



United Nations
Educational, Scientific and
Cultural Organization



International Centre for
Water Security and
Sustainable Management



GLOBAL WATER SECURITY ISSUES CASE STUDIES :

Water Security and the Sustainable Development Goals





Water Security and
the Sustainable
Development Goals

Published by the UNESCO International Centre for Water Security and Sustainable Management (i-WSSM), 125, Yuseong-daero 1689 Beon-gil, Yuseong-gu, Daejeon, Republic of Korea.

© UNESCO i-WSSM 2019

ISBN 978-89-98408-22-0 93300



This publication is available in Open Access under the Attribution-Share Alike 3.0 IGO (CC-BY-SA 3.0 IGO) license (<http://creativecommons.org/licenses/by-sa/3.0/igo/>) from the i-WSSM web page (<http://unesco-iwssm.org/board/select?bbsNo=0000000064&nttSn=35>).

The present license applies exclusively to the text content of the publication. For the use of any material not clearly identified as belonging to UNESCO i-WSSM, prior permission shall be requested from: iwssm@unesco-iwssm.org, 125, Yuseong-daero 1689 Beon-gil, Yuseong-gu, Daejeon, Republic of Korea.

The designations employed and the presentation of material throughout this publication do not imply the expression of any opinion whatsoever on the part of UNESCO i-WSSM concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Any ideas and opinions expressed in this publication are those of the authors and do not necessarily reflect the views of UNESCO i-WSSM and do not commit the organizations.

Suggested citation: UNESCO i-WSSM. 2019. *Water Security and the Sustainable Development Goals*. Global Water Security Issues (GWSI) Case Studies, UNESCO i-WSSM, Daejeon.

Editor-in-Chief:

Kwangsuop Lim, UNESCO i-WSSM

Bitna Lee, UNESCO i-WSSM

Editors

Hyoseop Woo, Gwangju Institute of Science and Technology

Dongjin Choi, Korea Research Institute for Environment & Development

Sungje Park, Future Resources Institute

Gwangseob Kim, Kyungpook National University

Sanguk Kim, Kangwon National University

Sewoong Jung, Chungbuk National University

Jungcheol Paik, Gangneung-Wonju National University

Andrew Guitard, K-water

Authors

Elias Salameh, Center for Strategic Studies (CSS), University of Jordan, Jordan.

Musa Shteivi, CSS, University of Jordan, Jordan.

Ghaida Abdallat, CSS, University of Jordan, Jordan.

Rakez Al-Zareer, CSS, University of Jordan, Jordan.

Neil A. Coles, School of Geography, University of Leeds, Leeds, UK.

& Institute of Agriculture, University of Western Australia. Perth WA, Australia.

Sarah M. Hendry, Dundee Law School, University of Dundee, Dundee, UK.

Najet Aroua, Laboratory of Architecture and Environmental Design (LaCoMoFa), Department of Architecture, University of Biskra, People's Democratic Republic of Algeria.

Noureddine Zemmouri, LaCoMoFa, Department of Architecture, University of Biskra, People's Democratic Republic of Algeria.

Robert J. Patrick, Department of Geography and Planning & Global Institute for Water Security, University of Saskatchewan, SK, Canada.

Pedro Roberto Jacobi, Institute of Energy and Environment, São Paulo University (IEE/USP), Brazil.

Pedro Henrique C. Torres, IEE/USP, Brazil.

Eduardo Gonçalves Gresse, University of Hamburg, Germany.

Petra Schneider, University of Applied Sciences Magdeburg-Stendal, Germany.

Tamara Avellán, United Nations University, Institute for Integrated Management of Material Fluxes and of Resources, Germany.

Youngdug Kim, The Wave Talk Inc., Republic of Korea.

Kihyeok Jeong, The Wave Talk Inc., Republic of Korea.

Water Security and the Sustainable Development Goals

Global Water Security Issues (GWSI) Case Studies

4/SEP/2019

Cover and inside design: ©Junghwan Kim, Pieona Books & i-WSSM

Cover photo (front): ©photo Michael Wood / Dreamstime.

Morrison Springs county park, US

Printed in Seoul, Republic of Korea. Pieona Books



GLOBAL WATER SECURITY ISSUES CASE STUDIES :

Water Security and the Sustainable Development Goals



United Nations
Educational, Scientific and
Cultural Organization



International Centre for
Water Security and
Sustainable Management

FOREWORD

Yang Su Kim

Director of UNESCO i-WSSM



Water challenges are increasingly impacting every region around the world facing the effects of climate change, urbanization, as well as natural disasters. Confronted with the on-going water-related challenges, addressing water security can be a practical approach to deal with the complex and interconnected challenges and enhance sustainability, development and human welfare.

Over the years, 'Water Security' has gained international attention since the International Hydrology Programme (IHP) placed an emphasis on 'water security' during its 8th phase, being implemented between 2014-2021, in line with the eight-year Medium-term Strategy of UNESCO (2014-2021). For instance, 'Water Security for Peace and Development' is the main theme of 9th World Water Forum which will be held in Senegal in 2021.

The significance of water security and the urgent need to conduct extensive research on emerging and future global water security issues, document these studies and disseminate them are globally being recognized.

Surprisingly, though, a variety of topics regarding water security have not been researched in depth. There is an urgent need to conduct extensive research on emerging and future global water security issues, document these studies and disseminate them.

In response to demand, UNESCO International Centre for Water Security and Sustainable Management (i-WSSM) published the Global Water Security Issues (GWSI) Case Studies with the aim of providing a starting point for discussion on a range of issues that collectively fall under the umbrella of water security, identifying the present issues, broadening discourses, bringing regional cases to the center, and sharing diverse perspectives.

The GWSI Case Studies, 'Water Security and the Sustainable Development Goals', provides rich explanations on the related issues of water security while taking into context various aspects such as governance, society, environment, and technology. The Case Studies sheds lights on how the approaches to water security play important roles to achieve multiple

priority development areas including climate action, conservation and restoration of ecosystems, national security, innovative technology, public health and well-being, clean water and sanitation, and enhancement of human integrity.

It is timely that UNESCO i-WSSM has decided to work in order to disseminate global water security issues. I give my sincere thanks to the authors, editors, reviewers, and staffs for their contributions. I also wish to extend my gratitude to the Asia Water Council for their partial financial support to publish the GWSI Case Studies.

Just as water is central to every aspect of life on earth, water security must lie at the heart of the new vision we forge for sustainable development for the century ahead. In this respect, the GWSI Case Studies makes an important contribution to addressing the challenges of water security and disseminate the issues to broader areas. I hope that the GWSI Case Studies encourages people around the world to actively contribute to enhancing water security and achieving sustainable development goals. For a sustainable and prosperous future for all, the current water challenges we face require collective action.



Yang Su Kim

Director of UNESCO International Centre for Water Security and Sustainable Management
(i-WSSM)

Part I

1

Water Security in Jordan	19
01 Introduction	20
02 Water Management Setup: Laws, Policies and Administration	20
2.1. Legal Framework	
2.2. Policy of Integrated Water Resources Management	
2.3. Sector Institutions: Roles and Responsibilities	
2.4. National Interest	
2.5. Water Policy Principles	
03 Security against Water Scarcity	23
3.1. Well Drilling Prohibition	
3.2. Pricing Extracted Non-Agricultural Water	
3.3. Metering the Groundwater Amounts Abstracted for Agricultural Uses	
3.4. Pricing Extracted Water for Irrigational Uses	
04 Security of Shared Water Resources	24
6.1. Dashboards and Data Integration for Real-Time Monitoring	
6.2. Models and Forecasts	
6.3. Example of Application: AquaVar DSS	
05 Security of Emergency by Guaranteeing Strategic Reserves	25
5.1. Water Storage in Concrete Structures	
5.2. Keeping Some Water in Dams	
5.3. Emergency Groundwater Wells	
5.4. Country-wide Interconnected Water Supply System	
06 Security against Water Pollution	26
6.1 Waste Water Treatment and Reuse	
07 Security of Infrastructure against Sabotage and Damage	28
7.1 Emergency Control Center	
08 Security of Locally Produced Food	28
09 Security against Climate Change	29
10 Media and Awareness Administration	30
11 Unsettled Security Issues	30
12 Conclusion	31

Water Security and Governance

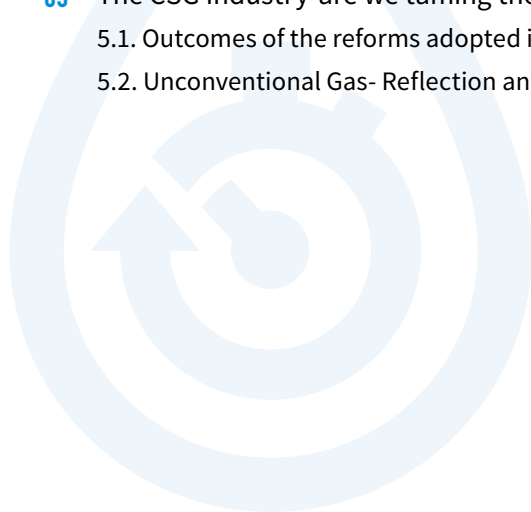
2

Security of Water Infrastructures against Sabotage and Damage in Jordan	35
01 Introduction	36
1.1. Research Theories: Why Targeting Water?	
1.2. The National Legislative Framework for Protecting Water Infrastructures	
02 Water Infrastructures Security Department (WISD)	38
2.1. Supervisory Control and Data Acquisition	
2.2. Information Sharing and Coordination Efforts	
2.3. Threat Notification	
2.4. Threats Action and Response	
03 Type of Threats and Case Studies	40
3.1. Damaging and Violating Water Infrastructures	
3.2. Chemical Contamination	
3.3. Biological Contamination	
3.4. Cyber Attack	
04 Critical Secured Water Resources	41
4.1. King Abdullah Canal	
4.2. Routes and Burial of Main Pipelines	
4.3. Trucked Water	
4.4. Desert Areas Water Security	
4.5. Historical Water Sources Security	
4.6. Civil Defense and Fire Department	
05 Precautionary Measures	44
06 Conclusion	44

Part II

3

Water Governance of Large-scale CSG Projects in Two Eastern Australian States: A Comparative Analysis	49
01 Introduction	50
1.1. Unconventional gas and water resources	
1.2. CSG, government policy and communities	
02 Developing a uniform Australian Policy for Unconventional Gas	51
2.1. Who owns the CSG resources and who regulates?	
2.2. Harmonisation: A federal unconventional gas policy?	
2.3. National unity and harmony grow out of concerns with CSG and water security?	
03 The Environmental and Water Law Reforms adopted in NSW	56
3.1. The development of water and environmental law in NSW	
3.2. The Environment: A change in focus for Policy development in NSW	
3.3 The challenge: Developing a robust state gas plan and a CSG policy	
04 The CSG Industry, Environmental and Water Law Reforms in QLD	60
4.1. Introduction	
4.2. The LNG industry in QLD – legislative beginnings	
4.3. Adaptive environmental management: - Queensland’s approach to regulating the unconventional gas industry	
4.4. How effective is the adaptive management strategy?	
05 The CSG Industry-are we taming the Genie?	63
5.1. Outcomes of the reforms adopted in NSW and QLD	
5.2. Unconventional Gas- Reflection and Lessons Learned	



Water Security and Society

4

Urban Growth Pattern and Water Supply Efficiency in Algiers, Algeria	77
01 Introduction	78
02 Research Methodology	79
2.1. Urban Growth Pattern and Water Issues in the Study Area	
2.2. Assessing Method	
03 Results and Discussion	83
3.1. Total water consumption vs water demand	
3.2. Water Demand Vs Water Demand Satisfaction Rate	
3.3. Water Demand Satisfaction Rate Vs. Urban Growth Pattern	
04 Conclusion	86

Part III

5

Building Water Security through Drinking Water Protection Planning with First Nations in Canada

91

01	Introduction	92
02	Pursuing water security	93
03	Context and background	93
04	Research method	94
	4.1 Establish Working Committee (Stage 1)	
	4.2 Source Water Assessment (Stage 2)	
	4.3 Identify risk management actions (Stage 3)	
	4.4. Develop an implementation strategy (Stage 4)	
	4.5. Review and update of the SWP plan (Stage 5)	
	4.6. Case Studies	
05	Research results	96
06	Discussion	98
07	Conclusion	98



Water Security and Environment

6

Governing Shallow Waters: SDG 6 and Water Security in Sao Paulo	101
01 Introduction	102
02 Methods	102
03 Water Security and the 2030 Agenda for Sustainable Development	104
04 Water Governance in Metropolitan São Paulo	105
05 Water Availability and Climate Dependence in the São Paulo Metropolitan Region	105
06 Emergence and Development of Water Crisis	106
07 Water Governance, Performance Assessment and the Localization of SDGs	107
08 São Paulo's Performance on Sustainable Development Goal 6: Ensure Availability and Sustainable Management of Water and Sanitation for All	108
8.1. Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all	
8.2. Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	
8.3. Target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	
8.4. Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	
8.5. Target 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	
8.6. Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	
8.7. Target 6A: By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	
8.8. Target 6B: Support and strengthen the participation of local communities in improving water and sanitation management	
09 Resistance to Lack of Transparency, Accountability and the Role of Societal Initiatives	111
10 Conclusion	112

Part IV

7

Dimensions of Water Security in the Global Context of Sustainable Development	119
01 Introduction	120
1.1. Dimensions of Water Security	
1.2. Global Change and Planetary Boundaries	
1.3. Global Change Syndromes	
1.4. Cause-and-Effect Analysis	
1.5. Scope of this article	
02 Methodology	123
03 Results: Correlating Water Related Global Change Syndromes and Agenda 2030	124
3.1. Cause-and-effect Analysis for Use Syndromes and Respective Cases	
3.2. Development Syndromes	
3.3. Sink Syndromes	
04 Conclusion	136



Water Security and Technology

8

Microscopic Impurities in Drinking Water and Solutions	141
01 Introduction	142
1.1. Problems caused by Microscopic Impurities	
02 Preexisting Solutions	142
2.1. Flow Cytometry	
2.2. Particle Counter	
2.3. Agar Culturing and Real-time PCR	
03 Seeking New Solutions	144
3.1. Principle & How system works	
3.2. Benefits	
3.3. Applications	
04 Conclusion	147

Figure of Contents

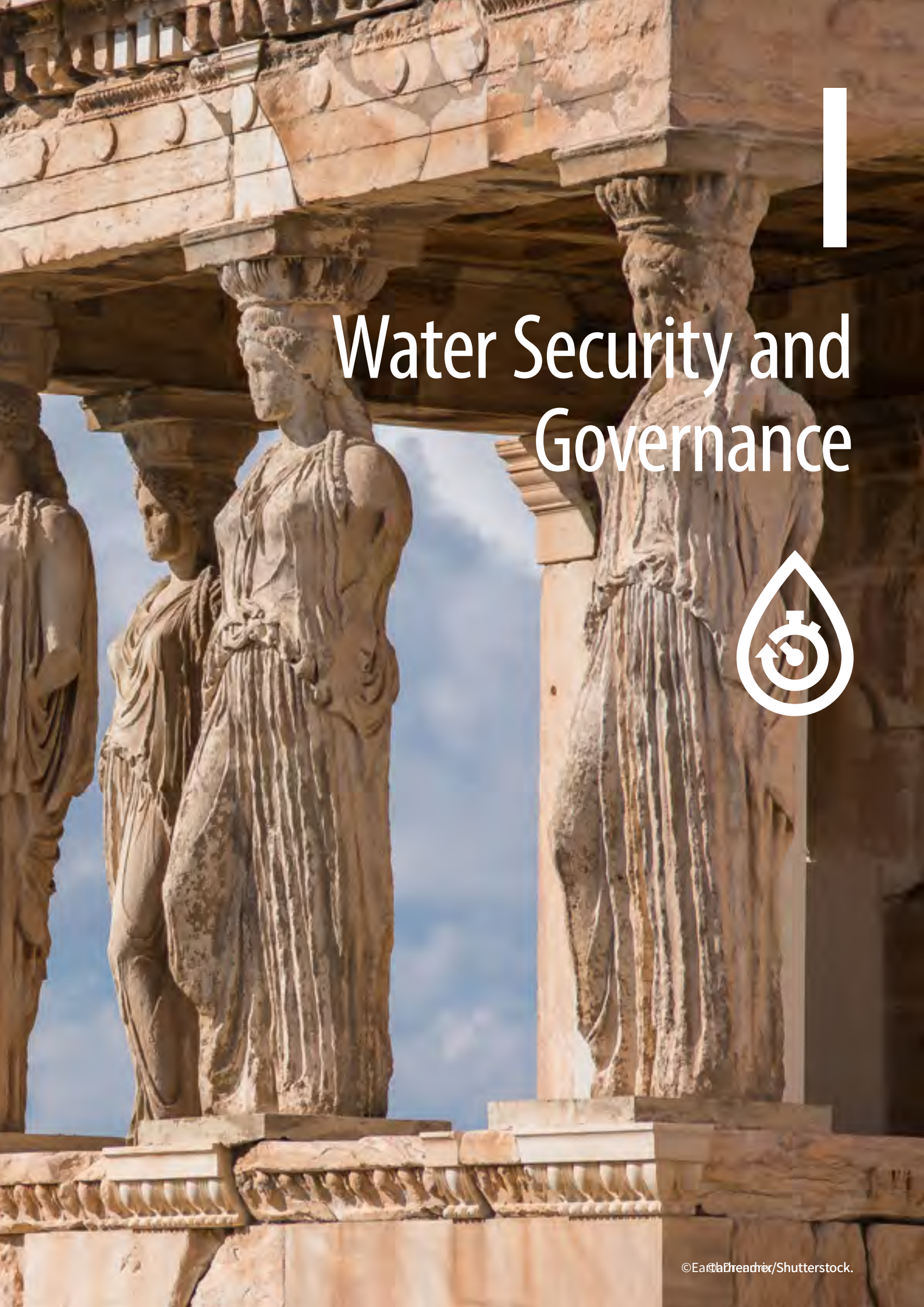
Figure 1-1	Mujib Dam 95km south of Amman with a capacity of 32 MCM	26
Figure 1-2	Salt City wastewater treatment plant in the middle reaches of Wadi Shueib northwest of Amman City	27
Figure 1-3	Wadi Sir Wastewater treatment plant in the lower reaches of Wadi Kafraïn west of Amman City	27
Figure 2-1	Monitoring the water infrastructure for violations threats and sabotage via cameras	38
Figure 2-2	Surface water monitoring system with water quantity and quality devices at the Center	38
Figure 2-3	Applied SCADA system on all cities and villages in Jordan through WSID	39
Figure 2-4	Major water resources (surface water (S.W) and groundwater (G.W)) in Jordan (modified after Water Resources in Jordan, MWI, open files)	41
Figure 2-5	The KAC location and extension (modified after Alkhoury et al., 2010)	42
Figure 2-6	The KAC with security systems (Fences and cameras)	42
Figure 2-7	Security and Burial of Disi – Amman main pipelines	43
Figure 3-1	Demonstration of the broader impacts of multiple CSG wells in the landscape with the roads and other infrastructure in a CSG field near Dalby State Forest, southern Queensland. Scale widthways: 6.8 kilometres. Source: Eco Logical Australia 2013	52
Figure 4-1	Algiers location (After Agence Nationale d'Aménagement du Territoire 1989)	78
Figure 4-2	Algiers urban growth pattern (After the National Office of Statistics 1998)	79
Figure 4-3	Algiers water supply perimeters (after ADE)	80
Figure 4-4	Evolution of water consumption 1999-2002 (After ADE)	82
Figure 4-5	Water consumption vs water demand	83
Figure 4-6	Variability of the total water consumption vs SPs' related indicators	83
Figure 4-7	SP demand vs water consumption	84
Figure 4-8	SP water consumption, water demand and water demand satisfaction rate	85
Figure 4-9	The water demand satisfaction spatial distribution through the city	85
Figure 5-1	Source Water Protection Planning Framework (Government of Canada, 2014)	94
Figure 6-1	Maps of Brazil, São Paulo State, and São Paulo Macrometropolis region. Map elaborated by Ana Lia Leonel (UFABC/FAPESP), 2018	103
Figure 7-1	Overview of the dimensions of water stress (World Resources Institute, 2013)	120
Figure 7-2	Estimates of how the different control variables for seven planetary boundaries have changed from 1950 to present (Source Stockholm Resilience Centre, 2013). The green shaded polygon represents the safe operating space (Source Steffen et al., 2015)	121
Figure 7-3	Cause-and-effect analysis of the Sahel syndrome	125
Figure 7-4	Cause-and-effect analysis for the Rural Exodus Syndrome	126
Figure 7-5	Rural and urban poverty headcount trends, national and regional, 1992-1993 to 2009-2010, in % (Mukwaya et al., 2012)	127
Figure 7-6	Impression of the Uganda eco-village in the Bigodi Wetlands Sanctuary in the Kibale region, established in 1992, providing nature and cultural village walks	127
Figure 7-7	Cause-and-effect analysis for the Katanga syndrome	128
Figure 7-8	Former lignite mining area in the Lusitia region in 1980 (Source Welt Journal)	129
Figure 7-9	Impression of the Lusatian Lakeland and the connecting channels	129
Figure 7-10	Cause-and-effect analysis for the Aral Sea Syndrome	130
Figure 7-11	Desiccation of the Aral Sea (Luxner & Drake, 2015)	131
Figure 7-12	Cause-and-effect analysis for the Favela Syndrome	132
Figure 7-13	The stages of urban development in Jakarta (Baker, 2012)	133
Figure 7-14	Cause-and-effect analysis for the Smokestack syndrome	134

Figure 7-15	Graph showing the historical evolution of SO ₂ emissions (Larsen et al., 2006), and Spatial and temporal distribution maps of average annual precipitation pH in China (Lei et al., 2016)	135
Figure 8-1	Diagram of Flow Cytometry	142
Figure 8-2	BD FACSCalibur™, an Example of Flow Cytometer	143
Figure 8-3	Diagram of Particle Counter	143
Figure 8-4	An Illustration of Direct Imaging	143
Figure 8-5	An Explanation of Time-Reversal Mirror Effect	144
Figure 8-6	Principle of TWT Sensor	145
Figure 8-7	An Ecology of TWT Sensor System	146
Figure 8-8	Diagram of Whole Inspection System Using TWT Sensor	147

Table of Contents

Table 1-1	List of dams, their capacities and water use (Ministry of Water and Irrigation -open files) DamCapacity MCM Use	23
Table 1-2	Existing municipal wastewater treatment plants in Jordan	26
Table 2-1	Water supply of Amman from far resources, their distances, quantities and pumping heads (Salameh et al., 2018)	42
Table 3-1	Commonwealth financial contributions to the States negotiated as part of the NPA	55
Table 3-2	Actions, policies and legislation enacted, amended or referred to in NSW to manage CSG activities and their impact on the environment, water resources, landholders and communities	58
Table 3-3	Queenland Legislation pertaining to Unconventional Gas (after Walton 2014)	61
Table 3-4	Actions and Policy changes undertaken in relation CSG and LNG industry development, export and management in QLD	62
Table 4-1	Calculation of SP indicators	81
Table 4-2	SP water consumption (After ADE)	81
Table 4-3	SP characterizing indicators	81
Table 4-4	SP Water demand (after the Ministry of Water Resources standard)	83
Table 4-5	SP Water demand fulfillment	84
Table 5-1	Identified risks to source water, Prairie Region	97
Table 6-1	São Paulo's performance on SDG 6 (clean water and sanitation), according to official data	109
Table 7-1	Use Syndromes (Schellhuber et al., 1997)	122
Table 7-2	Development Syndromes (Schellhuber et al., 1997)	122
Table 7-3	Sink Syndromes (Schellhuber et al., 1997)	122
Table 7-4	Selected Use syndromes and their relation to water stress	124
Table 7-5	Selected Development syndromes and their relation to water stress	130
Table 7-6	Sink syndromes and their water stress impacts	135





Water Security and Governance





1

Water Security in Jordan

Elias Salameh and Musa Shteivi

Elias Salameh, Center for Strategic Studies (CSS), University of Jordan.

e-mail: salameli@ju.edu.jo

Musa Shteivi, CSS, University of Jordan.

e-mail: mshteivi@css-jordan.org

Abstract

To secure water resources and achieve their continuous flow in arid and semi-arid areas of the globe is a highly challenging task because one is dealing with the “Management of Scarcity” threatened by droughts, climate changes, population growth, water quality deterioration, trans-boundary water bodies and social and political detriments. Therefore, solutions must be innovative, very strict and governed by laws and regulations applied equally to all stakeholders. Jordan, in addition to having characteristics of arid and semi-arid countries, since 1948, it has been affected by very strong refugee waves from Palestine, Lebanon, Iraq and Syria among others and hence its water situation has been throughout very critical. But, sound strict laws and by laws and implementation of adequate water security programs allowed the country to survive and to control its very scarce water resources in an exemplary way that can be applied also elsewhere. In the current work the water security issues in Jordan are addressed and the programs, action plans and measures to achieve water security are discussed.

Keywords

Water security, governing laws, strategies, policies and action plans

01

Introduction

Jordan is a country with very limited and scarce water resources, having at its disposal around 120m³ of water per person per year for all use sectors of municipal, irrigational and industrial uses compared to its needs of 1,200m³ per person per year which places it at the verge of the water poverty index (Salameh, 2000). The situation is largely aggravated by a huge influx of the Syrian refugees and the high population growth in the country. To achieve a high degree of water security compatible with its water resources base Jordan has adapted strategic plans, programs and measures. The paper will discuss strategic issues related to the water security of the country as summarized in the following categories:

- Legal framework, strategy and policy principals
- Security against water scarcity
- Security of shared water resources
- Security of emergency by guaranteeing strategic reserves
- Security against water pollution
- Security of infrastructure against sabotage and damage
- Security of locally produced food
- Security against climate change

“In general, the legal framework is of crucial importance for the development of Water Security for any country and for the water resources management.”

02

Water Management Setup : Laws, Policies and Administration

2.1. Legal Framework

In general, the legal framework is of crucial importance for the development of Water Security for any country and for the water resources management. In the case of Jordan, the Constitution establishes for equality before the law and equality of rights for all citizens. Water and sanitation are regulated by the Ministry of Water and Irrigation By-Law No. 14 of 2014 (MoWI, 2014), the Water Authority of Jordan Law No. 18 of 1988 (MoWI, 1988), and its amendments and the Jordan Valley Authority By-Law No. 30 of 2001(MoWI, 2001). Other relevant laws include the Public Health Law No. 47 of 2008 (MoH, 2008), the Environmental Protection Law No. 85 of 2006 (MoE, 2006), and the Groundwater By-law No. 85 of 2002 (MoWI, 2002) and its amendments.

These laws and by-laws govern the management of the entire water resources of the country and permit the building of sound Water Security in all its aspects such as: Security of resources, water uses, against pollution, misuse, sabotage, and depletion.

The "Water Authority Law of 1988 No.13" states in Article 5 that: The Ministry of Water and Irrigation shall carry the full responsibility for all water and wastewater systems and the related projects and shall set forth a water policy and submit it to the Council of Ministers for approval.

This article transfers the full authority of the country's water resources to the Ministry of Water and Irrigation and gives the mandate to the ministry to set up the water policy for the country. Therefore, this article guarantees the solemn right of allocating the country's water resources.

Article 25 states: All water resources available within the boundaries of the Kingdom, whether they are surface or ground waters, regional waters, rivers or internal seas are considered State owned property and shall not be used or transferred except in compliance with this Law.

This article establishes the sovereignty of the state over all the resources in the country and emphasizes that no party is allowed to use them without the official agreement of the ministry. This can be interpreted as a water security issue, granting the ministry the right to dynamically manage the resources according to social economic and political developments.

Article 6

In order to achieve all the objectives intended by this Law the Authority shall exercise the following responsibilities and tasks:

- A. Survey the different water resources, conserve them, and determine ways, means and priorities for their implementation and use.
- B. Set up plans and programs to implement approved water policies related to domestic and municipal waters and sanitation, and to develop water resources in the Kingdom and to use them for domestic and municipal purposes, including digging of productive wells, development of springs, treatment and desalination of waters, and execute works to augment the potential of water resources and to improve and protect the quality thereof. For this purpose, the term (municipal waters) means waters that are used for domestic, commercial, industrial and touristic purposes and which are supplied through the public networks.
- C. Direct and regulate the construction of public and private of wells, investigate water resources, and drill exploratory, reconnaissance and production wells, and license well drilling rigs and drillers.
- D. Study, design, construct, operate, maintain, and administer water and public waste water projects including collecting, purifying, treating, disposing of water and waste water, and the methods of dealing with water.
- E. Draw terms, standards and special requirements in relation to the preservation of water and water basins, protect them from pollution, and ascertain the safety of water and waste water structures, public and private distribution and disposal networks, and take the necessary action to ensure technical control and supervision, including, all necessary tests.
- F. Carry out theoretical-and applied research and studies regarding water and public waste water to achieve the Water Authority's objectives including the preparation of approved water quality standards for different uses and technical specifications concerning materials and construction in order to apply the findings to the Authority's projects in coordination with other concerned departments; and publish the final findings and standards so as to generalize their application by all means available to the Authority.
- G. Issue permits to engineers and licensed professionals to perform public water and waste water works; and participate in organizing, special training courses to qualify them in order to improve the standard of such works and to reduce water losses and pollution. All those involved in water and waste water works are requested to adjust their practice in accordance with the provisions of this Article and to obtain the specified permit accordingly.
- H. Regulate the uses of water, prevent its waste, and conserve its consumption.
- I. In addition the law states that: Any water resources that are not under the management, responsibility or supervision of the ministry, shall not be used in excess of personal or domestic needs or other acceptable private usage; nor in excess of legal water rights in accordance with the laws and regulations in effect including drinking, and irrigation rights applicable to the area of land which contains that resource.

2.2. Policy of Integrated Water Resources Management

The Ministry of Water and Irrigation advanced the concepts of "Integrated Water Resources Management (IWRM)" as a strategic tool to promote coordinated efforts towards the development and management of water, land, environmental resources and related issues in order to optimize water use efficiencies and to maximize the resultant economic and social welfare gains in an equitable manner, without compromising the sustainability of vital ecosystems. This medium- to long term strategy will enable meeting the sustainable goals of water and sanitation services. That would entail creating a capable environment of water resilience and minimizing water vulnerability within a framework of sound socio-economic and political atmosphere. IWRM also incorporates a provision for institutional and regulatory framework capable of enhancing human integrity with all its economic, social and political challenge (MoWI, 2016e).

2.3. Sector Institutions: Roles and Responsibilities

The Ministry of Water and Irrigation is responsible for the overall national leadership on policy, strategic direction and planning, in coordination with the Water Authority and the Jordan Valley Authority; the two sub-organizations of the Ministry. Under By-law No. 14 of 2014 (MoWI, 2014), the Ministry assumes full responsibility for water and public sewage and all related projects in the Kingdom. The ministry aims to: "Upgrade, develop and regulate the water sector and enhance the quality of water services".

It has a mandate to:

- Develop sectors' policies and strategies
- Endorse plans and programs related to water resources and their protection;
- Implement international agreements
- Develop laws, by-laws, regulations and normative and technical standards
- Develop private sector partnerships;
- Supervise the implementation of strategic plans and programs
- Follow up on the

2.4. National Interest

Jordan's overall national interest in developing its water resources is to achieve "sustainable water resources development" which was defined by the World Commission on Environment and Development (1987) as "the ability to meet the needs of the here and now without compromising the ability of future generations to meet their own needs". Population growth and improving living standards put additional pressures on the scarce water resources

and negatively impacts their quality if not planned and implemented with highest consideration to environmental and socio-economic consequences.

The interest of nations in their water resources increases the scarcer their water resources are and the value of water increases with increasing poverty of a country on water resources.

Jordan's national interest in water resources originates from a socio-economic and political arena which affects the whole situation and existence of this water scarce country. With the passage of time it has become a function of the country's security, stability and sustainability.

Therefore, the national interest in the water resources was directly reflected in forming "the Royal Committee on Water" in 2007 which was entrusted to develop a water strategy for the country and which was developed in 2009 and is being followed and updated continuously (Royal Committee on Water, 2009). That strategy has been expressed in general water policy principals which themselves have led to developing a dynamic water strategy for the country with different scenarios, action plans, programs and projects. Jordan's national interest in water resources is further complicated because of the shared resources it has with several neighbors in the context of regional instability and conflict.

For Jordan, sustainable water resources development means:

- A. A continuous supply of water to the population of Jordan sufficient in quantity and safe in quality is guaranteed and to supply the industrial and irrigation sectors with optimized water needs. Water prices should reflect the real cost including the capital and operational costs to compensate the nation for consuming its assets on natural resources.
- B. Protect the national water resources from degradation, depletion, misuse and in all aspects, maximize their productivity potentials and optimize their uses.
- C. Rights of next generations in the water resources, especially the non-renewable ones are guaranteed irrespective of the present interests, water needs and utilization. This means guaranteeing sustainability, security and safety of water resources, their yield and the conservation of biodiversity.

The three above mentioned national interests incorporate the social, economic, environmental and political elements. All of which aim at one goal, namely development without negatively impacting the natural system. Here it is worth mentioning that protecting water resources and maintaining their sustainability are complicated processes.

2.5. Water Policy Principles

First, we have to keep in mind that water resources are not evenly distributed in the country neither is population distribution, so maintaining a balance between preserving water resources and meeting the needs of population is a real challenge in a water scarce resources country such as Jordan. Second, with the increase of socio-economic developments, the population becomes more differentiated in their socio-economic stratification which could result in excessive use of water by some groups in the society and therefore an increasing demand for water which may result in undermining the water resources of the country.

The water policy principals of Jordan were developed by the Ministry of Water and Irrigation (MoWI, 2016e) and are illustrated and discussed in the following paragraph:

Water policies consist of a set of broader outlines of principles to be adopted to serve the national interests. In Jordan these water policy principles can be summarized in the following:

- A. The water resources of the country are a possession of the nation. The government and the parliament are responsible for their disposal to the different water use sectors and for their quantitative and qualitative conservation in accordance with the national interests.
- B. Drinking water has a priority over all other water uses. Its quality must at all times and in all places be within the set standards.
- C. All water resources of the country should be utilized to their utmost potentials under strict consideration of sustainability principles and preservation of biodiversity.
- D. Differentiation between water use and water consumption should accompany any allocation of water to the different use sectors (water use means borrowing water and returning it back to the environment, may be with different characteristics. Water consumption is exhaustion of water with irrelevant return flows).
- E. All water uses should be optimized (demand management), especially, water use in irrigation which should be exposed to strict comprehensive economic feasibility of the water use itself and of the national economy as a whole.
- F. Any exploitation of non-renewable water resources should be accompanied by national programs aiming at compensating next generations' rights in these resources. Such compensation can include investments to regenerate the exhausted resources at any time in the future.
- G. Wastewater should be considered as an integral part of the water resources. It should be treated to cope with the quality of the recipient water bodies or with the quality requirements of the next use.
- H. All water should be priced according to its capital and operational cost in addition to the cost required to regenerate it if any part of it is nonrenewable at the same rate of its exhaustion. This requires the optimization of the water supply to keep its cost as optimal as possible. So it is clear that the overall water policy of the country was based on diversification of optimal use of all water resources and trying to meet the water needs of all users at an acceptable level of satisfaction.

03

Security against Water Scarcity

As a water resources scarce country relative to the numbers of its indigenous population, in addition to guest workers and refugees, Jordan has gradually adapted a strategy aiming at making utmost use of its water resources. The strategy has been reflected in the following policies and programs:

Allocating to the different use sectors only the optimal water amounts needed for:

- A. Households to live in hygienic conditions.
- B. Industry provided with the needed amounts after introducing in plant recycling, and treatment and reuse of the wastewater whenever and wherever possible.
- C. Agriculture provided with amounts of water in accordance with plant water requirements after introducing water saving devices, advanced irrigation techniques such as drip or sub-surface irrigation, technical training of farmers and introduction of improved seeds, protected irrigation, such as green houses and mulch covers.
- D. Developing its surface and groundwater resources completely to a stage that there is, for example, no surface water flow of more than 5 MCM/yr where dams or weirs have not been constructed.
- E. Household waste waters are collected in sewerage systems and adequately treated in wastewater treatment plants to be reused after mixing with flood and base flow waters in irrigation.
- F. Industrial waste waters are treated within the industry's area to be either recycled, reused or discharged to nearby wadis if their qualities do not impair the Wadi's water quality.
- G. Brackish water is being desalinated for use in drinking and irrigation.
- H. Purchasing water from Lake Tiberias (Israel) to supplement the drinking water supply of the country.
- I. Desalination.

3.1. Well Drilling Prohibition

Driven by depleting aquifers and deteriorating water qualities the Ministry of Water and Irrigation (MoWI) approved in the early nineties of the last century a by-law prohibiting the drilling of new wells in most parts of the country, where aquifers were afflicted by depletion and quality degradation.

The by-law exempted governmental municipal water supply, universities, hospitals, industry and military camps from this prohibition. In addition, repairs of existing wells were allowed, but only with the same specifications of the well to be substituted.

All drilling companies were officially informed about the new by-law and about the fines introduced against those who violate the by-laws (worth mentioning here is that groundwater levels in Jordan generally lie tens to hundreds of meters below ground surface and therefore manual excavations are irrelevant). In spite of this restriction, illegal use was still common in certain areas especially those who have drilled the wells prior to the new policy.

3.2. Pricing Extracted Non-Agricultural Water

In 1998, a new tool for groundwater resources management was applied. According to that, a new regulation was issued putting a price for all the extracted groundwater used for purposes, except irrigation, but including industrial, commercial, universities, military, hospital and municipal uses.

On all wells producing water for the uses mentioned above, water meters were installed and read on a regular basis. The Ministry of Water and Irrigation was commissioned to read the meters and collect the bills.

Dam	Capacity(MCM)	Use
Wahda or Unity	110	Drinking and irrigation
Arab	20	Irrigation
Ziglab	4.3	Irrigation
Kufranja	8.0	Irrigation
King Talal	89	Irrigation
Shueib	2.3	Irrigation
Kafrain	7.5	Irrigation
Wala	16	Drinking
Mujib	32	Drinking
Tannour	16	Industry and irrigation
Zarqa Ma'in	UC	Drinking
Karak	UC	Irrigation
Ibn Hammad	UC	Irrigation and industry

UC = under construction

Table 1-1 List of dams, their capacities and water use (Ministry of Water and Irrigation - open files)

3.3. Metering the Groundwater Amounts Abstracted for Agricultural Uses

In 1999 the MoWI took a decision to install water meters on all the wells pumping water for agricultural uses. The first target of this program was to measure the abstracted amounts from each aquifer. The second came to remind farmers to abstract only the amounts of water stated in their well drilling license.

