtain AED 31,639 on a per hectare basis. This figure is almost double the figure obtained through the survey.

There could be two reasons for this anomaly. Firstly, it should be noted that of all the farms considered, the owner was present in his farms and did not fully rely on unskilled workers. This might explain the difference in profitability observed in the UAE survey results. Secondly, the source of water for all Omani greenhouse owners was groundwater only. There are no on-site desalination plants. Desalination of water is costly and has an important influence on the profitability. However, Omani farmers mentioned clearly that competition with imported vegetables is fierce and cucumber is the most profitable among all vegetables grown in greenhouses.

Table 3.26: Detailed profitability of Cucumber in greenhouses in Oman

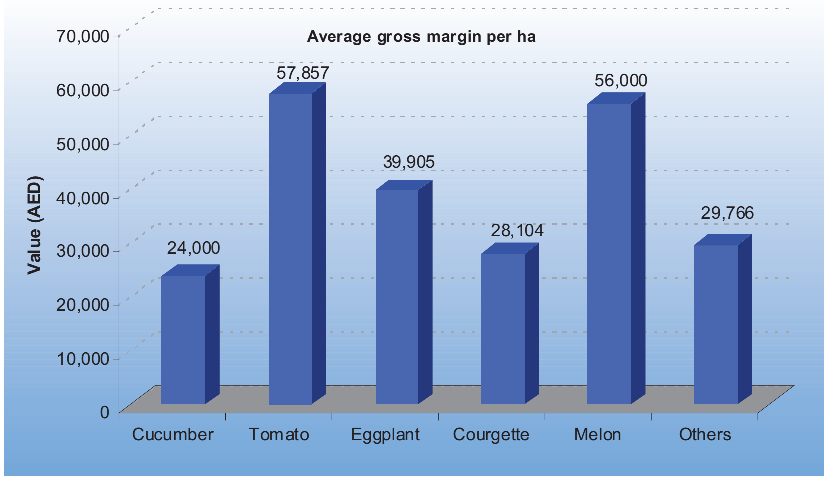
	Average of three cycles/year: Cucumber		
	Quantity	**Price**	**Subtotal**
Area m^2	319.5		
Revenue	6416.5	0.8	5347
Variable cost			
boxes	591.66667	2	1183
Labor	1		1100
Fertilizer			565
Insecticides			375
Fungicides			190
Seed (bag)	1	550	550
Electricity	3	83	249
Irrigation	17583.333	0	0
Total Variable cost Dirhams			**4212**
Fixed Cost (depreciation)			
Cover	3	43.1	129
Filter	3	55.6	167
Soil	3	18.75	56
House	3	113.3	340
Pipe	3	8.3	25
Total Fixed cost Dirhams			**717**
Total cost Dirhams			4929
Profit Dirhams/cycle			418
Profit Dirhams per year (3 cycles)			1,253
Net Profit/m^2/year			**3.9**

Source: Khadija Juma Ali Al-Ghazali, 2009.

Open-field vegetables

There are mainly five types of vegetables produced in the open field. These are cucumber, tomato, melon, eggplant and courgette (see Figure 3.14). These crops are grown on very small area. On average the area allocated to vegetables is only 8%. Thus the share of each vegetable is relatively small. This also affects profitability because it seems that these products are destined for niche markets; for instance, the area allocated to courgette is around 200 square meters whenever it is part of the crop-mix. The figure below shows the profitability of these crops on a hectare basis. The highest profitability is obtained for tomato with AED 57,857 per hectare. The average area allocated to tomato is 1,900 square meters, taking into account only farms producing tomato. Melon is classified second in terms of profitability with an average gross margin of AED 56,000 per hectare; the average area allocated to melon is 500 square meters with only one farm producing melon. Eggplant has an average gross margin of AED 39,905 per hectare. The average area allocated to eggplant is 2,700 square meters and only 7 farmers are growing eggplant, which represents less than 10% of total farms. Courgettes' gross margin is AED 28,104 per hectare with an average area of 2,200 square meters with only 8 farmers growing the crop. Cucumber has the lowest gross margin in all open-field vegetables with AED 24,000 per hectare, and an average cropped area of 4,250 square meters and five farmers involved in the process. The average profitability of all open-field vegetables taken together is AED 39,272 per hectare. The results obtained for open-field vegetables show that their profitability is higher than the profitability of vegetables produced under greenhouses. This is not totally bizarre as winter weather conditions in the UAE are ideal for vegetable production without any need for protection, as the temperature varies between 12° and 25° celsius.

Figure 3.14 Profitability of open-field vegetables



Farm-level profitability

A comparison of profitability at farm level is presented in Table 3.27. The most profitable farms are the ones using tertiary reclaimed water achieving a gross margin of AED 36,944 per hectare. If quaternary reclaimed water is provided the gross margin might be less since farmers will have to pay the cost of treatment and delivery of water. All farms that use reclaimed water are situated in Al Ain. The least profitable farms are the ones using groundwater (NoS) without access to price support achieved a gross margin of AED 2,001 per hectare followed closely by farms based on desalinated water and not having access to farm support prices. These correspond to group (DesFC+NoS) with an average gross margin of AED 2,090 per hectare. Farms that use on-site desalination plants have an average gross margin of AED 18,993 per hectare.

Table 3.27: Farm profitability

Group	Average total sales, variable costs and gross margin at farm level Dh/hectare			
	Average total revenue	**Average total Costs**	**Average total Gross Margin**	**Average Gross Margin/hectare**
DesFC	141,643	72,486	69,157	20,961
DesFC + NoS	52,367	36,262	16,104	2,090
NoS	58,851	60,193	-1,342	2,001
RW	142,707	18,947	123,763	36,944
DesPlant	114,294	50,447	63,626	18,993
All farms	**108,445**	**57,734**	**50,710**	**15,342**

The most relevant result is that farms based on reclaimed water perform better than all other farms despite the fact that they are not producing any vegetable crop. Vegetable crops are supposed to be the more profitable in theory, but not in this case study as vegetables are barely subsidized compared to Rhodes grass. Fifty percent of RW is allocated for Rhodes grass and the remaining fifty is allocated to palm trees.

The second most important result is the profitability of farms without direct subsidy (no support price). For this category of farms (NoS) the gross margin is AED 2,001 per hectare. This indicates low profitability for farms if the price support scheme is removed. The gross margin obtained by this group of farms is lower than the rent which varies between AED 12,000 and AED 20,000 per hectare per year.

For farms mainly based on tree crops, date palms represent 56% of the area; other trees represent 28% of the area, vegetables 9% and Rhodes grass 5%, which is used mainly for animal feeding inside the farm and not sold to the government. Thus in the absence of subsidy (support price) fruit trees represent the largest part of the crop mix, followed by vegetables. Forage crops represent only a small part of the crop mix. The low profitability of these farms is also due to the lower water quality. Salinity is a serious problem in many farms. Consequently, if water is managed appropriately in a way to reduce over-pumping, the profitability of these farms could be improved considerably.

Willingness to use wastewater

Farmers were asked if they would utilize the reclaimed water for farming instead of the water they are using currently or to complement the water currently used. The answers are summarized on Table 3.28. On average seven percent of the farmers affirmed they will use reclaimed water to irrigate vegetables. Five per cent are already using reclaimed water for Rhodes grass and they are the only ones willing to continue to use it in the future. Seven percent of farmers are and/or will use reclaimed water if available for date's production. All farmers who responded negatively mentioned the health risks and bad odor as the main reasons for the unwillingness to use reclaimed water in the future. Few farmers mentioned that using reclaimed water is dangerous or harmful.

Table 3.28: Farmers' willingness to use reclaimed water

Group	Willingness to use RW		
	Dates	Vegetables	Rhodes grass
DesFC		14%	
DesFC + NoS			
NoS	10%	5%	5%
RW	100%		100%
DesPlan		22%	
All farms	**7%**	**7%**	**5%**

Main Findings and Recommendations

Water production and distribution is an expensive business in an arid country such as the UAE. In order to manage efficiently the various resources it is useful to use economic analysis to understand the full costs and returns. From the analysis undertaken it is possible to summarize the findings as follows:

1. ***Cost and Value of Water***

- Groundwater is currently a free resource but can be valued at either the cost of producing the nearest alternative, desalinated water (CAPEX and OPEX) or the value obtained in the market as a water resource.
- Desalinated water can also be valued at cost or the value at which it is sold.
- There is no formal reclaimed water market as of yet; currently the value of this resource is the cost of treatment.

2. ***Implicit Water Subsidy***

- Based on the combination of value and cost, the total value of the implicit water subsidy in the UAE reaches AED 27.2 bn a year.

- Subsidies to groundwater use by for agriculture accounts for AED 9.2bn. A further AED 9.5bn is used in forestry and landscaping. The implicit subsidy for desalinated water is AED 7.2bn a year (assuming all users pay). Reclaimed subsidy is approximately AED 2.9bn. The remainder is system loss.
- With implicit subsidies, the abuse of limited water resource will also continue.

3. *Farm and Crop profitability*

- The number of farms and the cropped area in the UAE fluctuate and anecdotal evidence suggests this is in fast response to subsidies.
- In all cases, profitability of farming depends highly on the governmental subsidy. Subsidy removal will have a drastic effect on farming and only few farms will survive.
- Alfalfa, dates and milk production are low-value crop products (less than 1 AED per cubic meter) but produced in high volumes.
- Vegetables are high value crop products (AED 10 per cubic meter) but produced in relatively low volumes. The UAE weather conditions in winter are ideal for vegetable production in open-field without the need for protection.
- Greenhouses are not more profitable than open-field vegetables in the UAE for the following reasons: (1) Most farms depend solely on low skilled employees who are unable to manage computer assisted fert-irrigation technology; and (2) During the period April-October the ambient temperature exceeds 30° C requiring expensive cooling. Greenhouse technology is costly for the UAE.

4. *Food and Water security*

- Milk, dates, and meat production carry high virtual water content. Exporting these items is the same as exporting the agricultural subsidy.
- Production of water intensive products should be with a view to achieving food security without compromising water security.

5. *Limitations*

- The quality and scope of the data limits the specificity of this analysis. More data is needed.
- Water strategy need to be harmonized with local and federal strategies. Large populations require even more food security and water conservation.
- An economic analysis considering the full economic cost of energy and water for food production should be undertaken and decisions not on face value of financial analysis alone.

6. *Recommendations*

It is important that demand management is introduced which reflects more the true cost of water production and distribution; this is particularly important for the agricultural sector and the use of groundwater. Demand management could be achieved through the following strategies:

- Adoption of more developed pricing mechanisms, for example, charging prices for desalinated and groundwater resources which reflect the true costs and value of the resources;
- Better capacity building on the limits and costs of water resources in the UAE;
- Adapting crop use, volume of production, and irrigation systems to maximize economic (and social and environmental) returns on the water used;
- Adoption of desalination technologies (such as LET at MSF plants) that offer greater efficiency in terms of energy use, and to coordinate more between the Emirates in the procurement of new facilities to maximize possibilities of reducing CAPEX;
- Reducing losses in system infrastructure; and
- Developing wastewater collection and resale mechanisms.

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Endnotes

1. Although these results are quite different than the ones represented in Figure 6 which fully represents the reality of the agricultural mix in the UAE, our sample is quite representative as our interest is in the profitability of vegetables and greenhouses. These represent respectively 10 and 9% of our sample, which will allow us to draw reasonable conclusions about the financial profitability of on-field vegetables and vegetables grown under greenhouses.
2. Given that the figures obtained from the survey are very high we proceeded by checking real consumption of 4 farms over a period of 30 to 36 months by obtaining the records from the electricity company.