3.4. Pricing Extracted Water for Irrigational Uses

The Ministry of Water and Irrigation started a few years ago to charge the groundwater extracted for agricultural uses for amounts exceeding the requirements of family businesses. It has also introduced a block type of tariffs, where charges increase with the increasing amounts of extracted water.

Metering and pricing regulations are expected to result in saving appreciable amounts of groundwater, alleviating herewith over exploitation and salinization of aquifers.

04

Security of Shared Water Resources

Jordan shares water with its neighbor countries as follows:

- Surface and groundwater resources with Syria in the north.
- Surface water with the Palestinian Authority along the Jordan River from the Dead Sea to about 40km north of it.
- Surface and groundwater resources with Israel, from the Middle of the Jordan Valley to Lake Tiberias and along the Yarmouk River and along Wadi Araba from the Dead Sea to the Gulf of Aqaba.
- Disi-Saq groundwater with Saudi-Arabia along the southern borders of Jordan and limited amounts in quantity and quality of surface and groundwater along the border of the two countries in east Jordan.
- Negligible amounts of surface and groundwater along the border of the Jordan and Saudi Arabia in northeast Jordan.

As evident, much of the groundwater resources of Jordan are shared with neighbors, which by itself is not a problem. The problem sometimes arises during political conflict or instability and in other cases when countries fail to fulfill their obligation such as the case with Syria.

To guarantee its shares in the shared water resources as an issue of water security of the country, Jordan reached with its neighbors the following agreements and understandings:

The Unified Johnston Plan for sharing the Yarmouk and Jordan Rivers water among Jordan, Syria, Lebanon and Israel as agreed upon by the Arab League and Israel and guaranteed by the United States. This agreement was substituted by the peace treaty between Jordan and Israel in 1994 and by another agreement with Syria in 1987 in the course of negotiations to construct the Unity Dam on the Yarmouk River in the border area of the two countries.

The peace treaty with Israel of 1994 (Peace treaty, 1994) has defined Jordan and Israel shares in the remaining Yarmouk River water which reaches the borders of the two countries after coming out from the border line of Jordan and Syria. The agreement guaranteed a defined amount of water to Israel, herewith assuring that the rest of the water belongs to Jordan alone.

Jordan and Israel averted water conflicts by signing agreements to share the jointly owned water resources. This has added to the security of both countries without one country trying to take a larger amount of water than allocated in the agreements, herewith allowing for smooth integrated social and economic development.

Although, according to the 1987 agreement with Syria, Jordan was allocated 200 MCM/yr of the Yarmouk River water, Syria did not abide to that agreement. Jordan did its best

to guarantee its share in the Yarmouk River water but Syria has violated all agreements and until 2011 (Start of the uprising in Syria) has developed whatever it can of the surface and groundwater resources of the Yarmouk River basin. Therefore, there is still a dispute between the two countries and hence the Yarmouk River basin water resources including a part of the Unity dam water are, for Jordan, still insecure and threatened by conflicts.

Jordan and Syria also share the surface and ground waters of the basalt aquifer in central north Jordan and central south Syria. Here there is still no agreement about sharing these water resources. Syria is the up-stream country to both the surface and groundwater of the Basalt aquifer and it exploits both of the irrespective of Jordan's share in them and irrespective of environmental, social and political consequences of that over

exploitation both on Syria and Jordan. In that concern, these shared water resources are still very insecure to Jordan in spite of all Jordan's efforts to reach a sharing agreement with Syria.

“The problem sometimes arises during political conflict or instability and in other cases when countries fail to fulfill their obligation such as the case with Syria.”

05

Security of Emergency by Guaranteeing Strategic Reserves

Water resources in Jordan are threatened by a variety of factors which can interrupt water supplies to the population and for the different use sectors. Therefore, the Ministry of Water and Irrigation has developed many emergency measures for the case of supply interruptions, the most important of them are discussed below:

5.1. Water Storage in Concrete Structures

Concrete reservoir structures have been built all over the country to serve in supplying household water by gravity flow instead of direct pumping to users. Such reservoirs range in size from a few hundred of cubic meters to several hundred thousand cubic meters e.g. Daboug Reservoir and Abu Alanda reservoirs each with a storage volume of several hundred thousand cubic meters. The water Authority tries as much as possible to keep these reservoirs filled with water for emergency cases. They also serve as reserves when the water supplies are under maintenance or repair.

King Abdullah Canal with a total length of about 110km and a length of 65km from its intake at the Yarmouk River to the intake of the drinking water supply in Deir Alla can accommodate about 2 or 1.5 MCM in dynamic storage. This can also be considered as a storage reservoir in case of other supplies interruptions for both drinking and irrigation water.

Dams were constructed all over the country to store water mainly for drinking uses such as Mujib, Wala, Ibn Hammad, Unity and Zarqa Ma'in (under construction). These dams store flood and base flow water to serve as reserve to enhance the security of water supply.

Other dams and countless water harvesting weirs have also been built to store water for irrigation and industrial uses. In the southern and eastern dry parts of the country weirs serve in supplementary irrigation cattle watering and unintended artificial groundwater recharge.

Some dams collect, in addition to flood and base flows, treated wastewater which does not have immediate application in irrigation. Storage in this case serves two targets, namely, first: storing the treated effluents from time of production to times of need and second mixing it with fresh flood and base flow water to improve its quality.

All the above-mentioned structures store water from times of availability to times of need but they are also considered as emergency water structures to ensure the security of the water supply for all use sectors such as drinking, irrigation,

industry tourism and animal husbandry.

In addition, Jordanians are obliged by law and necessity to install concrete house hold water reservoirs or water tanks to store amounts of water for at least one week uses. Building codes dictate that each household or building should have a water storage facility accommodating water for, at least, one week use. This is an additional storage security measure, although its main causes are water shortages and inability to pump water continuously 24 hrs. a day 365 days a year.

5.2. Keeping Some Water in Dams

In order to secure water resources that are enough to satisfy irrigation water needs for one cropping season and to supply industrial needs for a few months certain amounts of water are reserved in dams each year after the end of the dry season and start of the rainy season. That is because it cannot be predicted, in advance, when it will start raining and when flood water will start reaching dam reservoirs. For example, at the end of the dry season; end of September around 10 MCM are left in storage in Wahda dam, 10 MCM in King Talal dam and in 7 MCM in Mujib dam for eventualities. This practice secures some water for drinking, irrigation and industry if rain does not start at the beginning of the rainy season. This is very important policy for all water use sectors, but very vital for the irrigation sector, because the planting time in the Jordan Valley area starts, almost together, with the start of the rainy season. If one waits for rain to irrigate it might come 5-6 weeks later after the planting time although that year might be a rain rich year. Therefore, waiting for rain to irrigate means loss of the production season.

5.3. Emergency Groundwater Wells

As a part of drinking water security, the Ministry of Water and Irrigation has drilled wells, not for regular use but, which can be operated in emergency cases. Such wells were drilled in all groundwater basins all over the country. In addition, industrial and irrigation wells producing drinking water qualities and lying close to the drinking water supply network are marked by the ministry as potential emergency supply wells.

5.4. Country-wide Interconnected Water Supply System

Although Jordan does not have yet a national water carrier from south to north and from east to west, Jordan's water supply system is interconnected throughout the country. This means that Jordan has the capability to transfer water through the interconnected water supply system from south to north and from west to east. Water pipelines can be operated either ways; to pump to a certain area or from it according to needs.

06

Security against Water Pollution

Water quality degradation is a major factor that can jeopardize the water security in Jordan as a country with very limited water resources, because water pollution can drive the country into more severe domain of water scarcity and water insecurity.

Being aware of the consequences of water quality degradation and its implications to the continuity of water supplies, health, agriculture, industry, social life, income of people, employment and poverty the Ministry of Water and Irrigation executed several programs and advances a number of laws, by-laws and regulations to ensure the quality of water in the country.

6.1 Waste Water Treatment and Reuse

6.1.1 Domestic Waste Water Treatment

In Jordan household's wastewater in Jordan is being treated in 33 wastewater treatment plants and the effluents reused, after mixing with better quality flood and base flow water, mainly in irrigation. Around 60% of Jordanian households are served with sewerage systems and centralized waste water

treatment. In addition, many smaller waste water treatment plants were constructed to serve remote areas, universities, army camps and small communities.

From a cultural perspective, there was a lot of opposition for the re-use of treated water that mainly stemmed from lack of knowledge and misperception about it. However, after long awareness campaign and outreach by the government, there is today wide acceptance for the policy related to wastewater treatment and reuse in irrigation in Jordan.

Name	Name	Name
Abu Nusseir	Ma'an	Shallala
Akedar	Madaba	Shoubak
Aqaba Mechanical	Mafraq	South Amman
Aqaba Natural	Fuheis/ Mahis	Tafila
Baqa'a	Jarash	Talibiya
Fuheis/ Mahis	Miyrad	Tal Mintah
Jarash	Mu'tah/ Mazar	Wadi Arab
Irbed	North Shuna	Wadi Hassan
Karak	Ramtha	Wadi Musa
Khirbet as Samra	Salt	Wadi Sir
Kufranja	Samra Mechanical	Za'atari
Lajjun	Samra Natural	

Table 1-2 Existing municipal wastewater treatment plants in Jordan



Figure 1-1 Mujib Dam 95km south of Amman with a capacity of 32 MCM

6.1.2 Industrial Waste Water Treatment

All industries in Jordan are obliged by law to treat their wastewater for reuse within the industrial plant premises or before it is discharged to the environment or before it joins the inflows of domestic wastewater treatment plants. That is only done when the industrial plant treatment produces effluents which can further be treated in a domestic wastewater treatment plant.

6.1.3 Management and Environmental Cost

The management efficiency of water pollution is measured by its performance. Sound management is achieved when water resources use is efficient and do not lead to environmental degradation. When water resources are misused or in cases of water pollution, overexploitation, ignoring sustainability principles and next generations' rights reflect inadequate water resources management and will have negative implication on the water resources themselves. Therefore, it should never be accepted that social, economic or any other type of development is used as a justification to deplete the water resources in quantitative or qualitative aspects. Otherwise, that will turn the development itself into a vicious circle, where degradation of water resources as an essential element of the environment and development negatively impact the development itself. And hence, development should take into account the water resources issues as serious as possible to avoid depletion and degradation of resources. Pollution and unsustainability of water supplies might lead to health, social, environmental and economic detriments and hence to political unrest. That has led the Ministry of Water and Irrigation to appropriately manage the water resources



Figure 1-2 Salt City wastewater treatment plant in the middle reaches of Wadi Shueib northwest of Amman City

by incorporating the management of these resources' environmental aspects sound social and economic analyses. Therefore, developmental projects resulting in water resources degradation must according to the Water Laws mentioned in the "Legal framework: incorporate the mechanisms and economic instruments to rehabilitate that degradation. Accordingly, this implies that any water developmental project should serve societal objectives and should be beneficial to the country. Hence the Ministry of Water and Irrigation and the Ministry of Environment laws and by-laws forces all water developmental plans such as water resources to be subjected to environmental feasibility.



Figure 1-3 Wadi Sir Wastewater treatment plant in the lower reaches of Wadi Kafraïn west of Amman City

07

Security of Infrastructure against Sabotage and Damage

7.1 Emergency Control Center

Due to the recent developments in the Middle East region and the arising of radical groups, the security of water resources and water systems has become mandatory in Jordan to protect water sources from attack and sabotage. This fact led the Ministry of Water and Irrigation mainly its sub-organization the Water Authority, to initiate the establishment of a center for protection to monitor and control water resources, reservoirs, stations, dams and all major facilities through the installation of surveillance cameras and appointment and training of specialized staff with qualification and experience to manage the monitoring and control systems (MoWI, 2016e).

The Center is linked to the various security agencies, such as the Command and Control Center in the General Security Directorate, to ensure integration and cooperation of duties and tasks.

Training of personnel was strengthened in coordination and cooperation of the Directorate of Workshops and Maintenance and has raised the sense of security of both the employees of the Center and of the Directorate.

A code of security system has been developed and is being applied to existing water system, to future water systems and those under construction.

In addition, the diversification of water resources used for municipal water supply assists somehow in the continuity of supply in case of damage and sabotage. As an example Amman City obtains its drinking water from the following sources: Disi which lies at about 300km south of Amman and supplies around 100 MCM/yr, Wala which lies at about 75km south of Amman and supplies around 45 MCM/yr, Mujib- Zarqa Ma'in which lies southwest of Amman at about 110km and supplies around 45 MCM/yr, Deir Alla which lies at about 45km northwest of Amman and supplies 60- 80 MCM/yr, Azraq which lies at around 100km east of Amman and supplies around 20 MCM/yr in addition to local sources in and around the city of Amman. This diversification of sources and areas, although not planned, forms a water security issue in case of damage to one or more of the supply projects, allowing for the continuation of supply from the other sources and herewith a certain water security against damage and sabotage.

The issue of water infrastructure security will be dealt with in details in another paper in this same series by Dr. Abdallat and Dr. Al-Zareer.

08

Security of Locally Produced Food

Water availability is the limiting factor of irrigated agriculture in Jordan. The other factors such as land, agriculture laborers, knowhow etc. are quite available. The presently allocated water amounts for irrigation are not expected to substantially increase in the case of Jordan except depending on the increases in the amounts of adequately treated wastewaters that can be used after mixing in irrigation.

Food production under the prevailing climatic conditions in Jordan for one person requires around 1000m³ per year (Salameh 2001 Water poverty index). The water resources of the country can satisfy only about 17% of its water needs to be self-sufficient in food production (Teimeh, 2016; El-Naser, 2009).

Jordan from within its territory is self-sufficient in vegetable production and almost self-sufficient in fruit production. But the country cannot produce enough cereals and meet for its inhabitants and produces part of them depending on the amount of rain it receives in a year. None the less additional water for irrigation means higher food security, higher employment rates and hence poverty alleviation and stronger societal security.

To achieve a higher food security position and due to the country's limited water resources and in order to keep pace with the increasing population Jordan undertook the following strategic measures to continue producing high amounts of agricultural produce:

Improving water use efficiency in the agricultural sector by introducing:

- A. Advanced irrigation systems such as drip irrigation instead of furrow irrigation, mulch covers of irrigated land and protected irrigation (green house). Knowing that drip irrigation requires only about 50% of the water used in furrow irrigation for the same quantity of produce (Teimeh, 2016).
 - Genetically improved plant seeds.
 - Water use in irrigation according to the concepts of plant water requirement.
 - Advanced irrigation devices and techniques.
 - Training of farm workers.
- B. Adequate treatment of municipal wastewaters (Secondary treatment), mixing with flood and base flow water and use in irrigation.
- C. Desalination of brackish water for use in irrigation.
- D. Building farmers associations: The Ministry of Water and Irrigation / Jordan Valley Authority together with the Farmers in the Jordan Valley area has established Water Users Associations (WUA) and included farmers in the decision-making processes, future plans, water budget, and coming programs and projects, as it was thought is necessary to

establish principles of participation, transparency, fairness, and teamwork. By now WUAs cover around 80% of the irrigated area in the Jordan Valley and it is planned to cover with WUAs the whole irrigated area in the Jordan Valley within the coming years. These WUAs have much helped in the fair distribution of the water resources which the Ministry put under their disposal for irrigation among themselves and have released the Ministry of the pressures to when droughts and climatic changes hit the country.

- E. A strategic intervention for food security as a result of water scarcity has been implemented through policies for importing, storing and distributing cereals to satisfy the needs of the country for a time period of up to one year.

The implementation of the above strategic measures allowed for higher water use efficiency and more food production per unit of used water which assisted in fostering food production security and created confidence between farmers (Farmers associations) and the government. Higher efficiencies in food production and optimization of water use are still expected once the increasing efficiency strategic measures are fully implemented.

09

Security against Climate Change

Little can be done in Jordan to change the trend of climate change, but some programs can be developed to alleviate the implications of such changes on the water security of the country. Therefore, some pro-active measures have been implemented and are being implemented to alleviate the climate change impacts:

- A. Advanced water saving techniques have been introduced to the irrigation sector to allow using less water for producing the same quantity of agricultural produce such as: drip irrigation, protected irrigation (irrigation in green houses), mulch irrigation, improved seeds, use of water according to plant water requirements and training of farmers. In addition, meetings of water users' associations or farmers' associations served as venues for experience exchange where farmers learned from each other experience and from those of experts in the ministries. All the above measures have led to water savings and increasing production of a better-quality agricultural produce.
- B. Carrying out of studies to store water in underground aquifers instead of surface storage in dams, weirs and pools in order to minimize evaporation and to make more water available for irrigation.
- C. Water reuse: Municipal as well as industrial wastewater are adequately treated in secondary treatment plants and mixed with flood and base flow water in order to be reused in irrigation. This is a secondary source of water in Jordan finding safe use in irrigation which is alleviating pressures on the fresh water resources of the country and allowing for other uses of the saved fresh water and combating climate change.
- D. Desalination of brackish water for irrigational uses; Brackish water, especially in the Jordan Valley area has since about 15 years been desalinated for use in irrigation. This has resulted in decreasing demands for irrigation water and allowed the fresh water used before for irrigation to be used for higher-water quality requiring water uses such as municipal use or saving some fresh water sources which are expected to decrease due to climate changes.
- E. Water harvesting: Flood flow waters especially in the dry eastern and southern parts of the country continue only for a few hours after which they reach saline flat and shallow playas (Qa'as) and to become salinized or to collect in shallow depressions and evaporate in the following days or weeks. This temporarily collected water has historically been used for cattle watering and very restricted supplementary irrigation. To make a better use of such water and as a measure to alleviate climate change the Ministry in cooperation with the armed forces have started two decades ago to build desert weirs and relatively deep excavations (A few meters in depth) to store such flood waters and minimize evaporation for the benefits of shepherd, nomads and local irrigation projects avoiding herewith some of the impacts of climate changes on Bedouins and their livelihood.

- F. Establishment of the Emergency Control Center and a Risk Management Department in the Ministry of Water and Irrigation in order to combat climate changes and droughts.
- G. Planning for sea water desalination as a security measure to guarantee continuity of water supply.
- H. Most of the previous measures are important to mitigate the negative impact of climate change and should be enhanced. But sea water desalination remains the only strategic choice that will help the country not only to offset the impact of climate change on the country but also to help in solving the water scarcity issue. Certainly, this is a costly solution but it must become the short-term strategic option.

The above-mentioned measures to alleviate climate changes are considered transformational proactive measures. Adaptation measures are expected to take place with time.

10

Media and Awareness Administration

Activities to increase the awareness of society about water security are conducted through different programs addressing the population through the media and press coverage of the most important events and activities carried out by the Ministry of Water and Irrigation to provide citizens with the necessary information. Such media campaigns are conducted in relation to attacks on water resources and communicating water awareness appeals through various media outlets to all segments of Jordanian society, especially in light of difficult water situation. Also, programs related to these awareness campaigns target schools, universities and community colleges students and distribute water saving devices to schools, ministries and other buildings aiming at optimizing the use of water in addition to the information about the water situation of the country, climatic change and threats facing the water system.

Although these awareness campaigns are important, the future the situation might require more targeted awareness programs as well as trying to integrate these issues in the educational system in permanent bases.

11

Unsettled Security Issues

Although many strategic and policy issues and proactive measures were undertaken in Jordan to alleviate the implications of water scarcity some issues have not yet been adequately addressed:

- Shared water with Syria
- Over-exploitation of aquifers
- Climate change; not adequately
- Future municipal water supply
- Next generations sustainable water supplies
- Sea water desalination

12

Conclusion

Fresh water is a basic need for humans and all terrestrial fauna and flora which cannot be substituted by any other substance. Drinking water from a human point of view of survival more important than food and in many countries is considered to be food stuff number 1. In addition, the development of irrigated agriculture and industry is also dependent on the availability of fresh water suitable quality.

Fresh water supplies for household uses, irrigation and industry have to be sufficient in quantity, suitable in quality and continuous. Therefore, security of water sources, their qualities and supply networks have to be guaranteed in all cases and all the time. Otherwise the population will suffer, the health of its members will deteriorate, their agricultural and industrial productivity will discontinue and may even cease.

In countries with limited water resources, such as Jordan, supplying water in adequate quantity and quality and in time is a tough enterprise. It is the management and of scarcity and its security.

In Jordan water security is at the highest consideration in the country's governance with the level of interest reaching the leadership of the country. Therefore, effectively, no window of opportunity was left without advancing policies, strategies, laws and by-laws and action plans to guarantee the security of the water sector.

Security against water scarcity has been reflected in developing all water resources of the country to their utmost, guaranteeing the state ownership of all water resources of

“Therefore, effectively, no window of opportunity was left without advancing policies, strategies, laws and by-laws and action plans to guarantee the security of the water sector.”

the country and extraction and their extraction and use must be licensed by the government. Agreements on transboundary water bodies have been achieved Water resources for emergencies have been secured by surface water storage, country-wide interconnected water supply networks and drilling and equipping emergency groundwater wells.

Waste water is being treated and reused, surface and groundwater protection measures undertaken and their protection zones defined to conserve

the water quality. In addition, a rigorous program for the protection of all the water supply components is now in place, especially as a policy issue after the threats of radical groups in Jordan and its surrounding countries, which are suffering of sabotage, civil wars and social and political unrest.

The above summarized policies, strategies and programs have led to secure water supplies, secure food and industrial production and to some extent alleviation of climate change impacts.

Although Jordan has implemented a rigorous program to achieve water security there are still some issues not yet completely settled such as: Overexploitation of aquifers and next generations' rights in them, some transboundary water bodies and climate change impacts.

It is hoped that Jordan will soon be tackling these issues in order to satisfactorily secure its water sector against natural and man-made threats.

References

- Ansari, N., Salameh, E. & Omari, H. (1999). Analysis of rainfall in the Badia region, Jordan. Al al-Bayt University, Research paper No. 1.
- Baban, S. & Al-Ansari, N. (2007). Living with Water Scarcity. Water Resources in the Jordan Badia Region. The Way Forward. University of Al-al Bayt Press. <https://www.researchgate.net/publication/37359486>.
- El-Naser, H. (2009). *Management of Water Resources*. WIT Press.
- IPCC. (2007). Intergovernmental Panel on Climate Change Fourth assessment (IPCC) report. *Climate Change*. Cambridge University Press, England.
- MoE. (2006). Ministry of Environment. The Environmental Protection Law No. 85.
- MoH. (2008). Ministry of Health, Public Health, Law No. 47.
- MoWI. (1988). Ministry of Water and Irrigation and Water Authority of Jordan, Law No. 18 of 1988 and its amendments.
- _____. (2001). Ministry of Water and Irrigation and Jordan Valley Authority, By-Law No. 30 of 2001.
- _____. (2002). Ministry of Water and Irrigation, Groundwater By-law No. 85 of 2002 and its amendments.
- _____. (2014). Ministry of Water and Irrigation, By-Law No. 14.
- _____. (2015). Ministry of Water and Irrigation. Year book 2015.
- _____. (2016a). Ministry of Water and Irrigation. Surface water utilization policy.
- _____. (2016b). Ministry of Water and Irrigation, Groundwater sustainability policy.
- _____. (2016c). Ministry of Water and Irrigation. Climate Changes policy for a resilient water sector.
- _____. (2016d). Ministry of Water and Irrigation. Decentralized wastewater management policy.
- _____. (2016e). Ministry of Water and Irrigation. National Water Strategy.
- _____. (2016f). Ministry of Water and Irrigation. Water demand management policy.
- _____. (2016g). Ministry of Water and Irrigation. Water reallocation Policy.
- _____. (2016h). Ministry of Water and Irrigation. Water substitution and reuse policy.
- _____. (2016i). Ministry of Water and Irrigation. Year book 2016.
- MoWI : Ministry of water and Irrigation. (Open Files).
- Peace Treaty Accord between Jordan and Israel. (1994).
- Royal Committee on Water. (2009). Water for Life, Jordan's Water Strategy 2008-2022, Amman, Jordan.
- Salameh, E. (2000). Redefining the water poverty index. *Water International*, 25(3), pp. 469-473. International Water Resources Association.
- _____. (2008). Overexploitation of Groundwater Resources and their Environmental and Socio-economic Implications: The case of Jordan. *Water International*, 33(1), pp. 55-68.
- _____. (1997). *Water quality degradation in Jordan*. Friedrich Ebert Foundation and Royal Society for the Conservation of Nature, Al-Kutba Press, p. 179, Jordan.
- Salameh, E. & Ansari, N. (2006). Prospects of wastewater management and water reuse in Jordan, in: Efficient management of wastewater, its treatment and reuse in four Mediterranean countries, Ed. Ansari et al. EU- MEDA Water, EM-WATER InWent, Alshaeb Press, Jordan.
- Salameh, E. & El-Naser, H. (2000a). Changes in the Dead Sea level and their impact on the surrounding groundwater bodies. *Acta hydrochimica et hydrobiologica*, 28(1), pp. 24-33. Weinheim.
- _____. (2000b). The interface configuration of the fresh-/Dead Sea water- Theory and measurements. *Acta hydrochimica et hydrobiologica*, 28(6), pp. 323-328. Weinheim.
- _____. (2005). Water situation in Jordan –Impacts of recently applied policies on the water sector in Jordan- *Hydrogeologie und Umwelt*, H. 33. Wuerzburg.
- _____. (2008). Restoring the shrinking Dead Sea –The environmental imperative. In Zereini, F. & Hoetzel, H. (eds.) *Climatic Changes and Water Resources in the Middle East and North Africa*, pp. 453-468. Springer Publishing Company.
- _____. (2009). Retreat of the Dead Sea and its effects on the surrounding groundwater resources and the stability of its coastal deposits. In Hoetzel, H., Moller, P. & Rosenthal, E. (eds.) *The Water of the Jordan Valley*, pp. 247-264. Springer Publishing Company.
- Salameh, E. & Frimmel, F. (2010). Upcoming water quantity and quality problems in arid and semi-arid climatic zones. Proceedings of the International Conference "Integrated water Resources Management" (IWRM) Publication of the Karlsruhe Institute of Technology, Germany.
- Salameh, E. & WI-Naser, H. (1999). Does the actual drop in Dead Sea level reflect the development of water sources within its drainage basin? *Acta hydrochimica et hydrobiologica*, 27(1), pp. 5-11. Weinheim.
- Teimeh, A. (1999). Climate and agro-ecological desertification in Jordan. The International Conference on the desert and dry lands development. Challenges and potentials in the new Millennium. Organized by the International Commission of Dry Lands and ICARDA, UNEP, Cairo Egypt.

_____. (2010). The impact of climatic change on land resources in Jordan, Conference organized by the World Bank, the National Center for Agricultural Research and the Ministry of Agriculture.

_____. (2016). Food security in Jordan Center of Strategic Studies University of Jordan Press, Jordan.

Water Sharing Agreement between Jordan and Syria of 1987. (1987).

World Commission on Environment and Development. (1987). From One Earth to One World: An Overview. Oxford: Oxford University Press.



2

Security of Water Infrastructures against Sabotage and Damage in Jordan

Ghaida Abdallat and Rakez Al-Zareer

Ghaida Abdallat, Center for Strategic Studies (CSS), University of Jordan.

e-mail: ghidaabdallat@yahoo.com

Rakez Al-Zareer, CSS, University of Jordan.

e-mail: rzareer@hotmail.com

Abstract

Due to regional instability in the Middle East (Syrian and Iraqi wars), which were connected to many threats and damage to the critical water infrastructures and resources in Jordan by individuals and/or terrorist groups (such as the Islamic State (Daash)). In order to secure public health and the environment, an advancing and intensified strategy for protecting water infrastructures has been launched through the “Water Infrastructures Security Department” at the Jordanian Ministry of Water and Irrigation. This paper provides explanation for the National Legislative efforts to protect water infrastructures in Jordan, where intensive monitoring has been started, covering the top priority of water resources and facilities, especially those situated at the Jordanian - Syrian - Iraqi borders. The measures are designed to protect water facilities of all types from individual or collective acts of sabotage, such as pollution, damage, violence and explosions. For that purpose the established Water Infrastructures Security Department in the Ministry of Water and Irrigation, its workings and corporations is explained with several case studies of sabotage, damage and terrorist attacks.

Keywords

Water infrastructures security, governing legislation, infrastructure security department, sabotage, terrorist attack

01

Introduction

The kingdom of Jordan, as a semi-arid country, has at its disposal the lowest fresh water availability among the most water stressed countries in the world. Jordan is bordered by Syria, Iraq, Saudi Arabia, Israel and Palestine, therefore, security of water resources is highly depended on stability and peace with and in the surrounding countries. Hereby, water stress threatens the re-establishments of military conflicts in the Middle East (Kliot, 2005).

With incrementing radicalism in the Middle East which has started threatening water infrastructures exposing herewith population health by pollution and their well-being by cutting water supplies, the country found itself forced to undertake rapid steps to counteract the radical groups and individuals and their potential to the water supply system.

The National Legislative Framework for Protecting Water Infrastructures (Article No 30, Law 18, 1988 and updated in 2014 (MWI, 1988; 2014), authorial several governmental agencies and including the Ministry of Water and Irrigation (MWI) to implement that law.

This act is designed to protect water infrastructures against damage, sabotage and terrorist attacks.

Moreover, an advanced strategy for protecting water infrastructure has been launched by the Water Infrastructures Security Department (WISD) of the MWI. This security action started in the middle of 2013, in parallel with the Syrian war when many sabotage and damage cases to water reservoirs and resources happened. Up to that, intensive monitoring system started covering the critical water resources and facilities, especially, those at the Jordanian - Syrian - Iraqi borders, which are considered of top priority. This action is a part of an ongoing effort to monitor the country's strategic water resources in order to detect and protect malfunctions and violations. Included in the security measures are refugee camps of all types (Palestinian camps in 1948 and continuing with the Syrian refugees), especially refugee camps close to the borders.

Different international agencies have contributed in developing the security of water resources against damage, sabotage and several water crises in Jordan. For instance the USAID agency, reported the responding to the water crisis in Jordan (USAID, 2007).

Additionally, Jordan supported the security of water infrastructure actions by hosting the International Conference "Water Cooperation and Propose Solutions to Prevent Water

Sources from Becoming Tools of War" in 2015 (MWI, open files).

As reported by Rossetti (2015) this conference enriched by the Strategic Foresight Group report, focused on professional water management, the impacts of water insecurity in the region and how to resolve them. Two reports, "Water and Violence: Crisis of Survival in the Middle East" and "The Hydro-Insecure: Crisis of Survival in the Middle East illustrated the challenges in water security and how it affects the Middle East" (SFG, 2014a; 2014b). Therefore, water insecurity serves to make internal and external conflicts in the region. Highlighting the ongoing conflict with the Islamic State (IS) in Syria, this has affected the majority of water sources there.

Overall, the reports focused on water security challenges and human security issues. Food insecurity, agricultural loss, migration and demographic shifts are all closely linked with water security.

In addition, the American Security Project (ASP) stated that the security of water is highly connected with peace and security issues in the Middle East, since water infrastructure is easy to contaminate or disrupt (Rossetti, 2015). Moreover, the United States Intelligence Community Assessment (US ICA) expected that water would become a target of terrorism in the area (US ICA, 2012).

Thus, the Jordanian Intelligence Department (JID), MWI and other agencies had been connected to a national focal point for gathering information on threats to the infrastructures and are coordinating the Jordanian government's response to incidents.

The critical water situation of Jordan has been caused by increasing population growth rate and waves of refugees, conflict and high potential for terrorism, increasing industrial and agricultural demands, aridity, drought and climate change. Therefore, saving fresh water resources in the country has become the most critical health, economic and security challenge. Jordan's water infrastructure systems include mainly surface and groundwater sources, mainly dependent on large variety of water resources: rivers, dams, springs, watershed boundaries, canals, pipes for transporting water, wastewater treatment plants, and aquifers.

“Saving fresh water resources in the country has become the most critical health, economic and security challenge.”

1.1. Research Theories: Why Targeting Water?

- A. Water presents a scarce and highly vulnerable source in Jordan
- B. Due to its scarcity, it is socially very sensitive, interruption or pollution will have strong political implications
- C. Water can be used as a tool to put pressure on the Kingdom of Jordan to draw from international fights against terrorism
- D. Putting economic pressure on the government of Jordan, which is already under heavy economic burdens
- E. Lessening the confidence of the population and its security organizations

1.2. The National Legislative Framework for Protecting Water Infrastructures

Jordan's water infrastructure systems are protected by the Water Authority of Jordan Law (Law 18, Article 30) (MWI, 1988; 2014), as a response to increasing terrorist attacks of different types, for instance:

- Physical disruption,
- Bioterrorism and/or
- chemical contamination, and
- Cyber-attack and manipulations.

The national legislative highlights essential steps towards security priorities, security success and emergency response programs within the water sector.

Due to this law “Any one shall be sentenced to no less than six months, and no more than two years imprisonment or to a fine no less than 1000 JD (approximately 1400 \$) and no more than 5000 JD (approximately 7000 \$), or both punishments” if he has committed any of the following acts:

- A. According to established plans and strategic priorities any sabotage in operating and maintaining public infrastructures: “Caused damage to any of the Authority projects, or ruined or destroyed any water resources or the Authority’s public sewers or acted in any way which may cause the damage or destruction of construction, equipment, vehicles or materials related to the Authority or any of its projects or public sewers”.
- B. Regulating water quality in water pipes, water bodies and aquifers (including enforcement): “Polluted any water resource, which is under the management or supervision of the Authority directly or indirectly, or caused its pollution and failed to remove the causes thereof within the period fixed by the Authority”. Regulating water quality in waterways, water bodies, and aquifers.

If man is found guilty of committing any of the deeds defined in paragraphs (a) and (b), the court shall convict the person and make him/her pay the total of the damages caused by his/her violation and compel him/her to eliminate the damage caused and restore the conditions as they existed before

the commission of such acts within the period specified by the court. If he/she fails to do so, the Authority shall have the right to carry out the necessary works and repairs and charge the convicted person with the total cost plus 50 percent.

Furthermore, this law is applied by several government agencies for instance: the Public Security Department (PSD), Armed Forces (AF), JID and WISD staff for all water sources and wastewater facilities protection. Where, all these agencies work on information concerning the risk of terrorist attacks on the water sector and the tools for minimizing those risks and responding to attacks with emergency plan.

The authority’s officials nominated by the Minister or the Secretary General, as the case may be, shall have the authority of judicial police in relation to the restraint of any of the crimes that are committed in violation of the provisions of this Law.

The Secretary General may issue a decision to remove by administrative means the violations and contraventions that are inflicted on the property, water and projects that fall within the Water Authority’s jurisdiction, and may, if the need arises, seek the assistance of members of the security forces for this purpose. He/she shall also have the right, through the competent court which considers the cases that contravene this Law as expedite cases, to go back on the contravener to reimburse the Authority for the expenses incurred to repair the damage and to restore the situation to its previous condition.

The officials of the Ministry and the Water Authority that are nominated by the Minister or the Secretary General, as the case may be, shall have the right to follow up the criminal cases before the competent courts, to obtain authenticated copies of the courts decisions relating thereto, and to follow up their implementation (MWI, 2014).

On the other hand, transboundary surface and groundwater with Israel is protected by the Peace Treaty that it was signed between Israel and Jordan in 1994 (MWI, open files).

02

Water Infrastructures Security Department (WISD)

This security department was established at the MWI in Amman to safeguard the water infrastructure from violations threatens and sabotage. The majority of country's water resources and facilities, including water supply pipe, dams, wells, pumping stations, reservoirs and wastewater treatment plants are connected via sophisticated cameras (high resolution) and control systems at the WISD. The staff and employees at the WISD use live monitor screens and remotely control the operations of the water resources, (Figure 2-1). When any suspicious movement is noticed they contact the security authorities.

In addition, the (WISD) is staffed with personnel from across a broad spectrum of different agencies for water infrastructure protection. Furthermore, the center is connected to the National Centre for Security, Crisis Management Department and the Public Security Department to provide technical data around the clock, 24 hours a day.

Water reservoirs in towns and cities are supplied with centrally controlled observation cameras. Vulnerable portion of remote water supply networks were also provided by centrally controlled electronic systems. Surface water conveyer systems are controlled by water quality devices, which measure sudden quality changes of parameters and pollution.

This monitoring center uses screens to monitor the strategic water locations categorized according to the National Policies Council's standards for water resources, using an early warning system. WISD started installing a comprehensive technical and security surveillance system for different vital water reservoirs and source for instance on the King Abdullah Canal along 110km (KAC), Disi pipe for conveying water along 320km



Figure 2-1 Monitoring the water infrastructure for violations threats and sabotage via cameras

and main dams in the country. Moreover, the water quality and quantity are monitored from any detected pollution and technical error through center's systems, (Figure 2-2).

In case of sabotage plans, special police groups are mobilized daily to control the main water infrastructure.

2.1. Supervisory Control and Data Acquisition

For protecting water and wastewater infrastructure, Supervisory Control and Data Acquisition (SCADA) systems have traditionally used combinations of radio and direct wired connections (Panguluri et al., 2011). The remote monitoring function of SCADA system is often referred to as telemetry.

Panguluri et al. (2004) reported that a SCADA water system normally consists of:

- Human - machine interface that the operator monitors and controls the process.
- Computer system that is connecting and gathering data on the process and sending commands (control) to the process.
- Remote monitoring units connecting to sensors in the process, and sending digital data to the supervisory system.
- Programmable logic controller (PLC), which are more economical, versatile, flexible, and configurable.
- Communication infrastructure that connects the supervisory system to several process and analytical instrumentation.

Data acquisition begins at the PLC unit, which includes meter readings and equipment status reports that are communicated to SCADA systems as required. Data is then compiled and formatted in such a way that a control room operator can make supervisory decisions to adjust PLC controls.

Physical and human operator controls the process through the first stage then linked to the SCADA system's databases and software programs to provide trending, diagnostic



Figure 2-2 Surface water monitoring system with water quantity and quality devices at the Center

data, and management information such as scheduled maintenance procedures, logistics information, detailed schematics for a particular sensor or machine, and expert system troubleshooting guides, (Figure 2-3). An important part of most SCADA implementations is alarm processing, for instance determining when alarms should be activated. Once an alarm event has been detected, one or more actions are taken such as the hotline telephone, or e-mails or text messages to inform management or remote SCADA operators.

However, SCADA system is connected to network and accessible from the Internet, therefore, the system is potentially vulnerable to remote attack. Therefore, this security system should be secured from cyber-attacks.

2.2. Information Sharing and Coordination Efforts

Several agencies work with WSID and they have established an Information Focal Point, representing the critical water infrastructures (vulnerable water sources). Since the start of the war in Syria, many threats, damaging and sabotaging to water infrastructures have been detected and resolved, mitigated or prevented as a result of enhanced communication systems and analysis. Additionally, the monitoring system as stated above is directly connected with the police departments and military that are at services 24 hours a day.

WSID actively exchanges information with various governmental agencies and private sector companies which focus on the national security. Thus, WSID can safeguard their infrastructures through warning messages such as indications, analysis and possibility of information exchange.



Figure 2-3 Applied SCADA system on all cities and villages in Jordan through WSID

“However, SCADA system is connected to network and accessible from the Internet, therefore, the system is potentially vulnerable to remote attack. Therefore, this security system should be secured from cyber-attacks.”

2.3. Threat Notification

In Jordan, the water sector is at a heightened alert, which has additional security of physical facilities and regular checks of gates, locks and fencing.

All water facilities have security patrols on sites and are directly connected with WSID via hotline telephone for emergency action and response. Emergency plans normally depend on threat magnitude and its direct impacts in affected areas such as damage the water supply or contamination of water bodies (MWI, open files). Therefore, providing public notice with an emergency plan and action is one of the direct responsibilities of WSID in case of threat.

2.4. Threats Action and Response

WSID has the authority to face threats through its operational and practical actions, warnings and advisories, technical feasibility to resolve from individual or and terrorist attacks (MWI, open files). Thus, a number of emergency plans and initiatives were developed with many agencies to mitigate the terrorist or individual threat as a fast response to the predicted events.

WSID has a hotline telephone in case any person has noticed unusual action to water and wastewater facility threat. Upon notice, threat assessment has to be carried out remotely and by facility security personnel. Upon assessment of the threat as credible, WSID can make appropriate notifications to other agencies to address the threat magnitude.

Afterwards, intensive and enhanced physical security covers the target water source to expand the monitoring and controlling in order to reduce the risk. Such as threats to the water quality and quantity become subjected to an emergency plan that will be conducted to secure the environment and citizen health. For instance, WSID can suggest an alternative water supply source instead of an attacked one.

It is important for the security center to classify all water infrastructures and systems according to their location, importance, capacities and topography as a database. This step supports the protection of vital infrastructures against any threat action.

03

Type of Threats and Case Studies

The WSID shows a robust threat assessment process (notification and appropriate response) with specialized technical experts and researchers in order to assess the level of threats and its affects. Local water reservoirs and facilities security has been maintained in the critical points such as canals, pumping facilities, storage facilities, and the network of water mains and subsidiary pipes.

Different types of attacks in the water sector have been uncovered, prevented and reported in Jordan, such as damages to water infrastructures, chemical and biological contamination of water supplies or toxin and cyber-manipulation.

3.1. Damaging and Violating Water Infrastructures

Damaging and sabotage of water facilities and infrastructures are considered as issues in Jordan, which greatly affect the population in a direct way. The majority of households receive water through the water supply once a week for 36 hrs. WSID and MWI took different actions to prevent any intended or by mistake accidents by using fencing, signs, cameras and helicopters for the control of long pipeline extensions. In addition, MWI increased the public awareness through media (newspaper, television and social media) about damaging water facilities and infrastructures and their punishments by law. The population has become quite aware and generally without being asked to or appointed to control water facilities, they do it and report to the police and movements indicating any evil actions or intentions.

However, many damaging actions for water pipeline and sabotage on water infrastructures were highlighted in Salt, Karak and Ma'an (MWI, open files). Namrouqa (2016) reported damaging the main water pipeline in Muaddi Village in the central Jordan Valley by a contractor's bulldozer. The damaged pipeline was counted as the fourth incident within 10 days. The main pipeline (six inch) carries water from Muaddi pumping station and distributes it to houses in the village. Technical teams worked for whole day to fix the main pipeline to rerun the water distribution program in the area. According to the Water Authority Law No. 22 for the year 2014 against violating contractors, the contractor paid the cost of the damaged pipeline and of all the wasted water (Namrouqa, 2016).

3.2. Chemical Contamination

Chemical attack on drinking water supplies is not an easy operation in Jordan, because all water supply stations are highly protected with security personnel, cameras, fences and wires. A hazardous chemical attack on a drinking water facility is difficult to carry out without site accessibility and knowledge of the facility details and components. In fact, the amount of accessible to public hazardous chemical needed to contaminate the drinking water storage of any Jordanian city would require an enormous dose (MWI, open files). Furthermore, there are procedures to control the water quality in each water supply facility, including water treatment, filtration and monitoring before entering the distribution pipelines.

In addition, monitoring water quality via sensors at the security department enables to detect any chemicals contamination directly. A reported case study in small drinking water supply reservoir of 1000m³ capacity, which was contaminated chemically (pesticide agents) by an individual (MWI, open files). That person was immediately arrested in order to be delivered to the state security court where the case was dealt with in accordance with the water security laws by laws. WSID responded to this action by removing the 1000m³ of water and cleaning the reservoir within one day in order to ensure good water quality that complies with the Jordanian standards. In this case no one was harmed by the pesticides because the poisoned water was not delivered to the water users.

Another case study reported by Al-Zareer that the Jordanian agencies trapped terrorists and extremists group who are planning to explode main water pipelines of different military sites.

3.3. Biological Contamination

This kind of attack or contamination is considered as harmful and serious threats (high risk) that are highly protected and cause illness or death of citizens. However, water reservoir contaminated with biological agents is very difficult to be brought about. In case of bacterial contamination it would not be risky due to applied treatment process such as filtration and disinfection of the water. Where bacteria are inactivated by the chlorination step at water treatment station. In case of parasites or viruses, the risk becomes harmful because they are not removed by chlorination process.

An investigated case study of terrorist attacks in 1996 targeted several huge water supply reservoirs in Amman (the capital), which delivered to the huge number of water users, around two millions of population in that time. This radical group used different chemical and biological agents in their attack. However, the governmental agencies defeated this attack and terrorists were immediately arrested and delivered to the state security court where the case was dealt with in accordance with the national water security law.

Another contamination case study in several districts for high ranking officials in Amman, water is a target of terrorists to threaten the national security. Different attacks were prevented by police in the diplomatic and officials districts.

3.4. Cyber Attack

Digital controls for pumps and treatment facilities are applied in all water facilities and infrastructures, using SCADA systems. However, there are vulnerabilities in the SCADA system that water system operators are connected and accessible to the Internet. Thus, water systems could be manipulated or attacked by hackers, viruses and programs, which could severely disrupt the operation of these systems. On the other hand, WSID`s SCADA systems are secured by technical experts and other security agencies and most of the systems enable to run the water systems without using digital systems.

Up to date, no cyber manipulation or attack is recorded. In case of this kind of attack there are different emergency plans to apply.

04

Critical Secured Water Resources

In Jordan, 500 water resources are secured by WSID technologies and staff, including dams, drinking water reservoirs, water pipelines, wastewater networks and treatment facilities. (Figure 2-4)

4.1. King Abdullah Canal

King Abdullah Canal (KAC) extends from the Yarmouk River at the border line of Jordan, Syria and Israel. Figure 2-5 shows the map of KAC location. In Syria different fighting groups control the northern side of the Yarmouk River, which supplies KAC with water that is used both for drinking and irrigation uses. Hence, this is considered as one of the most endangered drinking water supply systems world-wide.

Along KAC from its intake at the Yarmouk River to Deir Alla; the pumping station of drinking water (a distance of 65km) control cameras and tele stations for monitoring chemical parameters has been installed and operated to control the whole length of that Canal.

In addition, security portals drive along the canal and control it along its length. Also, the canal has been fenced on to the sides to a height of 160cm, as depicted in Figure 2-6.

The population residing along the canal was instructed to report any suspected action they observe. Knowing that more than 90% of Jordan`s population aged more than 15 years possesses mobile telephones, enhancing reporting to security departments with free and simple emergency numbers (111, 911 and 199).

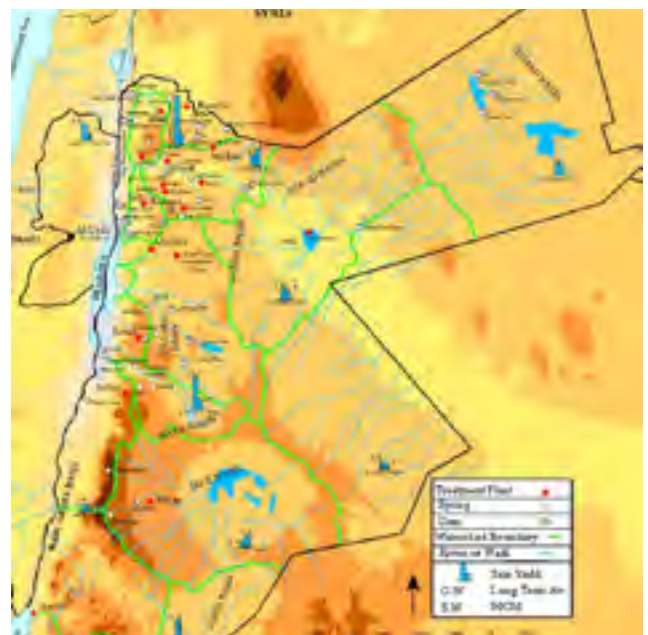


Figure 2-4 Major water resources (surface water (S.W) and groundwater (G.W)) in Jordan (modified after Water Resources in Jordan, MWI, open files)

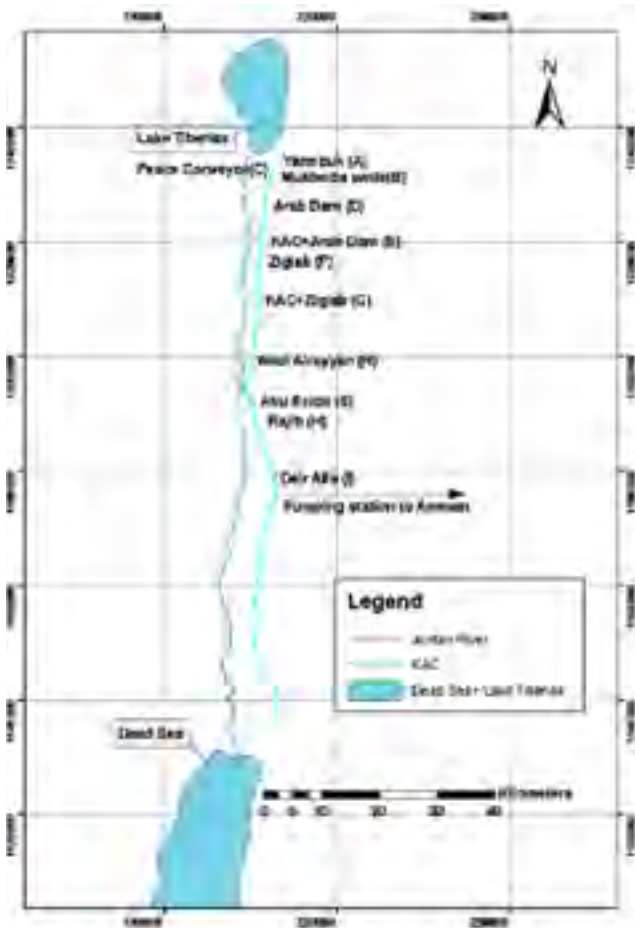


Figure 2-5 The KAC location and extension (modified after Alkhoury et al., 2010)

4.2. Routes and Burial of Main Pipelines

As a major security issues against sabotage and terrorism water pipelines are constructed below ground 1 – 3m and covered by sand to increase their mechanical elasticity. Ditches are then compressed and after short times of construction they can no more be recognized at ground surface as pipeline routes. For better security against sabotage and attack such pipelines are laid down as close as possible to main highways and roads much frequented by traffic and control teams. As examples the water pipelines (Table 2-1): Azraq – Amman, Disi – Amman, Wala – Amman, Mujib Zarqa Main Amman and Deir Alla – Amman all lie, along most of their routes, close to highways or main roads.

For instance, a few years ago, Disi water pipelines started conveying approximately 100 MCM of water from the Disi aquifer into Amman around 325km (MWI, open files). These pipelines have high potential of sabotage and damage due to its long route; therefore, they were constructed below ground and covered by sand, (Figure 2-7). Moreover, WSID brought two helicopters for Disi – Amman pipelines security and monitoring 24 hours a day (MWI, open files).

Water source	Distance to Amman [km]	Pumping head [m]	Water quantity [MCM/yr]
Disi	320	100	100
Azraq	110	650	20
Wala	55	250	22
Mujib-Zarqa-Ma'in	90	1500	45
Deir Alla (KAC)	55	1400	60

Table 2-1 Water supply of Amman from far resources, their distances, quantities and pumping heads (Salameh et al., 2018)



Figure 2-6 The KAC with security systems (Fences and cameras)



Figure 2-7 Security and Burial of Disi – Amman main pipelines

4.3. Trucked Water

For people, especially in the scarcely populated areas of the eastern and south eastern parts of the country (1–2 persons/km² on average) and in areas when the water supplied by the water networks to houses dose not suffice until the next pumping turn (36 hours a week) water is trucked for use in drinking, animal watering supplementary and irrigation or construction.

According to use, the type of trucked water must have a certificate about the source from where it was obtained, destination and use purpose. That is especially important when the trucked water is to be used for drinking and animal watering. In addition to the certificate about each water filling, date and time of filling, source and license of water type transportation (drinking, construction, etc.) control portal can stop any water truck to ensure the source and suitability for the intended use. The portal can also analyze the water and violation is strictly found in certain cases by imprisonment.

4.4. Desert Areas Water Security

Jordan, especially the eastern and southern parts are tribal areas with conflicts or cooperation about sharing the available surface water resources of flood flows, springs and very limited oases.

In some areas near the borders of neighboring countries, Saudi Arabia, Iraq and partly Syria in the far northeast tribes not easily recognize political boundaries because they have their own tribal areas across political borders.

In addition, wadis cross both political and tribal borders and fronts creating highly complicated system of tribal, political and hydrologic system. In order to avoid tribal conflicts and mutual sabotage and terror actions shepherds have been allowed to water their chattels across borders and tribal fronts according to tribal laws prevailing during pre-state times, when the only recognized laws were those of tribes. This political and tribal front trafficking allowance as controlled by desert armies of the bordering countries, succeeded in avoiding tribal conflicts and mutual sabotage actions.

Recently, since about two decades, water harvesting projects mostly constructing weirs on wadis crossing political borders and tribal fronts were carried out. But in order to avoid political or tribal conflicts over rights of water collected in weirs the rights of water utilization were clarified and agreed upon among the different tribes pressing access to the wadis water. Tribes among themselves control the water use and the desert police guarantee the sharing agreements.

4.5. Historical Water Sources Security

Historically, tribes and individuals secured their sources represented in springs, desert oases or dug holes by living around to protect the resources from incursions by other tribes or individuals.

Drinking water does not seem to have represented any major threat because of human feelings, but cattle watering by invasive use led historically to conflicts and even to wars lasting for decades. Although tribes and individuals had cooperated when source discharges declined or stopped in one or other source.

Security water sources, defending them and reaching agreements on sharing these resources have been a major task of all tribes in water scarce areas. But tribal rules, developed during the last few millennia, were able to somehow reach at just sharing and resolutions in case of disputes. Nonetheless, conflicts and wars from time to time.

4.5.1 Development of Historical Security System

In the arid and semi-arid parts of the globe humans tried to live as close as possible to water sources, such as fresh water lakes, oases, springs and perennial wadis, which secured their water supply throughout the year of wet and dry seasons. Such water sources provided humans in addition to water with some food (plants), fish and meat of hunted animals which came to water. Therefore, living close to these sources meant secured water and food sources.

With the passage of time four to six millennia ago, water started to be transported from source to residing place by animals (camels, horses and donkeys etc.). That created also a type of secured water the years over without having to live in the immediate vicinity of the water source.

“Intensive monitoring system was introduced to cover the critical and vulnerable water resources and facilities, especially, those at Jordanian borders with Syria and Iraq, the top priority sites.”

Increasing dryness and droughts forced humans to develop some primitive techniques to secure their water supplies throughout the year. Therefore, they developed water harvesting by excavating ditches and depressions of few meters in depth to collect flood water near wadi course to serve them during the dry season.

After that they started building cisterns in such formation with capacities of few to thousands of cubic meters where harvested rain water was stored a far from evaporation and pollution for use all over a year's time. This technique is still used in the Middle East

not only by nomads but also in villages, towns and cities as a supplementary water supply in increasing herewith the amount of secured water.

In Jordan and especially in remote areas this type of water storage in excavated ditches, depressions and cistern is practiced and represent a type of water secured system either on its own as a supplementary source for the dry seasons when not enough piped water reaches the population.

4.6. Civil Defense and Fire Department

Water has in addition to its use in households, industrial and agriculture a very vital role to play as fire extinguisher irrespective of its salinity or composition. Therefore, programs and measures have to be prepared to implement that role smoothly and in time. To achieve that the following measures and programs have been carried out:

- Water hydrants were installed on water mains (where water in the major pipes is always there) in accessible sites for fire engines without major traffic jams. The Department of Fire (civil defense) and MWI cooperated in the selection of the suitable sites for that purpose and distributed in the areas where fire is highly expected, within cities, towns, villages and even in open lands near forests and farming areas.
- Only the Civil Defense Department (CDD) was granted the access to the hydrants and they possess the necessary equipment to access the water in any time they need it and in a very fast way.
- Water for that purpose is not charged whatever amounts are used for fire extinguishers.

05

Precautionary Measures

In addition to all programs and measures undertaken to combat sabotage and damage preparedness for eventual cases has to be put in place to, as soon as possible, repair the damage or overcome its consequences. To achieve that the following measures have been prepared:

- Immediate mobilization of medical staff civil defense and the police
- Immediate mobilization of emergency repair groups
- Trained water managers to substitute the damaged water supply by changing water source or supply network or even by trucking water to areas affected by water supply interruptions
- In case of pollution, treatment on site as much as possible or discharge to safe places with minimized environmental impact.

06

Conclusion

The several and parallel wars in the Middle East increased the stress in the water sector, especially in Jordan. As a result, many sabotage, damage malfunction, violation and attacks to water reservoirs and resources happened. Therefore, intensive monitoring system was introduced to cover the critical and vulnerable water resources and facilities, especially, those at Jordanian borders with Syria and Iraq, the top priority sites.

The majority of water infrastructure systems in Jordan, including surface and groundwater, conveyed pipelines, supply stations and wastewater treatment plants are controlled, secured and monitored in a profound and intensive manner by WSID through MWI. MWI modified the National Legislative Framework for Protecting Water Infrastructures in 2014 in order to develop the punishments by law to safe water infrastructures against damage, sabotage and terrorist attacks.

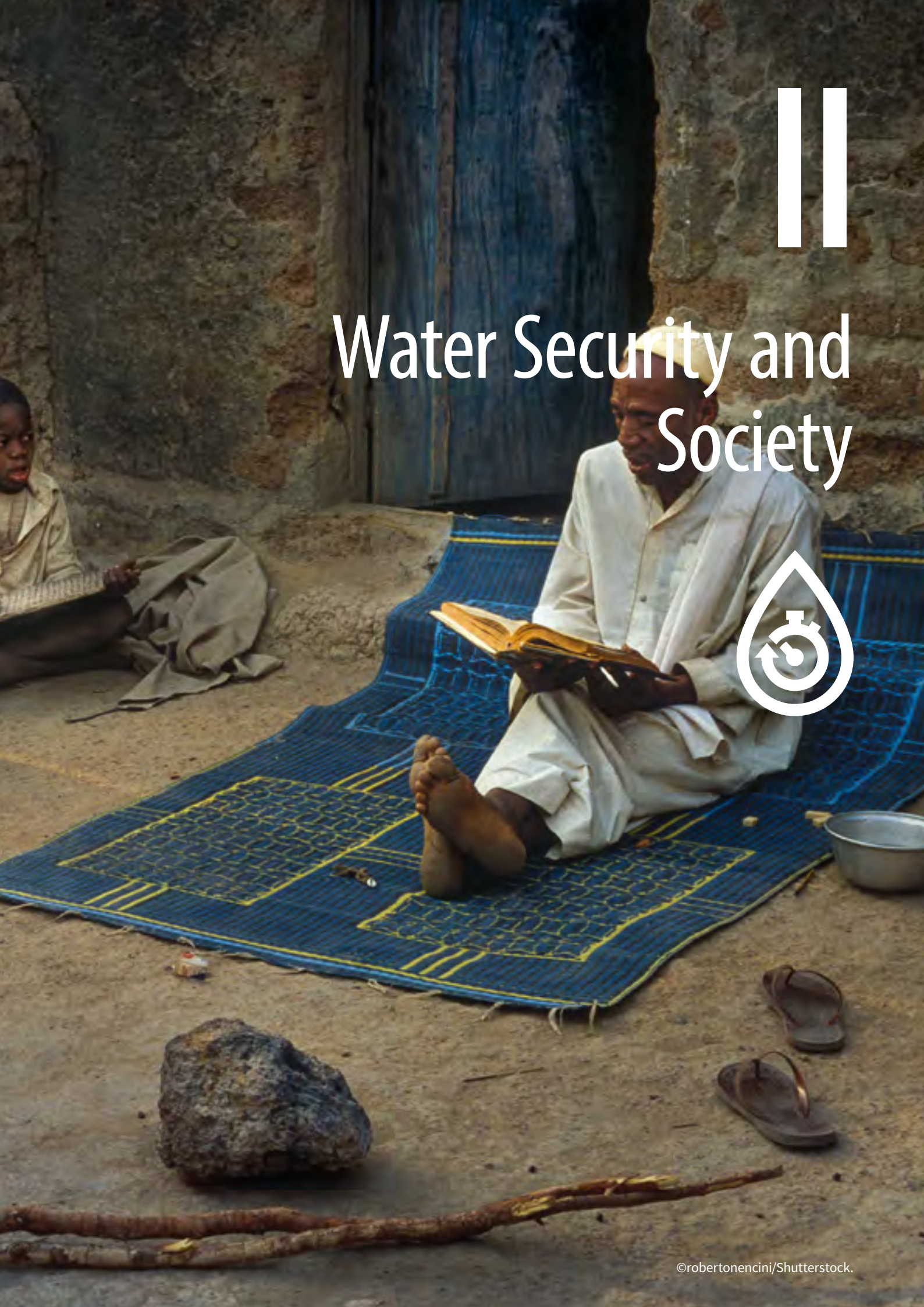
References

- Alkhoury, W., Ziegmann, M., Frimmel, F., Abbt-Braun, G. & Salameh, E. (2010). Water quality of the King Abdullah Canal/Jordan– impact on eutrophication and water disinfection. *Toxicological & Environ Chemistry*, 92(5), pp. 855-877.
- Kliot, N. (2005). *Water resources and conflict in the Middle East*. Routledge.
- MWI. (1988). Ministry of Water and Irrigation, Water Authority Law No. 18, Article 30.
- _____. (2010). *Water Resources in Jordan: A Primer*. Water Resources Management Division, Department of Environment and Conservation, Government of Newfoundland and Labrador in Jordan.
- _____. (2014). Ministry of Water and Irrigation,- Updated -Water Authority Law No. 18, Article 30.
- MWI: Ministry of water and Irrigation (Open Files).
- Namrouqa, H. (2016). Jordan Times, Amman to host int'l conference on means to prevent use of water for war, suppression. <http://www.jordantimes.com/news/local/amman-host-int%E2%80%99l-conference-means-prevent-use-water-war-suppression>.
- Panguluri, S., Phillips, W. & Clark, R. (2004). Cyber threats and IT/SCADA system vulnerability. *Water supply systems security*, 5-1.
- Panguluri, S., Phillips, W. & Ellis, P. (2011). Cyber security: protecting water and wastewater infrastructure. In *Handbook of water and wastewater systems protection*, pp. 285-318. Springer, New York, NY.
- Rossetti, P. (2015). *The Middle East Struggles with Water Security*. American Security project. <https://www.americansecurityproject.org/the-middle-east-struggles-with-water-security/>.
- Salameh, E., Shteiwi, M. & Al Raggad, M. (2018). *Water Resources of Jordan: Political, Social and Economic Implications of Scarce Water Resources*. World Water Resources, 1. Springer.
- SFG. (2014a). *The Hydro-Insecure: Crisis of Survival in the Middle East*. Strategic Foresight Group.
- _____. (2014b). *Water and Violence: Crisis of Survival in the Middle East*. Strategic Foresight Group.
- USAID. (2007). *Responding to the Water Crisis in Jordan*, USAID, Jordan.
- US ICA. (2012). *Global Water Security: Intelligence Community Assessment (US ICA)*.





Water Security and Society





3

Water Governance of Large-scale CSG Projects in Two Eastern Australian States: A Comparative Analysis

Neil A. Coles and Sarah M. Hendry

Neil A. Coles, Water@Leeds, School of Geography, University of Leeds / Institute of Agriculture, University of Western Australia.

e-mail: n.a.coles@leeds.ac.uk / ncoles@uwa.edu.au

Sarah M. Hendry, Dundee Law School, University of Dundee.

e-mail: S.M.Hendry@dundee.ac.uk

Abstract

The story of fracking in Australia is still unfolding and affecting rural communities, where shallow watertables, agricultural lands, community livelihoods and societal cohesion are impacted. Unconventional gas, specifically coal seam gas (CSG), released by fracking, was heralded globally as the new way forward in delivering cheaper energy for the future. The impact of gas extraction methodologies, industry governance and environmental policies adopted across different regions has influenced the broader community understanding of energy and water security, and environmental sustainability. This review assesses the use of water and environmental law to manage: a) the risk that the CSG industry may pose to Australia's natural land and water resources, water security, and agricultural development and; b) the potential to deliver the benefits offered by CSG.

The critical drivers for CSG development, level of community involvement, government policy engagement and potential long-term benefits are examined. A brief summary of alternative strategies deployed governments to manage, contain or embargo the development of the unconventional gas industry is given. The review examines alternate legal frameworks for addressing sustainability challenges associated with large-scale natural resource (LSNR) projects. How strong leadership, foresight, appropriate governance and policy settings is required can deliver balanced outcomes for water and energy security. The methodology adopted in this paper, uses a comparative analysis of the legislative and regulatory approaches in two eastern Australian States, namely New South Wales (NSW) and Queensland (QLD) and the relevant Federal legislation that provides the governance framework for initiating and monitoring LSNR energy projects, while delivering environmental protection and water security.

Keywords

Governance, water security, environment, policy, fracking, unconventional gas, energy, communities

01

Introduction

A transformation in thinking and approach is necessary to understand the water, energy and food nexus that underpins the development and expansionary nature of current global trade and productivity models, around which layers of policy and governance instruments are framed (Coles & Hall, 2012). This is particularly relevant to large-scale natural resource (LSNR) developments that rely on decadal timeframes, require significant investment and draw-in extensive external resources (such as water), and which can divide regional and rural communities in which the developments often take place. Global concerns about large coal and gas development projects, and their long-term potential to impact climate change, have markedly increased since the signing of the Paris Agreement in 2016. The impact that these projects can have on land values, job markets, energy prices and water security are compounded by the need to guarantee future global environmental sustainability. Australia has significant environmental and water resource allocation and water security issues owing to a wide range of factors (e.g. drought, water scarcity, competing resource use interests, and

biodiversity loss). Not the least being, that the politics of water in Australia ferments a difficult and complex setting, that impacts Australia's natural capital assets and the capacity of local, state and federal governments to balance both the environmental water requirements and the socio-economic water, food and energy demands.

1.1. Unconventional gas and water resources

Natural gas¹ is composed mainly of methane, it is colourless, odourless, lighter than air (Howarth et al., 2011), and although it may not impact on the senses, as an alternate source of heat and power it has the capacity to transform energy markets now and for the foreseeable future (Wright, 2012). Unconventional gas, a form of natural gas that can be released by fracking, was heralded globally as the new way forward in potentially delivering cheaper energy with a lower

carbon footprint relative to other sources (e.g. coal, oil). The development of these unconventional² gas resources, that are dispersed within geological formations (e.g. shale, coal seams);³ forms part of the low carbon transitional energy vision viewed as necessary to address climate change; given the potential resource may be large⁴ and conventional reserves are becoming depleted globally (Wood et al., 2011). Exploiting unconventional natural gas reserves often requires expensive, technical drilling operations and 'fracture stimulation' (or 'fracking') to extract gas at a viable or economic rate, making these resources both technology and price sensitive, and potentially environmentally damaging (Healy, 2012). This raises concerns about the effects on human health and the environment including land degradation and the potential to negatively impact on the quality, quantity and security of water resources (ORD, 2015).

In Australia, coal seams often contain both methane (known as coal seam gas, CSG) and water due to their near surface proximity, so in recovering the methane, water is required to be pumped out to depressurise the coal seam enabling the gas to be extracted. The volume of extracted or 'produced' water tends to be large in the early stages of CSG production and is normally expected to decrease exponentially over time, with very little water being produced in later years (Khan & Kordek, 2014). However, the withdrawal and disposal of produced water, along with contamination and groundwater depletion, are key environmental management factors linked to CSG production (Stearman et al., 2014). Parallel to these technological developments, is the need to provide flexible governance and legislation to manage public concerns, and deliver balanced outcomes for the water, food and energy nexus (Coles & Hall, 2012). More explicitly, address the potential for contamination of surface and groundwater resources alongside the minimisation of greenhouse-gas emissions. Contributing to these difficulties, are significant differences of opinion within the industry, community and government as to whether the unconventional gas industry can deliver the promised benefits for all.

1.2. CSG, government policy and communities

The exploitation of these new or unconventional energy sources requires the adoption of new extractive practices which are enabled by innovative technologies. As such, continued CSG expansion is tempered by several factors, including but not limited to: unexpected environment impacts due to complications in extraction methodologies; limited understanding of the fractured geology; perceived negative impacts on water resources; decline in water security; loss of prime agricultural land; and strongly polarised community attitudes (Coles, 2018).⁵

Due to the impact of the aforementioned LSNR development factors, some of which will be discussed here, the politics of natural resources, water chief among them, and large-scale extractive industry investments in Australia is an increasingly difficult and complex process, impacting at International,

“The politics of water in Australia ferments a difficult and complex setting, that impacts Australia's natural capital assets and the capacity of local, state and federal governments to balance both the environmental water requirements and the socio-economic water, food and energy demands.”

Federal and State levels. Since 2010, there have been 16 Parliamentary or Senate inquiries⁵ into different aspects of the unconventional (CSG and Tight Shale Gas, TSG) gas industry in Australia.⁷ Seven in New South Wales (NSW) (3) and Victoria (4) alone, where there was significant and highly organised opposition to onshore gas developments, resulting in moratoriums in NSW, the Northern Territory (NT) and Tasmania, and complete bans in Victoria (2016), and South Australia (2018). At the same time the industry also faced an increasingly hostile, energy dependent public, angry over rising domestic prices, caused by limited exploration and production opportunities in affected states (i.e. NSW & Victoria) and large-scale export supply contracts (QLD, WA, & NT) diverting local gas supplies.

Although still developing, the industry in the decade 2005-15, was under intense exposure from media,⁸ multi-government inquiries, disaffected communities⁹ and facing significant losses as markets and prices collapsed.¹⁰ Therefore, the industry and all levels of government, were forced to evaluate CSG and its benefits, given the production complications, poor community support, perceived threats to water security and prime agricultural lands, and less favourable royalties being delivered by plummeting global oil and gas prices (Peacock, 2016). Thus, the CSG industry lost its prime position as the new energy nirvana in Australia. In this volatile political cauldron, successive governments since 2000, were required to deliver recognisable improvements in environmental health, water security, natural resource management, and sustainable industries, that influenced political decisions, policy and investment in Australia for the next 20 years and beyond (Coles, 2015). This paper is written in three parts, firstly an examination of the development of a national approach to LSNR developments- namely the unconventional gas industry, secondly an assessment of the approach adopted in different Australian states-namely NSW and Queensland (QLD), and thirdly a discussion on the merits of these approaches.

“While the reforms provided for the separation of land and water title rights, enhancing a State Government’s ability not only to manage water as a separate issue, they also created a tradeable commodity.”

02

Developing a uniform Australian Policy for Unconventional Gas

The federal nature of Australia’s system of government, with various powers vested in the States and federally under the Constitution,¹¹ remains a challenging environment in which to devise and implement federal policy around the management and development of the nation’s natural resources (Kildea & Williams, 2010). The central pillar supporting the environmental legal system in Australia is the concept of “sustainable development”, first envisaged in the Brundtland Report (WCED, 1987). This report brought environmental stewardship to the forefront of policy initiatives globally during the early 1990’s. The Australian Government established a governance framework that: a) encapsulated the concept of environmentally sustainable development (ESD), biodiversity preservation and water security; and b) facilitates a coordinated approach to natural resource development whilst encouraging investment in the long-term benefits for Australia, over short-term gains (Coles, 2018).¹²

Water resource issues in Australia, therefore have continued to push the boundaries of environmental and sustainability legislation, as long-term water security faces increased challenges and trade-offs from competition between human, environmental and agricultural users. Over the last two decades it has been gradually accepted in Australia that additional pressure on rivers, water supplies, and rain-fed agriculture has come from climate change that has varied, the once considered reliable, delivery (timing and intensity), quality, quantity and security of water supplies. Overlaying these physical aspects of change are the socio-economic considerations and the wide-ranging political views (from climate sceptics, multiple corporate interests, greening social attitudes, family farms and protectionist naysayers) that shape water policy in Australia. Accordingly, Australian Federal Governments of various persuasions periodically sought to use policy and financial initiatives to garner co-operation between the Australian States and Territories.

Water resources, their long-term security and sustainability have taken on increasing importance as climate change has impacted on their security, durability, delivery capacity and water quality (Khan and Hanjra, 2008). Wide ranging water law reforms were finally agreed by all States, Territories and the Federal Government in 1994.¹³ While the reforms provided for the separation of land and water title rights, enhancing a State Government’s ability not only to manage water as a separate issue, they also created a tradeable commodity (Coles, 2015). The reforms were formalised under the Council of Australian Government (CoAG), Intergovernmental Agreement on a National Water Initiative (NWI) 2004 (NWC, 2011), which also targeted improvements in the economic efficiency of Australia’s water management through the Australian

Competition and Consumer Commission (ACCC). This built on the national environmental strategy¹⁴ that provided both a broad strategic direction and a framework for the State and Territory governments.

2.1. Who owns the CSG resources and who regulates?

Hydrocarbon resources are owned, under Australian law, by the State (at federal, state or territory level) on behalf of the community. Governments at all levels thus have a “stewardship” role in petroleum resource management (AGPC, 2009) with landholders (e. g. farmers or graziers) having a freehold or leasehold title to land,¹⁵ but in principle not the rights to mineral or petroleum resources. Significantly, while the federal government has national responsibility for the offshore development of gas,¹⁶ the onshore gas industry is principally regulated by State and Territory governments (EDOs, 2016). As a result, it is not surprising that this disparate process is often unable to: a) deliver unifying legislation that is an enabler for industry development across borders; or b) adequately address community concerns, water security issues, and environmental impacts consistently (Coles, 2018).

Consequently, there are a various assortment of petroleum and pipeline laws. This includes an extensive body of federal and state legislation governing upstream petroleum activities that manage the impact on the environment, heritage, resource development, native title, land rights and occupational health and safety (SCER, 2013a). Inevitably most are not specific to the oil and gas sector. This juxtaposition of

jurisdictions, industries and governments has created a range of departmental bodies, with influence across all levels of government, each having a role in regulating upstream petroleum activities (Coles, 2017). As a result, gas resources are subject to petroleum tenure rights granted by the State or Territory governments (IEA, 2012), which in recent years has been the nub of the problem. Not surprisingly, landholders have felt increasingly marginalised, overlooked by the State, in favour of large-scale CSG extraction operations (Figure 3-1) that may significantly impact their day to day operations, affect arable land use, reduce water availability, potentially affect water quality and thereby undermining water security.

2.2. Harmonisation: A federal unconventional gas policy?

Policies and practices to enhance sustainability and adapt to new industry developments are typically founded on addressing the “average” or “typical” LSNR developer (Marshall & Smajgl, 2013). This creates the risk that strategies employed will be irrelevant for some, will not be applicable in rapidly changing industry environments, not address changes in community attitudes during the often-decadal lifetime of LSNR projects and may be ignored (Marshall & Smajgl, 2013). Not surprisingly, at the time of writing, there are no overarching set of enforceable federal laws that regulate the various impacts associated with unconventional gas development in Australia (EDOs, 2016).