Annex 4

Governance, Legal and Regulatory Frameworks for water management in the United Arab Emirates

Annex 4

Governance, Legal and Regulatory Frameworks for water management in the United Arab Emirates

The governance, legal and regulatory frameworks are the foundations on which policy and management decisions are developed and implemented. These frameworks determine the authority, roles and responsibilities of the various organizations involved and set the parameters within which further ideas are considered. It is therefore important to understand the current systems in place in the United Arab Emirates (UAE) in the area of water, as any developments in strategic policy will be framed by, and impact, them.

Overview of governance framework for water management in UAE

The starting point for an analysis of the governance system in the UAE is its Constitution, and the division of powers between the Federal and the Emirate levels of authority is clearly demarcated within. Whilst water is not mentioned explicitly, by implication of some of its provisions (Articles 23, 120, 121, 122 reproduced in Appendix 4.1), natural (water) resources are the public property of the Emirates. This provides a solid legal backdrop to the current system of the Emirate governments' exercise of regulatory authority over water resources abstraction, use and protection from pollution.

By contrast, the legal status of non-conventional water resources, like desalinated water and reclaimed water , is not explicitly defined in the Constitution (unlike electricity). They therefore become in effect the property of the relevant producers, and as such are for them to dispose of and allocate for further use. Whilst strategic coordination and policy development for desalinated water is the responsibility of the Ministry of Energy and reclaimed water the responsibility of the Ministry of Environment and Water (MOEW), the operations and management of these non-conventional water sources takes places at the Emirate level with a variety of organizations involved ranging from municipalities to private companies.

Under the Constitution, there is no clear indication as to responsibilities for water conservation/ demand management, although under Article 23 "Society" is '…responsible for the protection and proper exploitation of such natural resources and wealth for the benefit of the national economy'. This onus to protect water resources and to ensure sustainable use has been taken on board by the federal legislature and executive through Federal Law 24/1999 with responsibility for this today given to MOEW. In terms of operations though, Emirate-level organizations are the most active in this area.

Thus, the constitutional emphasis on devolution and subsidiarity means that most organizations involved in water governance are found at the Emirate level. The resulting institutional systems in the seven Emirates have developed relatively independently of each other and there is little commonality between them. Article 118 of the Constitution does call for the Emirates to 'coordinate their legislations in various fields with the intention of unifying such legislations as possible'. Addressing this Article in the various laws that have been developed is limited, although there has been a transfer of ideas between the Emirate organizations in the area of natural water resources law in the last few years.

Overview of legal Frameworks and laws affecting water in UAE

Laws, regulations, standards and their enforcement are an important part of any governance system ensuring the protection of human and environmental health as well as economic efficiency. They give direction and clarity in many areas such as in responsibilities, roles, and standards for a particular environment or sector. At any level of governance, there are three key branches of the legal system with each having roles in framing, administering and enforcing laws. In the UAE the following system is in place:

The ***Legislature*** makes laws in accordance with the lawmaking process specific to each country. In the UAE, the federal-level lawmaking process is spelt out in detail in Articles 110 and 111 of the Constitution. Lawmaking at the Emirates level follows the procedures specific to each Emirate.

The ***Executive*** i.e., the government, implements, administers and, to some extent, enforces the laws issued by the Legislature. It may also issue subordinate legislation, called Regulations, for the implementation of the laws issued by the Legislature. In the UAE, the structure and functioning of the federal government is regulated by Articles 45 to 93 of the Constitution, while the structure and functioning of the Emirate governments is specific to each Emirate.

The ***Judiciary*** participates in the law enforcement process by meting out criminal sanctions, and it partakes of the implementation of the laws and regulations through the settlement of disputes and litigation arising out of the operation of laws and regulations. In the UAE, the structure and scope of authority of the federal (Union) judiciary is detailed in Articles 94 to 109 of the Constitution. The Union Judiciary has authority to settle disputes among the Emirates. The structure and scope of authority of the Emirate judiciaries is specific to each Emirate.

From these Federal and Emirate lawmakers, as well as from international agreements, the various organizations involved in water governance in the UAE are bound by the water and environmental laws, regulations and standards summarized in Table 1.

Arguably the most influential law is Federal Law No. (24) of 1999, Protection and Development of the Environment, which covers various areas that affect water management including:

- the requirements for Environmental Impact Assessments of developments;
- various aspects of environmental protection;
- environmental monitoring;
- emergency and disaster planning;
- protection of the marine environment from oil industries, transport;
- polluted water discharges;
- protection of drinking water quality from storage tanks;
- control of air emissions such as from vehicles, the burning of soil and liquid wastes, as well as from the oil extractive industries;
- handling dangerous substances; and
- nature reserves.

Following the passing of this law, numerous regulations have been established through decrees that cover specific areas of the environment or give more details of the various articles. For example, the Federal Environment Agency (now abolished) developed various guideline limits and some of these are directly relevant to the water sector in the UAE, such as those for air quality from stationary sources and water quality discharges into the sea from industrial sources. These standards, see for example Appendix 4.3 Table A4.3.1, have subsequently been adopted in the different Emirates to varying extents.

Water supply governance

The three main sources of water in the UAE - natural resources, desalinated and reclaimed water - and their subsequent use are managed, predominantly at the Emirate level, under differing institutional, legal and regulatory arrangements. Until recently these organizations were all public sector, but in the last few years, in some of the Emirates, there has been an increasing involvement of the private sector. Such moves have been designed to expand infrastructure and to increase effectiveness and efficiency in areas such as costs and service delivery. The result is a range of specialist institutions with different setups and ownership ranging from full government, through public/private partnerships to full concessions. For example, Tanqia wastewater in Fujairah is a wholly private owned company with a 33 year concession, whilst Sharjah Electricity and Water Authority (SEWA) is completely government-owned with private sector input only in certain areas of technical expertise.

Table 4.1: Some of the agreements and laws affecting the environment and water in the UAE

Legal Jurisdiction	Date of ratification and legal instruments in place
International agreements	1990 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their disposal (1989)
	1995 United Nations Framework Convention on Climate Change (1992)
	1998 United Nations Convention to Combat Desertification (1994)
	1999 Convention on Biological Diversity (1992)
	2002 Convention on Persistent Organic Pollutants (2001)
	2002 Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC Convention) (1998)
	2005 Kyoto Protocol (1997)
	2007 Ramsar Convention (1971)
Implementing Regional Agreements	1979 Kuwait Regional Convention for cooperation on the protection of the marine environment from pollution (1978)
	2003 Convention on Conservation of Wildlife and its Natural Habitats in the GCC countries
Federal Level	Federal Decree No. (77) of 2005 Regarding Protocol of Control of Marine Cross-Border Transport and Disposal of Hazardous and Other Wastes
	Federal Law No. (23) of 1999 on Exploitation, Protection & Development of Living Aquatic Resources in Waters of the State of UAE
	Federal Law No. (24) of 1999 Regarding the Protection and Development of Environment
	Ministerial Declaration No. (24) of 1999 System for Assessment of Environmental Impacts
	Cabinet Resolution/Decision No. (37) of 2001 Regulating Federal Law No. (24) of 1999 Concerning Protection and Development of the Environment
	Cabinet Resolution No. (3) of 2002 Concerning National Environmental Strategy and Environmental Action Plan for UAE
	Federal Law No. (11) of 2006 amending certain provisions of Federal Law No. (24) of 1999 concerning the Protection and Development of the Environment.
	Cabinet Resolution No. (12) of 2006 Concerning Air Pollution System
	Federal Decree No. (9) of 2007 regarding the Law (regulations) on Fertilizers and Agricultural Conditioners of the GCC Member States
	Federal Decree No. (10) of 2007 regarding the GCC Pesticides Law (Regulations)

There are also differences in the mandate and roles and responsibilities of the various organizations and laws. Some Emirates regulate and manage separately the different supply systems, whilst others combine them or link them and to other sectors. Desalination is understandably managed within the same organizations with electricity production, whilst reclaimed water is sometimes managed alone (Fujairah, Ajman and Abu Dhabi) or as departments within larger, usually municipal, structures. With the exception of Sharjah, natural resources are managed by separate organizations to water services.

Natural Water Resources

Groundwater continues to be the most widely used resource and although this is predominantly in agriculture, a few of the Emirates use it as a source of water for human consumption. It is also the strategic reserve so there is a need to protect the various aquifers to ensure water security during times of need. Surface water contributes little to the overall resource base but is locally important during the winter season especially where check dams are present.

At the Federal Level, the MOEW is responsible for developing strategic policies and plans for groundwater, establishing national standards in certain areas, and for coordinating activities with the Emirates and with other federal organizations. The vision of the MOEW is 'conserving environment and the natural resources for sustainable development' and this reflects the functions and organizational structure given under Ministerial Resolution No. (21) of 2009. The MOEW in 2009 assumed the various roles of the Federal Environment Agency (set up under Federal Law No. 7 2003 and abolished with Federal Law No. 7 2009).

Whilst water is a part of many aspects of Resolution No. 21, a number of the specific functions under Article (3) are particularly relevant:

- Developing plans, strategies and policies in the field of water;
- Developing programmes that ensure output in various sectors including water to secure food security;
- Ensuring environmental protection in economic and social plans for the country;
- Evaluating water resources and determining programmes and means that ensure good management and conservation; and
- Proposing legislation to support the Ministry's functions.

Within the MOEW, water comes under the remit of the Executive Director of Water Resources Affairs and Nature Conservation. It is unclear from the various data sources what the term 'water resources' in the MOEW's remit exactly refers to. Is it natural water resources (i.e. groundwater and surface water) or does it include non-conventional water sources too?

Groundwater

The MOEW has thus an important role in protecting and managing groundwater; however, the day-to-day operations and management of the resource takes places at the Emirate level. Here competent organizations, usually a department within the municipality, are responsible for managing the natural water resources including the implementation of articles of federal laws. The various competent authorities are:

- Abu Dhabi – Environment Agency Abu Dhabi (EAD);
- Dubai – Dubai Municipality (DM), Dept of Environment;
- Sharjah – Sharjah Electricity and Water Authority (SEWA) and Sharjah Environment and Protected Areas Authority (SEPA);
- Umm Al Quiwain - Umm Al Quiwain Water Authority (UAQWA);
- Ajman – Ajman Municipality, Directorate of Public Health and Environment (ADPHE);
- Ras Al Khaimah – Ras Al Khaimah Municipality Authority of Environment and Nature (RAKMAEN); and
- Fujairah – Fujairah Municipality, Soils Department (FMSD)

The development of protection measures and controls for natural water resources varies markedly between the competent authorities and will now be reviewed.

Groundwater Legal and Regulatory Controls

By implication of Articles 120, 121 and 122 of the Constitution, there is little doubt that the protection of groundwater r resources from over-abstraction or pollution comes under the scope of the authority of the Emirates, and that the Federation has limited authority in the matter. As a result, it comes as no surprise to find that there is no direct federal regulation of the matter. However, as highlighted earlier, the existing federal environmental protection regulation i.e., Federal Law No. 24 of 1999 on the Protection and Development of the Environment does address the protection of groundwater resources directly (Article 39) as well as indirectly, such as through the need for facilities for the disposal and treatment of waste, including wastewater, of municipal and industrial origin, and desalination plants, and that such activities are subject to prior environmental clearance requirements of that Law[1]. As a result of this federal regulation, all relevant projects should undergo an environmental impact screening prior to any separate licensing process under federal or Emirate law. The application of this article is variable across the Emirates.