Figure 3-1 Demonstration of the broader impacts of multiple CSG wells in the landscape with the roads and other infrastructure in a CSG field near Dalby State Forest, southern Queensland. Scale widthways: 6.8 kilometres. Source: Eco Logical Australia 2013

However, the socio-economic and environmental interplay, high level of community concerns and media coverage, combined to provide the impetus for significant law and industry reforms federally, and in affected States, during this critical decade (2005-15) that spanned these LSNR developments. During this period, communities were polarised into two main groups, either pro- or anti- fracking depending on the level of involvement in the industry and the degree to which their livelihoods, water security or arable lands were affected. More importantly for the industry, concerns surrounding land ownership, environmental impacts and water security linked to fracking and CSG extraction were coming to the fore (Coles, 2017) attracting strong media attention and straining political relationships between the Federal and State governments, landholders and local communities. The many-fold issues included:

- Potential environmental implications of fracking, its impacts on water quality, water availability and water security, and the disposal of large volumes of ‘produced’ water that may also be contaminated;
- Risks associated with creating new fractures that intersect adjacent aquifers that may impact local water resources, depleting near surface water tables, reducing water quality and availability;
- Potential loss of prime agricultural land causing increasing conflict over perceived infringements of landholder rights, water rights, land ownership, and land access for extractive operations (Johnston, 2001);¹⁷
- A perception of poor regulation and governance of the unconventional gas industry at all levels of government in all states and federally;
- Negative impact of LNG export industry on domestic gas availability and electricity (energy) prices, particularly in NSW;
- Limited local community co-benefits from gas developments, particularly affected infrastructure, coupled with a perceived loss of environment, land and water security;
- Reduced returns to the state from taxes and royalties due to the fluctuations in gas prices, export volumes and domestic demands, leading to limited funding being available to affected communities and land holders as compensation or for rehabilitation;
- Perceived strong influence of the resource developers and gas supply companies over governments and Australia’s’ natural resources; and,
- Methane leakage or ‘fugitive emissions’ impacting air quality, and the climate mitigation and adaptation strategies (Ray, 2013; Ross & Darby, 2013).¹⁸

Faced with this level of divisiveness, it was clear to the Australian Federal government that a new way forward was required by all parties. While the system of federated states applies ‘artificial’ political borders, the natural land and water resources within them are hydrologically interdependent and holistic (Clark, 1987). Therefore, gaining consensus on federal reforms has always been a contentious issue, particularly when co-operation and agreement between the state, territory and the commonwealth governments (often of different political persuasions) are required (Gardner et al., 2009). Thus, the federal government

found it necessary to examine the potential elements of Federal or Commonwealth legislation at its disposal to effectively direct or assist the States in the management of the LNG industry,¹⁹ and unconventional gas extraction (CSG) in particular, by providing an overarching legal framework with which the States were required to comply.

Well-founded fears surrounding over-allocation, competing industry and environmental water requirements, and the potential for severe water shortages within the Murray Darling Basin States²⁰

created impetus for water and environmental law reforms. These regulatory reforms were negotiated and implemented through COAG in the 20 years after the 1994 agreements, and as Australia struggled to cope with a decade long drought, climate change and socio-economic structural shifts, particularly in the eastern States (Coles, 2015). The approach adopted to regulate large-scale CSG/ TSG and LNG projects focussed on legislation covering the protection of water resources and aquatic ecosystems as significant natural resources. Strengthening the natural and water resources legislation was considered to be the most effective means of introducing new controls that may be applied nationally, and in conjunction with the States. Having recently used environmental legislation through the EPBC Act 1999²¹ to successfully implement national water law reform through the Water Act 2007,²² the Commonwealth government again examined this option in reforming CSG/TSG regulation.²³

In previous negotiations on Water and Environmental Law reforms from the early 1990’s successive federal governments sought to provide direction and unity through legislative and financial instruments to provide consistency and water security across Australia (Coles, 2015), specifically, for water allocation for human, industry and environmental uses. Within this context, the requirement to deliver recognisable improvements in environmental health, natural resource management and promote sustainability with respect to matters of national environmental significance (MNES) was paramount.²⁴ The potential to utilise the Australian Constitution²⁵ and international environmental obligations²⁶ to underpin federal policy and legislative reforms in Australia has been previously recognised (Crawford, 1991). In respect of the CSG industry, the federal government is able to act through precedent, that upheld the Commonwealth’s right to use constitutional powers, to regulate in respect to corporations, trade and environmental impact.²⁷

“More importantly for the industry, concerns surrounding land ownership, environmental impacts and water security linked to fracking and CSG extraction were coming to the fore.”

As in the case of previous reforms, the Commonwealth government was able to play the ‘intervention card’ of using constitutional powers to deliver protection of the environment and its associated water security (Coles, 2015).²⁸

2.3. National unity and harmony grow out of concerns with CSG and water security?

The federal government moved slowly to regulate the unconventional gas industry with a number of inquiries and reports into CSG activities commissioned between 2005 and 2010. In this short period, concerns arose over the Global Financial Crisis and its impact in Australia, there were three changes in Prime Minister, two federal governments, and nine premiers in NSW, Victoria and Queensland of varying political persuasions (Coles, 2017). Hence the focus was not on the industry (other than as a cash cow, or as an offset to CHG emissions targets) (Clark et al., 2011) but on internal political struggles, leaving the wider community to deal with events as they developed within each State bereft of specific overarching legislation.

In the early 2000’s the Commonwealth Government had continued to push additional water reforms, using powers under the NWC Act²⁹ to provide further support the States to complete their obligations created under the water and environmental law reforms. However, the State of NSW still retained the right to the control, use and flow of all water in rivers, lakes and aquifers as well as all water occurring naturally on or below the surface of the ground³⁰ within the State, provided it meets the national objectives set out in the Murray Darlin Basin Plan (MDBP). As we shall see in subsequent discussions, this was an important factor in determining NSW regulatory approach to assessing CSG projects and water security in that State.

In parallel negotiations Australian Government introduced further reforms in April 2008 aimed at managing the country’s water security by establishing the Water for the Future program.³¹ The program, in 2007/08 provided funding over a 10-year timeframe:

- ~\$6 billion to improve rural water use efficiency;
- ~\$3 billion to recover water for the environment;
- ~\$1 billion to establish new functions; and,
- ~\$1.5 billion to enhance urban water security (Higgins, 2012).

Furthermore, in 2010, the National Water Commission (NWC)³² responding to wide ranging calls for operational certainty from the LNG industry, and alternatively from the community for the industry to be restrained, released its position paper. The paper outlined an ‘adaptive and precautionary management’ approach to the CSG industry (NWC, 2010), a policy approach recently adopted by the Queensland government. The NWC report highlighted the need for a better understanding of the cumulative effects of multiple CSG projects on ecosystems, and noted:

“if not adequately managed and regulated, [the CSG industry] risks having significant, long-term and adverse impacts on adjacent surface and groundwater systems” (NWC, 2010).

Sentiments echoed in the “Golden Rules” report released by the International Energy Agency (IEA) two years later (IEA, 2012). In this document, the IEA laid out a global blueprint for the development of unconventional gas resources, placing emphasis on full transparency, regulation, measuring and monitoring of environmental impacts and promoting engagement with local communities as critical to addressing their concerns. This approach was acknowledged in submissions to Parliamentary and Senate Inquiries in Australia and touted as a starting point for industry regulation (EDO, 2016; Williams et al., 2014).

Chief among these concerns were: a) the extent of CSG reserves in the eastern States, many of which are proximate to townships, water resources or prime agricultural land; and b) the inadequate and inconsistent State and Federal regulation of CSG infrastructure and extraction activities (EDO, 2016). An opportunity was clearly created to deliver industry reforms focussing on delivering the potential benefits to those communities affected, without the significant loss of water security, biodiversity or arable land. Based on the recommendations of the NWC, the Prime Minister, Julia Gillard³³ announced the creation of the Independent Expert Scientific Committee (IESC) in 2011, to provide expert advice to the Federal and State governments.³⁴ After broad consultation, the Commonwealth government also inserted a ‘water trigger’³⁵ clause into the EPBC Act in 2012, to address concerns over significant impacts on a water resource in the MDB.³⁶ A water resource in this instance is defined as groundwater and/or surface water, and includes organisms and ecosystems that contribute to the physical state and environmental value of the water resource. A significant impact is defined as a real or not remote chance or possibility that it will directly or indirectly result in a change to:

- the hydrology of a water resource; or
- the water quality of a water resource,

that is of sufficient scale or intensity as to reduce the current or future utility of the water resource (and thereby water security), for third party users and thereby qualify as MNES.³⁷ The ‘water trigger’³⁸ is considered as the only federal environmental law that directly regulates unconventional gas development, or LSNR projects (EDO, 2016), although it may have limited applications.³⁹

Subsequently, the federal government negotiated the National Partnership Agreement (NPA) with relevant state and territory governments⁴⁰ to enhance co-ordination of CSG and large coal mining developments that may have a significant impact on water resources.⁴¹ The establishment of the IESC under the CoAG NPA in 2013, was a major step forward in providing independent support for the evaluation of proposed CSG projects (Williams et al., 2014). Further to these developments, the Commonwealth in conjunction

with the States, and with advice from the newly created IESC, developed additional policies and legislation that would support industry development while allaying concerns raised in the last decade. These included the National Harmonisation Regulatory Framework for Natural Gas from Coal Seams (The Harmonisation Framework) (SCER, 2013a) and the Multiple Land Use Framework, (MLUF) (SCER, 2013b)⁴² and further amendments to the EPBC Act.⁴³

These amendments became law on 22 June 2013, designating water resources a MNES, in relation to CSG and large coal mine development. This was a significant step in relation to providing for water security at a national level, unfortunately these amendments act in isolation from the climate, energy and agricultural policies, creating a potential schism between these nexus elements. Later amendments focussed on the CSG industry and State co-operation⁴⁴ through the National Partnership Agreement (NPA), using financial incentives (See Table 3-1) to ensure statutory support and implementation by assisting the States to modify their environmental, water or gas legislation. Both the Harmonisation Framework and MLUF were developed through broad industry and community consultation. Acknowledging that Australia cannot reap the benefits from unconventional gas if the social licence to operate and community confidence is not established and maintained.⁴⁵ Something that had been eroded in the previous decade.

The Harmonisation Framework based on the concept of applying leading best practice noted that: “governments should implement streamlined, transparent and consistent processes to ensure that industry activities are managed in accordance with the level of risk associated with those activities” (SCER, 2013b). Though a vast improvement on previous actions, the framework did not necessarily resolve the issues surrounding the role of the coal industry, greenhouse gas emissions and the impact of CSG, the distortion of the domestic gas (and thus energy) markets, or the governance actions that may be instigated by each State (Williams et al., 2014).

Further impetus for management action surrounding CSG (and coal, oil and gas industries) may be provided via the climate debate, with Australia signing the international Paris Agreement (COP21) on climate change in 2015.⁴⁷ This provides for another international trigger for action,

that as a party to the UN Convention on Climate Change, Australia is obligated to undertake actions to reduce emissions and the economic carbon footprint of the country. To date no significant actions have been instigated by the Commonwealth in this regard although actions and carbon targets have been proposed, again emphasising the discordance between energy, water and agricultural policies that are impacted by the inertia surrounding the national climate change debate.

Even though considerable policy and legislative progress was made during this crucial decade, there are still communities within the eastern States that were not satisfied with the approach adopted by the Federal and State governments and they have continued to push for further restrictions on fracking and the CSG industry. This evoked considerable debate, a Senate inquiry,⁴⁸ calls for a Royal Commission,⁴⁹ and the introduction of land access (or rights) and water restrictions for LSNR developments.⁵⁰ Confronted with this level disaffection and increasing uncertainty about the potential benefits of the CSG industry, individual state governments implemented different response strategies. Some of the measures, policies and regulations that have been undertaken in NSW and QLD to foster industry development, regulate the risks and address community-landholder concerns is addressed in the following sections.

States and Territory	2011-12(\$m)	2012-13(\$m)	2013-14(\$m)	Total
New South Wales	7.00	3.50	7.00	17.50
Victoria	4.05	2.03	4.05	10.13
Queensland	7.40	3.70	7.40	18.50
South Australia	1.25	0.62	1.25	3.11
Northern Territory	0.30	0.15	0.30	0.75
Total	20.00	10.00	20.00	49.99

Table 3-1 Commonwealth financial contributions to the States negotiated as part of the NPA⁴⁶

03

The Environmental and Water Law Reforms adopted in NSW

In the decade following the 1980 law reforms, various interstate and national agreements seemingly had negligible impact on the status of water resources, its allocation, security and environmental management in NSW (Kildea & Williams, 2010). In recent years, successive State governments in NSW have had to navigate often stark political view-points concerning water, energy, and land use; its security, allocation and ownership. In NSW, unlike Queensland, the CSG industry was comparatively in its infancy. The industry was developing and expanding at least a decade before the State introduced the NSW Gas Plan in 2015.

The rapid pace of development was such that by March 2011, petroleum titles or applications covered 45% of the State. At this time there was also considered to be a lack of oversight, inappropriate petroleum legislation and limited protections for affected landholders - given the level of 'invasive' activities that are linked to large-scale CSG development (Ecological Australia, 2013). By 2012, it was considered that the industry's development had outpaced the government's ability to regulate it, and the associated technical extraction practices including: a limited understanding of the impact of fracking technologies; the storage and disposal of 'produced' water; impact of released hydrocarbon on water quality; the reduction of near surface and groundwater tables that may affect water availability; and the management of fracking fluids and proppant (Coles, 2017). Both the water quality and availability issues were recognised as negatively impacting future water security, and as such, would deplete projected community, industry and environmental water requirements, creating uncertainty and increased competition pressures.

Therefore, in contrast to water law reforms-driven mainly by cross state and federal water management issues in the MDB, the NSW governments' response to growing concerns around CSG was limited (NSW Parliament, 2012). However, the legislative modifications that were initiated by NSW would be critical to the establishment of the States' CSG policy and legislation in regard to water security and the environment.⁵¹ A key element in the CSG debate is whether the associated extraction activities would contaminate or deplete water resources, with much of the available scientific evidence on this question contested (NSW Parliament, 2012). This section provides a brief overview of the development of water, environmental and CSG legislation in NSW, in response to the rapid industry development, LSNR projects and mounting community concerns.

3.1. The development of water and environmental law in NSW

Five years before Federation, the colony of NSW introduced the Water Rights Act 1896.⁵² Between 1896 and 1902 a further three pieces of legislation⁵³ were enacted to manage water. These acts, including the Water Rights Act, were subsequently consolidated into the Water Act 1912.⁵⁴ Alongside the Irrigation Act 1912, these pieces of legislation formulated the principles behind water management, allocation and development in NSW for nearly 60 years.⁵⁵ However, the ad hoc approach to water resources in NSW, since federation in 1901, has resulted in 100 years of piecemeal water allocation and environmental planning as the State developed (Coles, 2017).

The Water Act of 1912, when enacted provided for the security of water supply to land owners and water users across NSW, while also protecting the riparian rights of downstream water users within the State. These protections in NSW, prior to the legislation were considered tenuous at best, however while protecting States' rights and water security, little deference was given to other downstream States that may require flows to be directed across borders (Hubert & Patrick, 2000). Therefore the 'rights' that cover access, river flow, allocation and management of water resources, water security, and the associated benefits has a long and contentious history in NSW and between other States that expected cross-border water re-distribution. Water resources management was governed by a process that has often been divided by institutional and statutory complexities, and one that guarantee fragmentation rather than integration (Coles, 2017). This, inter alia, is reflective of the Australian tradition of segmented attitudes to natural resource management, based on legislation with long historical roots encapsulated in its staid institutional arrangements (Farrier et al., 1998).

Apart from the Water Act, there was little change in the State's water management policy, although there was some overarching constitutional agreements put in place between States and the Commonwealth during the time of federation in 1901,⁵⁶ and the subsequent River Murray Waters Agreement (RMWA) of 1914.⁵⁷ There were several other intergovernmental agreements on water management⁵⁸ during the mid-1900's but they tended to be between two or three MDB States⁵⁹ and/or the Commonwealth Government (Kildea & Williams, 2010). However, inter-jurisdictional management and allocation of and security of water for the environment, agricultural development and human consumption within the MDB remained largely unresolved.

3.2. The Environment: A change in focus for Policy development in NSW

From the 1970's onward, the declining health of the rivers in the MDB, a considerable proportion of which is in NSW, was cause for increasing concern. In response, the NSW government proposed new legislation to manage water allocation, quality and flow with the implementation of the NSW Clean Waters Act 1970.⁶⁰ Larger issues, such as salinity, species (biodiversity) decline,⁶¹ water quality deterioration, extensive algal blooms and environmental flows,⁶² drew more attention in later years, along with increased competition from alternate water use activities. These were dealt with initially under other legislation, including (but not limited to) the: Water (Amendment) Act 1971;⁶³ Private Irrigation Districts Act 1973; Irrigation (Amendment) Act 1974; Land and Environment Court Act 1979; and the Environmental Planning and Assessment (EPA) Act 1979. These pieces of legislation demonstrated a significant shift away from the 'business as usual' approach to water management and were focussed on improving or maintaining the environment, water quality and secure resources within NSW to lift productivity and manage water allocation (Coles, 2017). The Clean Waters Act was directed at the prohibition of pollution of waters except where such pollution is managed by way of a licence, although ultimately it creates the offence of the pollution of waters. Furthermore, the NSW EPA Act 1979 sought to encourage:

*“the proper management, development and conservation of natural and man-made resources, including agricultural land, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment” through “ecologically sustainable development”.*⁶⁴

More importantly it also provided for an increased opportunity for public involvement and participation in the environmental planning and assessment process within the State.⁶⁵ These Acts were further bolstered by the NSW Water Administration Act 1986,⁶⁶ Catchment Management Act 1989⁶⁷ and the Protection of the Environment Administration Act 1991 (NSW).⁶⁸ The more recent legislation, placing more emphasis on environmental (or natural resource) management and catchment planning. Realistically the introduction of this legislation at this time had limited effect in practice, but legislatively did have considerable potential for broader impact (Farrier et al., 1998). The increasing acknowledgement of land and water degradation around this time in Australia, during the Decade of Landcare,⁶⁹ created further pressure for both State and Federal governments to be more innovative and forthright in their administration of water and the environment. Sustainability and biodiversity issues were becoming more prevalent with federal initiatives⁷⁰ driving change legislative in the States for the next two decades. Particularly in NSW, having the largest land holding and water allocation within the MDB, and potentially extensive untapped CSG reserves that could satisfy the States burgeoning energy needs.

In NSW, legislation was introduced based on federal policies through amendments to existing or new legislation via: Water Legislation Amendment Act 1999; Protection of the Environment Operations (PoEO) Act 1997;⁷¹ Water and Environmental Planning Legislation (Amendment) Act 1997; Wetlands Management Policy 1996; Irrigation Corporations Act 1994;⁷² and PEA Act 1991. Further reforms were introduced into NSW with the proclamation of the Water Management Act (WMA) 2000,⁷³ which repealed the Water Rights Act 1912. The Water Management Act (WMA) was the culmination of many years of negotiation, discussion and successive State and Federal water initiatives. The WMA enshrines the concepts of catchment management planning⁷⁴ and integrated water resources management,⁷⁵ and promoted the concepts of ecological sustainability, equity and best practice.⁷⁶ Under the WMA water sharing plans (WSP's) and water access licences (WAL's) were issued by the Department of Water Resources⁷⁷ that provided both oversight and monitoring of licence conditions and catchment health, thereby generating state of the environment data.

However, at times the States (or the landholders and water users) did not always agree on the nature of the reforms, the timeframe for implementation, or the compensation offered by the Commonwealth Government. In 2007, for example a group of farmers took the NSW government to court over the legality of changes in water allocations that were decreased with the introduction of the WMA (Seneviratne, 2013). Licences granted under the Water Act 1912 were replaced with licences under the WMA. The Act was in part implementing the intergovernmental agreement to ensure the long-term sustainability of groundwater systems in the Murray Darling Basin (MDB) plan. However, these licensing issues did not extend to the mining and petroleum industries as they were covered under alternate laws and licensing provisions. The WSP proposed to significantly reduce the annual maximum volume of water for irrigation that could be drawn compared with entitlements under the Water Act 1912 in order to achieve the sustainable yield in line with the MDB plan. There were 5 grounds for appeal put forward by the farmers, including a constitutional challenge,⁷⁸ which were all subsequently dismissed. Further exacerbating the divide between the community, land holders, gas extractive industry and all levels of government over water security.

Eventually in 2007, the Commonwealth finally took management of, and control over the MDB through the Water Act 2007 (Cth) repealing the Murray-Darling Basin Agreement (MDB Agreement) enacted by the Murray-Darling Basin Act 1993 (Cth) in 1992,⁷⁹ given that it was failing to deliver the promised benefits and reforms within and between the Basin States. Another five years of discussion resulted in amendments to the Water Act 2007 (Cth), with the proclamation of the Murray-Darling Basin Plan (MDBP) 2012. Completing a cycle of Federal and State government reforms that had begun over 120 years ago, over the access to water, its flow, allocation, quality and security, with the adoption of the reasonable use approach by NSW in its initial Water Rights Act 1896. Thus, by the early 21st

Century, water and environmental legislative instruments (See Table 3-2) were in place in NSW, but unfortunately these did not adequately correlate with existing State and federal petroleum legislation or address the issues linked with the unexpected rapid expansion of the CSG industry or LSNR projects (including coal).

3.3 The challenge: Developing a robust state gas plan and a CSG policy

Over the two decades from 1996 to 2016, NSW became disproportionately reliant on imported energy to sustain demand, importing 95% of its domestic gas demand, exposing the State to high-levels of risk and uncertainty in both price and supply security (King, 2013). Furthermore, by 2015 a large number of domestic gas supply contracts were due to expire with longer term contracts likely to meet less than 15 % of the state’s demand by 2018 (BREE, 2013). At the same time domestic gas prices were predicted to rise as the remaining LNG trains in QLD are completed and begin exporting gas (Smail & Blumer, 2016). NSW gas supply issues are therefore more critical than other States, in terms of long-term low-cost supplies.⁸⁰ While the demand and prices

increased, alternative supplies from CSG developments were increasingly viewed with negativity and suspicion by affected landholders and communities, particularly where they affected prime agricultural lands and water security (Smail & Blumer, 2016). Community pressure to withdraw gas exploration and extraction licences was applied to successive NSW governments, not only to restrict the industry, but to also find alternative energy sources to counter the rising spectre of gas shortages and steep energy price rises (Coles, 2017).

In NSW, CSG activities, including exploration and production, require a petroleum title under the Petroleum (Onshore) Act 1991 (PO Act). However, there is no community or landholder ‘merit appeal’ right against the issue of a licence (EDO NSW, 2014). Amendments and additional legislation to manage the degree of community uncertainty, water security and environmental concerns would be required. Indeed, the review of CSG in NSW by the Legislative Council Standing Committee (NSW Parliament, 2012) in 2012, recommended that the PO Act 1991 be revised with a view to strengthening landholder rights and achieving a fair balance between the rights of landholders and CSG operators. In response, the NSW Government released the Strategic Land Use Policy (SLUP), first mooted in 2011, which included recommendations targeted at striking the “right balance

Action taken in relation to CSG developments	Legislation/Policies and amendments linked to CSG to strengthen the governance framework
<p>NSW Upper house initiated an enquiry into CSG 2011.</p> <p>Banned use of BTEX chemicals in 2011.</p> <p>Moratorium on fracking existed from Dec 2011 to July 2012.</p> <p>A number of test cases are being developed to challenge CSG operations in NSW with the Environmental Defenders Office representing the Barrington-Gloucester-Stroud preservation Alliance.</p> <p>Tougher rules on the fracking process used to extract coal seam gas introduced in 2013 via the SEPP Mining Amendment including:</p> <ul style="list-style-type: none"> • A ban on the use of evaporation ponds for the disposal of extracted water associated with petroleum production. • Two Codes of Practice for the CSG industry covering exploration, well integrity and fracture stimulation, following a review by the Chief Scientist & Engineer. • Multi-agency assessment of applications for CSG exploration activities. • Removal of the previous five-year royalty holiday for CSG producers. <p>Revision of the EPA ACT in the NSW Parliament in November 2017, enacted on 1 March 2018 with most of the changes coming into effect from this date. Others will take longer to come into effect as they require further guidance and consultation.</p>	<p>Petroleum (Onshore) Act 1991.</p> <p>Protection of the Environment Operations Act 1997.</p> <p>Protection of the Environment Administration Act 1991 (NSW).</p> <p>Water Management Act 2000.</p> <p>Water Act 1912. (Superceded by WMA).</p> <p>Work Health and Safety (Mine and Petroleum Sites) Act 2013.</p> <p>Threatened Species Conservation Act 1995.</p> <p>Heritage Act 1977.</p> <p>Environmentally Hazardous Chemicals Act 1985.</p> <p>Code of Practice for Coal Seam Gas – Fracture stimulation activities (NSW Code).</p> <p>Well Integrity Code of Practice (NSW Code).</p> <p>State Environmental Planning Policy, SEPP (Mining, Petroleum Production and Extractive Industries) 2007.</p> <p>Strategic Regional Land Use Policy 2013.</p> <p>State Environment Planning Policy 2011.</p> <p>NSW Gas Plan 2014.</p> <p>Environmental Planning and Assessment Amendment Act 2017 (NSW).</p>

Table 3-2 Actions, policies and legislation enacted, amended or referred to in NSW to manage CSG activities and their impact on the environment, water resources, landholders and communities

between Australia's agricultural, mining and energy sectors whilst ensuring the protection of high value conservation lands."⁸¹ The NSW Government provided additional guidelines and information publications under the umbrella of SLUP to strengthen the regulation of the CSG industry (NSW Parliament, 2012).

Prompted by federal policy initiatives,⁸² the government launched the NSW Gas Plan⁸³ which focussed on determining appropriate areas to undertake CSG activities using amendments to the State Environmental Planning Policy (SEPP) Act 2007.⁸⁴ The act provides an operational framework that considers an activities sustainability through assessing both the economic benefits and evidence of negative impact on the environment (including water) or communities. Concerns that had been well documented (NSW Parliament, 2012). Furthermore, the NSW Chief Scientist noted in 2014 that the significance of water and environmental health to the livelihoods of affected communities has made CSG development a particularly emotive social concern, which necessitates a robust approach to regulation.⁸⁵ The introduction of the plan also extinguished all pending CSG exploration licence applications and legislated the NSW Environment Protection Authority (EPA) as the lead regulator for CSG activities.⁸⁶ Subsequently, all gas activities are required to hold an environment protection licence (EPL) issued by the EPA that sets out legally enforceable,⁸⁷ site-specific conditions and controls, with respect to pollution minimisation and environmental safeguards.

The revised framework now rests upon multiple pieces of legislation, which provide for the strongest regulation of CSG exploration and extraction in Australia.⁸⁸ The NSW government introduced the Strategic Regional Land Use Policy (SRLUP) to manage any CSG proposals that are on land identified or verified as Strategic Agricultural Land,⁸⁹ linked to additional amendments proposed to the SEPP Act which would prohibit CSG development:

- on or under land in and within 2km of a residential zone or future identified residential growth areas; and
- on or under land which is a Critical Industry Cluster (CIC).⁹⁰

By March 2014, the NSW government applied a ban⁹¹ on CSG exploration licenses, and bought back a large number of licences, with only one major CSG drilling proposal remaining in the state's north-west (Grattan Institute, 2014). This negative view would ultimately compound the energy (gas) supply issues and create political fallout in regard to electricity pricing and power uncertainty within the State.⁹² An issue as yet unresolved despite warnings from the Australian Energy Market Operator (AEMO), gas suppliers and energy generators. Leaving NSW and the rest of the eastern States energy grid vulnerable to rapid price increases and potential blackouts during peak periods (AEMO, 2017).

As a point of resolution to these on-going issues, it has been suggested that rather than developing individual legislation for each element of the CSG industry it may be appropriate for NSW to take a similar approach to that established in

Queensland. That is to adopt a national approach to CSG activities as outlined in The Harmonisation Framework particularly in circumstances where affected water resources (both surface and groundwater) exceed the bounds of the State.⁹³ In 2017, the NSW government after extensive review also recommended changes and amendments to the EPA Act 2017⁹⁴ to support new guidelines that will:

- create a consistent framework for setting the scope of the environmental impact statement (EIS);
- ensure earlier and better engagement with the community and other stakeholders;
- improve the quality of Environmental Impact Assessment (EIA) documents and identification of water resource security issues (including future impacts);
- provide a standard framework for setting conditions for the construction and operation of projects;
- provide greater clarity on the approved project to improve post-approval compliance; and
- increase accountability for the practice of EIA professionals.

Additional improvements, not included in the draft guidelines, are also being developed. These will give further guidance on an approach to cumulative impact assessment and professional practice requirements for those undertaking an EIA. These would be underpinned by the commonwealth EPBC Act 1999, through the water trigger and the identification of MNES that offer protection for significant water resources within the States. Thus, gradually bringing the legislation more in line with the federal harmonisation policy and delivering similar outcomes as those in QLD, although using a different governance framework. A summary of actions, policies and legislation modified in NSW over the last decade to account for CSG activities and potential impacts on water, the environment and communities are highlighted in Table 3-2. Many of these actions were achieved through the insertion of Federal policy guidelines and legislation⁹⁵ into State legislation since 2012.

04

The CSG Industry, Environmental and Water Law Reforms in QLD

4.1. Introduction

While the other states have banned, or impeded industry development based on the response from affected communities and landholders, QLD, in contrast to other states, continues to support the CSG industry due to the potential benefits delivered to the State. While other states in the eastern states' gas network introduced moratoriums or bans, growth in CSG exploration and production in QLD were encouraged by the State. In 2000, the QLD government mandated that by 2005, 13 per cent of all power supplied to the state electricity grid would be generated by gas and this would increase to 15 per cent by 2010, and 18 per cent by 2020 (Geoscience Australia, 2016). This support set the stage for the rapid expansion of CSG extraction and the development of a massive LNG export hub in Gladstone, although mandatory excision of gas to satisfy the domestic gas market was not introduced (as had been the case in Western Australia).⁹⁶ This section will first review the early legislation that applied to gas developments; Second provide an assessment of the environmental legislative framework in QLD as it applies to the gas industry; and third provide an overview of the adaptive environmental management (AEM) adopted in Queensland for large scale natural resource projects.

4.2. The LNG industry in QLD – legislative beginnings

The Queensland Government in 2011 adopted an AEM framework for the regulation of activities such as petroleum, geothermal and greenhouse gas storage.⁹⁷ Prior to this enactment, various legislation, regulations and policies covered different aspects of petroleum industry and its impact on water security, environmentally sustainability and communities. In particular the disparate environmental legislation⁹⁸ that operated in QLD, that covered the CSG industry at that time, was essentially a mosaic of many parts of the legal system and operates at distinct levels of government. These are interlinked, forming (an often confusing) safety net with an emphasis on protecting the environment (McGrath, 2011).

Exploration for conventional oil and gas in QLD dates to the 1960s,⁹⁹ with Queensland's governance of the industry being informed by experiences in conventional gas and oil activity and latterly the CSG industry.¹⁰⁰ The industry was legislatively managed under the Petroleum and Gas Act (Qld) 1923 (PG Act) and regulated under the Petroleum Regulation

Act 1966.¹⁰¹ As the gas industry developed, more specifically the CSG industry showed signs of promise, amendments to existing legislation and regulatory procedures were required to satisfy: a) changes in technology and extraction methodologies; and b) issues raised around environmental impacts and sustainability (Coles, 2018).

Revisions of the PG Act and associated regulations were subsequently aligned to the Mineral Resources Act 1989 and the tightening of legislation around environmental protection.

As discussed previously, during the early 1990's the drive for environmental protection and sustainability was being generated at both international and federal levels with Australia's signature of the United Nations Convention on Biodiversity in 1992.¹⁰² The Convention imposes extremely wide and important obligations on Australia to conserve biodiversity in both terrestrial and marine ecosystems though Article 8.¹⁰³ Signing the convention was a precursor to the introduction of the Inter-Governmental Agreement on the Environment (1992)¹⁰⁴ and the associated NSESD¹⁰⁵ that provides broad strategic directions and a framework for State governments. The policy, enacted through the EPBC (Cth) Act 1999, provides overarching federal legislation that was incorporated into the state Environmental Protection (EP) Act (Qld) 1994.¹⁰⁶

Large-scale development of CSG in QLD began in 1996 and with the rapid expansion in exploration and reservoir identification. Further exploration, identified that QLD had enough reserves to deliver massive amounts of LNG into the global export markets, would require both an LNG export terminal and extensive gas infrastructure. Critical issues, given the large area affected, number of communities and landholders involved, and that the major shipping route would need to pass through the Great Barrier Reef Marine Park (Coles, 2018). This applied enormous pressure on the government to create a policy and legislative framework that would allow for this rapid expansion. As the CSG industry was using innovative technologies and developing in areas not previous explored for extractive gas purposes, fit for purpose legislative and regulatory reforms were required (Coles, 2018).

The government formulated and approved the Water Act 2000 (QLD)¹⁰⁷ and the Petroleum and Gas (Production and Safety) Act 2004 (PG Act 2004).¹⁰⁸ The industry was regulated under the Petroleum Regulation, 2004, further tightening the regulatory aspects of environmental protection, water management¹⁰⁹ and monitoring associated with the industry.¹¹⁰ While initially providing focus for the industry, owing to the rate at which the industry and associated issues grew, additional reforms were required to deal with the changing environment and markets in which the CSG industry operated. The Queensland legislation and administering departments as it applies to the CSG industry is given in Table 3-3 (below) with later legislation and amendments given in Table 3-4.

4.3. Adaptive environmental management: - Queensland's approach to regulating the unconventional gas industry

The CSG-LNG operations in Queensland were subject to environmental and other laws to minimise their impacts, including stringent monitoring¹¹¹ and compliance regimes,¹¹² but there remained doubts within the local communities (and other groups)¹¹³ as to whether the long-term or cumulative impacts are dealt with adequately. The QLD government continued to modify its position on the gas industry promoting its environmental (and pro-industry) credentials through the introduction of the Blueprint for the Gas Industry in 2009 (DEEDI, 2009). During the time of the launch Premier Bligh articulated that 'the right balance needed to be achieved' and that the 'environmental and community

concerns' needed to be addressed.¹¹⁴ A similar sentiment to that echoed in NSW 5 years later.

While the focus in QLD over the past two decades has been on developing the CSG industry, there has been extensive, often ad hoc development of legislation to deal with controversial CSG issues as they arose including: overlapping tenements (Zillman & Atkinson, 2002), impacts on groundwater and aquifers, water security (Walton, 2013), and conflict with strategic cropping and land access issues (Qld Government, 2010a).¹¹⁵ Consequently, the industry is now regulated by at least six government departments and seven main pieces of legislation (Walton, 2014) (Table 3-3 & Table 3-4).

An alternative responsive process was sought by the QLD government that could incorporate the legislative amendments, be flexible, address widespread concerns, and

Legislation	Department	Purpose
Petroleum and Gas (Production and Safety) Act 2004 and the Petroleum Act 1923 and Water Act 2000 (s 479)	Qld – Department of Natural Resources and Mines	To regulate petroleum and gas exploration tenures, safety, production and pipelines. In particular tenure approvals and dealings; regulation of the land access framework; coal seam gas compliance unit and cumulative assessment of impacts on groundwater.
Water Supply (Safety and Reliability) Act 2008	Qld – Department of Energy and Water Supply	To regular the quality of drinking water where production has an impact on the drinking supply for an urban community.
Gasfields commission Act 2013 and the State Development and Public Works Organisation Act 1971	Qld – Department of State Development, Industry and Planning	To improve sustainable co-existence between landowners, regional communities and the onshore gas industry. The office of Coordinator General is responsible for assessing and approving major projects under the State Development and Public Works Organisation Act.
Public Works Organisation Act 1971 and Water Act 2000 (Ch 3)	Qld – Department of Environment and Heritage Protection	To provide for environmental and groundwater regulation for the industry. The department assesses the environmental impacts and issues an environmental authority.
Petroleum and Gas (Production and Safety) Act 2004 and Forestry Act 1959	Qld – Department of National Parks, Recreation, Sport and Racing	To regular the use of State land eg State forests.
Environment Protection and Biodiversity Conservation Act 1999	Cth – Department of Sustainability, Environment, Water, Population and Communities	To protect and manage matters of national environmental significance including water resources.

Source: Various government agencies and publications, specifically the Queensland Competition Authority, Coal Seam Gas Investigation (July 2013)

Table 3-3 Queensland Legislation pertaining to Unconventional Gas (after Walton 2014)

allow the industry to grow. AEM has traditionally been applied to complex environmental problems where the impact or management of activities are unknown or have a high level of uncertainty (Gregory et al., 2006). The core of the concept is “learning by doing” in which activities are monitored and assessed against a set of criteria to determine their likely impact over time, and where ecological resilience uncertainty exists. However, for an AEM to be effective it requires the establishment of clear objectives, appropriate performance indicators, monitoring metrics and criteria for evaluation or response (Swayne, 2012).

The regulatory framework is required to be sufficiently flexible and responsive to allow the agency with oversight to modify its regulatory approach in response to the data, feedback, compliance reporting and conclusions established through AEM (Allan, 2007). Furthermore, to date, AEM does not have a particularly strong track record (Gregory et al., 2006), so it is of interest that the government should adopt such a strategy for an emerging industry like unconventional gas. The QLD government’s AEM approach is touted as a full system evaluation which allows the government to monitor the industry and instigate change where required.¹¹⁶

At the same time as QLD was implementing its CSG policies, the Australian Government was implementing new policy and legislation through: a) The National Partnership Agreement; b) National Harmonisation Regulatory Framework for Natural Gas from Coal Seams; and c) Multiple Land Use Framework, and amendments to the EPBC (Cth) Act.

4.4. How effective is the adaptive management strategy?

While AEM is not a decision-making framework it provides the basis for making informed decisions and assessing the effectiveness of the risk management strategies (including an Environmental Management Plan)¹¹⁷ in place for an activity or project (e.g. pipeline construction). A successful AEM regime will require the government to devote significant resources to monitoring, reporting and analysis to provide the necessary institutional capacity to deliver the CSG AEM strategy (Jones, 2009). Part of this cost was offset under the NPA with the federal (or Commonwealth) government contributing A\$18.5M (Table 3-1) to assist QLD in introducing best practice through the Harmonisation Framework. The NPA and amendments to the EPBC Act by the Commonwealth (including the water trigger), create impetus for reforms in QLD, whose government, as a signatory, was legally obliged to respond (Coles, 2018).