With the exception of Sharjah, laws have been passed for controlling and managing groundwater. Abu Dhabi and Ras Al Khaimah passed the first comprehensive measures in 2006:

- Abu Dhabi Law No. (6), 2006 on Regulation of Well Drilling followed by Executive Rules no 6, 2007;
- Dubai Law No. (15) of 2008 on Protection of Groundwater in the Emirate of Dubai;
- *Proposed* Sharjah Law, 2007 Protection of Water in Sharjah Emirate.
- Umm Al Qaiwain, Law No. (2) 2008 protection of groundwater and regulation of well drilling in Umm Al Qaiwain Emirate;
- Ajman Law No. (4) 2009 Regulation of Well Drilling and Consumption of Groundwater; and
- Ras Al Khaimah Law No. (5) 2006, Regulation of Well Drilling.

These laws are very similar in structure and content and include provisions for the collection of information on where and how much water is being used, the development of licensing frameworks to control current and future abstractions, as well as punitive systems for protecting the water quality and quantity. The most developed law is Abu Dhabi's Law No. (6) 2006 and it has been used as a template by some of the other Emirates. Its main provisions are:

- the drilling of new wells, the deepening of existing wells, increasing a well's diameter, increasing the well's extraction capacity, replacing an existing well, and the extraction and use of groundwater, including its transportation and sale, by the owner of the relevant land/well, are all subject to license requirements (Article 3). If a well is drilled without a license, both the land owner and the contractor are liable to a fine of between AED 10,000 and 50,000, and to imprisonment for a term of between 3 and 12 months (Article 19). Moreover, unlicensed wells become public Emirate property, without compensation (Article 2);
- carrying out of the well drilling business by contractors is also subject to licensing requirements (by implication of Article 4);
- licenses are subject to terms and conditions, including, in particular, a term of duration of two years, renewable (Articles 4 and 11);
- well owners are to maintain the well and related equipment and facilities, and to meter the extraction of groundwater (Articles 8 and 17), under penalty of a fine of up to AED 10,000 (Article 24);
- the government (Abu Dhabi Environment Authority - EAD) has well-spacing authority (Article 16);
- the government (EAD) has authority to stop drilling (and, presumably, extraction) operations in progress if they do not meet the terms and conditions of the relevant license (Article 15), under penalty of a fine of from AED 10,000 to AED 20,000 (Article 23);
- the government (EAD) has authority to (a) cancel a groundwater extraction license if the extraction affects groundwater quality, and (b) "rationalize" – i.e., restrict – groundwater extraction in general (Article 18), under penalty of a fine from AED 10,000 to AED 20,000 (Article 23);
- wells which exist at the time the new Law has come into effect must be notified to the government (EAD) (Article 25), under penalty of a fine of up to AED 10,000 (Article 24), but subject to no deadline for compliance;
- the government (EAD) has authority to enter and inspect any land and to collect information, including, in particular, for law enforcement purposes, subject to advance notice being provided to the owner of the land or premises (Article 26);

- law enforcement officials are to report violations of the Law to the courts, for further disposition (Article 28); and
- Fees are charged for the processing of applications and the grant of licenses (Article 29).

In reviewing the provisions of the various laws and their enforcement, it was found that many of the key features needed to regulate well drilling and groundwater extraction and use were in place. Most of these laws establish provisions for new wells or those that are to be further developed; however, not all cover existing wells and the main area of concern was in the monitoring and enforcement of the various articles (as highlighted in Table 4.2). In a number of the laws, there is the provision to establish protection zones for groundwater. Some include details on the actual control measures (metering, pumps etc), and on the data to be provided by well-owners such as the use of the water and estimated rate of abstraction (Dubai).

The most difficult area is in regulating existing wells. These wells, and traditional groundwater rights (aflaj), which pre-date regulatory legislation, play a significant role in much of the country's rural areas. Their use is grounded on the deep and diffuse conviction of the owners that, regardless of what the Constitution says regarding natural resources being the property of the Emirates, groundwater belongs to the landowner, for him to extract and dispose of as he sees fit. As a result, managing their rights (and convictions) in the context of a new law introducing regulation of water resources abstraction and use, raises delicate issues of "expropriation"[2].

Table 4.2: Natural water resource legal and regulatory provision

	EAD	DM	SEWA	SM	UAQWA	ADPHE	RAKMAEN	FMSD
Information gathering/inventorying	**	*	**		*	*	*	
Licensing of wells and their further development	***	*	**		*	*	*	
Regulating drilling	***	*	**		*	*	*	
Regulating abstraction and rates	*	*	**		*	*	*	
Regulating use		*	**		*	*	*	
Monitoring and Enforcement	*	*	**	*	*	*	*	
Pollution Protection	**3		**		*	*	*	
Explicit link to Federal environmental clearance requirement								
Integration with other water sources				**	*			

Sources: Abu Dhabi Law No. (6), 2006; Dubai Law No. (15) of 2008; *Proposed* Sharjah Law, 2007; Umm Al Quwain Law No. (2) 2008; Ajman Law No. (4) 2009; Ras Al Khaimah Law No. (5) 2006.

* = legal and/or regulatory provision present
** = legal and/or regulatory provisions present and setup
*** = legal and/or regulatory provisions present, setup and monitored and enforced

A further difficult area is the actual implementation, administration and enforcement by the different Emirates' competent organizations of their water legislation. This tends to be problematic in any jurisdiction, and the Emirates of the UAE are no exception, with large variations in actions. A number of reasons may be put forward to explain this including a lack of both numbers and adequately trained law enforcement capacity, and the political difficulties such actions would bring. Inspectors do exist but their numbers and mandate varies greatly across the different Emirates.

Thus groundwater is regulated and managed by seven different organizations at the Emirate level and one at the Federal level. Different laws, regulations and practices have resulted; this is sub-optimal given the importance of this strategic water reserve. There is a need to agree at the national level various standards and regulations for management and information collection and these should then be implemented by the competent authority within the Emirates. This harmonization would bring a greater understanding and protection of the resource. An annotated proposal for this harmonized regulatory framework for the different Emirates is given in Appendix 4.2.

Surface Water

Whilst the greatest natural water resource is groundwater, surface water during certain times of the year and in specific areas, can become a locally important input to the water balance equation. The focus of most legislation and regulations is groundwater and there is little coverage of surface water. Under Federal Law No. (24) 1999, various articles refer to the 'water environment' which is defined as '…inland waters including ground springs, and valleys waters…' These articles refer to the protection of the water environment from pollution from various sources associated with economic activities, particularly the oil and gas industry.

In practice there has been little development of laws or regulations for surface waters. The Emirati laws do not refer to surface water, although with increased access by people to the wadis, there is a need to control the disposal of materials in the catchments. In urban areas surface water comes under the jurisdiction of the municipalities and is managed by storm water drains that go straight to the sea.

In rural areas over 140 storm water dams have been built by the MOEW to harness and manage the surface water resources. These are constructed in cooperation with the individual Emirate competent authorities in which they are built, and follow international design and construction regulations and standards from organizations such as the World Dam Commission. The MOEW, local authority and relevant sector representatives cooperate to agree access to this water reservoirs. The quality of the water behind the dams is also managed through the cooperation of these institutional representatives. There is an agreement that dumping in the water or in the surrounding area will be minimized and the MOEW takes near monthly samples of the water for laboratory analysis to monitor the quality of it.

One exception to the general lack of control over surface water is Wadi Wurayah in Fujairah which in 2009 was established as the first protected mountain area of the UAE. This protection zone, situated wholly within Fujairah Emirate, was established to safeguard fresh water springs, pools and streams that provide its unique wildlife with a renewable and safe drinking resource.

As with groundwater, surface water is managed by seven different authorities and there has been little development or enforcement of measures to protect the wadis, flow waters or receiving seas. The dumping of polluting materials can be found in many catchments, thus impacting the quality of the waters during flow events. There is a need again to develop national protection and technical standards which should be coordinated with those for groundwater. The MOEW should oversee such developments and work with the competent authorities in the Emirates on establishing monitoring and enforcement measures.

Non-Conventional Water Resources

The manufacture of water from either seawater or wastewater has grown rapidly in importance in the water balance of the UAE over the last decade as Annex 1 highlights. These new sources also bring many new and complex institutional, legal and regulatory challenges especially given the huge finances involved and the potential health and environmental risks. Controls have to be much more stringent than those for natural water resources.

Desalinated Water

Many different specialist organizations are involved in the production, transmission, distribution and control of desalinated water. At the Federal level the Ministry of Energy is responsible for developing strategic policies and plans for desalinated water, establishing national standards in certain areas, and for coordinating activities with the Emirates, with other federal organizations as well as with GCC counterparts. There are currently no federal laws concerning desalinated water, although of course Federal Law No. (24) 1999 affects the abstraction and discharge of water from the sea.

An recent development at the Federal level has been the passing of Cabinet Decree No. (37) 2009 which will lead to even greater coordination within the sector. Under this decree a Council for Electricity and Water is in the process of being formed, to be headed by the Minister of Energy, to coordinate and enhance activities between the major authorities and organizations involved in the production and distribution of desalinated water. This is an important move as there are an increasing number of organizations involved in various aspects of water production, transmission and distribution and many of these are outside the public sector.

The four large organizations directly responsible for the production and distribution of desalinated of water at the Emirate level are Abu Dhabi Water and Electricity Authority (ADWEA)[4], Dubai Water and Electricity Authority (DEWA)[5], Sharjah Electricity and Water Authority (SEWA)[6] and the Federal Electricity and Water Authority (FEWA)[7]. The last, FEWA, is responsible for serving the needs of the four Northern Emirates. With the exception of Abu Dhabi, these authorities are government owned. The private sector is involved in various aspects of design, construction and operation. Companies have been established that are highly specialist and are responsible for various aspects of the production, distribution and control system. In Abu Dhabi a system of highly specialized organizations has been established for specific parts of the water system. The private sector are involved to a much greater extent here, particularly in the area of water production, although majority government ownership always remains in place with contracts being predominantly Build, Operate and Transfer (BOT) or Build, Own, Operate and Transfer (BOOT).

In addition to these large Emirate based authorities, there are an increasing number of smaller organizations, often associated with large housing developments, which are licensed to produce and desalinate their own water. Some, such as Dubai's Palm Water, are licensed for extended periods, whilst others such as the Tourism Development and Investment Company in Abu Dhabi have a fixed period of operation.

A small but important part of the desalinated water supply system to both consumers and commercial enterprises is bottled desalinated water. There are many companies involved in this business and their activities are controlled at the Federal level by the Emirates Standards and Metrology Authority (established under Federal Law No. (28) 2001). These companies are a mixture of governmental and private sector organizations.

A final group engaged in desalinating water are individual landowners, usually involved in agriculture. They have small systems reverse osmosis systems installed to provide water of a suitable quality for their activities. Their activities, based on abstracted groundwater, tend not to be licensed or regulated. This is obviously a gap in organizational control falling between natural resource and desalinated water management.

Desalinated Water Legal and Regulatory Controls

The production of desalinated water is both technically complex and expensive, and is predominantly mixed with that of electricity. These factors, in tandem with the natural monopoly of water authorities and the potential for environmental impact, ensure that it is one of the most regulated sources of water in the UAE. To control the activities of this ever-increasing group of organizations, regulators have been established in many of the Emirates. They have introduced technical, health, safety, economic and environmental regulations and standards to varying extents to ensure adequate protection is in place for many aspects of the desalination process, transmission and use. The regulations have evolved under a number of influences with standards often adopted from organizations such as the International Desalination Association (IDA), International Organization for Standardization (ISO), the International Water Association (IWA) and World Health Authority (WHO). Each Emirate has different standards and different monitoring and enforcement systems in place.

In recent years various standards and regulations have been introduced through a further level of governance, GCC level agreements. Ministers responsible for electricity and desalinated water in the six countries meet to discuss and agree standards for various aspects of this sector twice year. Following approval at this level, the standards are then sent to the national ministries, and in the case of the UAE, to the Emirate-level organizations for further acceptance and implementation, adjusting as needed for individual plant specifications. Whilst these regulations have been highly technical to date, there are moves to introduce more explicit standards for environmental protection such as for brine discharge. The level of adoption by operations is difficult to assess at present.

The regulations and standards that have been developed for the desalinated water sector are necessarily complex and affect the design, engineering, building and operations of the plants. Some of the current environmental discharge standards for different desalination plants in Abu Dhabi are given in Appendix 4.3.1 and show the development of increasingly stringent values. It was difficult to determine the various standards in place at other desalination plant locations as some of the authorities were reluctant to divulge such information. This highlighted a lack of transparency and confirmed the views of many contractors involved in the sector. The lack of coordination in setting standards and even changing values during construction has already led to delays and additional costs in a number of projects in the UAE.

The Abu Dhabi regulator, the Regulation and Supervision Bureau (RSB), is the most transparent of the regulators and is now perceived to be a model to follow. It is a wholly independent organization that reports directly to the Executive Council and its role and responsibilities are clearly defined under various Abu Dhabi laws[8]. Its activities covers desalinated and wastewater and electricity and its website gives details on all licences issued, and regulations established. The RSB holds open consultations regularly with key stakeholders on future areas of regulation (e.g. price control reviews, water supply regulations). Dubai has now taken the first steps in developing a similar regulatory organization under Executive Decision No. (2) of 2010, which establishes an independent Bureau called the Regulation and Supervision attached to the Dubai Supreme Energy Council.

Looking forward, the number of organizations in the UAE involved in desalinating water is likely to increase in the near future with a greater role being played by the private sector (as highlighted in recent new articles concerning DEWA[9]). This trend, coupled with the increasing transfer of desalinated water across the different Emirates (ADWEA supplying water to FEWA) and moves to develop a national (and even GCC) water grid, require the setting of clear national standards that are adopted by all. Whilst water production is obviously a local activity, increased efficiency and effectiveness and agreed levels of health and environmental protection could be gained if national standards could be coordinated. The standards currently used by the different regulators differ little but should be rationalized and agreed on for the different receiving bodies, such as whether the plant is situated on the Indian Ocean or the Arabian Gulf. These set limits should be backed up with common guidelines and standards for monitoring and enforcement such as agreements on sampling frequency, online vs. grab samples, baseline surveys, and laboratory analysis methods and standards.

The coordination of such activities is one of the functions defined for the recently created Council of Water and Electricity. However, there is a need to define environmental as well as technical specifications and this should be a jointly coordinated effort between the Ministry of Energy and the MOEW. Recent moves in this direction by committees at the GCC level should also be reflected in any deliberations.

Reclaimed water

Until 1970, sewage disposal by septic tanks and tankers was widely practised in most parts of the country. However in the last decade, the provisions for the collection, treatment and then re-use of wastewater through networked systems has been markedly increased in the UAE and its potential as a third water source has been increasingly realized. In most of the Emirates reclaimed water is used mostly for the irrigation of amenity areas but there is increased interest in using it for many other uses such as in industrial processes, district cooling and agriculture. The subsequent increase in recent years in infrastructure provision and legal and institutional development reflect both the technical expansions of facilities as well the need to protect public health and the environment from any possible harmful consequences.

In all the Emirates, except Umm Al Quwain, there is a mixture of network and tanker wastewater collection and various levels of treatment and technologies are in use. About 50% of communities in RAK Emirate are not covered by a sewerage system, whilst in Sharjah nearly all of the wastewater is treated but a mixture of sewerage network and tankers (%) are used (See Annex 1 for more details). Given the potential risks involved with this sector a range of institutional provisions, legal and regulatory frameworks and standard setting have evolved which will now be reviewed.

Until recently the Federal level organization responsible for reclaimed water was the General Secretariat of UAE Municipalities. However, this was abolished in the middle of 2009 and its jurisdiction and services were transferred to the MOEW. At the moment this is not an active area of legislative or regulatory development with responsibilities still to be confirmed. Hence, as with all other aspects of water management in the UAE, the organizations primarily responsible for reclaimed water management are based at the Emirates level.

In some of the Emirates one principal organization is involved in collecting treating and disposing of wastewater. In Sharjah, for example, the Drainage Department within Sharjah Municipality is managing the whole wastewater industry through the supervision, operation and maintenance of the sewerage system, pumping stations, irrigation trunks, surface water network and the treatment plants. Similarly the Abu Dhabi Sewage Services Company (ADSSC), licensed and regulated by the independent regulator (RSB), was established in June 2005 as a public organization wholly owned by the Abu Dhabi government. Contrarily Dubai Municipality is responsible for managing the wastewater projects execution, operation and maintenance through 3 of its departments:

- The Drainage and Irrigation Department is responsible for the supervision of sewerage, Irrigation and treatment plants infrastructure designing and execution;
- The Sewage Treatment Plants Department is responsible for the operation and maintenance of the sewage treatment plants; and
- The Sewerage and Irrigation Network Department is responsible for the operation and maintenance of the sewerage and irrigation network.

In recent years the private sector has become increasingly involved in managing sewage services through Public Private Partnerships (PPPs) with the first concession granted in Ajman with the establishment of Ajman Sewerage Private Company Limited (ASPCL). Following the passing of the 2002 Ajman Sewer Law, a 27.5 year concession was granted to ASPCL to finance, build, commission, operate and maintain a sewerage system and deliver wastewater services (Global Water Intelligence, 2010). More recently a 33-year concession was awarded to Tanqia (a private company principally owned by Elwan, Mubadala Development Company and Overseas Trading Company) by the Government of Fujairah. In the other Emirates the private sector plays varying roles ranging from advice in the design phases, through sewerage infrastructure development to operations and maintenance. For example, in Ras Al Khaimah, the Municipality's Sewerage Authority in the Public Works and Services Department, has outsourced the collection, operation and maintenance of the sewerage network and sewage treatment plant to the private company Earth Cad.

In addition to the principal Emirates-level organizations, there are an increasing number of smaller organizations involved in the reclaimed water sector. Recent moves by mega-developers and other organizations to manage their own decentralized provisions have meant further private sector involvement. Companies such as Nakheel, Emmar, Dubai Holding, Sports City are constructing the wastewater infrastructure for their projects, including sewage treatment plants, sewerage network, pumping stations and treated effluent distribution networks to serve these communities. In Abu Dhabi this was facilitated by the passing of Law No. (19) of 2007 which established the provision for other sewerage service companies to be licensed by the Regulation and Supervision Bureau and connected to ADSSC's assets and since then Zonescorp and other organizations have received licences for this activity.

To date the main organizations involved in the use of reclaimed water have been the various municipalities, or the mega-developers using their own resources. However, in recent years in some Emirates, reclaimed water use has expanded beyond the traditional areas of watering amenity areas, to include the irrigation of golf courses, district cooling and groundwater recharge. In some of the Emirates the actual operations are outsourced to various companies as, for example, in Abu Dhabi where 14 companies are involved in using reclaimed water for amenity landscaping. In a move to rationalize and open up the market/potential for reclaimed water use, ADSSC is now permitted under Abu Dhabi Law No. (12) of 2008 to sell reclaimed water to any body or company rather than distribute to just the Department of Municipalities.

Reclaimed Water Legal and Regulatory Controls

Given the potential health, economic and environmental impacts of poor wastewater management various laws, regulations and standards have been developed which control its input, collection, treatment, disposal and re-use. The Federal Law No. (24) of 1999 sets a framework for the protection and development of the environment in the UAE. Three articles pertain to water reclamation and reuse: (1) Article 35 prohibits the discharge of untreated substances, wastes or liquids from all establishments, which may directly or indirectly cause pollution to the water environment; (2) Article 37 requires the development of standards and specifications to be observed by industrial establishments authorized to discharge degradable polluting material after treatment, and to specify persistent polluting substances that all industrial establishments shall not discharge to the marine environment; and (3) Article 38 enables the competent authority to take samples of the discharges to ensure that they comply with the approved standards. Many of the Emirates have passed laws encompassing these articles[10].

However, it is the area of regulations and standards that is most crucial to managing effectively and safely reclaimed water. An effective regulatory framework must cover the three main parts of the system:

a) Control on matter entering the sewerage network;

b) Control over the collection, treatment and disposal sewage system; and

c) Control over the subsequent use of reclaimed water and sludge.

The regulations in place in the Emirates controlling the input of material into a sewerage network are variable (see Appendix 4.3). Sharjah already has controls in place for various activities, and in 2007 the RSB of Abu Dhabi released new regulations for public consultation that address trade and industrial effluent control. These are comprehensive, and were brought into effect in June 2010. (See www.rsb.gov.ae/uploads/teregs2010.pdf)

Where standards do exist they tend to be based on international best practice as little research has taken place in the UAE to ascertain the relevant values for this environment. The most difficult part of controlling this part of the dirty water system is monitoring and enforcement given the spatial spread and localized nature of sewer inputs. This has yet to be addressed adequately in any of the Emirates.

The second area of control, the collection treatment and disposal system, is the most developed area of regulation in this sector. Effluent standards have been defined and enforced in most of the Emirates. Whilst there is little coordination in the development of many of these standards, the general trend amongst the various organizations is to adopt international practices and standards for wastewater treatment plants. In addition the contractors brought in to design, build or operate the various plants and systems will often bring their own standards which become the basis for any activities.

Of course, setting the standards is only the start of ensuring the reclaimed water processing is adequate. There are examples within the UAE where agreed standards are not translated into design specifications and operations, often because of limits of funding. There are also problems in some of the Emirates of setting overly long lists of parameters of standards, many of which have little or no real significance in effective control. These increased the monitoring, administration and enforcement burden and associated costs for little demonstrable gain in safety.

Any regulation of the final part of the system, the use of reclaimed water or the sludge, has direct links to the standards of the output from the wastewater treatment plants. The key to effective standard setting in this part of the system is to define the quality, based on the use to which the reclaimed water will be put. There is thus a need for approved/classified reuse activities that might include irrigation of urban areas, unrestricted irrigation of agricultural areas, restricted irrigation of agricultural and forestry areas, irrigation of domestic gardens, toilet flushing, fountains and water features, air conditioning processes, street cleaning and dust suppression, vehicle washing, concrete manufacture, and fire fighting. Various standards for different types of activities have been defined by many different international organizations as well as the individual Emirates as Appendix 4.3 highlights.

The RSB of Abu Dhabi is in the process of introducing regulations and standards for the various residual components after a lengthy public consultation period. The Recycled Water and Biosolids Regulations 2010[11] specify three Public

Health Standards, PI, PII and PIII that are to be applied to specific reuse activities see Table 4.3. These define both general physico-chemical characteristics along with three important microbiological standards. In addition, limits for 17 elements are specified as part of the irrigation standards. The standards stand up well to international comparison and are not unnecessarily stringent, but are realistic, affordable, and enforceable. Perhaps of great importance is the system of control that is being planned which brings international best practices in this area to the UAE. In many of the Emirates there is a lack of clarity in some places as to the actual control mechanisms in place.