The state government subsequently introduced legislative amendments such as the Mineral and Energy Resources (Common Provisions) Act 2014, Environmental Offsets Act 2014 and the Water Reform and Other Legislation Amendment Act 2014 (WROLA Act), in an attempt to achieve greater clarity and harmonisation within government departments and between industry developers and community groups. To further aid the government in this quest, in 2015 it

Actions	Policy and legislation amendments (2000-16)
<p>Banned use of BTEX chemicals.</p> <p>Blueprint for LNG development in Queensland launched in 2010.</p> <p>Queensland adopts “adaptive management” approach to manage environmental issues related to fracking to enable best practice to be implemented as technologies to develop (July 2011).</p> <p>A total ban on underground coal gasification (UCG) was introduced in Queensland in 2016. The moratorium also applies to the in situ underground gasification of oil shale.</p>	<p>Queensland Gas Supply and Demand Action Plan (2016).</p> <p>Coal Seam Gas Water Management Policy 2012.</p> <p>Blueprint for Queensland’s LNG Industry (2009).</p> <p>Environmental Offsets Act 2014.</p> <p>Environmental Protection Regulation 2008 (Amended).</p> <p>Mining Amendment 2013.</p> <p>Mineral and Energy Resources (Common Provisions) Act 2014.</p> <p>Mineral Resources Act 1989. (Amended).</p> <p>Water Reform and Other Legislation Amendment Act 2014 (WROLA Act).</p> <p>Regional Planning Interests Act 2014.</p> <p>The National Gas (Queensland) Act 2008.</p> <p>Energy and Water Ombudsman Act 2006.</p> <p>Water Supply (Safety and Reliability) Act 2008 (Qld).</p> <p>A framework for the next generation of onshore oil and natural gas in Queensland 2016.</p> <p>Mineral and Energy Resources (Common Provisions) Regulation 2016 (enacted July 1, 2017).</p> <p>Vegetation Management (Reinstatement) and Other Legislation Amendment Bill 2016 (Reinstatement Bill).</p>

Table 3-4 Actions and Policy changes undertaken in relation CSG and LNG industry development, export and management in QLD

launched the Queensland Gas Supply and Demand Action Plan that is aimed at reinforcing Queensland's status as a leading jurisdiction for on-shore gas supply, market development and demand issues. However, there is now a complicated set of legislative requirements to be applied in conjunction with a series of statutory guidelines and QLD Government policy documents (See Table 3-3 & Table 3-4).

The actions, policy initiatives and regulations amendments undertaken by the QLD government are intended to facilitate the development of the CSG-LNG industry and allay community, landholder, water security and environmental concerns (Coles, 2018). While considerable angst was generated around CSG activities, the QLD government has demonstrably focused on the facilitation of LSNR gas extraction and export projects, promoting the benefits likely to accrue and downplaying the potential negative impacts associated with these massive developmental projects.

Successive governments have tried to introduce greater fairness in terms of respecting existing land tenure (ownership) and water rights under which the resources are located, by the introduction of legislation and regulatory tools to provide guidance to both affected parties and the developing industry. In taking the AEM route, Queensland has played devil's advocate in that, on the one hand they are providing the framework for development, and on the other the opportunity for grievances to be addressed by affected parties (Coles, 2018). However, given the complexity of the current system and the lack of information or hard scientific data on the longer-term impact of the CSG industry, the consequences of such actions are yet to be determined.

05

The CSG Industry-are we taming the Genie?

This analysis highlights the land, energy and water security issues that States in Australia have grappled with in the last two decades as the CSG industry rapidly expanded, covering vast areas of the states of NSW and QLD (EDO NSW, 2014). How this expansion has created conflict between landholders, farmers, communities and industry investors when they are faced with inadequate governance measures, poor legislation, limited cross-departmental policies and no avenue for consultation. In accounting for the differing approaches to CSG development and regulation adopted by the two eastern states, it is worth noting that the CSG industry in QLD has been operating since 1996. Unlike NSW, it had 15 years to develop a planning and regulatory process for CSG/LNG, encouraging investment in a massive CSG/LNG export facility within the State. While the NSW government, consumers and industry were blindsided by the rapid expansion associated with the CSG industry, a similar story was being played out at the national level, with the federal government ill-equipped to deal with the size and pace of CSG resource developments, left with deploying inadequate governance strategies to cope with these complex multifaceted issues. These included managing disgruntled landholders, polarised communities, water security and biodiversity concerns, loss of prime agricultural lands and if left unresolved, a looming energy crisis, particularly in NSW (Coles, 2017).

5.1. Outcomes of the reforms adopted in NSW and QLD

The adoption of the AEM framework provides avenues in QLD for affected parties to settle disputes, regulation of the industry, and for defining appropriate compensation. The supporting framework provides for long-term environmental monitoring that will provide subsequent governments with more informed evidentiary based options when dealing with large scale natural resource developments. The CSG AEM strategy adopted in QLD and latterly espoused by the national gas harmonisation framework, is viewed as a constructive way forward in LSNR development. As each new and emerging issue is identified, the risks are evaluated, and decisions are supported by a strong compliance and enforcement framework. The associated risks are assessed through information collected on industry developments, innovation, public submissions and data made available through compliance reporting. This system allows the government to monitor the industry, instigating changes when required, and allow industry best practice, water security measures and environmental management strategies to be integrated and implemented as new technologies develop.

However, in NSW, the signing of the NPA and implementation of the Harmonisation Framework through the SEPP Act 2007,

PO Act 1991, the creation of the EPA, the reinforcement of the Water Management Act 2000 (NSW), and the strengthening of the SLUP through sustainability legislation led to the almost complete cessation of CSG activities in that State. This approach, as discussed, had the unintended consequences of limiting gas supplies in NSW at the exact moment that its supply contracts were due to expire, export opportunities were high and alternative domestic sources were being redirected, resulting in the ramping up of the domestic gas and electricity prices at a time when demand was increasing. This left the public, given the high-profile negativity surrounding the environmental, arable land and water resources impacts coupled with limited financial returns to the State, in a quandary about what exactly were the benefits of CSG.

More latterly, there has also been disquiet voiced around increased gas and electricity prices foretold in 2012 and beyond (Cassidy & Kosev, 2015). Household electricity prices in eastern Australia, as of June 2017, have more than doubled over the past decade. Since 2007, this has been driven by network costs and, most recently, generation costs due to high gas prices.¹¹⁸ While power prices have indeed fluctuated and generally increased in NSW in 2016-2018, there has been considerable apathy (at a national level in particular) in developing definitive policies, that considered the environmental, climate and water security implications to counter this trend, even though the natural resources, energy capacity and investment opportunities have been available. A national inquiry was launched into electricity pricing, and focussed on domestic gas supplies in particular, with the federal government announcing a National Energy Guarantee (NEG) in late 2017, with a public consultation paper released in 2018 (ESB, 2018).¹¹⁹ The energy security board (ESB) suggested that the NEG could be implemented through amendments to the Australian Energy Market Agreement (AEMA), the National Electricity Law (NEL) and the National Electricity Rules (Rules). By establishing a rule change process, the NEG if agreed and implemented, could be refined over time without the need for disruptive large-scale reviews (ESB, 2018).

Power failures in South Australia and shifting federal policies in regard to Climate Change¹²⁰ precluded investment in renewables and potentially large-scale gas power stations, affecting gas exploration and domestic supplies, and ultimately the price of energy in the eastern states. In the last two years, international markets have skewed the development and income generated from the large scale CSG-LNG export projects, having detrimental effects on the eastern states gas and energy markets (AEMO, 2017).¹²¹ In this context, the benefits of the CSG industry are yet to materialize, and volatility in gas prices (globally) has created uncertainty around whether the promised benefits, through royalties, jobs and taxes will be delivered.¹²² Benefits, that were fast disappearing, almost as quickly as they were discovered.¹²³

Whether those affected communities are likely to be compensated now and into the future is a mute-point.

Australian gas continues to flood into Asia markets, due to contractual obligations, resulting in a regional glut and depressed international prices. Gas that was being redirected from domestic market, and thus resulting in skyrocketing prices in eastern Australia, prompting outcries for greater government intervention.¹²⁴ At the same time, Australian Gas and Light (AGL) suggested it was considering re-importing gas from Japan to overcome steep price increases (this was comprised of the gas Australia had originally contracted to export!). An idea that gained some credence when the federal government suggested support for gas swaps to ensure domestic supplies.¹²⁵ There was now pressure mounting on State governments to lift bans on gas exploration, particularly from South Australia, the most affected state in terms of loss of power and limited options. There are also calls for a national domestic gas reserve policy, an option legislated in Western Australia.¹²⁶

In 2018, the coalition Australian Government acted on the Chief Scientist's recommendation that new measures are needed to improve reliability and investment certainty in the electricity sector by introducing the National Energy Guarantee¹²⁷ as a strategy to encourage harmony across the States, gas suppliers, electricity providers, landholders, and consumers; but also, to manage fluctuations in both the domestic supply and energy prices. However, this policy initiative did not have widespread support within its own party, the cross-benches or Labor opposition, let alone all the states that may be affected.¹²⁸ Nor did it consider environmental, land and water security issues, while also attempting to address climate change and Australia's international commitments. Ultimately the NEG policy, resulted in another change of Prime Minister in Australia, with Malcolm Turnbull resigning from parliament on 31 August 2018. The policy was later abandoned.

5.2. Unconventional Gas- Reflection and Lessons Learned

But what did Australia really gain from this recent 'bonanza'? What are the benefits and the lesson learned? This will largely depend on the policy and regulatory setting at both State and Federal levels in Australia. In regard to the CSG industry, Queensland has demonstrated that decision-making needs to incorporate the precautionary principle with authentic adaptive management and that CSG extraction using fracking technologies can be undertaken safely using best operating practice. The deliberations between conflicted parties demonstrated the utmost importance of communication, providing direction in the debate, the effect of multi-interest representation and in clearly defining the objectives, benefits and intent of new and far reaching legislation. If the policy objectives in themselves are not fully comprehended by the target audience or are too vague so as to have multiple interpretations, then implementation and acceptance of the policies becomes much more difficult. Indeed, the NSW Chief Scientist noted in the 2014 compliance report that there

were considered to be six high-level principles for regulatory best practice: Certainty, Openness, Transparency, Flexibility (risk and outcome-based), Practicality and Efficiency (NSW Chief Scientist & Engineer, 2014).

In reviewing the multi-faceted effect of policies and legislation on an emerging industry and the future prospect of a Nation, it is noteworthy that each of the main agreements on the industry development, water resource management and environmental protection have taken place against a federal setting that has continued to evolve (Kildea & Williams, 2010). This review has demonstrated the value of providing structure, certainty and that much needed governance reforms are necessary to engender co-operation and provide security to the broader community, for the environment and investors in large-scale multi-decadal natural resource projects.

However, by 2016 there was no ‘nationally consistent application of leading practices for the regulation of industry activities’ (EDO, 2016). More importantly, broad consultation, inter-governmental cooperation and political will is essential if the community’s expectations regarding regulation of the unconventional gas industry are to be met. To this end, it remains to be seen, if the State and Federal governments in pinning their actions and gambling their integrity on the various approaches adopted in QLD, (AEM), NSW (Regulatory Framework), or Federally (NPA), and trusting that these governance mechanisms are flexible enough to manage any adverse environmental impacts, may prove to be hopeful at best, and environmentally destructive at worst.

Furthermore, this case study has demonstrated that a structured approach to policy development that provides fact-based scientific information as evidentiary support is required to assist, communities, the industry and the media, in appreciating balanced land use when envisioning the development of a new and emerging industry. A policy approach that on the one hand rewards the industry and on the other hand protects local community interests, landholders, water security and environmental values. A flexible integrative governance framework that addresses the broader co-benefits, losses and accrued impacts of large-scale multidecadal natural resource developments. A vision that is necessarily long-term, based on flexibility, but is robustly defined and supported by co-ordinated government actions.

These pressures lead to the gritty political economy question: ‘how are natural resources defined and managed, and for whose benefit?’ Answering this question requires careful analysis and underpins the nature and uncertainty of what determines a sustainable resource, and how a trade-off is

“The deliberations between conflicted parties demonstrated the utmost importance of communication, providing direction in the debate, the effect of multi-interest representation and in clearly defining the objectives, benefits and intent of new and far reaching legislation.”

quantified, against a backdrop of satisfying short to medium term energy demands at the expense of long-term water security and food productivity. In addition, this analysis has shown that by applying ‘nexus’ thinking to legal instruments and governance issues in resolving the trade-off between food, water and energy security, we can encourage the development of resilient land and water security management strategies that support balanced land use and shared natural resource outcomes.

This analysis has also shown that there is a requirement to establish appropriate governance frameworks that are inter-operable and flexible at both State and Federal levels. That the unconventional gas industry (or any industry development) needs to be accountable to the public and landholders, deliver quantifiable benefits (including energy), and ensure long-term water security and environmental protection, either through self-regulation or government intervention. The loss of environmental integrity, water resources and arable land, the cost of which if unregulated would be inestimable, and the impact multi-generational, need to be assessed against the backdrop of energy security and climate change policy. Without considering a nexus

approach to energy, food and water security governments run the risk of creating poorly crafted legislation, disjointed policies, discouraging investment and disenfranchising communities.

In a timely reminder, a statement from the IEA on the way forward for energy and governments of all political persuasions:

“There is no single story about the future of global energy: in practice, government policies will determine where we go from here” (IEA, 2016).

While natural gas is still recognised as playing a key role in the transition to a low-emission future, the size of this role will depend on the pathway that the Australian energy industry takes and the level of oversight and assistance offered by governments of all persuasions.¹²⁹ The new Australian Government has now recognised that previous governments of all political persuasions have been culpable for the decade-long failure to effectively integrate energy, water and climate policy, creating uncertainty in the market, affecting investment decisions and therefore both price and security. As result, indecision has driven consumer unrest, landholder disillusionment, failure to guarantee food and water security, industry reluctance to invest and policy inertia, creating an uncertain future in a time of changing climate, when strong leadership, long-term vision, and political certainty is required.

References

Plans & Policies

- Commonwealth of Australia. (1996). National Strategy for the Conservation of Australia's Biodiversity.
- National Strategy for Ecologically Sustainable Development. (NSED). (1992). Prepared by the Ecologically Sustainable Development Steering Committee.
<http://www.environment.gov.au/about/esd/publications/strategy/index.html>.
- NSW Gas Plan. (2014). NSW Government.
- Queensland Gas Supply and Demand Action Plan. (2016) <https://www.dnrm.qld.gov.au/our-department/corporate-information/policies-initiatives/mining-resources/gas-supply-demand-action-plan> (accessed 20 August, 2017).
- Queensland Government. (2010a). Protecting Queensland's Strategic Cropping Land: A Policy Framework. Department of Environment and Resource Management.
- _____. (2010b). Land Access Code. Department of Employment, Economic Development and Innovation.
- _____. (2011). Adaptive Environmental Management Regime for the Coal Seam Gas Industry Policy. Dept. of Environment and Natural Resources. <https://www.ehp.qld.gov.au/management/non-mining/adaptive-management.html>.
- _____. (2016). A framework for the next generation of onshore oil and natural gas in Queensland.
- SCER. (2013a). A National Harmonised Regulatory Framework for Natural Gas from Coal Seams. Commonwealth Government.
- _____. (2013b). Multiple Land Use Framework (MLUF). Commonwealth Government.

Articles, Books, Media articles, Reports, Submissions

- AEMO. (2017). Submission to the Independent Review into the Future Security of the National Electricity Market (Finkel Review). The Department of Environment and Energy. Aust. Govt.
- AGPC (Australian Government Productivity Commission). (2009). Review of Regulatory Burden on the Upstream Petroleum (Oil and Gas) Sector, AGPC, Melbourne.
- Allan, C. (2007). Can Adaptive Management Help Us Embrace the Murray-Darling Basin's Wicked Problems. In Pahl-Wostl, C., Kabat, P. & Moltgen, J. (eds.) *Adaptive and Integrated Water Management*, p. 69. Springer, Dordrecht.
- Bureau of Resources and Energy Economics (BREE). (2013). Gas Market Report, October 2013, pp.17- 41. Canberra.
- Cassidy, N. & Kosev, M. (2015). Australia and the Global LNG Market. Reserve Bank of Australia. Bulletin.
- Clark, S. (1987). 'Working paper on Inter-Jurisdictional Water Resources' (Working Paper), Constitutional Commission, 1.
- Clark, T., Hynes, R. & Mariotti, P. (2011). Greenhouse Gas Emissions Study of Australian CSG to LNG. Worley Parsons.
- Coles, N. (2015). Water Industry (Law) Reforms: The adoption of Australian Drinking Water Guidelines in Western Australia-from Targets to Aspirations. *New Water Policy and Practice Journal*, 1(2). Policy Studies Organization.
<http://www.ipsonet.org/publications/open-access/water-policy>.
- _____. (2017). Fracking Australia, from nirvana to crisis management? The unconventional gas industry in eastern Australia and the development of the associated Federal and State water and environmental policy and legislation. LLM Thesis Water Law. International Water Law Research Institute, School of Social Sciences. University of Dundee. Scotland. UK.
- _____. (2018). Using an adaptive environmental management framework to regulate the unconventional gas industry: a case study of Queensland, Australia. *New Water Policy and Practice Journal*, 1(5). Policy Studies Organization. (Accepted In press).
- Coles, N. & Hall, P. (2012). Water, energy and food security: Technology challenges of thinking in a Nexus perspective. *IEEE Technology and Society in Asia*. Oct. 26-28. 2012.
- Commonwealth of Australia. (2016). The Senate Select Committee on Unconventional Gas Mining: Interim Report. ISBN 978-1-76010-403-0. http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Gasmining/Gasmining/Interim_Report/c02.
- Crawford, J. (1991). The Constitution and the Environment. *Sydney Law Review* 11, p. 24.
- Cullen, P. (2011). This Land Our Water. ATF Press, Adelaide, Australia.
- DAFF. (1995). Decade of Landcare Plan- National Overview. In DEPARTMENT OF AGRICULTURE, F. A. F. (ed.). Canberra, ACT: Australian Government.
- Department of Employment, Economic Development and Innovation (DEEDI). (2009). Blueprint for Queensland's LNG Industry. Queensland Government.
- Department of Environment and Resource Management (DERM). (2011, March). Guidelines: Model Conditions for Coal Seam Gas Activities, Queensland Government.
- Department of Natural Resources and Mines (DNRM). (2014). Land and Mine Policy: Next generation of onshore oil and natural gas in Queensland. State of Queensland.
- Eco Logical Australia. (2013). Shale gas development in Australia: potential impacts and risks to ecological systems, Report for the Australian Council of Learned Academies (ACOLA), Securing Australia's Future: Project 6, Engineering Energy: Unconventional Gas Production.

- EDO NSW. (2014). A review of NSW Coal Seam Gas Regulation and International Best Practice. Legal Briefing Paper. Prepared for Our Land Our Water Our Future.
- EDOs of Australia. (2016, March 14). Submission responding to the Select Committee Inquiry into the adequacy of Australia's legislative, regulatory and policy framework for unconventional gas, p. 21.
- Energy security board (ESB). (2018, February). National energy guarantees draft design consultation paper, p. 56.
- Farrier, D., Kelly, A., Comino, M. & Bond, M. (1998). Integrated lands and water management in New South Wales: plans, problems and possibilities. *Australasian Journal of Natural Resources Law and Policy*, 5(2), pp. 153-185.
- Fisher, D.E. (2000). Water Law, LBC Information Services, North Ryde, Sydney, N.S.W., p. 64.
- Gardner, A.W., Bartlett, R.H. & Gray, J. (2009). Water Resources Law. Lexis Nexis Butterworths, Chatswood. NSW. p. 647.
- Geoscience Australia and Bureau of Resources and Energy Economics (GA&BREE). (2014). Australian Energy Resource Assessment, 2nd Ed. Grattan Institute. (2014, October). Gas at the crossroads, Report, p. 9.
- Gregory, R., Ohlson, D. & Arvai, J. (2006). Deconstructing Adaptive Management: Criteria for Applications to Environmental Management. *Ecological Applications*, 16(6), pp. 2411-2414.
- Healy, D. (2012). Hydraulic Fracturing or 'Fracking': A Short Summary of Current Knowledge and Potential Environmental Impacts. A Small-Scale Study for the Environmental Protection Agency (Ireland) under the Science, Technology, Research & Innovation for the Environment (STRIVE) Programme 2007–2013. University of Aberdeen.
- Hepburn, S. (2015). Submission to the Victorian Parliamentary Commission: Onshore Unconventional Gas Regulation: Land Access, Compensation and Environmental Management. Deakin Law School, Director, EMI Partners.
- Higgins, K. (2012). Australia's Water Reform journey. Department of Sustainability, Environment, Water, Population and Communities. <http://www.oecd.org/tad/sustainable-agriculture/49213483.pdf>.
- Howarth, R.W., Santoro, R. & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. A letter. *Climatic Change*. DOI 10.1007/s10584-011-0061-5.
- Hubert, C & Patrick, D.J. (2000, September). One hundred years + of riparian legislation in New South Wales. *Australian Environmental Law News*, 3, pp. 39-45.
- IEA & IRENA. (2017). Executive Summary of Perspectives for the energy transition-investment needs for a low-carbon energy system. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/Perspectives_for_the_Energy_Transition_2017.pdf.
- International Energy Agency (IEA). (2012). World Energy Outlook 2012: Golden Rules for a Golden Age of Gas, p. 15.
- Johnston, S. (2001). Whose right – The Adequacy of the Law Governing CSG Development in Queensland. *Australian Mining and Petroleum Law Journal* 259.
- Jones, G. (2009). The Adaptive Management System for the Tasmanian Wilderness World Heritage Area – Linking Management Planning with Effectiveness Evaluation. In Allan, C & Stankey, G. (eds.) *Adaptive Environmental Management*, p 228. Springer, Netherlands.
- Khan, S. & Hanjra, M. A. (2008). Sustainable Land and Water Management Policies and Practices: A Pathway to environmental sustainability in large irrigation systems. *Land Degradation and Development*, 19(5), pp. 469–487.
- Khan, S. & Kordek, G. (2014). Coal Seam Gas: Produced Water and Solids Prepared for the Office of the NSW Chief Scientist and Engineer (OCSE). School of Civil Environmental Engineering, University of New South Wales.
- Kildea, P. & Williams, G. (2010). The Constitution and the management of water in Australia's rivers. *Sydney Law Review*, 32(3), pp. 595-616.
- Marshall, N.A. & Smajgl, A. (2013). Understanding Variability in Adaptive Capacity on Rangelands. *Rangeland Ecology & Management*, 66(1), pp. 88-94. <http://www.bioone.org/doi/abs/10.2111/REM-D-11-00176.1>.
- McGrath, C. (2011). Synopsis of the Queensland Environmental Legal System. 5th ed. ISBN 978-0-9775464-1-1.
- NSW Chief Scientist & Engineer. (2013). Initial Report on the Independent Review of Coal Seam Gas Activities in NSW ('O'Kane Report'), p. 52. www.chiefscientist.nsw.gov.au/coal-seam-gas-review.
- _____. (2014). Study of regulatory compliance systems and processes for coal seam gas.
- NSW Parliament. (2012). Legislative Council. Inquiry into coal seam gas / General Purpose Standing Committee No. 5. [Sydney, N.S.W.]: The Committee, 2012. – xxi, 330 p.; 30 cm. (Report No. 35).
- NWC. (2010). "Position Statement: Coal Seam Gas and Water". December, Australian Government.
- _____. (2011). The National Water Initiative—securing Australia's water future: 2011 assessment, Canberra. Australian Government.
- Office of Research and Development (ORD). (2015). Assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources. Washington, D.C. USA.
- Ray, R. (2013). Shale Gas: Evolving Global Issues for the Environment, Regulation and Energy Security. 2. LSU. J. of Energy Law and Resources.

- Ross, C. & Darby, P. (2013, December). Unconventional Gas: Coal Seam Gas, Shale Gas and Tight Gas. An introduction and overview of issues relevant to the development of unconventional gas in Victoria. Research Service, Parliamentary Library. Department of Parliamentary Services. Research Paper No 2.
- Seneviratne, S. (2013, August 9). *Arnold v Minister Administering the Water Management Act 2000 (No 6) NSWLEC 73*. *Environmental Law Reporter*, 32(13-039).
- Stearman, W., Taulis, M., Smith, J. & Corkeron, M. (2014). Assessment of Geogenic Contaminants in Water Co-Produced with Coal Seam Gas Extraction in Queensland, Australia: Implications for Human Health Risk. *Geosciences*. 4(3), pp. 219-239.
- Swayne, N. (2012). Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach? *Environmental and Planning Law Journal*, 29(2), pp. 163-185.
- Walton, M. (2013). The Queensland CSG Industry: Miners Versus Farmers – Do the 2010 Water Act Amendments for Underground Water Management Ease the Tension? 32 ARELJ 19.
- _____. (2014). Queensland Shale Gas: A Rocky Road for the New Kid on the Block. *Australian Business Law Review*, 42(1), pp. 16-28.
- Williams, J., Stubbs, T. & Milligan, A. (2014). Coal Seam Gas: Challenges and Opportunities. Report for BREE Australia. Canberra, Australia.
- Wood, R., Gilbert, P., Sharmina, M., Anderson, K., Fottitt, A., Glynn, S. & Nicholls, F. (2011). Shale gas: a provisional assessment of climate change and environmental impacts. Tyndall Center, University of Manchester, Manchester, England. http://www.tyndall.ac.uk/sites/default/files/tyndallcoop_shale_gas_report_final.pdf.
- World Commission on Environment and Development (WCED). (1987). Our Common Future: Report of the WCED. General Assembly, Forty-second Session, Supplement No. 25 (A/42/25).
- Wright, S. (2012, July 14). An unconventional bonanza. Special Report Natural Gas. *The Economist*.
- Zillmann, B. & Atkinson, C. (2002). Changes to Queensland Coal Seam Gas Regime. 21 AMPLJ 145.

Internet

- Coal seam gas: The explosive debate. (2013, August 19). <https://www.australianmining.com.au/features/coal-seam-gas-the-explosive-debate/> (accessed July, 2016).
- Department of Environment and Heritage Protection. (DEHP). <https://www.ehp.qld.gov.au/management/non-mining/adaptive-management.html> (accessed 10 August, 2016).
- Geoscience Australia. (2016). 'Unconventional Petroleum Resources'. www.ga.gov.au/scientific-topics/energy/resources/petroleum-resources/unconventional-resources (accessed July, 2018).
- <http://oilprice.com/Energy/Energy-General/The-Great-Glut-Why-LNG-Markets-Might-Not-Balance-Before-2025.html>.
- <http://uk.reuters.com/article/asia-lng-supply-demand-idUKL8N1BJ03P> (accessed December, 2016).
- <http://www.abc.net.au/news/2016-08-01/gas-prices-higher-in-australia-than-in-export-destinations/7680106> (accessed December, 2016).
- <http://www.abc.net.au/news/2017-02-28/colin-barnett-to-eastern-states-copy-wa-gas-policy/8311950> (accessed 28 February, 2017).
- <http://www.abc.net.au/news/2017-03-15/gas-companies-guarantee-domestic-supply/8357376> (accessed 15 March, 2017).
- <http://www.abc.net.au/news/2017-04-18/federal-government-considering-gas-swaps-deal-to-free-up-supply/8449462> (accessed 18 April, 2017).
- <http://www.abc.net.au/news/2017-04-20/accc-to-investigate-gas-markets-lack-of-transparency/8457368?section=business> (accessed 20 April, 2017).
- <http://www.abc.net.au/news/specials/coal-seam-gas-by-the-numbers/promise/> (accessed July, 2016).
- <http://www.abc.net.au/science/articles/2013/12/04/3861669.htm> (accessed March, 2017).
- <http://www.appea.com.au/oil-gas-explained/benefits/economic-benefits/> (accessed 10 August, 2016).
- <http://www.economist.com/node/21556291> (accessed December, 2017).
- <http://www.energyandresources.vic.gov.au/about-us/publications/Gas-Market-Taskforce-report> (accessed August, 2016).
- <http://www.environment.gov.au/water/coal-and-coal-seam-gas/office-of-water-science/npa> (accessed February, 2017).
- <http://www.resilience.org/info/primer> (accessed July, 2016).
- <http://www.resourcesandenergy.nsw.gov.au/> (accessed July, 2016).
- <https://industry.gov.au/resource/UpstreamPetroleum/AustralianLiquefiedNaturalGas/Pages/default.aspx> (accessed January, 2017).
- <https://www.aemo.com.au/Media-Centre/AEMO-has-released-the-2016-National-Gas-Forecasting-Report> (accessed January, 2017).
- <https://www.business.qld.gov.au/industry/csg-lng-industry/regulatory-framework-csg-lng> (accessed 25 July, 2016).
- <https://www.dnrm.qld.gov.au/our-department/corporate-information/policies-initiatives/mining-resources> (accessed July, 2016).

<https://www.ehp.qld.gov.au/management/non-mining/adaptive-management.html> (accessed August, 2016).

<https://www.theguardian.com/environment/2015/mar/24/coalition-seek-advice-australia-post-2020-emissions-targets> (accessed January, 2017).

<https://www.theguardian.com/environment/2017/mar/09/energy-shortages-in-2018-19-without-national-reform-market-operator-warns> (accessed July, 2018).

IEA. <https://www.iea.org/newsroom/news/2016/november/world-energy-outlook-2016.html> (assessed November 2016).

IEA. <https://www.iea.org/topics/naturalgas/> (accessed July, 2016).

King, J. (2013, August 5) (Partner) <http://www.corrs.com.au/thinking/insights/dont-kill-the-golden-goose-before-it-lays-an-egg-time-to-review-restrictions-on-the-unconventional-gas-sector/> (accessed July, 2016).

Lock the gate. www.lockthegate.org.au/ (accessed July, 2016).

Moratorium extended on fracking in NSW, July 22, 2011 Online. (accessed July, 2016). <https://www.australianmining.com.au/news/moratorium-extended-on-fracking-in-nsw/>.

No Fracking Way. <http://www.frackingfacts.com.au/blog/> (accessed July, 2016).

NSW, EPA. (2015). Conventional and unconventional gas. EPA2015/0854 December 2015. www.epa.nsw.gov.au.

Peacock, M. (2016). LNG boom turns to bust as falling oil price hits exports. Updated 21 Jul 2016. <http://www.abc.net.au/news/2016-07-21/lng-gas-bust-slashes-tax-revenues/7649336> (accessed July, 2018).

ProPublica web site. <http://www.propublica.org/series/fracking> (accessed March, 2017).

Protect the limestone coast. <http://www.protectlimestonecoast.org.au/summary-of-countries-that-have-taken-action-against-fracking-may-2015/> (accessed July, 2016).

Smail, S. & Blumer, C. (2016). Vote Compass. Updated 2 Jun 2016, 3:20pm. (accessed July, 2016). <http://www.abc.net.au/news/2016-06-02/vote-compass-coal-seam-gas-csg/7467884>.

www.parliament.vic.gov.au/57th-parliament/edic/inquiries/article/1391 (accessed April, 2017).

www.qca.org.au/Other-Sectors/Productivity/Completed-Reviews/Coal-Seam-Gas.

Zillman, B. (2004). Petroleum and gas: in with the new, but keeping the old (accessed 10 August, 2016). <http://www.allens.com.au/pubs/res/formay04.htm>.

Notes

1. Natural gas supplies 22% of the energy used worldwide, and makes up nearly a quarter of electricity generation, as well as playing a crucial role as a feedstock for industry. Natural gas is a versatile fuel and its growth is linked in part to its environmental benefits relative to other fossil fuels, particularly for air quality as well as greenhouse gas emissions. However, the competitive landscape is formidable, **policy pressures** can evolve rapidly, and gas infrastructure is not cheap. <https://www.iea.org/topics/naturalgas/> (accessed 3 July, 2018).
2. Natural resources that are classified as 'unconventional' are those that require 'greater than industry-standard levels of technology or investment to exploit'. Geoscience Australia, 'Unconventional Petroleum Resources'. <http://www.ga.gov.au/scientific-topics/energy/resources/petroleum-resources/unconventional-resources> (accessed July, 2018).
3. Unconventional gas resources include natural gas found in coal beds (CSG), in shale (TSG), low quality reservoirs (tight gas), or as gas hydrates. CSG is almost pure methane; conventional gas is around 90 per cent methane with ethane, propane, butane and other hydrocarbons making up the remainder. <https://www.csiro.au/en/research/energy/hydraulic-fracturing/what-is-unconventional-gas> (accessed July, 2018).
4. International Energy Agency (IEA) announced that the long-term global proven recoverable gas reserves stood at 216 trillion cubic metres (tcm) at the end of 2014; <https://www.iea.org/topics/naturalgas/> (accessed July, 2018).
5. There is particularly strong opposition to CSG activities from local community groups in NSW, QLD and Victoria. For example: 'CSG Free Northern Rivers' (Northern NSW); 'Western Downs Alliance' (Darling Downs, QLD); 'Gippsland Action Group' (Central Victoria). See map: http://www.lockthegate.org.au/find_supporter_groups (accessed July, 2018).
6. Four Nationally and twelve across all States and territories.
7. For examples see www.energyandresources.vic.gov.au/about-us/publications/Gas-Market-Taskforce-report ; www.parliament.vic.gov.au/57th-parliament/edic/inquiries/article/1391; <http://www.chiefscientist.nsw.gov.au/reports>; www.qca.org.au/Other-Sectors/Productivity/Completed-Reviews/Coal-Seam-Gas (accessed July, 2018).
8. See <http://www.abc.net.au/news/specials/coal-seam-gas-by-the-numbers/promise/>; Coal seam gas: The explosive debate. August 19, 2013. (accessed July, 2016). <https://www.australianmining.com.au/features/coal-seam-gas-the-explosive-debate/> (accessed July, 2018).
9. See <http://www.economist.com/node/21556291>.
10. See <http://uk.reuters.com/article/asia-lng-supply-demand-idUKL8N1BJ03P>.
11. Commonwealth of Australia Constitution Act 1900.
12. The global shift toward sustainability provided a gateway to reform environmental management, land use and the water industry through the Council of Australian Governments (CoAG). Two mechanism, the *Inter-Governmental Agreement on the Environment (1992)*, and the *National Strategy for Ecologically Sustainable Development (NSESD) (1992)* that are the pillars of environmental legislation in Australia today.
13. *1994 CoAG Water Reform Framework Agreement-CoAG meeting, Feb. 1994, Communiqué, Attachment A.*
14. NSESD 1992- <http://www.environment.gov.au/about/esd/publications/strategy/index.html>.
15. Note that any underlying native title can coexist with other land title rights.
16. Offshore petroleum operations beyond designated state and territory coastal waters are governed by the *Commonwealth Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGSA)*.
17. For example, Hepburn (2015) notes in a submission to Victorian parliament that '*deep-rooted schisms exist between the legal and social perceptions of land ownership where minerals are vested in the State*' and highlights the need '*for a comprehensive delineation of the 'access' interface between land and mineral ownership.*'
18. Environmental concerns connected with unconventional gas extraction are extensive. Concerns centre on potential water pollution from fracking through poor well management and construction causing: i) fracking fluid contamination through natural or induced fractures; ii) groundwater contamination after flow-back and iii) well casing failure causing direct aquifer contamination.
19. Note that LNG has been exported from Australia since 1989, with the North-West Shelf Venture in WA exporting up to 16.3 mtpa.
20. The Murray-Darling Basin comprises the largest agricultural and irrigated area in Australia and is governed by the State of Queensland, NWW, Victoria and South Australia, and the Australian Capital Territory.
21. *Environment Protection and Biodiversity Conservation (EPBC) Act (Cth) 1999.*
22. *Water Act 2007(Cth).*
23. The principles of ESD are set out in *EPBC Act 1999, Vol. 1, Ch1. Pt1 s 3A. (a-e).*
24. *EPBC Act 1999, Vol. 1.Pt. 2 Ch. 3 Div 1.*
25. Under s 51(xxix) of the Commonwealth of Australia Constitution Act 1900.
26. Under the UN Convention on Biodiversity (UNCBD) 1992, and the UN Framework Convention on Climate Change (UNFCCC) 1994.

27. Pursuant to the 'Corporations Power': *NSW v Commonwealth* (2006) 229 CLR 1 (the 'Work Choices Case'); the 'Trade and Commerce Power': *Murphy ores Incorporated Pty Ltd v Commonwealth* (1976) 136 CLR 1; [1976] HCA 20; the 'External Affairs Power': *Commonwealth v Tasmania* (1983) 158 CLR 1 ('Tasmanian Dams case').
28. During the period between 1996-2012 the Commonwealth government was able to circumvent state objections and use heads of powers granted to it under the constitution to initiate water law reforms through the *EPBC Act 1999 (Cth)*, *EPBC Reg. 2000 (Cth)* and *Water Act 2007 (Cth)*.
29. *National Water Commission Act 2004 (Cth)* and came into force on 17 December 2004. The NWC was later decommissioned by the Abbott government in 2013.
30. <https://www.claytonutz.com/knowledge/2014/october/changes-to-water-management-in-nsw-more-flexibility-for-water-trades-and-clearer-controls> As described in the *Water Management Amendment Act 2014*.
31. The program's key priorities were i) Taking action on climate change; ii) Using water wisely; iii) Securing water supplies, and iv) Supporting healthy rivers and wetlands.
<https://www.environment.gov.au/resource/water-future-fact-sheet>.
32. Created by the Australian government under the *National Water Commission Act (Cth) 2004*.
33. The Hon. Julia Gillard, MP, Prime Minister, 'New focus on scientific evidence to build community confidence in coal seam gas and coal mining', Media release, 21 November 2011, p. 1.
34. This was later enacted under the *EPBC Amendment (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development) Bill 2012 [Provisions]*, after recommendations by the Senate Environment and Communications Legislation Committee.
35. The water trigger allows the impacts of proposed CSG coal seam gas and large coal mining developments on water resources to be comprehensively assessed at a national level. As a result of the water trigger, the Minister can set appropriate conditions as part of the project approval to ensure that any significant impacts on a water resource are acceptable. The definitions of CSG development and large coal mining development in the *EPBC Act* require the significance of the impacts of an action to be considered with other developments, whether past, present or reasonably foreseeable.
36. *EPBC Act, 1999. ss. 24D, 24E*.
37. Whether or not an action is likely to be significant depends upon the sensitivity, value, and quality of the environment which is impacted including other public benefit outcomes, or to create a material risk of such reduction in utility occurring. It also depends upon the intensity, duration, magnitude and geographic extent of these impacts.
38. The water trigger legislation relies on two main heads of power under the Constitution. These heads of power are the power to regulate constitutional corporations and to regulate trade and commerce.
39. The trigger only applies to CSG and is circumscribed in how it may be applied through the *EPBC Act 1999, s.134. & s. 136 (2) (fa)*.
40. The National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development (the NPA) was entered into in 2012 between the Australian Government and state governments of Queensland, New South Wales, Victoria and South Australia (the Parties).
<http://www.environment.gov.au/water/coal-and-coal-seam-gas/office-of-water-science/npa>.
41. Commonwealth government becomes involved only when projects could have a significant impact on MNES protected under the *EPBC Act, 1999, D2 S505C & 505D*.
42. The MLUF does not propose changes in the existing accountabilities, roles and responsibilities of State and Territory government agencies. The MLUF describes five desired outcomes, and eight general principles intended to achieve these outcomes.
43. *EPBC Act 1999, Sch 1. Pt 1 D3 ssFB s24D & 24E*.
44. The Commonwealth government and the other parties to the agreement (The States) recognise that they have a mutual interest in (a) the long-term health, quality and viability of Australia's water resources; and (b) the sustainable development of coal seam gas (CSG) and coal mining industries, given their potential contribution to Australia's energy security and balance of international trade.
45. <https://www.environment.gov.au/water/coal-and-coal-seam-gas>.
46. In accordance with the *Intergovernmental Agreement on Federal Financial Relations, 2013 (Cth) Sch. D*.
47. Although Australia signed the Paris Agreement on December 12, 2015, it was ratified and went into effect on 4 November 2016. The first session of the Conference of the Parties (COP) serving as the Meeting of the Parties to the Paris Agreement (CMA 1) took place in Marrakech, Morocco from 15-18 Nov. 2016.
48. On 12 November 2015, the Senate resolved to establish the Select Committee on Unconventional Gas Mining inquiry on the adequacy of Australian legislative, regulatory and policy framework for unconventional gas mining including CSG/TSG.
http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Gasmining/.
49. <http://senatorlazarus.com/csg-inquiry/>.
50. Landholders' Right to Refuse (Gas and Coal) Bill 2015. The bill proposes to a) make gas or coal mining activities undertaken by a constitutional corporation without prior written authorisation from landholders unlawful, and b) ban constitutional corporations from engaging in hydraulic fracturing operations for coal seam gas (CSG), shale gas and tight shale gas (TSG).

51. CSG activities in NSW are regulated under the *Petroleum (Onshore) Act 1991 (PO Act)*, *Protection of the Environment Operations Act 1997 (POEO Act)*. and the *EPA Act 1979*. In addition, CSG activities are required to comply with the *EPBC Act 1999 (Cth)*, and the *Water Management Act 2000*, in NSW.
52. *Water Rights Act 1896 (NSW)*. Note the *Water Act 1912* and the *Water Irrigation Act 1912* remained in force for nearly 88 years until being repealed in 2000, by the introduction of the *Water Management Act 2000 (NSW)*, such that: ‘*The Act to be repealed on the whole commencement of Sch 7, to the extent that it applies to this Act, to the Water Management Act 2000.*’
53. *Artesian Wells Act 1897 (NSW)*, the *Water Rights Act 1902 (NSW)* and the *Water & Drainage Act 1902 (NSW)*.
54. *Water Act 1912 (NSW)*. An Act to consolidate the Acts relating to Water Rights, Water and Drainage, Drainage Promotion, and Artesian Wells.
<http://www.legislation.nsw.gov.au/#/view/act/1912/44>.
55. *Irrigation Act 1912 No 73*. Led to the formation of the Water Conservation and Irrigation Commission in 2013. Later repealed by the *Water Management Act 2000*.
56. *Commonwealth of Australia Constitution Act 1900* (The Constitution), came into force on 1 January 1901.
57. *RMWA (1914)* was negotiated by the Commonwealth, New South Wales, South Australia and Victoria, and implemented by legislation in each jurisdiction in 1915. The RMWA addressed issues raised by downstream States in regard to river flows, was operational for 70 years, and is notable in that it was the first intergovernmental water agreement in Australia.
58. These tended to cover the associated issues of water conservation, irrigation, water rights and water supply as these jurisdictions are at times inextricably linked.
59. The *MDB States* are QLD, NSW, ACT, Victoria and South Australia.
60. *NSW Clean Water Act 1970 No 78*. An Act to make provisions with respect to the prevention or the reduction of pollution of certain waters; and for purposes connected therewith. The Act was repealed by Sch 3 to the *Protection of the Environment Operations Act 1997 No 156* with effect from 1.7.1999.
http://www.austlii.edu.au/au/legis/nsw/repealed_act/cwa1970131/. Defines “waters” to mean any river, stream, lake, lagoon, swamp, wetlands, unconfined surface water, natural or artificial watercourse, dam or tidal waters (including the sea), or part thereof, and includes water stored in artificial works, water in water mains, water pipes and water channels, and any underground or artesian water, or any part thereof.
61. “*The concept of biodiversity emphasises the interrelatedness of the biological world and the importance of those interrelationships in maintaining diversity. It covers the terrestrial, marine and other aquatic environments such as rivers, streams, wetlands and groundwater systems.*”
Commonwealth of Australia (1996). National Strategy for the Conservation of Australia’s Biodiversity.
<http://chm.environment.gov.au/strategy/>.
62. “*The concept of an environmental flow includes (but is not limited to): the volume or water over some time base; velocity of water in channel; duration of flow events; water-level; natural and human induced variation flows on an annual and longer time scale; need for pulses of high flows (e.g. to stimulate fish breeding); and the rate, of change of flow*”
Cullen, P. (2011). *This Land Our Water*. ATF Press, Adelaide, Australia.
63. Along with further Amendments to Act in each year between 1976-81, 1983-86, and 1988.
<http://www.legislation.nsw.gov.au/#/view/act/1912/44/history>.
64. *Environmental Planning and Assessment Act (NSW) 1979*, Part 1, s 5 a (i), (vii).
65. *Ibid* 1979, Part 1, s 5 c.
66. *The Water Administration Act 1986* creates the Department of Water Resources in NSW.
67. The *Catchment Management Act 1989* seeks to "Identify and rectify natural resource degradation and to promote the sustainable use of natural resources" and introduced the concept of catchment management plans (CMP's- that later evolved into Water Sharing Plans), and Catchment Management Authorities (CMA's).
68. This ACT constituted the Environment Protection Authority of NSW in 1991.
69. The Decade of Land care policy was launched in Wentworth (NSW) by the then Prime Minister Bob Hawke, as a motivating force to tackle land degradation, using a process that relies heavily on local community groups, within a framework that recognised the responsibilities of the Commonwealth, state and local governments (DAFF, 1995).
<http://www.bobhawkelandcareaward.com.au/bob-hawke-speech.pdf>.
70. See NSES D.
71. An Act to protect the environment; to replace other environment protection legislation; and for other purposes.
Replaced the *Clean Waters Act 1970*.
72. A consequence of this Act was the creation of privatised irrigation corporations through the transfer of ownership and operations of the irrigation areas and irrigation districts in NSW.
73. *Water Management Act 2000*, An Act to provide for the protection, conservation and ecologically sustainable development of the water sources of the State, and for other purposes. The Act was subsequently amended in 2002, and 2004 after consultation and litigation by disgruntled landholders and irrigators.
74. First introduced under the *Catchment Management Act 1989*.

75. *Ibid* 2000. Ch. 3. s 3 (f);
76. *Ibid* 2000. Ch 3. s 3 (a-h);
77. In 2014 the Water NSW Act 2014 created the Water NSW which is now responsible for water in NSW. The Water Management (Amendment) Act 2014 was also introduced to improve water security and water trading.
78. This was not the first case brought before the court in regard to WSP, WAL's, and changes provided for under the WMA. The constitutional challenge failed on the same basis as *Arnold v Minister Administering the Water Management Act 2000* [2010] HCA 3; (2010) 240 CLR 242 because the replacement of licences was not an acquisition of property under the Australian Constitution.
79. The MBDA replaced the 1915 *River Murray Waters Agreement* (RMWA) in 1993.
80. Gas powered generation (GPG) is extremely useful in power generation systems undergoing emissions reduction, although high gas prices in Eastern Australia, is challenging the economics of gas fired power against existing coal and some new renewables. AEMO submission to the *Finkel Review* 2017.
81. Brad Hazzard MP, 'NSW Government adopts rigorous strategic approach to regional land use planning' (Media Release, 21 May 2011).
82. NPA, 2012; The Harmonisation Framework 2013; Amendments to the EPBC Act 1999 (Cth).
83. NSW Gas Plan 2014. Government of NSW.
84. *SEPP ACT 2007* (NSW).
85. NSW chief scientist report 2014/12. Independent Report of Coal Seam Gas Activities in New South Wales, Final Report, 30 September 2014.
86. *Ibid* NSW Gas Plan 2014.
87. See *Protection of the Environment Operations Act 1997* No 156. Sch 2A.
88. Andrew Stoner MP and Brad Hazzard MP, 'Government Unveils New Protections for Agricultural Land' (Media Release, 11 September 2012).
89. *SEPP ACT 2007 (NSW)* Part 4AA, Divs 1–5 (cll 17A–17U), Sch 1 [6].
90. *EPDC Act 1999 (Cth)*, Act No. 47, V1, Ch2, Pt2, sd FB, (Registered 12 July, 2016).
91. A moratorium on CSG activities was recommended (No 35) by the NSW Parliamentary Committee that "no further production approvals are issued until the deficiencies in the regulatory framework are addressed and a comprehensive, effective and transparent regulatory regime is put in place." (NSW Parliament 2012).
92. <http://www.abc.net.au/news/2017-03-09/looming-gas-shortage-will-threaten-nations-power-supplies/8337204> (accessed June, 2018).
93. Progress towards a national approach is ongoing through the NPA and The Harmonisation Framework. (Ch. 3).
94. *Environmental Planning and Assessment Amendment Act 2017 (NSW)*.
95. *Revisions of the SEPP Act 2007 (NSW) Sch 1 & Sch 2*.
96. Western Australia introduced a domestic gas reservation policy in 2006, which requires new gas developments to supply the equivalent of 15 per cent of their gas exports to the Western Australian domestic gas market, with the aim of maintaining domestic gas prices below export parity.
97. Department of Environment and Heritage Protection. (DEHP) (accessed July, 2018). <https://www.ehp.qld.gov.au/management/non-mining/adaptive-management.html>.
98. An "environmental legal system" is a suite of laws and administrative structures that regulates the impact of people on the natural environment and quality of life in a particular jurisdiction or geographic area. See Fisher DE, *Australian Environmental Law*. 2nd Ed, Lawbook Co, Sydney, 2010.
99. Note the oil and gas industry was initially regulated under the *Petroleum Act 1923 (Qld)*, before being repealed by the *Petroleum and Gas (Production and Safety) Act 2004 (Qld)*, although not all aspects of the Act were to be extinguished as those sections that pertain to native title in the 1923 Act are retained. One of the main catalysts for the introduction of the new act in 2004 was the rapid expansion of Queensland's CSG industry. Therefore, it was not surprising that an entire chapter is dedicated to this topic (in the Act), and a further corresponding chapter is inserted into the *Mineral Resources Act 1989*. The 2004 Act also clarifies the relationship between petroleum tenements and mining tenements for minerals other than coal or oil-shale. (see Zillman 2004). <http://www.allens.com.au/pubs/res/formay04.htm> (accessed June, 2018).
100. Department of Natural Resources and Mines. 2014. Land and Mine Policy: Next generation of onshore oil and natural gas in Queensland. State of Queensland.
101. *Petroleum Regulation Act 1966 (Qld)* Amended up to SL No. 122 of 1996. This Act was repealed in 2004 by the *Petroleum Regulation Act 2004* Ch 3. S 45.
102. *United Nations Convention on Biological Diversity (CBD) 1992*.

103. *UNCBD 1992. Article 8 In-situ conservation. (a, c-e, k).*
104. Inter-Governmental Agreement on the Environment 1992- <http://www.environment.gov.au/about/esd/publications/igae/index.html> (accessed July, 2018).
105. *Ibid* NSESD 1992.
106. Note: A bilateral Environmental Impact Assessment (EIA) is in place between the Commonwealth and Queensland involving EIA processes linking EPBC Act to the *Environmental Protection Act 1994 (Qld)* for mining (and gas), *State Development and Public Works Organisation Act 1971 (Qld)* for significant projects, and the *Sustainable Planning Act 2009 (Qld)* for other assessable development.
107. *The Water Act 2000 (Qld)* was introduced following the Water Law Reforms introduced under the CoAG agreements in 1996 and allows for the protection and sustainable use of water resources and linked to the PG Act 2004 (Ch 2, S188). This was particularly important in linking water use and the CSG industry (which has significant impacts on groundwater and generates produced water from gas extraction activities – particularly hydraulic fracking).
108. The revised *PG 2004* Act provides for ESD (Ch 1 Part 2 S3 (1) a & i), compensation of owners (Ch 1Pt2 S3 (1) h) and Commercial CSG production requires petroleum tenure (s 800).
109. Unlike water extracted by a landowner via a water bore, ‘associated or produced water’ is considered as a regulated waste in Queensland, following the introduction of the Water Supply (Safety and Reliability) Act 2008 (Qld), s201A.
110. *Ibid PG Act 2004* Ch1 Pt 3 D2 S15A; Ch2, Pt4, S185-187;
111. *Ibid PG Act 2004* Ch2, Pt 5.
112. *Ibid PG Act 2004* Ch10, Pt 1AA. & Ch 11.
113. See for example www.lockthegate.org.au/; and <http://www.frackingfacts.com.au/blog/>.
114. Queensland, *Debates*, Legislative Assembly, 17 September 2009, pp2395-2397.
115. Queensland Government, 2010. Protecting Queensland’s Strategic Cropping Land: A Policy Framework. Department of Environment and Resource Management.
116. <https://www.ehp.qld.gov.au/management/non-mining/adaptive-management.html>.
117. See *EP. Reg. 2008 (Qld), Sch.5*.
118. https://www.energy.gov.au/sites/g/files/net3411/f/enr032-1017-powering-forward-brochure_faweb.pdf.
119. The National Energy Guarantee (Guarantee) is an opportunity to resolve some of the most vexing policy issues challenging the National Electricity Market in Australia. As recommended in the Finkel review, Energy Security Board members are also simultaneously exploring a range of other complementary measures including strategic reserve/s, demand response and day ahead markets to ensure we have the operational flexibility we need in the rapidly changing electricity market.
120. Successive governments have established taskforces to examine climate policy, including the 2006 taskforce headed by the then head of the prime minister’s department Peter Shergold, which recommended the Howard government introduce an emissions trading scheme and two reports by professor Ross Garnaut to the former Labor government to inform its emissions trading scheme, which the Abbott government repealed in 2014. <https://www.theguardian.com/environment/2015/mar/24/coalition-seek-advice-australia-post-2020-emissions-targets>. There has been additional redirections in climate policy that have created uncertainty in power generation options in Australia leaving the nation with mismatch of resources, policies and ineffective energy grids.
121. Indeed, to forestall power shortages in late 2017, the NSW premier, Gladys Berjiklian planned to revert a court order to shut down one of the biggest coal mines in the state as the mine is the main fuel provider to one of the biggest power plants in NSW. The uncertainty about its closure helped spike the power prices in NSW. <https://www.sbs.com.au/yourlanguage/arabic/en/article/2017/10/09/nsw-government-prevent-potential-power-shortage> (access July, 2018).
122. <https://www.smh.com.au/business/agl-energy-abandons-gas-production-and-exploration-20160204-gml73w.html> (accessed July, 2018).
123. <https://www.sbs.com.au/news/origin-flags-533-million-impairment-hit> ; <https://www.afr.com/business/origins-360m-canary-in-the-coal-seams-20180208-h0vsg7> (access July, 2018).
124. Although in March 2017, the major east coast gas companies have given the Federal Government a guarantee they will make gas available to meet domestic demands. There still remained uncertainty how this would be achieved. <http://www.abc.net.au/news/2017-03-15/gas-companies-guarantee-domestic-supply/8357376>.
125. <http://www.abc.net.au/news/2017-04-18/federal-government-considering-gas-swaps-deal-to-free-up-supply/8449462> (accessed July, 2018).
126. <http://www.abc.net.au/news/2017-02-28/colin-barnett-to-eastern-states-copy-wa-gas-policy/8311950> (accessed July, 2018).
127. <https://www.energy.gov.au/government-priorities/better-energy-future-australia> (accessed July, 2018).
128. <https://independentaustralia.net/politics/politics-display/barnaby-joyce-neg-coal-and-general-nutcase-stuff,11750> (accessed August, 2018).
129. <https://www.aemo.com.au/Media-Centre/AEMO-has-released-the-2016-National-Gas-Forecasting-Report> (accessed July, 2018).

Acronyms- Abbreviations

ACCC	Australian Competition and Consumer Commission
AEM	Adaptive Environmental Management
COAG	Council of Australian Governments
Cth	Commonwealth
CSG	Coal Seam Gas
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EP Act	Environmental Protection Act 1994 (Qld)
EPBC Act	Environmental Protection and Biodiversity Conservation Act (Cth)
ESB	Energy Security Board
ESD	Ecologically Sustainable Development
IEA	International Energy Agency
IESC	Independent Expert Scientific Committee
LNG	Liquefied Natural Gas
MDB	Murray Darling Basin
MNES	Matter of National Environmental Significance
mpta	million tons per annum
NPA	National Partnership Agreement
NSESD	National Strategy for Ecologically Sustainable Development
NSW	New South Wales
NWC	National Water Commission
NWI	National Water Initiative
PG Act	Petroleum and Gas Act 1923
QLD	Queensland
TSG	Tight Shale Gas



4

Urban Growth Pattern and Water Supply Efficiency in Algiers, Algeria

Najet Aroua and Nouredine Zemmouri

Najet Aroua, Polytechnic School of Architecture and Urbanism of Algiers, Laboratory of Architecture and Environmental Design (LaCoMoFa), Department of Architecture, University of Biskra.

e-mail: arouanajet@yahoo.fr

Nouredine Zemmouri, Urbanist-Architect, LaCoMoFa Department of Architecture, University of Biskra.

e-mail: zemmouri@bath.edu

Abstract

The world is patently becoming more urbanized and water resources less available due to climate change impacts and growing demand. Cities in developing countries suffer more from water shortage and cope with by intensifying both conventional and nonconventional production. As a result, water demand satisfaction has been concretely improved but the integrated water resources management objectives are more often missed. The question is how relevant is the water demand satisfaction rate in assessing water supply efficiency and subsequently the water management sustainability?

This paper argues that some urban features matter for water supply efficiency and aims to better understand the relationship between them. Specific objectives are to (i) assess the water demand satisfaction rate and (ii) compare against a couple of indicators characterizing the urban setting. Algiers is selected as the demonstrative case for this study.

Results show that (i) no indicator characterizing the urban setting would alone be able to describe the local water context and (ii) water supply efficiency strongly depends on water resources availability and the demand level as well as on the urban growth pattern that might aggravate if not engender water related risks.

Keywords

Algiers, integrated water resources management, urban growth pattern, water supply efficiency

01

Introduction

The world is patently becoming more urbanized and water resources less available due to the impact of climate change and the growing demand. Cities in developing countries in particular would be doubly vulnerable as they mainly deal with water shortage by overexploiting their resources and intensifying the production of both conventional and non-conventional resources. Mainly based on structural measures, the strategy would have negative effects on the natural environment and the local resilience face to water related risks. Thus, even though water demand satisfaction has been (is being) concretely improved, the integrated water resources management (IWRM) objectives are often missed.¹

Then the question is how relevant is the water demand satisfaction rate in assessing water management efficiency?

Actually water issues are complex being that they are at the crossroad of several urban skills, purposes and interests. Indeed the water demand satisfaction does depend on various indicators characterizing the urban setting (e.g. urban density, urban design) and the water delivery capacities (e.g. production, supply, storage). Therefore, any sustainable urban design/planning processes should better reflect these interconnected indicators as a first step in the perspective of

“How relevant is the water demand satisfaction rate in assessing water management efficiency?”

IWRM strategy. Accordingly, the urban pattern alternative is to consider water as an integral part of the natural ecosystem as well as a social and an economic goods controlling water supply, wastewater and storm water systems.

Now during the period of this study IWRM principles would not seem to be systematically translated into concrete actions in local plans and governance practices (Bruce, 2005; Aroua, 2005). Furthermore, recent studies have shown that the natural environment does still need (inter alia) for proper knowledge to be transdisciplinary, action-oriented and contextually defined in addition to an appropriate institutional-professional arrangement in order to be incorporated into urban projects (Ingegard, 2000; Wamsler et al., 2013; Aroua, 2017).

It may give rise to concern about the water governance process - including IWRM- in parallel with the water sensitive urban design approach. Accordingly, this paper aims to examine the relationship between the urban growth pattern and the water supply efficiency. If that relationship is better understood, urbanism could contribute to minimize its impacts on the natural environment and subsequently preserve water resources and ecological processes' sustainability.

The theoretical background of the study falls within the urban ecology approach focusing on the sensitive relationship between the natural and the urban systems (Forman, 2014; Marzluff et al., 2008). The approach considers urban effects as being strongly dependent on the urban growth pattern designating either spatial sprawl, densification processes or new urban settlement projects. The study does also refer to the IWRM objectives related to water supply and access to improved drinking water in particular (www.un.org).

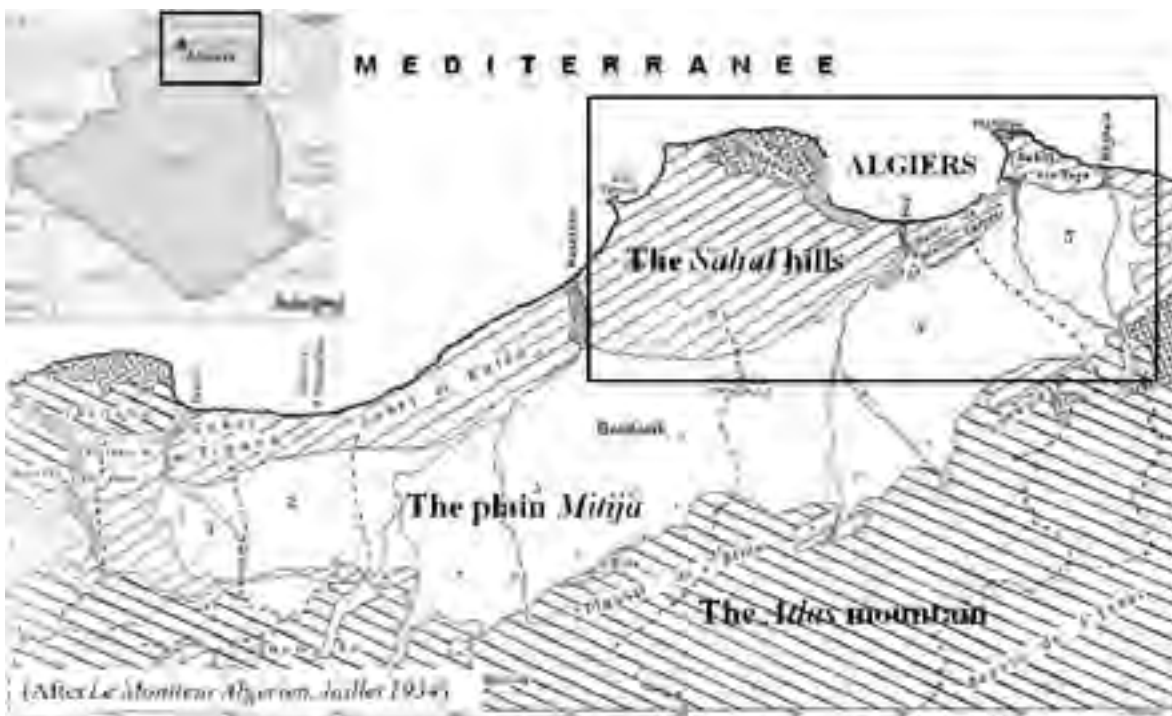


Figure 4-1 Algiers location (After Agence Nationale d'Aménagement du Territoire 1989)

02

Research Methodology

2.1. Urban Growth Pattern and Water Issues in the Study Area

Algiers is a coastal city located in northern Algeria (Figure 4-1). The latitudes and longitudes are 36° 46' 34" N, 3° 03' 36" E respectively. The city has a Mediterranean sub-humid climate impacted by contrary atmospheric flows from the Atlantic (cold) and the Sahara (hot) alternatively. The annual average temperature is about 12,8°C. Annual precipitation varies between 600 and 800 mm/year. Within the urbanized area, the water flow (surface water) is approximately 3489 hm³/year of which about 35 to 45% are lost by evaporation as the local hygrometry rate would be 88 to 90%.

As shown on Figure 4-1, local physical features include three landscapes:

- the plain named «Mitija», having an area 100km in length and a width of 25km, about 135,000ha, low slope of 0 to 3%, crossed by some permanent rivers.
- a set of hills named «Sahel», approximately 62,000 ha, slope of 3 to 12% and altitude around 250m.
- a mountain chain named «Atlas», approximately 89,700ha, altitude between 1,000 to 1,600m.

Algiers integrates 57 urban municipalities within an area of 809,22km² where approximately 2,783,287 people lived at the study time interval (1999-2002). The population grows both naturally and through migration. About 6% of population is in precarious position, living in decrepit social housing or informal districts from the historical city centre and the first periphery (After 1998 National Census). Indeed the comparative high level of urbanization seems to be due to both formal and informal processes progressively invading the farmland and the no urbanizable risk areas.

Actually, after Algeria's independence (1962), the city of Algiers has been roughly developed in three steps. The first (1962-1980) was to densify and even overcrowd the original medieval city and French colonial districts (dating from the XIXth century) in addition to set the number of slums (at present, the Government is pursuing a comprehensive program to eradicate slums). These districts constitute the very densely populated city centre (327,1 inhab/ha in 1998) albeit the population is nowadays declining. The second (1980-1997) has been to extend (first periphery, 85,7 inhab/ha in 1998) all around mainly in the form of social housing projects impelled by the Government. The third step (1997 to present) represents the ongoing spatial urban in the western and southern areas of Algiers from both public and private residential housing projects (second periphery, 17,2 inhab/ha in 1998).

The urban growth pattern results from some housing programs dealing with the demand pressure according to the land availability rather than a development strategy (Deluze, 1988). As shown in Figure 4-2, it does de facto constitute the number of new dense residential hubs generating additional water demand and wastewater challenges within 50km radius in the city.²

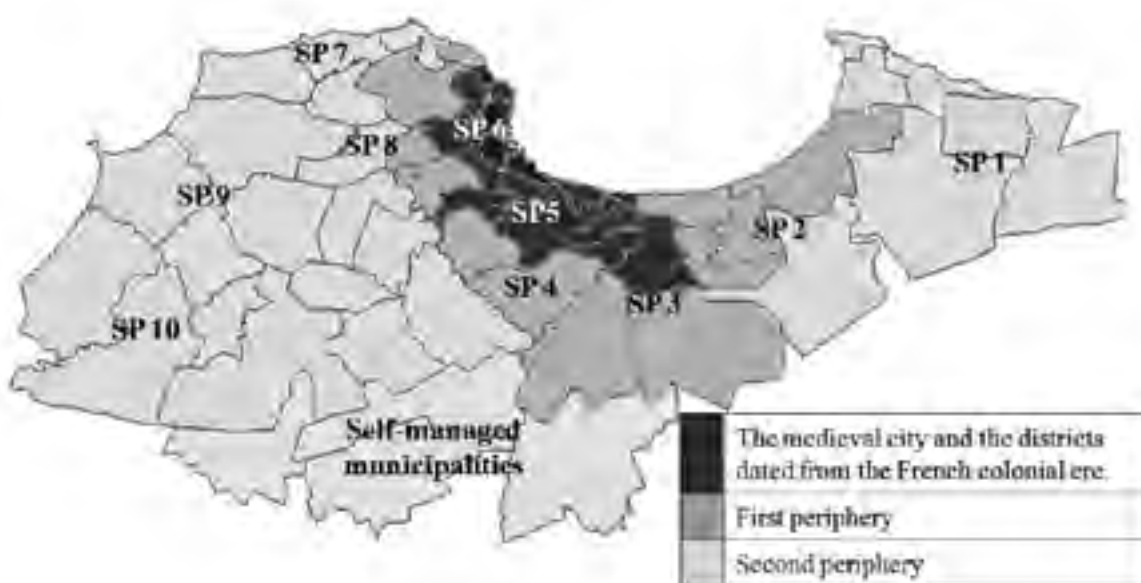


Figure 4-2 Algiers urban growth pattern (After the National Office of Statistics 1998)

At present, Algiers is continuing with its outward expansion seemingly with neither a suitable urban water sensitive strategy nor a sufficient plan to address/manage environmental impacts. As a result, the city faces common water related risks such as shortages, pollution, landslide and flooding.³ In addition, since 1987, surface and groundwater resources are being intensively extracted from neighbouring water sub-basins.⁴ Till 1994, the drinking water supply has been continually improved as hundreds of wells were drilled in the south-western tables in particular (www.mree.dz). Groundwater was generally used for the drinking water supply (domestic use) up to 70%. However, it is no longer the case as Algiers experienced a dramatic decline in rainfall in 2001 and as a result, the Government implemented an emergency program «Algiers Supply Security» (ASS) in order to fill extremely urgent water needs.

The ASS program consisted in three processes. The first was to transfer from nearby dams' water up to 150,000m³/day, the second was to mobilize non-conventional resources and the third was to launch the «Plan Orsec-sécheresse». Unconventional water resources were mainly obtained from sea water desalination and supposed to cover about 5% of Algiers water needs during the emergency crisis. The «Plan-Orsec-sécheresse» is automatically implemented in times of shortage as like the study time interval (1999–2002) giving priority to the water drinking supply that could be scheduled one day out of three if necessary.⁵

2.2. Assessing Method

This paper focuses on the water supply efficiency as being the demand satisfaction primarily while distinguishing the global demand from the domestic demand. The main objective of this work is to assess the water demand satisfaction rate and compare it with a couple of indicators characterizing the urban setting. The method is based on data collection techniques as well as literature review and interviews with representatives from the Government Agency Algérienne des Eaux (ADE) which is in charge of the public water delivery services and the Ministry of Water Resources.⁶

Quantitative data related to water demand and consumption is drawn from the Ministry of water resources and the ADE respectively. The data covers four years from 1999 to 2002 (Table 4-1). That period is ultimately more relevant to study since water services were still managed by the Government Agency.⁷ Furthermore, Algiers had faced a major water shortage crisis during this period that resulted in the establishment of the emergency supply program. Therefore Algiers' specific items have been captured from the urban master plan and official social-economic statistics from that time interval.

The study considers two demographic parameters:

- the population size (indicator I.1),
- the demographic growth rate (indicator I.2)

two urban parameters:

- the urban density (indicator I.3),
- the location from the centre (indicator I.4)

and two technical parameters:

- the networking rate (indicator I.5),
- the water infrastructure capacity (indicator I.6).



Figure 4-3 Algiers water supply perimeters (after ADE)

Parameter	Indicator	Municipality level	Supply perimeter level
Demographic	1	Population (2003)	Quantitative (No of inhab in 2003) Calculated sum
	2	Demographic growth level	Qualitative transformed into quantitative value : Negative (-1), Low to null (0), Medium to high (1), High to very high (2) Calculated average
Urban	3	Urban density	Quantitative (inhab/ha) Calculated average
	4	Urban growth step	City Centre (C), First periphery (P1), Second periphery (P2) After the location
Technical	5	Networking rate	Quantitative : %/municipality Calculated average
	6	Water infrastructure capacities	Transfer capacity (T) Storage capacity (S) Distribution capacity (D) After the location

Table 4-1 Calculation of SP indicators

SP	Nb of municipalities	Population (2003)	Net-working rate (%)	Domestic consumption (l/inhab/day)				Total consumption (l/inhab/day)			
				1999	2000	2001	2002	1999	2000	2001	2002
1-Rouiba	6	217665	86	51,01	50,52	40,60	39,97	51,67	67,71	58,37	57,37
2-Dar El Beda	3	260544	87	50,10	46,96	39,71	41,37	60,38	62,54	51,86	56,43
3-Alger-Est	5	329214	86	57,81	50,76	48,10	42,72	91,91	91,14	80,90	87,27
4-G. de Constantine	3	271775	95	57,20	54,62	50,64	39,51	67,55	66,57	60,72	47,45
5-Alger-Sud	3	201558	96	59,08	57,83	53,93	42,21	86,22	86,43	75,96	61,54
6-Alger-Centre	4	322957	100	42,00	40,67	33,42	29,40	75,66	75,50	57,24	55,69
7-Alger-Nord	6	299508	98	43,58	41,82	42,94	35,65	65,74	61,65	61,07	48,32
8-Alger-Ouest	9	336074	92	74,88	73,10	61,72	55,23	104,15	103,72	88,13	77,81
9-Cheraga	8	253432	81	54,65	49,60	47,44	53,18	97,62	86,50	86,27	87,88
10-Zeralda	6	158478	82	44,80	49,70	39,11	22,57	107,29	93,70	96,22	81,67
$\Sigma = 53$		$\Sigma = 2651205$	City average =90	53,51	50,96	45,76	40,18	81,40	78,82	68,82	64,23

Table 4-2 SP water consumption (After ADE)

SP	Demographic indicators		Urban indicators		Technical indicators	
	I.1 (Population)	I.2 (Dem. Growth trend)	I.3 (location)	I.4 (inhab/ha)	I.5 (Networking %)	I.6 (lowest capacities)
1-Rouiba	21765	0,5	P 1	25,61	86	T - S
2-Dar El Beda	260544	1,5	C - P 2	22,97	87	-
3-Alger-Est	329214	0,5	P 2	41,90	86	T
4-G. de Constantine	271775	1,0	C- P 1	200,03	95	T
5-Alger-Sud	201558	0,0	C	149,76	96	-
6-Alger-Centre	322957	-1,0	C	319,05	100	-
7-Alger-Nord	299508	0,5	C	313,05	98	-
8-Alger-Ouest	336074	0,5	P 1 - 2	81,37	92	T-S
9-Cheraga	253432	1,5	P 2	18,80	81	T-D
10-Zeralda	158478	0,5	P 2	10,61	82	T

Table 4-3 SP characterizing indicators

analysis is developed at the urban supply perimeter (SP) level. As per Algiers there are ten urban SPs including 53 municipalities amongst 57 since four municipalities do self-manage their local water services.⁸

The paper refers to the water demand as determined by the Ministry of Water Resources according to the population size on the one hand and the water consumption volume as billed by the ADE on the other hand.⁹ Then some data needs to be calculated as noticed on Table 4-1.

Table 4-1 lists the considered parameters (demographic, urban, technical) with related qualitative and quantitative indicators at the municipality level in addition to the calculation method for designating the corresponding SPs' values.

The global volume consumed is fragmented so that the domestic use (l/inhab/day) is distinguished from other uses (irrigation, industry, administration).

As shown on Figure 4-3, each supply perimeter does incorporate from 3 to 9 municipalities with variable population and urban densities.

Table 4-2 lists SPs with corresponding number of municipalities, population in 2003 and the networking rate (%) compared with the total water consumption (l/inhab/day) and the domestic water consumption (l/inhab/day).

Likewise, the largest and most populated SPs are located in the first and second periphery. Table 4-3 compares demographic, urban and technical indicators at the SP level.

The data provided designate the critical water context during the study time period as the global volume of consumption continually declined in parallel with the water production as shown in Figure 4-3. However, Figure 4-4 shows that the emergency supply program launched in 2001, seems to have slowed down – but not restored completely – the consumption level whereas the number of subscribers has remained comparatively stable (about 300000 during the study time period after the ADE).¹⁰

After ADE, some municipalities were irregularly supplied owing to the lack of either transfer, storage or distribution local capacities. The lack of transfer capacities has been more significant in the western and south-western regions, while the lack of storage capacities has been more significant in the eastern and southern regions. However, after the ADE the gap was going to be filled shortly.

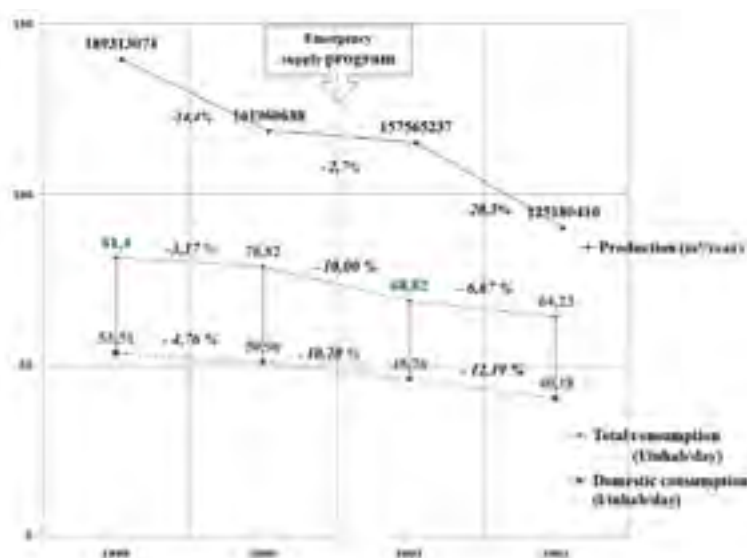


Figure 4-4 Evolution of water consumption 1999-2002 (After ADE)

The average water consumption in each SP is appreciated against the city average (9) during the study time period (See Table 4-2). Accordingly, three groups could be distinguished:

- SP with global volume of consumption below the city average: SP 1 – 2 – 4 – 7.
- SP with global volume of consumption roughly equivalent to the city average: SP 5 – 6.
- SP with global volume of consumption beyond the city average: SP 3- 8- 9- 10.

The notable difference between the global volume of consumption and the domestic consumption can be attributed to the priority order and additional housing projects which created some new water consumption hubs. In addition, ADE considers the volume consumed as billed to formal subscribers only. Within informal settlements, the population generally connected illegally. Their consumption is neither counted nor paid.¹¹ That water volume being distributed but not counted would be considered as economically lost.

03

Results and Discussion

3.1. Total water consumption vs water demand

As shown on Table 4-4 and shown in Figure 4-5, the total water demand is calculated after the official standard fixed by the Ministry of Water Resources. It designates an average demand at the SP level during the study interval (1999-2002). Table 4-4 compares the water consumption against the water demand and resulted gap between them.