Table 4.3: Some of the RSB public health standards for reuse of reclaimed wastewater

Parameter	Unit	P1	PII	PIII	Assessment criteria
Faecal Coliforms	CFU/100 ml	<100	<1000	-	Maximum allowable concentration
Intestinal Enterococci	CFU/100 ml	<40	<200	-	
Helminth Ova	Number/l	<0.1	<1	<1	
pH	-	6-8	6-8	6-8	Average
BOD	mg/l	10	10	20	Maximum allowable concentration
TSS	mg/l	10	20	30	
Turbidity	NTU	5	10	n/a	
Residual Chlorine	mg/l	0.5-1	0.5-1	n/a	Average
Dissolved Oxygen	mg/l	$\geq$1	$\geq$1	$\geq$1	Average

PI: irrigation of urban areas, PII: unrestricted irrigation of agricultural areas, and
PIII: restricted irrigation of agricultural and forestry areas

Source: www.rsb.gov.ae/uploads/rwbregs2010.pdf

The biosolids byproducts of wastewater treatment is also usable. From analyses undertaken by the various wastewater treatment managers and regulators, it has been found that the quality of the sludge produced from the majority of the plants can be classified as exceptional quality, Class A (USEPA), making it suitable for land application and for agriculture purposes (see Annex 1 for more details). The heavy metal content in the sludge was found to be well below the USEPA permissible limits. The RSB regulations specifiy two types of use: BI is unrestricted use and B2 is controlled use. Various standards for these classes are given in Table 4.4.

Table 4.4: Some of the RSB public health standards for reuse of biosolids

Parameter	Unit	B1	B2	Assessment criteria
Escherichia coli	CFU/g dm	<1,000	<100,000	Maximum allowable concentration
Salmonella	CFU/2g dm	<1	-	
Helminth Ova	Number/50g dm	<1	<10	
Treatment system to reduce volatile solids by	%	>38	>38	Mean
Treatment system to dry raw sludge to	% dm	>95	>95	
Treatment system to dry stabilized sludge to	% dm	>75	>75	
Treatment system to maintain a pH of	pH	>11.5 for 24 hours	>11.5 for 24 hours	

H1: Unrestricted public access. H2: Controlled public access.

Source: www.rsb.gov.ae/uploads/rwbregs2010.pdf

The actual re-use of reclaimed water is the least coordinated and controlled of all the activities within this sector. To date its use has restricted, largely because of limitations in the distribution network (although tankers are used in Ras Al Khaimah) but also because of an undeveloped regulatory system that has failed to ease the general caution of both government and the public. This is likely to change in the next five years and it is important that greater policy, legal and regulatory focus is given to the area allied with a development of relevant and coordinated organizations to manage and operationalize this.

Conclusions on water supply governance

From the review of the institutional, legal and regulatory frameworks for water supply systems, it becomes apparent that there is fragmentation that is likely to cause inefficiencies and ineffectiveness. Whilst it is not suggested that Article 23 of the Constitution is re-interpreted in the area of water resources, there is a great need for national coordination in natural water management to protect the strategic reserve, as well as in non-conventional water development, to bring greater returns on investments. This coordination needs to come in many different areas ranging from standards setting, to linking the management and regulation of the various water sources more fully, and to future planning.

In the specific area of standards the international experience suggests the following system brings effectiveness in regulation:

- Government sets the standards (often on the advice of the regulator);
- The construction and operations organizations achieve the standards; and
- Regulators monitor and enforce the standards.

In the case of the Emirates, the setting of regulations standards should be coordinated at the Federal level, across ministries and Emirate level authorities/agencies. The agreed terms would then be implemented by the competent authority within each Emirate. The benefits would be to:

- Provide a cogent system of regulation and control throughout the Emirates;
- Avoid the use of standards with lists of unimportant parameters;
- Avoid potential problems arising from the private sector involvement with standard setting;
- Provide a transparent system that would satisfy the needs of consultants and contractors in design; and
- Provide the government at all levels with the assurance that the system is fair and that it protects both public health and the environment.

Water Use Governance

Water consumption in the UAE is high by international standards, although these average figures mask a range of variations in patterns, as Annex 2 highlights. The largest sectoral use continues to be in agriculture, but domestic and commercial consumption is rising, reflecting the changing economic structure of the country. Institutions and legal and regulatory frameworks in the area of water use management are more complicated than in the supply side of the water balance and usually straddle many sectors. Any moves towards reducing demand are often perceived to be in direct opposition to the objectives of the various sectors such as increasing agricultural production on increasing tourist visits. To date institutional, legal and regulatory frameworks for water use management have been developed to only a limited extent in the UAE.

The general approaches to direct water use regulation may be classified under three headings:

a. Regulation through administrative allocation, where a central government body determines how much water is available for use in various sectors/areas;

b. Regulation through authorized tariffs on natural water resources to protect the public good, and might involve economic measures such as a water mining tax or a depletion allowance. This is generally the responsibility of central government. These should be set by an independent national organization; and

c. Regulation through the levying charges by producers of water for their services. In this context, water is a private good and any levies need to be highly regulated in themselves to stop excessive profit taking from natural monopolies over which private operators have control. Without an independent regulator, then the global experience shows that the setting of tariffs becomes politically dominated by the vested interest of land owners or by social activists who are concerned that water pricing will adversely affect the welfare of the poor.

Economic-based approaches (above b. and c.) to water use management transmit information about water scarcity to users to encourage changes in behaviour, so hopefully leading to reductions. In many international studies it has been found that there is a direct link between volume consumed and prices charged, but this varies between sectoral users. In work by Griffin (2006) in the US and Reynaud (2003) in France, the demand elasticity for industry varied widely (between -0.15 and -0.98) and was very much linked to sectors. In similar work, recent analysis of 24 US agriculture water demand studies from 1963-2004 by Schierling *et al.* 2006, suggest a mean price elasticity of around -0.48. These values highlight that water demand is relatively inelastic to pricing but is variable. This area has also important social, economic and political considerations in any discussions on water pricing that need to be taken into account.

In the UAE there are no Federal level organizations directly involved in water use management and responsibilities for this falls to the various Emirates. There are, however, indirect Federal controls on water use within the various sectors and their strategic policies. At the Emirate level, there are various initiatives from different organizations to manage water use and encourage water conservation. For natural resources management, there are no authorized tariffs (regulation as in b. above) and to date any controls on groundwater use has been an indirect result of changing agricultural polices and subsidy regimes rather than actual legal or regulatory frameworks. Emirate level organizations such as the Abu Dhabi Agriculture and Food Security Authority have recently announced a re-structuring of their agricultural sector with one of the aims to reduce water consumption. This will be supported by the recently formed permanent higher committee for water and agricultural strategy in Abu Dhabi[12] which aims to help balance water demand management with food security needs.

In the sectors using desalinated water, most of the Emirates are actively managing water use through levying charges by the producing authorities (regulation c. above). As highlighted in Annex 3, the introduction of slab tariffs by DEWA, SEWA and FEWA are some of the first steps in regulating the use of this expensive resource. Early figures indicate reductions in consumption[13] although given the recent decline in population in some Emirates the extent of this is difficult to verify. Whilst the slab tariff system is not universally applied, it is an important step in reducing demand and there has been a harmonization of tariffs between the three authorities.

There have been other initiatives within some of the emirates to control water use through non-price approaches. These have often come through the departments of municipalities who have legislated various building regulations which require particular water use efficiencies through the adoption of smarter designs or technologies. For example in Dubai[14] there is a drive for green buildings which are designed to save water (and energy) and the news phase of guidelines and specifications, Green Building Regulations – Stage II[15] have been launched in March 2010. This is managed by the Emirates Green Building Council, and whilst only a few have been accredited so far, a further 450 buildings are awaiting assessment under the Leadership in Energy and Environmental Design (LEED) evaluation structure[16]. Similar initiatives are found in some of the other emirates such as the Estidama regulations in Abu Dhabi[17] which includes a pearl rating system, but is applicable only to new buildings.

From the analysis undertaken, it is obvious that water use management is limited so far and has few institutional, legal or regulatory foundations from which to build. This is of course a politically difficult area and any sort of charging is fraught with tension. There are difficulties also associated with the cross-sectoral nature of the subject and that those entities who are responsible for producing water do not necessarily have control over its subsequent allocation or use. In Abu Dhabi, for example, the provision of desalinated water is defined under Law No. (2) 1998 concerning the Regulation of the Water and Electricity Sector (and subsequently amended by Law No. (19) of 2007), where Article (30) states that 'It shall be the duty of the Abu Dhabi Water and Electricity Company to ensure that there is provided sufficient production capacity to ensure that, '***at all times, all reasonable demand for water and electricity in the Emirate is satisfied***'. The term 'reasonable' demand is open to wide interpretation and has been used by some to gain supplies of desalinated water for activities that most people would find 'unreasonable' in an arid country.

The need for greater sectoral coordination in water use management is being increasingly recognized. In Abu Dhabi, for example, the Economic Affairs Unit of the Economic Affairs Authority (EAA) is currently working with other government and non-government entities to develop a comprehensive Demand Side Management (DSM) strategy for electricity and water consumption within the Emirate. The objective of the EAA in coordinating this activity will be to develop an integrated overall DSM strategy to assist the Emirate in meeting its short and long term water (and energy) needs. The partners in this include members of the ADWEA group of companies, the RSB, EAD, the Urban Planning Council, Emirates Wildlife Society and others.

Main Findings and Recommendations

1. The institutional, legal and regulatory framework for water in the UAE is relatively fragmented and disparate with many different authorities/agencies involved.
2. Following the articles in the Constitution, water has been predominantly managed at the Emirate level and this has not been without its own success. However, given the increasingly water stressed situation and rapidly developing economies, it is now important to think more strategically and across Emirate boundaries.
3. The present institutional setup is a series of separate agencies, many of whom overlap in their roles, whilst gaps in key areas also exist.
4. There is very limited strategic or operational planning between the various water sources and/or water uses.
5. In terms of laws and regulations there are large variations in the formulation and passing of measures, as well as in their implementation.
6. Standards for many aspects of water supply vary between areas and authorities that neighbour each other and share the same sea.
7. There is limited access to information held by the individual organizations meaning that planning and decision-making is not always based on current and comprehensive information.
8. There is an urgent need for a coordinating body to be established, that can bring together authorities in the emirates and federal government. The first steps towards this would be an organization that takes onboard and expands the remit of the current Council for Water and Electricity and the proposed National Water Council of the MOEW to cover all water sources and uses. This should be cross-ministerial and should answer to the Cabinet, so that water is planned and managed in an integrated manner that will serve the economic development plans of the country.
9. There should be greater coordination and rationalization in the development of standards and regulations.

Annex 4.1

UAE Constitution, adopted 18 July 1971, as amended (the relevant excerpts are given below)

Article 23

The natural resources and wealth in each Emirate shall be considered to be the public property of that Emirate. Society shall be responsible for the protection and proper exploitation of such natural resources and wealth for the benefit of the national economy.

Article 120

The Union shall have exclusive legislative and executive Jurisdiction in the following affairs:

1. Foreign affairs.
2. Defence and the Union Armed Forces.
3. Protection of the Union's security against internal or external threat.
4. Matters pertaining to security, order and rule in the permanent capital of the Union.
5. Matters relating to Union officials and Union judiciary.
6. Union finance and Union taxes, duties and fees.
7. Union public loans.
8. Postal, telegraph, telephone and wireless services.
9. Construction, maintenance and improvement of Union roads which the Supreme Council has determined to be trunk roads. The organisation of traffic on such roads.
10. Air Traffic Control and the issue of licences to aircrafts and pilots.
11. Education.
12. Public health and medical services.
13. Currency board and coinage.
14. Measures, standards and weights.
15. Electricity services.
16. Union nationality, passports, residence and immigration.
17. Union properties and all matters relating thereto.
18. Census affairs and statistics relevant to Union purposes.
19. Union Information.

Article 121 (as amended by Constitutional Amendment No.1 of 2004)

Without prejudice to the provisions of the previous article, the Federation shall solely be in charge of enacting laws on the following matters:

Work relation and social securities; real estate and expropriation in the public interest; handover of criminals; banking; insurance of all kinds; protection of flora and fauna; major legislations relating to Penal Code, Civil and Commercial Transactions Code, Companies Law, Code of Procedures before the civil and penal courts; protection of moral, technical and industrial property rights; copyrights, printings and publication rights; import of weapons and ammunitions unless the same was for the use of the Armed Forces or Security Forces of any Emirate - other aviation affairs which are not within the Federation executive competencies; determination of territorial waters and organization of navigation overseas; organization and method of establishing financial free zones and scope of excluding the same from the implementation of the Federal Legislations provisions.

Article 122

The Emirates shall have jurisdiction in all matters not assigned to the exclusive jurisdiction of the Union in accordance with the provisions of the two preceding Articles.

Annex 4.2
Annotated Proposed Uniform Emirate-Level Regulatory Framework for Water Resources

1. Definitions

2. Ownership or other legal status of water resources

Statement of the ownership of water resources. The provision must reflect Article 23 of the Constitution, which provides that “The natural resources and wealth in each Emirate shall be considered to be the public property of that Emirate.” As a result, natural water resources must be declared to be the property of each Emirate. Man-made, non-conventional water resources like treated wastewater and desalinated water may or may not be so declared (see the discussion in the main body of this report)

3. Water resources inventory and monitoring

Subject to the standards and specifications set by the federal government (MOEW)[18], duty of Emirate governments to:

- compile an inventory and monitor the quantity and quality of water resources;
- establish and maintain repositories of relevant data and information at Emirati level; and
- regularly supply such data and information to the federal government for the purposes of recording in a centralized federal-level Water Data Bank. ***Note:*** This particular obligation will be instrumental to the discharge by the Federal MOEW of its statutory function under Article 3 (4) of Federal Cabinet Resolution No. (21) of 12 May 2009 concerning the internal organizational structure of the Federal MOEW, as amended.

4. Water resources plans

- Duty of Emirates to prepare and periodically review a Water Master Plan for each Emirate, reflecting the national water policies, strategies, plans and criteria developed by the Federal MOEW[19]
- minimum contents of Emirati Water Master Plans
- standard procedures for the preparation and approval of Emirati Water Master Plans

5. Regulation of water resources abstraction and use

- Free right to abstract water from a natural source for household use
- Free right to excavate a shallow well (by hand) for household use
- License required to abstract water for all other purposes and uses, including to drill a new well for groundwater exploration/exploitation purposes, to deepen or enlarge an existing well, to replace an existing well - process leading to the grant of a license - criteria for decision-making - standard terms and conditions of licenses including conditions as to the sale of water - term of duration - record-keeping by the licensing authority - forms to be employed (these can be left to Regulations)
- Licenses to be renewable on request
- Licenses to be subject to review, amendment, suspension and cancellation under given circumstances (but no compensation due if amendment, suspension or cancellation are due to *force majeure* or emergency circumstances, or failure of the licensee to abide by the law and by the terms and conditions of the license)
- Licenses to be transferable through succession when the licensee passes away or the licensed concern is sold
- Licenses can(not) be sold

6. Existing wells (and abstraction rights)

Owners of wells and, in general, the holders of traditional rights in any natural water source, which are in existence at the time the new Law comes into effect, to notify government of existing well(s) and rights within one year of the coming into effect of the new Law, under penalty of closure of well or extinction of right

7. Regulation of well drilling profession

- License required to exercise the profession of well driller - process leading to the grant of a license - criteria for decision-making - standard terms and conditions of licenses - term of duration - record-keeping by the licensing authority - forms to be employed (these can be left to Regulations)
- Licenses to be renewable on request
- Licenses to be subject to review and amendment, suspension and cancellation under given circumstances (but no compensation due if suspension or cancellation are due to *force majeure* or emergency circumstances, or failure of the licensee to abide by the law and by the terms and conditions of the license)
- Licenses not to be transferable

8. Control of water pollution

- Permit to discharge effluents from all sources into (a) the bed of any wadi, (b) directly into known aquifers, (c) on or under the ground in a declared Water Management Area (see No.9 below), and (d) at sea - process leading to the grant of a permit - criteria for decision-making - standard terms and conditions of permits, including standards of effluent quality - term of duration - record-keeping by the permitting authority - forms to be employed (these can be left to Regulations)
- Permits to be renewable on request
- Permits to be subject to review, amendment, suspension and cancellation under given circumstances (but no compensation due if amendment, suspension or cancellation are due to force majeure or emergency circumstances, or failure of the permittee to abide by the law and by the terms and conditions of the permit)
- Permits to be transferable through succession when the permittee passes away or the permit-holding concern is sold

9. Protection of vulnerable water resources

- Power of government to designate (a) natural surface water resources at risk of depletion or contamination, and the relevant catchment, and (b) the recharge areas of aquifers also at risk of depletion or contamination, as, respectively, Water Management Areas (WMA) and Groundwater Management Areas (GMA)
- Process of designating a WMA/GMA
- Power of government to restrict land use practices and activities inside a WMA/GMA
- Power of government to impose reasonable limitations on the volumes/rates of water which can be abstracted freely or under a license or under a notified pre-existing right inside a WMA/GMA
- Power of government to amend or withdraw WMA/GMA designations

10. Development and promotion of wastewater reuse, conservation measures and efficient water use practices

- Authority of government to develop and promote the reuse of reclaimed water, water recycling, efficient water utilization technologies and practices, rainwater harvesting, in furtherance of the national policies developed by the Federal MOEW[20]
- Authority of government to enforce (and upgrade) the minimum reclaimed water quality standards developed by the Federal MOEW[21] in relation to the intended uses

11. Construction of dams

Construction of dams or other works which block the free flow of water in wadis subject to government authorization - process leading to the grant of an authorization - standard terms and conditions of authorizations - term of duration - record-keeping by the authorizing authority - forms to be employed (these can be left to Regulations) (***Note:*** If the dam or other work is for the purposes of abstracting and using water from a wadi the authorization will be attracted by a water abstraction license under heading No. 2 above and, as a result, there will be no need to go through a separate authorization process)

12. Water resources fees and charges

- Authority of government to charge fees for the performance of regulatory and other functions for the management and protection of water resources, notably, the processing of applications for the grant and renewal of licenses, permits and authorizations under this Law, and the provision of data to members of the public on request
- Subject to the national policies and standards set by the Federal MOEW[22], authority of government to levy a charge on the abstraction and use of natural water resources, and to set the rates of charges

13. Emergency powers

Authority of government to declare a water-related emergency and to take measures to deal with such emergency (in particular, power to curtail water abstractions and uses in progress and wastewater discharge operations in progress, and to issue instructions regarding the operation of desalination plants, wastewater treatment facilities, and dams)

14. Review of administrative decisions

- Right to appeal an administrative decision before a higher-ranking government authority – relevant procedural rules
- Right to appeal a final administrative decision before the courts of law

15. Powers of entry and inspection

- Authority of designated government officials to enter land, farm or facility for purposes of research, water resources monitoring and data collection, rehabilitation or other remedial work, provided advance notice is given to the owner or operator concerned
- Authority of designated government officials to enter land, farm or facility for purposes of inspecting compliance with the law, to examine records to be kept by the owner or operator under the law, to take samples of any water, effluent or other substance for further investigation, and duty to file reports of violations for further disposition (by the government, by the courts of law)
- Authority to bring in the police if entry is refused
- Compensation for damages caused (but none if entry is denied and police is bought in)

16. Penalties

- In particular, seizure of un-licensed wells and of water abstraction equipment

Appendix 4.3
Various standards used in the water sector

Table A4.3.1: Standards for discharges into the sea from desalination plants

Table	Parameter	Units	FEA Limits 2006	Licensed limits					
				Fujairah	Abu Dhabi				
					Desal Site 1	Desal Site 2	Desal Site 3	Desal Site 4	Desal Site 5
Table 1 Physical Properties	TSS	Mg/l	50	≤ 25.0	30	30	30	30	30
	TDS (intake)	Mg/l							44700
	TDS (discharge)	Mg/l	1500	≤1500			49500		
	Max Limit	%	5			5	22	5	5
	pH	pH Units	6 - 9	6-9	6.5–8.5	6.5-8.5	6.5-8.5	6.5-8.5	
	Temperature (intake)	° C							35
	Temperature (discharge)	° C					42.6		43
	Max Limit	° C	5			9	10	?	1
Table 2 Chemical Properties	Ammonia	Mg/l	2	≤ 2	0.5	0.5	0.5	0.5	0.5
	Biochemical Oxygen Demand (BOD)	Mg/l	50	≤ 20	30	30	30	30	30
	Chemical Oxygen Demand (COD)	Mg/l	100	≤ 125	100	100	100	100	100
	Cyanide	Mg/l	0.05	≤ 0.05	0.1	0.1	0.1	0.1	0.1
	Oil	Mg/l	10	≤ 10.0	10	10	10	10	10
	Phenols	Mg/l	0.1	≤ 1	0.1	0.1	0.1	0.1	0.1
	Phosphate	Mg/l	2	≤ 2	3	3	3	3	3
	Nitrate as N	Mg/l	40	≤ 40					
	Nitrogen Kjeldahl KN	Mg/l		≤ 10					
	Sulphides	Mg/l		≤ 0.10					
	Residual Chlorine	Mg/l	1	≤ 1	0.15	0.15	0.15	0.15	0.15

Table A4.3.1 (continued): Standards for discharges into the sea from desalination plants

Table	Parameter	Units	FEA Limits 2006	Licensed limits					
				Fujairah	Abu Dhabi				
					Desal Site 1	Desal Site 2	Desal Site 3	Desal Site 4	Desal Site 5
Table 3 Trace Metals	Arsenic	Mg/l	0.05	≤ 0.05	0.1	0.1	0.1	0.1	0.1
	Antimony	Mg/l		≤ 0.1					
	Barium	Mg/l		≤ 2					
	Beryllium	Mg/l		≤ 0.05					
	Cadmium	Mg/l	0.05	≤ 0.05	0.1	0.1	0.1	0.1	0.1
	Chromium	Mg/l	0.2	≤ 0.1	0.5	0.5	0.5	0.5	0.5
	Cobalt	Mg/l		≤ 0.2					
	Copper	mg/l	0.5	≤ 0.5	0.5	0.5	1	0.5	0.5
	Iron	mg/l	2	≤ 2.0	1	1	2	1	1
	Lead	mg/l	0.1	≤ 0.1	0.1	0.1	0.1	0.1	0.1
	Manganese	mg/l	0.2	≤ 0.2	1	1	1	1	1
	Mercury	mg/l	0.001	≤ 0.001	0.001	0.001	0.001	0.001	0.001
	Nickel	mg/l	0.1	≤ 0.1	0.5	0.5	0.5	0.5	0.5
	Selenium	mg/l	0.02	≤ 0.02	0.05	0.05	0.05	0.05	0.05
	Silver	mg/l	0.005	≤ 0.005	0.1	0.1	0.1	0.1	0.1
	Vanadium	mg/l			1	1	1	1	1
	Zinc	mg/l	0.5	≤ 0.5	1	1	5	1	1
	Halogenated Hydrocarbons and Pesticides								

Source: Federal Regulation of Law No. 24, 1999, Technical Guide 53, 1995, and Local Order 61/1991 of the Dubai Municipality that has been adopted and put into force by the Emirate of Fujairah.