SP	Water consumption average (l/inhab/day)	Water demand average (l/inhab/day)	Gap between the water consumption and the water emand(%)
1-Rouiba	67,94	128,93	-47,30
2-Dar El Beida	57,80	162,20	-64,36
3-Alger-Est	87,80	160,37	-45,25
4-G. de Constantine	60,57	179,75	-66,30
5-Alger-Sud	77,53	199,33	-61,10
6-Alger-Centre	66,02	207,00	-68,10
7-Alger-Nord	59,20	195,50	-69,72
8-Alger-Ouest	93,45	184,00	-49,21
9-Cheraga	89,56	107,23	-16,48
10-Zeralda	94,72	107,69	-12,04
City average	73,31	163,20	-55,08

Table 4-4 SP Water demand (after the Ministry of Water Resources standard)

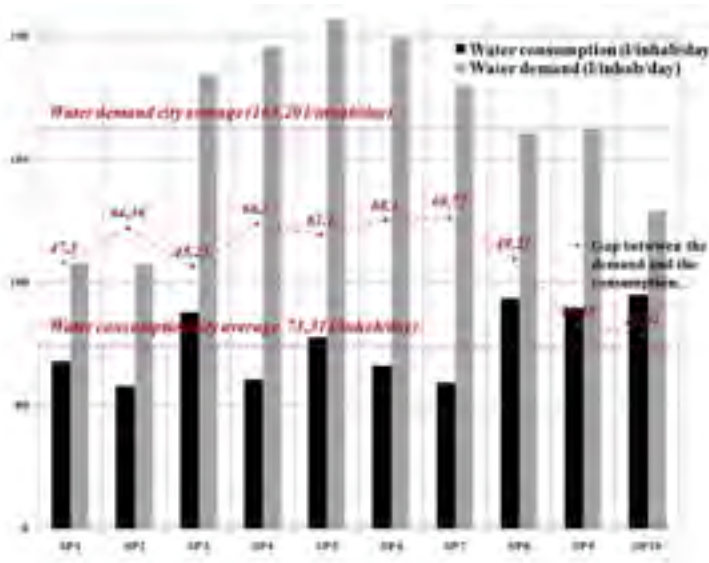


Figure 4-5 Water consumption vs water demand

The water consumption overall represents less than half of the demand. The gap between demand and consumption varies from one SP to another. The worst situation is observed in SP 7 (-69,72%), whilst the best is observed in SP 10 (-12,04%) relatively. SP 2, 4, 5, 6, and 7 suffer from a wide gap between demand and consumption (beyond the city average), whilst SP 1, 3, 8, 9 and 10 suffer from a gap roughly near or below the city average.

When compared against SPs' related indicators, the water consumption shows further variability as follows (Table 4-4, Figure 4-6):

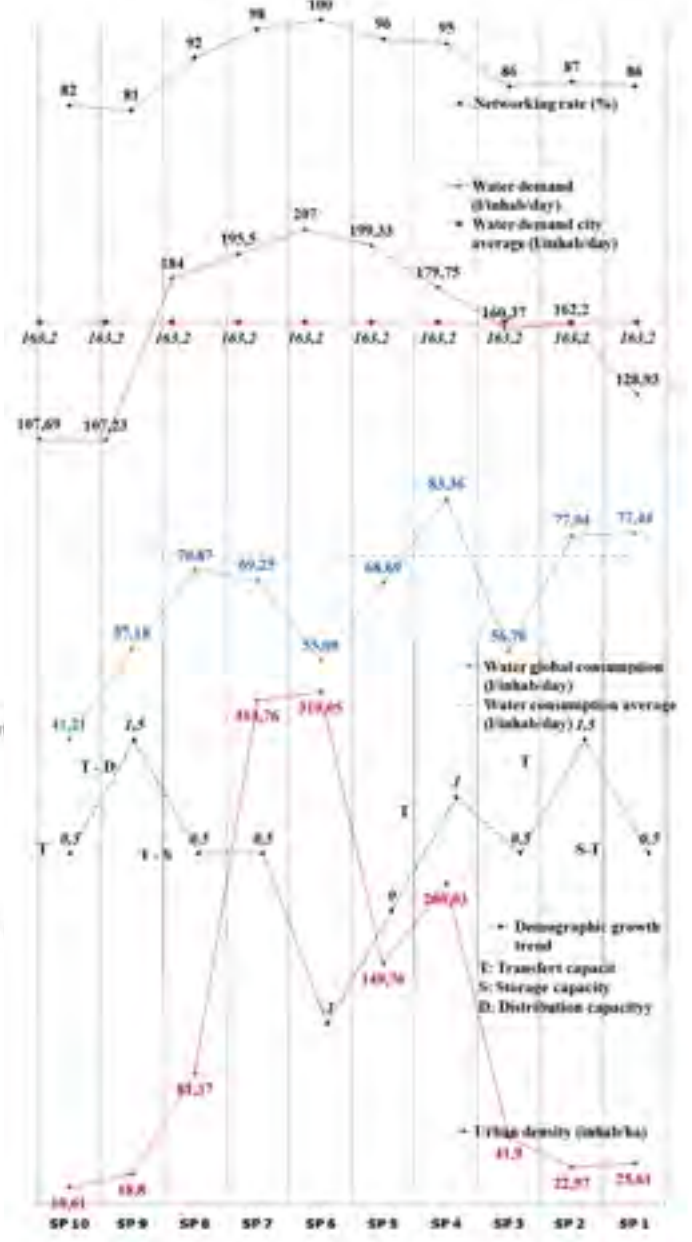


Figure 4-6 Variability of the total water consumption vs SPs' related indicators

Demographic indicators: Water consumption is compared to the population size (I.1) and the demographic growth trends (I.2). It could be noticed that SPs with water consumption below the city average (1, 2, 4 and 7) are moderately populated comparatively and do register either very high or negative demographic growth.

Urban indicators: Water consumption is compared to the urban density (I.3) and the location from the city centre (I.4). Water consumption is below the city average in SPs with either low or high urban density. Except for SP 6 and 7 that are partly located in the centre, this group is located in the first and the second periphery.

Technical indicators: Water consumption is compared to the networking rate (I.5) and the water infrastructure capacities (I.6). Water consumption is below the city average in SPs with either suitable or low transfer/storage/distribution capacities.

Table 4-4 and Figure 4-6 show that when considered individually, indicators characterizing the SP's context would not bear clear evidence of any direct relationship with the water consumption level. The following paragraph shows that it is no more the case when they are cumulated.

3.2. Water Demand Vs Water Demand Satisfaction Rate

The comparative analysis shows a regular reduction of water consumption in addition to an increasing gap between the demand and the production during the study time period (10). The standard water allocation as fixed by the Ministry of Water Resources (150l/inhab/day) was not satisfied in any SP. Table 4-5 compares the water demand against the water consumption average and gives resulted satisfaction rate at the SP level as follows:

SP	Water consumption average (l/inhab/day)	Water demand average (l/inhab/day)	Water demand satisfaction (%)
1-Rouiba	67,94	128,93	52,70
2-Dar El Beida	57,80	162,20	35,63
3-Alger-Est	87,80	160,37	54,75
4-G. de Constantine	60,57	179,75	33,70
5-Alger-Sud	77,53	199,33	38,90
6-Alger-Centre	66,02	207,00	31,90
7-Alger-Nord	59,20	195,50	30,28
8-Alger-Ouest	93,45	184,00	50,80
9-Cheraga	89,56	107,23	83,52
10-Zeralda	94,72	107,69	87,95
City average	73,31	163,20	50,01

Table 4-5 SP Water demand fulfillment

As shown in Figure 4-7, three groups could be distinguished:

- SP with demand satisfaction rate below the city average: SP 2, 4, 5, 6, 7.
- SP with demand satisfaction rate near the city average: SP 1, 3, 8.
- SP with demand satisfaction rate beyond the city average: SP 9, 10.

That result confirms the official information provided by the Ministry of Water Resources and ADE as:

- The total surface water resources (300,000m³/day) and groundwater resources (282,000m³/day) mobilized → Σ= 582,000m³/day
- The total water demand 600,000m³/day,
- The evaporation losses (about 15%) + Pipelines' leakages (about 40%) → Σ= 45%

Hence the available resources should be approximately:

55% of 582,000m³/day = 320,100m³/day ~ half the water demand volume.

Despite the global dissatisfaction of the water demand, the satisfaction rate seems to vary depending on the SP location: within central SPs (more aging municipalities: 2 partly, 4, 5, 6 and 7), water demand is almost satisfied at one-third. Within SPs located in the first periphery with medium to notable demographic growth, the demand is satisfied at 50%. Whilst SPs located in the second less populated periphery, more than 50% of the demand has been fulfilled.

Figure 4-8 gives more clarification about the singularity of indicator I.4 as compared with water consumption, water demand and the water demand satisfaction rate against the city average.

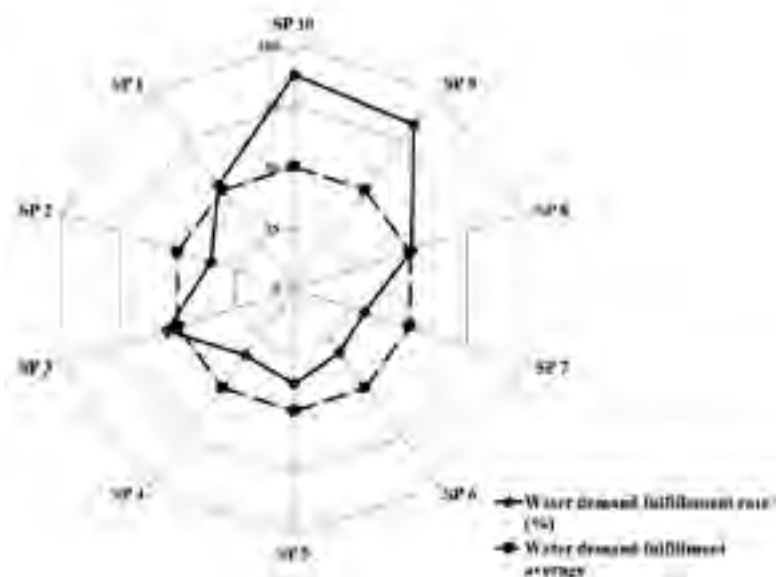


Figure 4-7 SP demand vs water consumption

3.3. Water Demand Satisfaction Rate Vs. Urban Growth Pattern

Results show that the water demand average satisfaction rate is approximately 50%. However, three groups of SP stand out in relation to the city average. They describe three urban growth steps and three urban design patterns as follows and shown in Figure 4-9:

First, SP 9 and 10 located south-western city, have recently urbanized. They constitute the second periphery with a residential predominant activity (if formal or informal) in addition to a notable administrative activity. The water satisfaction rate is beyond the city average. However, the high rate of demographic growth does augur of a larger gap between water demand and water consumption in addition to the aggravation of the contamination risk. That would propel them into Step 2.

Second, SP 1, 3, and 8 located western, eastern and east-southern city experienced urbanization earlier than the SPs in the first periphery. They include numerous dense housing districts (if collective or individual). The satisfaction rate is near the city average. The high to medium demographic growth rate does augur of an eminent urban saturation of some municipalities in addition to the aggravation of water related risks (pollution, flood, and landslide). That would propel them into Step 3.

Third, SP 2, 4, 5, 6 and 7 located northern city can be described as the historical centre (individual housing) and districts dating from the French colonial era (collective housing) with mixed activities even if the residential activity remains predominant. The water satisfaction rate is beyond the city average. The demographic growth is almost negative or null (historical urban districts). The water related risks are critical locally.

With regard to the local context during the study time period, water demand satisfaction seems to mainly depend on water resources production and water infrastructure capacities. The situation is likely to be more critical as per the demographic trends and subsequent urban growth that is expected in some municipalities. Shortly, each SP is at risk if demand increases. Thus, existing or ongoing urban overcrowding will likely increase the gap between demand and consumption and aggravate water related risks.

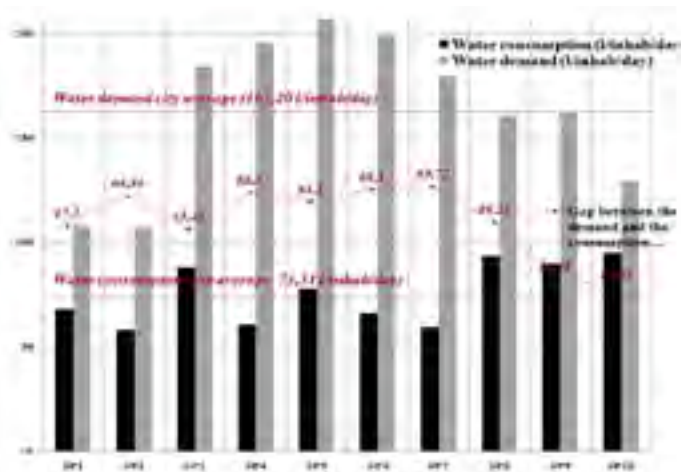


Figure 4-8 SP water consumption, water demand and water demand satisfaction rate

It can be noticed that SP 2, 4, 5, 6 and 7 which have low demand satisfaction rates include most populated municipalities. They register high demographic growth rates and/or high urban densities. These municipalities are located in the centre integrating most aging districts having aged water system.

SP 1, 3 and 8 have demand satisfaction rates of approximately 50% and include municipalities suffering from low transfer and storage capacities whilst SP 9 and 10 register lowest demand and subsequently best consumption level and demand satisfaction rates.

Based on these results, it could be argued that the location from the city centre (1.6) becomes significant because of implicitly designating the population size, the growth trend and the urban density. Namely, central SPs seem to have a disadvantage with regard to low or inappropriate water facilities (technical parameters) that closely depend on the urban growth pattern (building design and density) and overpopulation (high demographic growth trend).



Figure 4-9 The water demand satisfaction spatial distribution through the city

04

Conclusion

This study aims to better understand the relationship between urban growth patterns and water delivery efficiencies based on the assessment of the water demand satisfaction rate. It has distinguished various urban areas following a set of demographics, spatial and technical parameters compared with the city average. It has considered a critical time period (four years) as per the water supply conditions and means.

As a result, this paper concludes on three preliminary results related to the methodology, the case study and future prospects.

First, as per the methodology: this research has focused on the relationship between urban growth patterns and water supply efficiency in a specific climate and socio-economic context. The study established an original method that aims to provide a better understanding on how they interact. The method has been developed in three steps: (1) was to compare the water consumption of different users in order to appreciate the domestic consumption against the total consumption, (2) was to assess the water demand satisfaction rate comparing water demand against water consumption and (3) was to compare the water demand satisfaction rate with a couple of indicators characterizing the urban setting.

Actually, the results would have been more relevant and action-oriented if they have invested longer time interval and smallest spatial areas considering biophysiology items and land use patterns in more detail (incl. architectural features). Thus, the method would have rather provided more reliable and homogeneous data. Furthermore, in situ surveys would have been notably useful for capturing the population behaviour dealing with water issues within formal and informal districts.

Second, as per the case study: Results show that no indicator characterizing the urban setting would alone be able to describe the local water context. Yet water supply efficiency strongly depends on water resources availability and the demand level as well as on the urban growth pattern that might aggravate if not engender water related risks. Moreover, after ADE, the water infrastructure capacity has not been developed in parallel with the urban growth and thus does call for perpetual urgent upgrading actions. Indeed, Algiers has expanded faster than its water facilities neglecting local hydro-dynamic processes and global water cycle features (Aroua, 2005).

Actually, the water supply deficiency is tied up both to natural and anthropogenic causes. The rainfall deficit did naturally reduce the water potential. Likewise, aging and damaged infrastructure have left nearly half the distributed volume.

Thus, it has been necessary to mobilize more than twice the volume needed in order to satisfy the demand in addition to the production of unconventional water resources (After the Ministry of Water Resources).

Third, as per future prospects: Urban water systems could not be extended indefinitely but urban growth patterns should be reviewed and better adapted to the natural environment and hydrological systems in particular. The urban water cycle should be considered as a circular process so that it could be incorporated to the global water cycle with lowest possible risk of contamination and disturbance. Since then any urban sustainable development strategy should consider water issues at two main parallel levels. At the local level, it has to consider the environment threshold and based on preliminary impact studies. At the global level, it has to harmonize the distribution of the population and urban settlements as well as main socioeconomic activities across the water basin and even more the bioregion. Additionally, future perspectives would be to adapt the urban planning/design to the local hydrosystem features investing the urban water metabolism approach (Serrao-Neumann et al., 2017).

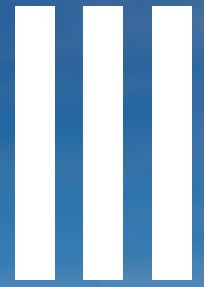
References

- Algérienne des Eaux. (ADE).
- Agence Nationale d'Aménagement du Territoire. (ANAT). (1989). *Schéma d'aménagement régional, Région centre*, Phase 2.
- Aroua, N. (2005). *Les ressources en eau dans le processus de planification urbaine durable, Cas de l'agglomération d'Alger*, Ecole Polytechnique d'Architecture et d'Urbanisme d'Alger, Mémoire de Magister, 184p+ Annexes.
- _____. (2011). *The hydrometeorological risks within urban area*, *Revue du Nord*, Collection Art et Archéologie, Hors Série n°15, Sept. 2011, <http://rdn.revue.univ-lille3.fr>.
- _____. (2017). *Incorporating climate prescriptions into urban projects. Euromed II - Marseille case sud*, (submitted).
- Bruce, M. (2005). *Integrated water resources management, institutional arrangements and land use planning*. *Environment and Planning A*, 37(8), pp. 1335-1352.
- Deluze, J. (1988). *L'architecture et l'urbanisme d'Alger. Aperçu critique*. Ed. OPU-Mardaga.
- Forman, R. (2014). *Urban ecology: Science for the cities*, Cambridge University Press.
- Ingegard, E. (2000). *The use of climate knowledge in urban planning*. *Landscape and urban Planning*, 48, (1), pp. 31-44.
- Marzluff, J., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., ZumBrunnen, C. & Simon, U. (Eds.). (2008). *Urban Ecology, An International Perspective on the Interaction Between Humans and Nature*. ISBN: 978-0-387-73412-5.
- Serrao-Neumann, S., Renouf, M., Kenway, S. & Low Choy, D. (2017). *Connecting land-use and water planning: Prospects for an urban water metabolims approach*, *Cities*, 60, pp. 13-27.
- Wamsler, C., Brink, E. & Rivera, C. (2013). *Planning for climate change in urban areas : from theory to practice*, *Journal of Cleaner Production* n°50, pp. 68-81.

Notes

1. The Global Water Partnership defines IWRM objectives as being social equity, economic efficiency and ecological sustainability (www.gwp.org).
2. The successive urban master schemes vainly recommended the protection of surrounding fertile lands but the urban sprawl has progressively phagocyte the plain (Aroua, 2011).
3. The water service was supposed to be more improved later on in partnership with the Société des eaux de Marseille.
4. Algiers is a historical city dating from the Xth century developed all around the harbour. It becomes the Capital of a developing country from the modern era (starting from the XVIth century). Its location along the bay does naturally promote trades and food supply mainly from the surrounding hinterland and neighbouring provinces.
5. By the end of 1998, the water supply network had been rehabilitated and extended to western municipalities recently densified or settled. Per consequent, at that time Algiers' water supply network was 2,700km long with almost 82% connection rate average.
6. The local government agency *Algérienne des Eaux* (ADE) used to manage the water service till 2006.
7. From 2006, the water service is managed by the private society *Société des eaux et de l'assainissement d'Alger* (SEEAL) based on an agreement contract between the Ministry of Water Resources (Algeria) and the Société des eaux de Marseille (France).
8. For ease lecture of the text, «Algiers» and «the city» designate 53 municipalities regrouped into SPs.
9. Referring to the Ministry of Water Resources, the water demand does vary following the demographic size of the municipality between 85l/inhab/day (< 10,000 inhab), 100 l/inhab/day (10 to 20,000 inhab), 160 l/inhab/day (20 to 50,000 inhab) and 180 l/inhab/day (50 to 100,000 inhab). The national standard water allocation is 150 l/inhab/day.
10. The water production has decreased from 189,313,074m³/year in 1999 to 125,180,410m³/year in 2002 (ADE, 2003).
11. That is no more the case in Algiers since the private society *Société des eaux et de l'assainissement d'Alger* (SEEAL) managing water service in Algiers from 2006, did launch a new program «Quartiers en Développement» in order to progressively remedy. It did succeed in increasing subscribers by thousands from informal and precarious districts. www.seaal.dz.





Water Security and Environment





5

Building Water Security through Drinking Water Protection Planning with Indigenous Communities in Canada

Robert J. Patrick

Robert J. Patrick, Department of Geography and Planning & Global Institute for Water Security, University of Saskatchewan.
e-mail: Robert.patrick@usask.ca

Abstract

Water security, measured by access to safe drinking water and sanitation (United Nations Sustainable Development Goal #6), is something that most Canadians take for granted. However, Indigenous communities in Canada continue to experience frequent and often long-lasting boil water advisories, unreliable drinking water service and inadequate sanitation infrastructure - all expressions of water insecurity. This paper reports the outcome of six innovative water planning initiatives that aim to improve access to safe drinking water within Indigenous communities in Canada. While these planning initiatives help to identify conditions contributing to water insecurity, as well as specific remediation measures, these planning initiatives also reveal Indigenous traditional knowledge relating to water. This knowledge, or water relationship, includes the healing and medicinal properties of water, the importance of women as 'water-keepers' as well as the spiritual relationship with water long-held by indigenous people. These water relationships help broaden the current water security discourse to reveal a more nuanced conceptualization of water security beyond water quality and quantity. In Canada, the term Indigenous People refers to First Nations, Métis and Inuit Peoples. Only First Nation communities are included in this study.

Keywords

Canada, First Nations, drinking water protection plans, water security, Indigenous planning

01

Introduction

Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself. It is vital for reducing the global burden of disease and improving the health, welfare and productivity of populations (UN Water for Life).

Clean water and sanitation is the focus of Sustainable Development Goal #6 (UNDP, 2016). Specific targets identified under Goal #6 include improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing water recycling and safe reuse globally by 2030. At the global scale, progress toward this target is showing positive results. Global scale reporting provides helpful insight of progress toward, or away from, global targets for sustainability. However, global scale statistics often do not always reflect conditions at the regional and local scale. The extent to which This water is safe to drink and readily available is variable, unpredictable and dependent on many factors including local political and economic factors as well as local governance structures (Wutich et al., 2017; Cook & Bakker, 2012). This is true not only in the developing world but also in the more developed world (Arsenault et al., 2018; Patrick, 2011). Arguably, nowhere is this more pronounced than in Canada where there is a disproportionate number of Indigenous communities affected by poor water quality (Arsenault et al., 2018; Collins et al., 2017).

In a nation-wide survey of water and wastewater conditions in Indigenous communities in Canada, Neegan and Burnside (2011) recorded 30% of First Nation water systems to be classified as high risk systems. More recently, 134 water systems in 85 Indigenous communities across Canada were reported to be under a boil water advisory (Arsenault et al., 2018). This statistic represents approximately one-in-five communities on a boil water advisory at any one time. Global scale reporting does not always capture uneven access to water and sanitation services experienced nationally and regionally. What is most often captured by global scale reporting is that Canada ranks among the global elites with respect to human development index (HDI) scoring of 9.20 out of 10 (2015) and showing a consistent upward trend since 1990 (8.49) placing Canada in the top 10 of all 188 ranked countries. In addition, the World Health Organization reports that almost 100 percent of Canada's population has improved

facilities for drinking water and sanitation, indicating a high degree of water security. However, on the sub-national scale, these statistics yield a false representation of local conditions experienced by Indigenous people. Indigenous people in Canada include First Nations, Inuit and Metis. For the purpose of this paper, the focus will be on First Nations people and their communities in the Canadian Prairie Region spanning the Canadian Provincial Provinces of Alberta and Saskatchewan.

This paper will report the findings from case study research to outline the 'First Nations water problem'. The research is based on a series of six source water protection plans (SWP plans) conducted with First Nation communities in the Canadian prairie region. The planning process identified many causal factors contributing to the water problem.

However, the planning process also brought together community and non-community members, provided space for information exchange, facilitated relationship building and encouraged traditional water knowledge sharing between and among participants. While the results of the SWP plans illustrate what might be interpreted as a lack of water security, or water (in)security, the ancillary output of these plans illustrate community engagement in plan-making, water knowledge sharing, respectful relationships and community empowerment through land use planning. In combination, these ancillary outputs point to what Jepson et al. (2017) refer to as "human capabilities and a relational approach". In short, the ability of a community to engage in plan-making with numerous partners requires both human organization and capability as well as relationship-building based on trust and reciprocity. It is argued in this paper that water security ought to be measured not only by material access to water and sanitation as noted by Jepson et al. (2017) but also by a community's relationship with water.

In the face of inadequate infrastructure stemming from colonial practices and paternalism of the federal government (Hanrahan, 2017) Indigenous People in Canada have maintained a spiritual connection with water based on inter-generational knowledge sharing (Arsenault et al., 2018; Hanrahan, 2017; Blackstock, 2001). This paper argues that water security ought to be measured, at least in part, by the degree to which respectful relationships exist between and among humans and the natural world. The outcome of this paper, in part, answers the call for a more nuanced perspective on water security that goes beyond water quality and availability (Wutich & Ragsdale, 2008).

“Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself. It is vital for reducing the global burden of disease and improving the health, welfare and productivity of populations.”

02

Pursuing water security

Water security is presented in mainstream academic literature as a multi-faceted concept embracing water availability, flood hazard avoidance, environmental governance as well as health and sanitation (Lall et al., 2017). Arguably, water security is a key determinant of human development and personal well-being. In the absence of water security human health may become jeopardized and community health placed at risk (O'Connor, 2002). Ultimately, the degree to which individuals and communities experience water security will determine the potential for human development and personal well-being (Wutich & Ragsdale, 2008).

Recent literature presents a more nuanced, critical approach to water security that explores less about obtaining water, and more about sustainable and just hydro-social processes in support of human capabilities (Jepson et al., 2017). This approach is less concerned with the mechanics of water provision but more with the hydro-social condition that fosters community development, respectful relationships, human dignity and healthy social relations. This paper seeks to extend this critical approach to water security through an examination of six cases of SWP processes with Indigenous communities in Canada. These six communities are all First Nations.

03

Context and background

In Canada, one-in-five of the 700 Indigenous communities are on a boil water advisory at any time, with many advisories lasting decades (Arsenault et al., 2018). Approximately 30% of Indigenous community water systems are classified as high risk systems. Boil water advisories are 2.5 times more frequent for First Nation communities than for non-First Nation communities (Patrick, 2011; Eggerton, 2006). In addition, approximately 30% of First Nation water systems in Canada are classified as high risk systems and the number of water-borne infections in First Nations communities is an alarming 26 times higher than the Canadian national average (Patrick, 2011; Eggerton, 2008). While these alarming statistics are frequently reported in the literature, much less reported are the causes of these contamination events. To trace the origin of these events requires some reflection on the impacts of colonialism at the community level.

In Canada, the colonization process that began in the mid-1800s became institutionalized through the federal government's "Indian Act of 1876" (TRC-Canada, 2015). The Indian Act (Government of Canada, 1985) set out to control all aspects of Indigenous people's lives including, but not limited to, the creation of "lands reserved for the Indians", or "Indian Reservations". For the federal government to promote permanency on the "Indian Reservations" a housing program was required. The poor quality of housing was equally matched with insufficient supply of housing, a condition leading to overcrowding measured by multiple families living under one roof with subsequent human health problems. For example, rates of tuberculosis in the First Nation population remain 20-30 times higher than Canadian born, non-First Nation rates. Tuberculosis has long been linked to overcrowded housing, poor air circulation, and lack of sanitation. Today, First Nation housing in Canada continues to be developed ahead of critical infrastructure such as properly constructed landfills, community water distribution systems, and community sewer and drainage systems. The legacy of poor planning practice is visible today by the absence of piped water and wastewater services in many First Nation communities. For example, the common method of water distribution in First Nations is 'trucked' water. Trucked water is filled at a water treatment facility and then delivered, house by house, to in-ground household water cisterns. Cisterns are aging, damaged by time and neglect, and often contaminated by surface water infiltration (Patrick, 2018; Bradford et al., 2016).

On the wastewater side, the absence of adequate infrastructure planning means that for many homes a 'shoot-out' pipe transfers raw sewage into a backyard area (Patrick et al., 2017). In other instances, a 'pumper truck' hauls sewage from a household septic tank to a community sewage lagoon. These sewage lagoons, many still in operation today, are not

lined with an impermeable barrier and therefore groundwater seepage is an ongoing problem. The federal government authorized and funded landfill development practices wherein large open pits were excavated to receive all forms of solid waste material. These open pits are unregulated, and worse, unlined, allowing contaminants to seep into the groundwater and surface waters. The majority of prairie First Nations source their drinking water from groundwater supplies.

The Indian Act (Government of Canada, 1985) and specifically the ‘Indian’ reservation system, served to disconnect Indigenous people from access to land and healthy water thereby imposing a condition of ‘institutionalized’ water (in)security. The human health impacts of the federal government’s drinking water provision for First Nation in Canada – a system rife with technical and design system flaws which, in combination with fragmented federal and provincial governance structures, continues to produce often deplorable water quality conditions for First Nations. The primary causal factor of poor water and sanitation infrastructure is the legacy of colonization wherein the federal government sought to disconnect Indigenous people from their land, water, and culture in the name of assimilation.

And yet, in spite of these and other human injustices imposed on Canada’s indigenous Peoples, First Nations continue to thrive and adapt under these technical, institutional and cultural challenges. The means by which First Nations have been able to adapt and thrive is a display of human resilience, identity, and connection to the land and water. In this paper, it is these human qualities and community relationships that will be woven into the evolving definition of water security.

In the section that follows, a planning process known as source water protection (SWP) will be introduced. This approach involves the active engagement of community members in a deliberate planning process aimed at the protection of drinking water sources. To date, a number of SWP plans have been developed and implemented with First Nation communities across the Prairie region.

04

Research method

Source water is untreated water from either groundwater or surface water sources that supplies drinking water for human consumption. SWP is a vital first step in the protection of water supplies, often referred to as the first step in the multi-barrier approach to safe drinking water (CCME, 2004).

The multi-barrier approach (MBA) to clean drinking water is “an integrated system of procedures, processes and tools that collectively prevent or reduce the contamination of drinking water from source to tap in order to reduce risks to public health” (CCME, 2004). The goal of the MBA in drinking water

management is to reduce the risk of drinking water contamination through the presence of system redundancies, or barriers, built into the water system. CCME (2004) described three main components in the MBA beginning with protecting the source of water from the threat of contamination. The second barrier is the treatment of drinking water through various methods including chlorination, filtration, as well as other chemical and mechanical treatments. The third barrier is maintenance, monitoring and testing of the water distribution system.

SWP planning offers a means of addressing land management problems in order to protect drinking water quality (Patrick, 2014). Through SWP planning we see opportunity to not only ‘reclaim’ Indigenous planning (Matunga, 2013) but also to enrich and broaden the definition of water security.

“The goal of the MBA in drinking water management is to reduce the risk of drinking water contamination through the presence of system redundancies, or barriers, built into the water system.”

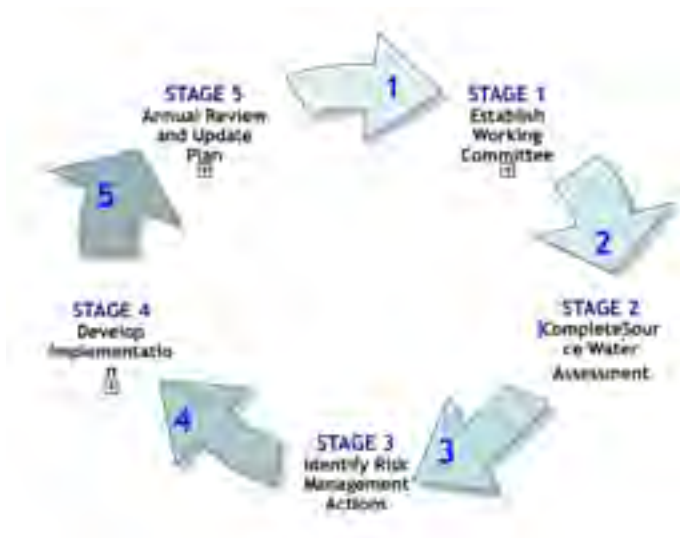


Figure 5-1 Source Water Protection Planning Framework (Government of Canada, 2014)

The SWP planning process used in the six study areas adopted a five-stage SWP planning framework (Government of Canada, 2014). This planning framework represents a structured, rational planning approach for the specific purpose of assisting First Nations with drinking-water protection (See Figure 5-1). The following is a description of the planning framework.

4.1 Establish Working Committee (Stage 1)

The first stage of the plan-making process involved creation of a working committee made up of key actors from the community. The purpose of the working committee is to elucidate local knowledge of local water conditions generally including, but not limited to, local drainage, drinking water quality, water quantity, wastewater management, and natural and human induced threats to local water sources. Using the planning framework (See Figure 5-1) the working committee is tasked with overseeing development of the plan in collaboration with community members, provincial health officials and other trusted individuals with local knowledge of past and present land uses and hydrological conditions. The community members include Elders, elected councillors, water treatment plant operators, as well as representatives from key departments of the First Nation including community health, education, and lands management departments.

A consensus-based approach to decision making is employed for the plan-making process. This approach encourages open communication to build cooperation and trust between all working committee members. Meetings are held in the community following traditional protocols including an opening and closing prayer, shared meals, respect for Elders and other traditional protocols.

4.2 Source Water Assessment (Stage 2)

The second stage of the SWP planning framework involves completion of a source water assessment of the local community water system and water supply area. The assessment for each community includes the collection of information relating to the source of water, location of the water intake, type of water treatment and distribution system, extent of service area, number of residential units and other commercial and institutional users served by the water system.

Following the description of the water system, an inventory of potential contaminant sources is undertaken. Using local knowledge, the working committee develop an inventory of all known, or perceived, land uses and activities with potential

“A consensus-based approach encourages open communication to build cooperation and trust between all working committee members.”

to degrade water quality. This inventory includes all human-generated sources (point source and non-point source) as well as natural sources (erosion, turbidity).

The final component of the source water assessment is a risk assessment of known and perceived threats to the water source. We define risk as the likelihood of an occurrence multiplied by the potential impact of the occurrence. Both the likelihood and impact of occurrence range in numeric value from 1 (most unlikely and insignificant, respectively) to 5 (almost certain and catastrophic, respectively). The likelihood of an occurrence may be low (train derailment), but the impact of such an occurrence very high (long term groundwater contamination). This process generated healthy discussion, but almost always

clear consensus. It is important to not that risk values are merely relative values and are not intended to reflect an accurate measurement of risk. What the values do provide is a means of ranking one threat as higher or lower than another threat. The purpose of the risk ranking is to allow a score to be attached to each threat. This is helpful in Stage 3 where the identified risks become prioritized leading to the identification of management actions.

4.3 Identify risk management actions (Stage 3)

Upon completion of the risk ranking (Stage 2), the working committee will focus attention on the many different management action to address identified potential risks to source water. Management actions are selected with the purpose to reduce, or eliminate, identified risks to source water. For most risks, a single management action is not sufficient. Local knowledge and experiences of the working committee is critical in this phase.

Management actions may take one of two forms: Structural or non-structural. Structural management actions include land alteration and build infrastructure while non-structural include communication and education. A blend of these types provides the greatest reach in terms of management action effectiveness. Again, the breadth of knowledge and experience held by members of the working committee will contribute to creative, yet effective, management actions to reduce risk to source water. Consensus on a set of management actions is a goal for the working committee.

4.4. Develop an implementation strategy (Stage 4)

Following the identification of the necessary management actions for each noted risk the working committee next develops an implementation strategy. Developing an implementation strategy requires timelines for tackling management actions as well as the identification of

partnerships to get things done. Implementation is critical to plan-making and the defining factor of success for any plan. Working committee members put in long hours discussing details of the plan. Implementation allows the working committee to see the results of their efforts and to celebrate early success of the planning process.

The second critical aspect of developing an implementation strategy is the identification of key partners to assist with each management action. In each community, there is a recognized need for cooperation among and between various departments within each First Nation in order to accomplish the management actions.

4.5. Review and update of the SWP plan (Stage 5)

A full review of the SWP plan should occur on an annual basis with a purpose to report plan implementation progress, to re-evaluate management actions, and to re-engage the working committee and the broader community on planning progress and next steps. A benefit of the annual SWP plan review includes sustaining momentum to implement the plan, opportunity to celebrate success from the plan, and opportunity to adjust or update the plan based on new information feeding into the plan.

4.6. Case Studies

The results of six case studies from First Nation communities in Canada are reported in Table 5-1. In each community a source protection plan was developed in partnership with community members and leadership and facilitated by the lead author. Following a community-based participatory research model (Kyoon-Achan et al., 2018) the goal of the partnership was to follow the prescribed SWP planning model (Figure 5-1) to identify any threats to a community's drinking water source, assess the degree of risk for each threat, and to assign management actions to reduce each threat. The result of each plan was an implementation strategy with identified management actions, timelines and stakeholder partners.

05

Research results

Research results from the six studies will be reported in this section. Table 5-1 indicates the perceived threats to local water sources as reported by key participants for each study area. The names of each study area are not provided to protect community identity. The results reported for the six communities are from across two Canadian provinces, Alberta and Saskatchewan. Two of the communities reported in this paper are from Alberta (AB), the other four are located in Saskatchewan (SK). In all cases, these are First Nation communities.

The results from this research point to a number of potential causal factors contributing to the water quality problem for First Nations. The most commonly reported threat to source water relates to sewage disposal, either at the household level in 'shoot-outs' and septic systems or at the community level in sewage lagoons. Other commonly reported threats to drinking water quality include the poor condition of household water cisterns, abandoned wells, unprotected well-heads and unauthorized solid waste dumpsites.

The method of sewage disposal in Indigenous communities varies considerably across the country and is a function of community size, geographic location, local capacity to fund and manage sewage disposal and other factors. For this reason, aggregate numbers only tell part of the sewage disposal challenges facing First Nations in Canada. For example, Neegan Burnside (2011) report that almost 85 percent of sewage treatment on First Nations is by a community wastewater system. However, in many First Nation communities, houses are isolated and not connected to a community water service. In these instances, wastewater from individual homes is discharged in a 'shoot-out' pipe to a backyard area. This method of disposal raised concern for human and wildlife health and safety. The Neegan Burnside (2011) report notes that a significant number (over 50 percent) of First Nation community sewage lagoons are either at, or over, capacity. Climate change is now exacerbating annual flood condition in the Prairie region resulting in sewage lagoon overflows. This condition points to an increasing need for wastewater infrastructure renewal and replacement in many First Nation communities. Water security is not only tied to potable water delivery but also to wastewater treatment.