Table A4.3.2: Standards for industrial waste water discharges into public sewerage network to treatment work

Permissible limits for wastewater discharge to sewers				
Parameter	**Unit**	**Abu Dhabi**	**Dubai**	**Sharjah**
Biochemical Oxygen Demand (BOD)	mg/l	1,000	1,000	1,000
Chemical Oxygen Demand (COD)	mg/l	3,000	3,000	3,000
Total Suspended Solids (TSS)	mg/l	500	500	500
Total Dissolved Solids (TDS)	mg/l	3,000	3,000	3,000
Conductivity	ìmhos/cm			5,000
Settled matter after 2 hrs	ml/l	100		100
pH	value	6-9	6-9	6-9
Aluminum (Al)	mg/l	5.0	5.0	5.0
Arsenic (As)	mg/l	0.5	0.5	0.5
Bromine (Br)	mg/l		1.0	1.0
Barium (Ba)	mg/l	1.0		
Boron (B)	mg/l	2.0	2.0	2.0
Cadmium (Cd)	mg/l	0.2	0.2	0.2
Chloride (as Cl-)	mg/l	500	500	600
Chromium (Cr)	mg/l	1.0	1.0	1.0
Cobalt (Co)	mg/l	1.0	1.0	1.0
Copper (Cu)	mg/l	1.0	1.0	1.0
Cyanide (CN)	mg/l	1.0	1.0	1.0
Fluorine as Fluoride (F-)	mg/l	5.0	5.0	5.0
Lead (Pb)	mg/l	1.0	1.0	1.0
Lithium (Li)	mg/l	1.0	1.0	1.0
Manganese (Mn)	mg/l	1.0	1.0	1.0
Mercury (Hg)	mg/l	0.01	0.01	0.01
Molydenum (Mo)	mg/l	0.5	0.5	0.5
Nickel (Ni)	mg/l	1.0	1.0	1.0
Ammonia - Nitrogen (NH3-N)	mg/l	40	40	40
Total Kjeldahl Nitrogen	mg/l	N/A		125
Oil and Grease (Non-soluble)	mg/l	50		50
Phenols (Total)	mg/l	50		10
Phosphorous (P)	mg/l	50	50	30
Selenium (Se)	mg/l	0.5	0.5	0.5
Silver (Ag)	mg/l	0.5	0.5	0.01
Sulphate (SO4)	mg/l	500	500	500
Sulphide (S)	mg/l	5.0	5.0	5.0
Total Toxic Metals	mg/l	5.0		
Vanadium (V)	mg/l	1.0	1.0	1.0
Zinc (Zn)	mg/l	2.0	2.0	2.0

Source: Sharjah Treatment Plant, Drainage Department.

Reclaimed Water Treatment Standards

The general parameters analyzed help to assess the effectiveness of the wastewater treatment process and to evaluate variability in the quality of the wastewater prior to its release to the environment. They also represent water quality values that, if exceeded, can often restrict treated wastewater sources from being considered for irrigation purposes (Pescod, 1992; FAO, 2000; Metcalf and Eddy, 2003; Abu-Madi, 2004).

- Faecal Coliform: Even when the BOD is reduced to low levels (<20 mg/l), the treated effluents may still contain large amounts of pathogenic bacteria, viruses, protozoa, and helminth ova. From the perspective of effluent reuse, these characteristics are at least as, if not more important, than the conventional BOD and COD values.
- Biochemical Oxygen Demand (BOD): typically ranges from 10 to 20 mg/l for most municipal wastewaters. Values below 100 mg/l pose no restriction to irrigation use.
- Total Suspended Solids (TSS) typically ranges from 10 to 20 mg/l for most municipal wastewaters. Values below 100 mg/l pose no restriction to irrigation use.
- Chemical Oxygen Demand (COD): typically ranges from 25 to 50 mg/l for most municipal wastewaters. Values below 150 mg/l pose no restriction to irrigation use.
- pH: typically ranges from 6.5 to 8.5 for most municipal wastewaters. These values are comparable to most natural surface waters and are considered to pose no restriction to irrigation use. A continued long-term use of waters outside this pH range could eventually alter naturally occurring pH levels in surface soils to which they are applied and therefore could possibly lead to micro nutrient imbalances and potential future crop production and fertility problems.
- Electrical conductivity (EC): these values range widely within municipal wastewater and like some natural water sources exceed levels that would be recommended for irrigation. Municipal wastewater with EC values less than 1,000 µS/cm (1.0 dS/m) are considered of good quality and should pose no problems for irrigation use.
- Nutrients: One of the main advantages of using wastewater irrigation is that it can often enhance the fertility of the lands to which it is applied. This can add considerably to potential crop yield and therefore the associated agricultural resource value. Nutrient loading rates, while significant, are seldom at levels that would present a concern when using municipal wastewater for irrigation. Most nutrient levels are well within the range that can be assimilated by plants if the wastewater is applied at a rate and frequency that conforms to active crop growth. Potential contamination of groundwater would only be a concern under extremely shallow groundwater levels, unsuitable soil conditions, or gross mismanagement of the applied wastewater. Since all these factors are carefully considered as part of the guidelines, potential contamination of the groundwater should not present a problem. The following nutrients should be analyzed and reported as part of the comprehensive wastewater quality characterization process:
    - Nitrogen can be evaluated in a number of different forms. Evaluation of nitrogen by analyzing for NO3-N, NH4-N, NO2-N, and TKN should be conducted. The typical range for total nitrogen of most municipal wastewater is 10 to 20 mg/l. This means that if 300 mm of wastewater were applied, a N loading of 30 to 60 kg/ha/yr would be applied to the land base. Providing wastewater is not applied in quantities that exceed the field moisture capacity during periods of wastewater applications, and is applied during the active crop growing season, such loadings can be easily assimilated by the growing crop without harmful health or environmental concerns developing.
    - Phosphorus is to be evaluated as total dissolved phosphorus. The typical range of total dissolved phosphorus in municipal wastewater is between 2 and 6 mg/l. If 300 mm of wastewater were applied, this would translate to a P loading of 6 to 18 kg/ha/yr. Since these levels are considered to be reasonably low and phosphorus is effectively immobilized in most soils at shallow depths, the potential for adverse impacts

on groundwater quality is remote. Care must be exercised, however, to ensure wastewater applications are applied at rates that do not exceed the infiltration capacity of the soils as high phosphorus levels in surface runoff and erosion sediments can create significant environmental concern if washed into neighboring lakes, streams or other surface water bodies.

- Potassium is another major nutrient present in wastewater of value for crop production that should be evaluated. The typical range for potassium in most municipal wastewaters is 5 to 40 mg/l. If 300 mm of wastewater were applied, this would translate to a K loading of 15 to 120 kg/ha/yr. Such levels are readily assimilated by the actively growing crops and are thus not considered to be of an environmental or health risk.

Table A4.3.3: Standards for reclaimed water use USEPA

USEPA Guidelines for water reuse				
Type of Reuse	**Treatment Required**	**Reclaimed Water Quality**	**Recommended Monitoring**	**Setback Distances**
Agricultural Food crops commercially processed	Secondary Disinfection	pH = 6-9 BOD ≤ 30 mg/l SS = 30 mg/l	pH weekly BOD weekly SS daily	100 m from potable water supply wells
Orchards and Vine yards		FC ≤ 200/100 ml Cl_2 residual = 1 mg/l min.	FC daily Cl_2 residual continuous	30 m from areas accessible to public
Pasturage Pasture for milking animals	Secondary Disinfection	pH = 6-9 BOD ≤ 30 mg/l SS ≤ 30 mg/l	pH weekly BOD weekly SS daily	100 m from potable water supply wells
Pasture for livestock		FC ≤ 200/100 ml Cl2 residual = 1 mg/l min.	FC daily Cl_2 residual continuous	30 m from areas accessible to public
Forestation	Secondary Disinfection	pH = 6-9 BOD ≤ 30 mg/l SS ≤ 30 mg/l	pH weekly BOD weekly SS daily	100 m from potable water supply wells
		FC ≤ 200/100 ml Cl_2 residual = 1 mg/l min.	FC daily Cl_2 residual continuous	30 m from areas accessible to the public
Agricultural Food crops not commercially processed	Secondary Filtration Disinfection	pH = 6-9 BOD ≤ 30 mg/l Turbidity ≤ 1 NTU FC = 0/100 ml Cl_2 residual = 1 mg/l min.	pH weekly BOD weekly Turbidity daily FC daily Cl_2 residual continuous	15 m from potable water supply wells
Groundwater recharge	Site-specific and use-dependent	Site-specific and use-dependent	Depends on treatment and use	Site-specific

Source: USEPA (1992).

Table A4.3.4: Criteria for non-potable reclaimed water use in the State of California

Purposes of using recycled water	Minimum requirements for types of recycled water to be used
Use of recycled water for irrigation	
Surface irrigation of food crops; parks and playgrounds; school yards; residential landscaping; unrestricted access golf courses; other uncontrolled access irrigation areas	Disinfected tertiary recycled water (a)
Surface irrigation of food crops where the edible portion is produced above ground and not contacted by the recycled water	Disinfected secondary-2.2 recycled water (b)
Cemeteries; freeway landscaping; restricted access golf courses; Unrestricted access ornamental nursery stock and sod farms; pasture for animals producing milk for human consumption; controlled access non-edible vegetation	Disinfected secondary-23 recycled water (c)
Orchards and vineyards where the recycled water does not come into contact with the edible portion of the crop; non-food bearing trees; fodder and fiber crops; pasture for animals not producing milk for human consumption; seed crops not eaten by humans	Undisinfected secondary recycled water (d)
Use of recycled water for recreational impoundments	
Used as a source of water supply for non-restricted recreational impoundments	Disinfected tertiary recycled water
Used as a source of water supply for restricted recreational impoundments and for any publicly accessible impoundments at fish hatcheries	Disinfected secondary-2.2 recycled water
Used as a source of water supply for landscape improvements that do not utilize decorative fountains	Disinfected secondary-23 recycled water
Use of recycled water for cooling	
Used for industrial or commercial cooling or air conditioning that involves the use of a cooling tower, evaporative condenser, spraying or any other mechanism that creates a mist	Disinfected tertiary recycled water
Used for industrial or commercial cooling or air conditioning that does not involve the use of a cooling tower, evaporative condenser, spraying or any other mechanism that creates a mist	Disinfected secondary-23 recycled water
Use of recycled water for other purposes	
Flushing toilets and urinals; priming drain traps; industrial process water that may come into contact with workers; structural fire fighting; decorative fountains; commercial laundries; construction of backfill around potable water pipelines; artificial snow making for commercial outdoor use; commercial car washing	Disinfected tertiary recycled water
Industrial boiler feed; non-structural fire fighting; backfill consolidation around non-potable piping; soil compaction; mixing concrete; dust control on roads and streets; cleaning roads, sidewalks and outdoor work areas; industrial process water that will not come into contact with workers	Disinfected secondary-23 recycled water
Flushing sanitary sewers	Undisinfected secondary recycled water

(a) 'Disinfected tertiary recycled water' means a filtered and subsequently disinfected water that meets the following criteria: (1) The filtered wastewater has been disinfected in accordance with the manner prescribed in the code. (2) The median concentration of total coliform bacteria measured in the disinfected effluent does not exceed a most probable number (MPN) of 2.2 per milliliter utilizing the bacteriological results of the last seven days for which analyses have been completed, and the number of total coliform bacteria does not exceed an MPN of 23 per milliliter in more than one sample in any 30 day period. No sample shall exceed an MPN of 240 total coliform bacteria per 100 milliliter.

(b) 'Disinfected secondary-2.2 recycled water' means recycled water that has been oxidized and disinfected so that the median concentration of total coliform bacteria does not exceed an MPN of 2.2 per milliliter for the last seven days and the number of total coliform bacteria does not exceed an MPN of 23 per milliliter in more than one sample in any 30 day period.

(c) 'Disinfected secondary-23 recycled water' means recycled water that has been oxidized and disinfected so that the median concentration of total coliform bacteria does not exceed an MPN of 23 per milliliter for the last seven days and the number of total coliform bacteria does not exceed an MPN of 240 per milliliter in more than one sample in any 30 day period.

(d) 'Undisinfected secondary recycled water' means oxidized recycled water.

Table A4.3.5: WHO guidelines for using treated wastewater in agriculture

Type of irrigation	Health-based target for helminths eggs	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 ml)	Notes
Unrestricted	$\leq$ per litre (arithmetic mean)[b,c]	4	$\leq 10^3$	Root crops.
		3	$\leq 10^4$	Leaf crops.
	Hith-growing crops:[d,e] No recommendation	2	$\leq 10^5$	Drip irrigation of high-growing crops.
	Low-growing crops:[d] $\leq$ 1 per litre (arithmetic mean)	4	$\leq 10^3$	Drip irrigation of low-growing crops.
	E	6 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency.[a]
Restricted	F	3	$\leq 10^4$	Labour-intensive agriculture (protective of adults and children under 15).
	G	2	$\leq 10^5$	Highly mechanized agriculture.
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank.

a. For example, for secondary treatment, filtration and disinfection: BOD, <10 mg/l; turbidity, <2 NTU; Cl2 residual, 1 mg/l; pH, 6?9; and faecal coliforms, not detectable in 100 ml (State of California, 2001).

b. When children under 15 are exposed additional health-protection measures should be used.

c. A rolling arithmetic mean should be determined throughout the irrigation season. The mean value of $\leq$ 1 egg per liter should be obtained for at least 95% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per liter). With some wastewater treatment processes (e.g. waste stabilization ponds) the hydraulic retention time can be used as a surrogate to assure compliance with $\leq$ 1 egg per liter.

e. No crops to be picked up from the soil. (Based on WHO, 2006).

Table A4.3.6: Dubai Municipality's standards for effluent reuse and discharge

Parameter	Restricted irrigation (mg/l)	Unrestricted irrigation (mg/l)	Discharge in the marine (mg/l)
pH (number)	6 – 9	6 – 9	6 - 9
BOD	20	5	30
COD	200	150	50
TSS	30	15	30
TDS	2,000	2,000	
NH_3	10	5	10
NO_3	50	50	
N	50	5	
PO_4	30	30	0.1
SO_4	400	400	
S	0.1	0.1	0.1
Free residual chlorine	1 - 2	1 - 2	1 - 2
Cl	500	500	
Na	300	200	
Al	5	5	
As	0.1	0.05	0.05
Ba	1	0.5	
Br	0.3	0.1	
B	1	0.5	
Cd	0.01	0.01	0.05
Cr	0.05	0.05	0.5
Co	0.05	0.05	
Cu	1	0.5	0.5
CN	0.05	0.05	0.1
F	2	1	
Fe	5	1	2
Pb	0.2	0.1	0.1
Li	0.05	0.05	
Mg	150	150	
Mn	0.5	0.1	
Hg	0.001	0.001	0.001
Mo	0.05	0.01	
Ni	0.1	0.1	0.1
Se	0.02	0.02	0.02
Ag	0.01	0.01	0.005
V	0.1	0.1	
Zn	5	5	0.1

Table A4.3.7: Sharjah Municipality's specification and standards of effluent water reuse for land irrigation purposes

Parameter	Unrestricted land irrigation (mg/l)	Restricted land irrigation (mg/l)
pH (unit)	6-9	6-9
TSS	15	30
TDS	1,500	2,000
Conductivity (Mmohs/cm)	2,300	3,000
BOD	15	20
COD	150	200
Oil and Grease	0.5	0.5
Phenols	0.001	0.002
Ammonical N	5	10
Total nitrogen	50	50
Organic N kjeldah	10	10
Total sulfate	400	400
Sulfides	0.1	0.1
Total chlorine	0.5	0.5
Aluminum	5	5
Arsenic	0.05	0.1
Barium	0.5	1
Beryllium	0.1	0.3
Boron	0.5	1
Cadmium	0.01	0.01
Chloride	500	500
Chromium	0.05	0.05
Cobalt	0.05	0.05
Copper	0.5	1
Cyanide	0.05	0.05
Fluoride	1	1
Iron	1	5
Lead	0.1	0.2
Lithium	0.05	0.05
Magnesium	150	150
Manganese	0.1	0.5
Mercury	0.001	0.001
Molybdenum	0.01	0.05
Nickel	0.1	0.1
Phosphorous	30	30
Selenium	0.02	0.02
Silver	0.01	0.01
Sodium	200	300
Vanadium	0.1	0.1
Zinc	5	5
Viable path Ova and Cyst	Nil	Less than 1
Total fecal coliform (MPN/100 ml)	100	1,000
Salmonella and Shigella (MPN/L)	Nil	Nil

Table A4.3.8: Recommended standards for restricted irrigation in the UAE

Parameter	Unit	Recommended standards
Biochemical Oxygen Demand (BOD)	mg/l	20
Chemical Oxygen Demand (COD)	mg/l	200
Total Suspended Solids (TSS)	mg/l	30
Total Dissolved Solids (TDS)	mg/l	2,000
Dissolved Oxygen	mg/l	3<
Free Residual Chlorine (FRC)	mg/l	1-2
pH	number	6-9
Aluminum (Al)	mg/l	5.0
Arsenic (As)	mg/l	0.1
Barium (Ba)	mg/l	1.0
Beryllium (Be)	mg/l	0.3
Boron (B)	mg/l	1.0
Cadmium (Cd)	mg/l	0.01
Chloride (as Cl^-)	mg/l	500
Chromium (Cr)	mg/l	0.05
Cobalt (Co)	mg/l	0.05
Copper (Cu)	mg/l	1.0
Cyanide (CN)	mg/l	0.05
Fluoride (F)	mg/l	2.0
Iron (Fe)	mg/l	5.0
Lead (Pb)	mg/l	0.2
Lithium (Li)	mg/l	0.05
Magnesium (Mg)	mg/l	150
Manganese (Mn)	mg/l	0.5
Mercury (Hg)	mg/l	0.05
Molybdenum (Mo)	mg/l	0.05
Nickel (Ni)	mg/l	0.1
Ammonia - Nitrogen (NH_3-N)	mg/l	10
Nitrate (NO_3)	mg/l	50
Organic Nitrogen (N)	mg/l	50
Oil and Grease (Non-soluble)	mg/l	0.5
Phenols (Total)	mg/l	0.002
Phosphorous (P)	mg/l	30
Selenium (Se)	mg/l	0.02
Silver (Ag)	mg/l	0.01
Sodium (Na)	mg/l	300
Sulphate (SO4)	mg/l	400
Vanadium (V)	mg/l	0.1
Zinc (Zn)	mg/l	5.0
Total Count Faecal coliform	MPN/100 ml	<1,000
Total E. Coli	MPN/100 ml	< 100
Eggs of Parasite (Worms)	No./l	<1.0
Protozoa cysts/eggs	No./l	<1.0
Salmonella, Shigella and Vibrio Cholerae	-	Nil

Table A4.3.9: Recommended standards for restricted irrigation in the UAE

UAE Federal sludge reuse standards		
Parameter	**Unit**	**Maximum allowable limits**
Cadmium (Cd)	mg/kg	20
Chromium (Cr)	mg/kg	1,000
Copper (Cu)	mg/kg	1,000
Lead (Pb)	mg/kg	1,000
Mercury (Hg)	mg/kg	10
Molybdenum (Mo)	mg/kg	20
Nickel (Ni)	mg/kg	300
Selenium (Se)	mg/kg	50
Zinc (Zn)	mg/kg	3,000

Endnotes

1. By virtue of the List of projects subject to environmental clearance requirements, featured in the Executive Order No.37 of 2001.
2. The aborted Federal Water Act Regarding Protection and Development of Water Resources prepared in 2008 acknowledges the existence of such rights, in the relevant Definitions clause (Article 1.24) and, indirectly, in the transitional clause making a generous allowance for the owners of existing wells (Article 49).
3. Water quality protection outsourced to Rochester Institute of Technology, Abu Dhabi campus.
4. ADWEA was set up under Abu Dhabi Law No (2) of 1998, and amended by Law No (19) of 2007.
5. DEWA was set up under Dubai Decree No. (1) of 1992 The Establishment of Dubai Electricity and Water Authority with certain provisions amended under Dubai Decree No. (13) of 1999.
6. SEWA
7. FEWA was setup under Federal Law No 31 for 1999 regarding the establishment of FEWA, UAE Federal Law No. (9) of 2008 Amending Some of the Provisions of Federal Law No. (31) of 1999 Establishing the Federal Electricity and Water Authority.
8. Law No. (2) 1998 Concerning the Regulation of the Water and Electricity Sector in the Emirate of Abu Dhabi and amended under Law No. (19) of 2007, Law No (9) of 2009.
9. Gulf News, 14/03/2010, pg 10, *Regulatory unit will help ensure fairness*.
10. Ajman 2002, The Sewer Law; Fujairah, 2004, The Wastewater Law-Local Order No.1; Abu Dhabi, Law No. 2 of 1998 (and amended by Law No. 19 of 2007).
11. See for more details: http://www.rsb.gov.ae/uploads/WRRRegConsApr09Eng.pdf
12. Abu Dhabi Crown Prince Directive no. (87) 2009
13. See for example http://www.gulfbase.com/site/interface/NewsArchiveDetails.aspx?n=129052
14. Dubai Circular No. (161) of 2007 on the Implementation of Green Building Criteria in the Emirate of Dubai
15. See http://www.zawya.com/printstory.cfm?storyid=ZAWYA20100309150956&l=150900100309
16. See http://gulfnews.com/news/gulf/uae/environment/only-six-green-buildings-in-dubai-yet-1.522102
17. See http://www.estidama.org/

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Annex 5
Stakeholder Meeting

12th November 2009

Annex 5
Stakeholder Meeting
12th November 2009

The Ministry of Environment and Water in cooperation with the International Center for Biosaline Agriculture (ICBA) held a brainstorming meeting on 12th November 2009 at ICBA in Dubai to kick-off the water conservation strategy for the UAE, Figure A5.1. The main objective of the meeting was to discuss the key issues that face the water sector and to identify the roadmap for the water conservation strategy. Representative stakeholders from key institutions, ministries and universities attended the meeting, Table A5.1.

Figure A5.1: kick-off seminar of the water conservation strategy for the UAE

Table A5.1: Stakeholders and their contact information

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