The poor condition of household water cisterns was frequently reported in this study as a high risk to human health. Household cisterns are typically buried adjacent to, or beneath, a home to hold potable water. Across the study area, household cisterns are aging and often in poor condition owing to natural deterioration, weathering and damage from water delivery trucks. During this research, there were many reports of contamination in the water

cisterns from surface runoff infiltration, dead rodents and other contaminants. Monitoring studies have confirmed that household cisterns in many communities are contaminated. As a result, households were reverting to bottled water for human consumption.

human and domestic animal interference. Natural conditions such as flooding also increase the risk of groundwater contamination entering a well-head. Other frequently reported risks to source water include poorly constructed solid waste landfills and unauthorized solid waste dump sites.

Abandoned wells, particularly those that are uncapped, were reported to be a threat to groundwater supplies. In addition, many community wells were not adequately protected from

Risk Rank	Alberta No.1	Alberta No.2	Saskatchewan No.1	Sask No.2	Sask No.3	Sask No.4
High Risk	Household water cisterns	Diesel spillage	Septic tank 'Jet outs'	Sewage Lagoons	Vulnerable community well	Auto-wreckers Storage years
	Industrial drilling	Illegal dump sites	Agricultural land	Private wells	Septic tank 'shoot-outs'	Sewage mounds and lagoons
	Transport hazardous goods	Livestock close to wells	Septic fields	Cisterns	Abandoned wells	Sewage pumping stations
	Septic 'shoot outs'	Abandoned vehicles	Sewage lagoons	Flooded wells	Illegal dumpsites	Road transport and stormwater along lakeshore
Moderate Risk	Pipelines	Abandoned wells	Backyard mechanics	Animal carcasses	Landfill	Wildfires, organics entering lake water
	Commercial fuel tanks	Private fuel tanks	Old vehicles	Agriculture	-	Float planes on lake
	Recreational "off-roading"	Rail transport and rail lines	Private fuel tanks	Horses	-	Trailer park sewage
	Illegal dump sites	Pesticide containers	-	Dogs	-	Lake use in general, vehicles going through ice.
Low Risk	Septic fields	Abandoned septic tanks	Aerial spraying	Diesel Shed	Former industrial sites	Litter in the lake
	landfill		Recreational activities	Backyard mechanics	Old sewage lagoons	Fire retardant entering lake
	Private fuel tanks		Agricultural waste	Garbage sites	-	Cabin owner pumps and fuel
	Sewage lagoon		Dugouts and ponding water	-	-	Motor boat fuel spills

Table 5-1 Identified risks to source water, Prairie Region

06

Discussion

Prior to colonization Indigenous people's lives centred around decision-making that required capacity for planning. Planning settlements, migration, hunting and food gathering. Survival on the land was predicated on the collective ability to plan, organize and take action. The arrival of Western planning was a tool of colonialism to organize, displace, control, and otherwise wise usurp Indigenous sovereignty over the land and water. The result of Western planning practices created many of the current infrastructure problems that plague many first Nation communities, particularly those problems related to water and wastewater services.

The SWP planning process described above follows a community-based participatory research model. This model seeks to engage a community, through a working committee, as equal partners in a planning exercise to identify local threats to the drinking water source. The working committee consists entirely of community members tasked with development of the planning document. This participatory model provides a framework for organizing the planning process. However, the questions asked and the ensuing discussions that follow form the output of the plan. These questions and discussions are wholly determined by the committee. In each case study community, the plans evolved as a participatory project.

It became evident early in the planning process that what was being produced was much more than a planning document.

The mix of people on the working committee, the sharing of water stories, the attention to cultural protocols, respect for Elders and the sharing of different knowledge types (local knowledge, traditional knowledge and western science knowledge) empowered the each working committee to organize around a topic of collective concern. The relationships that developed during the SWP planning process between community individuals and between First Nation and non-First Nation people supported collaboration, trust-building, and a focus on actions to protect source water. Through this process, it was revealed that First Nations hold a personal, if not spiritual relationship with water. For example, committee members made frequent reference to the healing and medicinal powers of water, the need to protect water for future generations, the belief that women were the keepers of water, and that water was our first home – in the womb. It is these human relationships between and among community members in combination with the human relationship with water and nature that produce a more nuanced definition of water security.

“Water security may be interpreted as something other than just water availability and water quality but also the human and community relationship with water.”

07

Conclusion

The current state of water and wastewater service in many First Nation communities is but one example of injustice inflicted upon Indigenous people in Canada. The results of this study provide abundant evidence of community risk exposure to source water contamination. Based on this evidence it would be intuitive to suggest that First Nations lack water security.

However, it is argued that water security should not be defined solely on the basis of the quality of water supply. Nor should it be defined as a quantifiable, pre-determined amount of water. What other metrics might contribute to a more holistic understanding of water security? It is suggested here that water security ought to include other dimensions such as the ability to engage multiple actors from within and outside a community, capacity to organize around a community planning process, access to funding and university research assistance and especially community respect for water. While many Indigenous people in Canada lack the same degree of water quality and quantity as non-Indigenous people. Indigenous people hold a deep respect and appreciation for water, a close relationship to the land and the water, and a perspective that water represents something much more than a resource for human (mis)use.

The SWP planning process has also served a 'relational' perspective by drawing people and community together to share information, traditional knowledge and water stories. This research contributes to a growing literature that recognizes the place of human relationship building, community empowerment, respect and reciprocity as foundational components of water security. Based on these results, water security may be interpreted as something other than just water availability and water quality but also the human and community relationship with water.

References

- Arsenault, R., Diver, S., McGregor, D., Witham, A. & Bourassa, C. (2018). Shifting the Framework of Canadian Water Governance through Indigenous Research Methods: Acknowledging the Past with an Eye on the Future. *Water*, 10(49), pp. 1-18.
- Blackstock, M. (2001). Water: A First Nations' spiritual and ecological perspective. *BC Journal of Ecosystems and Management*, 1(1), pp.1-14.
- Bradford, L., Bharadwaj, L., Okpalauwaekwe, U. & Waldner, C. (2016). Drinking water quality in indigenous communities in Canada and health outcomes: a scoping review. *International Journal of Circumpolar Health*, 75, pp. 323-336.
- Canadian Council of Ministers of the Environment. (2004). Source to tap. The multi-barrier approach to safe drinking water. Prepared by the Federal-Provincial-Territorial Committee on drinking water.
- Collins, L., McGregor, D., Allen, S., Murray, C. & Metcalfe, C. (2017). Source Water Protection Planning for Ontario First Nations Communities: Case Studies Identifying Challenges and Outcomes. *Water*, 9(7), pp. 1-19.
- Cook, C. & Bakker, K. (2012). Water security. Debating an emerging paradigm. *Global Environmental Change*, 22, pp. 94-102.
- Eggerton, L. (2006). Safe drinking water standards for First Nations communities. *Canadian Medical Association Journal*, 174(9), p. 1248.
- _____. (2008). Despite federal promises, First Nations' water problems persist. *Canadian Medical Association Journal*, 178(8), p. 985.
- Government of Canada. (1985). Ottawa: Indian Act (R.S.C., 1985, c.1-5) (cited 2018 June 09). Available from: <http://laws-lois.justice.gc.ca/eng/acts/I-5/>.
- _____. (2014). Ottawa: First Nations On-Reserve Source Water Protection Plan. Guide and Template (cited 2018 June 10). Available from: https://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-HQ-ENR/STAGING/texte-text/source_1398366907537_eng.pdf.
- Hanrahan, M. (2017). Water (in)security in Canada: national identity and the exclusion of Indigenous peoples. *British Journal of Canadian Studies*, 30(1), pp. 69-89.
- Jepson, W., Budds, J., Eichelberger, L., Harris, L., Norman, E., O'Reilly, K., Pearson, A., Shah, S., Shinn, J., Staddon, C., Stoler, J., Wutich, A. & Young, S. (2017). Advancing human capabilities for water security: A relational approach. *Water Security* 1, pp. 46-52.
- Kyoon-Achan, G., Kinew, J., Phillips-Beck, W., Ibrahim, N., Sinclair, S. & Katz, A. (2018). Innovating for transformation in First Nations health using community-based participatory research. *Qualitative Health Research*, 28(7), pp. 1036-1049.
- Lall, U., Davis, J., Scott, C., Merz, B. & Lundqvist, J. (2017). Editorial: Pursuing water security. *Water Security*, 1, pp. 1-2.
- Matunga, H. (2013). Theorizing Indigenous Planning. In Walker, R., Natcher, D., Jojola, T. (eds.) *Reclaiming Indigenous Planning*, McGill Queens University Press, pp. 3-34.
- O'Connor, D. (2002). Report of the Walkerton Inquiry: Part Two, A Strategy for Safe Drinking Water. Ontario Ministry of the Attorney General, Queens' Printer for Ontario, Toronto, ON. 588 pp.
- Patrick, R., Machial, L., Quinney, K. & Quinney, L. (2017). Lessons Learned Through Community-Engaged Planning. *The International Indigenous Policy Journal*, 8(2), pp. 1-19.
- Patrick, R. (2011). Uneven access to safe drinking water for First Nations in Canada: Connecting health and place through source water protection. *Health and Place*, 17, pp. 386-389.
- _____. (2014). Source water protection planning: A role for planners. *Alberta Professional Planners Institute Journal*, 13, pp. 12-15.
- _____. (2018). Adaptation to Climate Change Through Source Water Protection: Case Studies from Alberta and Saskatchewan, Canada. *The International Indigenous Policy Journal*, 9(3), pp. 1-17.
- Truth and Reconciliation Commission of Canada. (2015). Winnipeg: Truth and Reconciliation Commission of Canada: Calls to Action (cited 2018 June 09). Available from: https://nctr.ca/assets/reports/Calls_to_Action_English2.pdf.
- United Nations Development Program (UNDP). (2016). United Nations Sustainable Development Goal #6. (cited 2019 August 02). Available from: <https://www.un.org/sustainabledevelopment/water-and-sanitatio>.
- Wutich, A., Budds, J., Eichelberger, L., Geere, J., Harris, L., Horney, J., Jepson, J., Norman, E., O'Reilly, K., Pearson, A., Shah, S., Shinn, J., Simpson, K., Staddon, C., Stoler, J., Teodorom, M. & Young, S. (2017). Advancing methods for research on household water security: Studying entitlements and capabilities, socio-cultural dynamics, and political processes, institutions and governance. *Water Security*, 2, pp. 1-10.
- Wutich, A. & Ragsdale, K. (2008). Water insecurity and emotional distress: Coping with supply, access, and seasonal variability of water in a Bolivian Squatter settlement. *Social Science & Medicine*, 67(12), pp. 2116-2125.



6

Governing Shallow Waters: SDG 6 and Water Security in São Paulo

Pedro Roberto Jacobi, Pedro Torres and Eduardo Gonçalves Gresse

Pedro Roberto Jacobi, Institute of Energy and Environment (IEE), University of São Paulo (USP).

Email: prjacobi@gmail.com

Pedro Torres, IEE, USP.

Email: pedrotorres@usp.br

Eduardo Gonçalves Gresse, University of Hamburg.

Email: Eduardo.Gresse@uni-hamburg.de

Abstract

From 2013 to 2015, Brazil faced a severe water crisis that led 1,485 out of its 5,561 municipalities to declare a state of emergency. The year 2014 was the driest in the history of the State of São Paulo since meteorological data started to be collected in the 1930s. The drought affected over 20 million people in the São Paulo metropolitan area alone inasmuch as the volume of the city's main system of reservoirs started to dramatically decrease in mid-2013, and was depleted in the following year. Whereas extreme weather events have caused water shortages and many other social, economic and environmental impacts around the world, the São Paulo water crisis unearthed a series of challenges in terms of water security. Besides the persistent pollution of watershed areas and poor natural resource management and planning, the absence of data, transparency and lack of room for social participation in water governance are key factors that explain the unprecedented water crisis in Latin America's largest metropolitan region. To be sure, the 2014 São Paulo water crisis showed that, for any metropolitan region to successfully design climate change adaptation and sustainable development strategies at large, it is crucial to understand the political nature of water security. The aim of this paper is therefore to highlight the main causes and effects of severe water shortages in São Paulo Macrometropolis and, based on empirical evidence, share the main experiences, challenges and opportunities for water governance improvement in dense metropolitan regions. To this end, it draws on a framework of environmental governance analysis and effectiveness of institutional agreements to assess how São Paulo Macrometropolis is complying with SDG 6 targets. We argue that the lessons learned from São Paulo water crisis might strength strategies for other megacities and metropolitan areas, especially in the Global South.

Keywords

Sustainable Development Goals, sustainable management of water and sanitation, water, security, climate change ee São Paulo, Brazil

01

Introduction

Water crises have multiplied in many parts of the planet. Besides those affected almost constantly, as is the case of Sub-Saharan Africa and the Northeast of Brazil, the picture has become more recurrent in regions where a large metropolis is located such as São Paulo, Brasília, Rome, Nairobi, and large cities mostly in California and Australia. In this chapter we analyze the water crisis that hit São Paulo Macrometropolis between 2014 and 2015. This analysis is performed in the context of climate change and addresses how the State of São Paulo has been responding to 2030 Agenda's Sustainable Development Goal (SDG) 6.

The enactment of the 2030 Agenda for Sustainable Development by 193 UN Member States in September 2015 marked the agreement on a time-bound, global and at the same time context-specific agenda for sustainable development consisting of 17 SDGs and 169 targets (UN General Assembly, 2015). Although the responsibility to implement and deliver the agenda by 2030 is primarily assigned to national governments (Ibid. UN General Assembly, 2015, 47; 55), it acknowledges the role of non-state actors such as civil society, private sector and academia and encourages their participation into its implementation and monitoring processes (Ibid. UN General Assembly, 2015, 47; 55).

In this context, the 2030 Agenda and its SDGs present strategic tools for global, subnational and local governance, and for data assessment on critical issues for sustainable development such as water security. Cities and subnational government will play a key role in climate change adaptation and mitigation (Heijden, 2018) and environmental issues in general. Cities and subnational levels are therefore key for implementing the 2030 Agenda and for SDGs success.

Contrary to common sense, the São Paulo metropolitan region is part of an area of insufficient clean water availability, in a region of hydrological complexity. There is a constant tension in the process of dispute around the decision-making process and its outcomes (Torres et al. 2019b). This presents the challenge to improve equity in the distribution of water in the metropolis and to reduce and equilibrate distortions, strengthening access to the public water supply system. It also emphasizes aspects of transparency and accountability, considered to have an important role in a process of a democratic public policy with multilevel governance (Lynn et al., 2000; Young, 2009). Within the context of formulation and implementation of a participative governance (Warner, 2005), multiple categories of stakeholders, institutions, inter-relations and issues, each of them representing specific arrangements and interests at stake and possibilities of negotiation, demands interdependencies, that indicate the limitations of government and the need of strong links with local governments, the private sector and social organizations. The challenge is to articulate the actions of different public actors, within watersheds as it is defined by Brazilian water legislation.

02

Methods

The main sources of quantitative data and documents from primary sources were obtained from São Paulo State Sanitation Company – SABESP and the Meteorological Station of the Astronomical and Geophysical Institute of University of São Paulo - IAG / USP) and secondary (Climate Prediction Center of the National Oceanic and Atmospheric Administration - CPC / NOAA).

Besides, this study draws on SDG 6 (clean water and sanitation) targets and indicators in order to assess São Paulo State's (i.e. subnational) performance on the 2030 Agenda's water security goals. Based on data from government agencies¹ (e.g. SEADE, IBGE, IPEA), this analysis seeks also to investigate the extent to which the performance analysis of SDGs can guide water security governance and decision-making processes in São Paulo and elsewhere. This strategy is helpful to unearth possible gaps in the employment of such global goals in the analysis and performance of subnational and/or local governance.

“Cities and subnational levels are therefore key for implementing the 2030 Agenda and for SDGs success.”



Figure 6-1 Maps of Brazil, São Paulo State, and São Paulo Macrometropolis region. Map elaborated by Ana Lia Leonel (UFABC/FAPESP), 2018

03

Water Security and the 2030 Agenda for Sustainable Development

During the 2012 United Nations Conference on sustainable development, also known as Rio+20 Conference, world leaders agreed on an intergovernmental process towards defining global goals for sustainable development (UN General Assembly, 2012, 245–251). Among other things, the idea of setting goals within a Post-2015 Agenda was to build upon and broaden the scope of the earlier Millennium Development Goals (MDGs). The establishment of a specific goal for clean water and sanitation is a good example of this process. While the MDG (Sachs, 2012) agenda has barely addressed water security, management and basic sanitation (Goal 7, Target 10, c.f. UN General Assembly, 2001), the new agenda would bring more light to these issues from the outset.

In fact, the outcome document of Rio+20 *The Future We Want* highlights the most pressing challenges regarding water security. Accordingly, it advocates for ambitious policies and for an integrated and context-specific approach to water, energy and land-use planning, development, conservation and management. One that takes specific gender, cultural needs and the full and effective participation of civil society into account (UN General Assembly, 2012, 24; 75). As a result of this new approach, the Sustainable Development Goal 6 (SDG 6) for clean water and sanitation was created along with targets and indicators for ensuring availability and sustainable management of water and sanitation for all (UN General Assembly, 2015; see also United Nations).

The years preceding the ratification of the 2030 Agenda for sustainable development have witnessed wide and intense consultation and negotiation processes that included an unprecedented number of stakeholders (Kanie et al., 2017). Governments, experts and organizations from all over the world got together to define a common, global agenda for sustainable development. In the same period (2013-2015), Brazil faced its worst drought in 84 years and a critical water shortage hit the country's most populous state São Paulo. This severe water crisis in São Paulo revealed that climate aspects such as reduction in rainfall levels are not sufficient to explain or address crises alike. Water governance and therefore the responsibility of actors and institutions involved in this process are also fundamental aspects of a crisis that has not yet been resolved (Jacobi et al., 2015, Torres et al. 2019a). Against this background, a closer look at the water governance in metropolitan São Paulo is crucial to both unearth and understand critical aspects of water management crises as well as the main challenges to effectively address them.

According to UNESCO International Hydrological Program (IHP), Water security is the “[...] ability to assure

a population access to adequate quantities of water of acceptable quality for the purpose of sustaining human health and health of ecosystems in a river basin, and also to ensure efficient protection of life and property against water-related disasters - droughts, floods, landslides, sinking of soils” (UNESCO-IHP, 2012a).

The theme of SDG 6, therefore, is the present relationship in the definition mentioned above, including not only the safety of human populations, but the water necessary for the functioning of ecosystems, for the maintenance of cycles and for sustainability, that is, their nexus.

On the one hand, the water crisis in São Paulo and the lack of governance, on the other, the goals and the monitoring from the SDG 6. These are the connections that we will present here in this work, as well as the importance of civil society to ensure publicity and guarantee the fulfilment of the agenda that allows a territory with safe and available water to all.

04

Water Governance in Metropolitan São Paulo

The current Brazilian model of water management, in force since 1997, proposes an integrated, decentralized and participatory framework of policy. It innovates as it gives power to decentralized water basin institutions, demanding a process of negotiation between different public agents, users and organized civil society. The São Paulo metropolitan region is composed of 39 municipalities with a population of over 21 million inhabitants, representing 46% of the State of São Paulo, and 55% of State's GNP (EMPLASA, 2018). In addition to the high population density, the region is marked by the complexity of an urban environment with a high occupation and cluttered and intense use of land.

Population growth in SPMR has demanded investments by the State Company of Basic Sanitation of the State of São Paulo (SABESP) in the expansion of the supply system, with the increase of the capacity of the treatment plants or in the development of the water sources. SABESP, which serves most municipalities of the São Paulo metropolitan region, is a mixed capital company that was founded in 1973 and is currently responsible for supplying water and collecting and treating sewage in the 369 municipalities of the State of São Paulo.

It is considered one of the world's largest sanitation companies in terms of population served. It supplies 27.9 million people with water and provides sewage collection services to 21.6 million people, and is responsible for around 27% of the investments in basic sanitation in Brazil. Public water supply in SPMR is made through eight water treatment plants operated by SABESP, which is responsible for the sanitation of 39 the municipalities of SPMR with more than 20 million people served. The public supply in the metropolitan region of São Paulo (SPMR) is made through eight water treatment plants operated by the company SABESP, which is responsible for the supply of nine million inhabitants, supplying 45% of the water consumed. This system was responsible until the crisis to supply SPMR with 31m³/s, being 24.8m³/s to supply household consumption.

05

Water Availability and Climate Dependence in the São Paulo Metropolitan Region

Since 1950, seven periods of more pronounced shortage has occurred. This shows that reductions in the annual volume of rainfall are not rare situations and should be considered in the planning of the supply system of the metropolitan region of São Paulo. It is interesting to verify, however, the behavior of the supply system between the two most recent crises. The penultimate dates back to 2004 and the last one started in 2013. These cycles are related to the El Niño-Southern Oscillation (ENSO) as shown by Côrtes et al. (2015) and discussed later in this paper. In periods of excessive rainfall, there were cases where the storage capacity of the reservoirs was oversupplied. In those cases, the surplus volumes were released to the rivers at the downstream.

More recently, between January 2005 and December 2012, the system was working under normal conditions. Taking the monthly water averages available to the population, it turns out that the system has always worked close to the operational limit or, sometimes, above it. Considering that this is a normal situation, one should ask how the system would look in case of a drought that is longer or more intense. Considering that the system, in a normal situation, works very close to its full operational capacity, it is evident that it cannot withstand a more significant reduction in the volume of rainfall. There would be no operational gap and the low elasticity of the system was demonstrated. The maximum volume was below the level obtained in the previous year, which could have been used for the design of strategies preventive measures.

A study conducted by Côrtes et al. (2015) shows that the dams recharge periods with predominance of the El Niño phase present higher rainfall volume, which is in resonance with Santos et al. (2012) and studies for the interior of the State of Silva Dias et al. (2013) for the city of São Paulo. Another point to note, according to the study by Côrtes et al. (2015) is that during El Niño the rainy season extends to autumn (which is traditionally drier) and expands the recharge of the Cantareira System.

06

Emergence and Development of Water Crisis

Rain below average contributed to the aggravation of water supply in the watersheds classified as critical, due to the low hydric availability – qualitative and/or quantitative. In São Paulo Macrometropolis hydric scarcity is structural due to deforestation around reservoirs and inadequate occupation of watershed areas, including pastures. But the crisis is mainly caused by the pollution of waterways in the Alto Tiete basin, thus reducing significantly the water stock for domestic use. Relative scarcity constitutes a secular reality of São Paulo, given that the city is located in the river bed, with reduced availability of water. It also should be mentioned that Alto Tiete water basin shares with neighboring Piracicaba/ Capivari/Jundiá basin, that provides 31m³/s, and imports 6m³ water from a distance of 200km south in the State.

Although the levels of the Cantareira System and climate forecasts indicate more consistently the existence of problems from May 2013, it is only at the beginning of 2014 that the government of the state of São Paulo acknowledged the existence of a water supply crisis. As the water outlet did not suffer a significant reduction, being above the water inlet in the system, the water level dropped rapidly. In May 2014, the level of two reservoirs was very low, making it impossible to transfer them by gravity to a third reservoir. What remained in these reservoirs consisted of a volume intended to accommodate sediment and whose exploitation was not foreseen. Called "dead volume", this reserve has come to be called a "technical reserve" in a communication strategy aimed at smoothing the impacts of the crisis. The government tried to convince the population that this was a strategic reserve for times of crisis. It incorporated the "dead volume" (or "technical reserve") at the level of the Cantareira System, artificially increasing the level of this system.

The crisis showed the fragility of the system of water governance in the metropolitan region. It highlighted the inadequate practices of water management for decades, mainly linked to the bad quality of waterways due to the non-conclusion of the main sewage treatment system, which has been very much delayed, and implies directly to the impossibility of its use to supply the population, the noncompliance with legislation linked to decentralization, participation and integration of policies.

Decisions were taken at the central level of government linked directly to the governor. The lack of transparency and accountability is manifested mainly by not promoting initiatives that stimulate co-responsibility of the population, as the crisis was hindered by authorities until the moment it was not possible anymore. The main reason was the interference of an electoral agenda at the State level: the government did not want to take an anti-popular

position promoting a preventive turnover, notwithstanding the situation was becoming extreme (Jacobi et al., 2015). Peripheral neighborhoods and settlements lived under permanent interruptions of water supply, although the water management company affirmed that there were no abnormalities in supply.

The main cause for the worst water crisis in the region emphasized by the state government of São Paulo and by the main means of communication, was the lack of rain in the summer 2013/2014. It has to be stressed that since the end of 2013, the level of the reservoirs had been falling, due to climatic factors, but other aspects that led to a critical situation of reservoirs responsible for most of the water supply of the region. It is necessary also to emphasize the fact the slowness of the State Company of Sanitation SABESP, that has grant of water and the State government to take measures along the year to avoid the problem of water scarcity and stress to happen, as it did in the main metropolitan region of the country.

But other factors have also to be considered, and probably the most relevant is that SPMR has an environmental liability and given this situation of the water crisis can be related directly to the logic that predominates to obtain more water for the region at further distance with very costly projects, instead of treating and taking care of waterways and rivers and reservoirs as already mentioned.

Other factors to be considered are deforestation and inadequate land use in watershed areas (Coutinho et al., 2015), the lack of planning for the construction of new reservoirs and the lack of investments to reduce leaking that attain around 30% (SABESP, 2013) and the lack of institutional coordination are relevant causes of the crisis (Rodrigues & Villela, 2015).

The State of São Paulo government and the main vehicles of communication have very much focused on the lack of rain in the summer 2013-2014. Since the end of 2013, the level of the reservoirs had been falling, due to climatic factors, but other aspects that led to a critical situation of reservoirs responsible for most of the water supply of the region. It is necessary to emphasize the fact the slowness of the State Company of Sanitation SABESP, which has grant of water and the State government to take measures along the year to avoid the problem of water scarcity and stress to happen, as it did in the main metropolitan region of the country.

07

Water Governance, Performance Assessment and the Localization of SDGs

Indicators of Sustainable Development Goals (SDGs) can be important instruments for policy alignment because they have to express in a succinct and concrete form the norms, interests, and aspirations of different actors and can function as a bridge between the normative domain and policy implementation (Pintér et al., 2017, p. 113). This is evidenced by Rosa dos Santos et al. in regard to water governance (Rosa dos Santos et al., 2018). Accordingly, the analysis of water governance in light of SDG 6 targets and indicators is particularly useful to reveal the status quo, the progress made and the persistent gaps in water management at different levels (i.e. from the global to the local). This type of goal-based performance analysis is also relevant as it highlights the numerous aspects and challenges of governance as well as the importance of integrated approaches and public policies for sustainable development.

To support the implementation of 2030 Agenda and its SDGs at the national and subnational levels, numerous reports and initiatives have emerged in Brazil. Among them, one of UNDP Brazil's guidelines deserve special attention. In 2016, UNDP Brazil (or PNUD, abbreviation in Portuguese) published a roadmap that seeks to support and provide policymakers and non-state actors with guidelines for the implementation and monitoring of the SDGs at the so-called subnational level in Brazil (PNUD, 2016). This publication presents the notion of

“This type of goal-based performance analysis is also relevant as it highlights the numerous aspects and challenges of governance as well as the importance of integrated approaches and public policies for sustainable development.”

“localization of the SDGs,” regarding localization as the process of taking into account the subnational contexts while implementing the Agenda 2030, from setting goals and targets to the determination of the means of implementation, and the use of indicators to measure and monitor progress (Ibid, PNUD, 2016, p.12) translation and emphasis by the authors).

In Brazil, a wide range of state and non-state actors are working for the dissemination and implementation of the 2030 Agenda. The Brazilian Institute of Geography and Statistics (or IBGE, abbreviation in Portuguese) and the Institute for Applied Economic Research (or IPEA,

abbreviation in Portuguese), for example, are the government agencies responsible for the adaptation of SDG targets and indicators to Brazil's context. These institutions also provide technical assistance to the National SDG Commission, an advisory body established in 2016 consisting of multiple stakeholders (government, private sector, academia and civil society actors) to “internalize, disseminate and give transparency” to the implementation of the Agenda 2030 in Brazil (Comissão Nacional ODS Brasil, 2017).

More recently, IBGE has created an online platform with the first indicators for monitoring the SDGs in Brazil (IBGE) and IPEA launched a proposal for the national adaptation of the SDGs (IPEA, 2018). Also, the Civil Society creates the Civil Society Working Group for the 2030 Sustainable Development Agenda in Brazil a group with more than 40 non-governmental organizations. Despite the efforts to implement the 2030 Agenda in Brazil, no specific targets, indicators and thus systematic database are available for the monitoring and evaluation of 2030 Agenda's implementation at the subnational level. The localization of SDGs in Brazil is, therefore, still an incipient and on-going process.

For the purpose of this paper, the next section analyses São Paulo's water governance in light of SDG 6 targets and indicators. Given the lack of specific targets and indicators for the subnational level, this study is based on the global targets and indicators ratified at the United Nations for SDG 6 (See Table 6-1). To this end, it draws on data from different, but complementary sources, namely the State Government's current Multiannual Plan as well as official reports from government agencies (e.g. ANA, CETESB, and IBGE). It is important to mention that for some SDG 6 targets there are no consolidated data or adapted indicators yet. In those cases, government's programmes and the respective budget allocated for them are presented and discussed. Recommendations provided by scholars and civil society actors are also addressed in order to enrich the debate on water governance issues.

São Paulo's Performance on Sustainable Development Goal 6: Ensure Availability and Sustainable Management of Water and Sanitation for All

The 2017 Report on the progress towards the Sustainable Development Goals reveals that more than 2 billion people around the globe are living in countries with excess water stress. The level of water stress is calculated based on SDG indicator 6.4.2, namely the ratio of total freshwater withdrawn to total renewable freshwater resources, considering a threshold of 25 per cent (United Nations, 2017, p. 9). As a matter of fact, water stress is not only a problem to be addressed in desert regions and countries. Brazil, for instance, has one of the largest water reserves in the world but faces serious water shortages. In this context, the recent (and still not resolved) water crisis in São Paulo, Brazil's most industrialized and populous State, reveals interesting aspects on the importance of water governance.

The 2030 Agenda and its Sustainable Development Goals (SDGs) are inspiring numerous initiatives aimed at improving public management in Brazil. Among other things, local (i.e. municipal) and state governments are increasingly using the SDGs in their strategic planning. As mentioned above, Brazilian agencies are still working on the adaptation of the SDGs. The State of São Paulo, in turn, has not yet implemented this agenda in its Multiannual Plan (Plano Plurianual or PPA, for the abbreviation in Portuguese). It is possible, however, to assess São Paulo's performance on SDG 6 by analysing and compiling the information available in its latest PPA and on other official data provided by government agencies such as the Brazilian Institute of Geography and Statistics (or IBGE, abbreviation in Portuguese), São Paulo's Environmental Company (or CETESB, abbreviation in Portuguese) and the National Water Agency (or ANA, abbreviation in Portuguese).

IBGE and SABESP official data was used to evaluate the current situation of each target and sub-target. Some data could be underestimated and are contested by civil society in a recent report (GTSC para Agenda 2030, 2018).

8.1. Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all

According to IBGE in 2016, São Paulo virtually achieved Target 6.1 as 99.9% of State's population used safely managed drinking water services, representing the best performance in terms of access to drinking water in Brazil (IBGE).

8.2. Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

IBGE is still working on the construction of indicator 6.2.1 (See IBGE). According to the Government of São Paulo, 96.5% of the State's population used safely managed sanitation services in 2013 (Governo do Estado de São Paulo, 2015a, p. 41; p. 57).

8.3. Target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

Indicators 6.3.1 and 6.3.2 are also under construction (See IBGE), but the latest Atlas do Esgoto report, published in 2017 by the National Agency of Water, reveals that the sewage collection and treatment in the São Paulo account for 87% and 64%, respectively (Agência Nacional de Águas, 2017, p. 31). The report estimates that the investment required to universalize sewage collection and treatment in Brazil until 2035 is R\$ 149.5 billion (ca. 38 billion USD). For the same purpose, the State of São Paulo must invest 13% of this amount (around 5 billion USD) (Ibid., Agência Nacional de Águas, 2017, pp. 72-73). According to São Paulo's current Multiannual plan, the budget allocated for the State Secretariat of Sanitation and Water Resources for this term (2016-2019) is R\$ 7.3 billion (around 1.8 billion USD) (Governo do Estado de São Paulo, 2015b, p. 15).

As far as water quality is concerned (indicator 6.3.2), CETESB latest report on the quality of water in the State of São Paulo reveals that, in 2017, 47% of water analysed was considered excellent or good. This number is based on the Water Quality Index for Public Supply (Índice de Qualidade da Água Bruta para fins de Abastecimento Público, in Portuguese) (CETESB, 2018, p. 115).

Target	Indicator	Performance
6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1 Proportion of population using safely managed drinking water services	99.9% (2016)
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Pro portion of population using safely managed sanitation services, including a hand-washing facility with soap and water	96.5% (2013)
6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1 Proportion of wastewater safely treated 6.3.2 Proportion of bodies of water with good ambient water quality	64% (2017) 47% (2017)
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	No consolidated data available 36.1%(2016)
6.5 By 2030, implement integrated water resources management at all levels, including through trans boundary cooperation as appropriate	6.5.1 Degree of integrated water resources management implementation (0-100) 6.5.2 Proportion of trans boundary basin area with an operational arrangement for water cooperation	Data available only for the national level Not applicable for São Paulo
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1 Change in the extent of water-related ecosystems over time	No consolidated data available
6.A By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.A.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	Under construction; detailed analysis required
6.B Support and strengthen the participation of local communities in improving water and sanitation management	6.B.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	Under construction; in São Paulo, lack of transparency and room for participation

Table 6-1 São Paulo's performance on SDG 6 (clean water and sanitation), according to official data

8.4. Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

Indicators 6.4.1 and 6.4.2 for Brazil are still under construction (See IBGE). While no consolidated data for change in water-use efficiency over time is available (indicator 6.4.1), it is possible to analyse the level of water stress (according to indicator 6.4.2) in the country and per region. The latest report by Brazil's Ministry of Cities for water and sanitation services points out that no state in Brazil has reached the first and second thresholds for water withdrawal, with a loss of distribution of less than 20% and between 20 and 30%, respectively. In 2016, the national average of water withdrawal was 38.1% and São Paulo, ranked 8th in Brazil, performed slightly better than the average, with 36.1% of distribution loss, behind Tocantins, Goiás, Rio de Janeiro, Paraná, Minas Gerais, Distrito Federal and Mato Grosso states only ahead of Espírito Santo in Southeast region (Ministério das Cidades, 2018, pp. 41–42).

8.5. Target 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

There are no disaggregated data available for the subnational level (See IBGE). In 2016, the degree of integrated water resources management implementation (indicator 6.5.1) in Brazil was 50.5%. In turn, the proportion of transboundary basin area with an operational arrangement for water cooperation (indicator 6.5.2) was 64.2% (Ibid.). To analyse São Paulo's performance on the indicator 6.5.1, more data is necessary. In any case, it is possible to report that, in the current Multiannual Plan (2016–2019), the State of São Paulo allocated R\$ 797.4 million (ca. 200 million USD) across two programmes that are in line with indicator 6.5.1 (Governo do Estado de São Paulo, 2015b, p. 15; 2015a, pp. 56–57).² The indicator 6.5.2, in turn, is not applicable for the State of São Paulo.

8.6. Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

Indicator 6.6.1 is under construction (IBGE) and there are no consolidated data for the change in the extent of water-related ecosystems over time in São Paulo. Nevertheless, it is important to report that the deforestation rate of Atlantic Rainforest in São Paulo has importantly decreased since the early 2000s. In the period 2016–2017, 90 hectare were

deforested, representing a decrease of 87% comparing with the former period (2015–2016). Yet the deforestation rate between 2014 and 2015 was 45 hectares, i.e. 50% of current rate, which means that zero deforestation is a persisting challenge (SOS Mata Atlântica & INPE, 2018, p. 50). According to São Paulo's current Multiannual Plan (2016–2019), almost 3.5 billion Reais (or 875 million USD) are allocated across three programmes for environmental protection, ecological restoration and sanitation (Governo do Estado de São Paulo, 2015b, p. 14).³

8.7. Target 6A: By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

This target is under analysis and construction (IBGE). A detailed analysis is required to define whether this target and its indicator (6.A.1, Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan) are applicable for the State of São Paulo.

8.8. Target 6B: Support and strengthen the participation of local communities in improving water and sanitation management

This target is also under analysis and construction (IBGE). It presents a broad indicator (6.B.1, Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management), to which there is no consolidated data for the State of São Paulo. The lack of systematized data for target 6B is also highlighted by the 2018 Spotlight Report launched by the Civil Society Working Group for 2030 Agenda in Brazil (GTSC para Agenda 2030, 2018, p. 31).

As far as the participation of the civil society in São Paulo's water governance is concerned, controversy and contestation are at stake. While the State Government reports that public consultations to address society's demands on several issues, including water and sanitation, have taken place (Governo do Estado de São Paulo, 2015a, pp. 18–20), scholars have stressed the lack of transparency and room for public debate and participation in improving water and sanitation management, especially during the 2013–2015 Water Crisis in São Paulo (Jacobi et al., 2015). This lack of transparency is confirmed, for instance, by the lack of systematic data on the civil society's participation in water and sanitation management.

09

Resistance to Lack of Transparency, Accountability and the Role of Societal Initiatives

São Paulo government's strategy to deal with the water crisis was to emphasize on the reduction of the pressure in the water distribution system. The reduction of pressure according to SABESP is a technology practiced normally by sanitation companies to reduce water leakages. During the water crisis, SABESP intensified this process to confront the water scarcity and to avoid – according to the information available in its site – the exhaustion of its reservoirs and contribute to the maintenance of supply until normality of rain is recovered. The central and intermediate neighborhoods were very little affected given that buildings and unfamiliar households have adequate water reservoirs and in general did not suffer lack of water.

This reduced the leakage losses in distribution piping (estimated at 30%), but damaged several districts located in higher areas of the São Paulo metropolitan region. There was rationing in several neighborhoods, with the interruption of supply lasting a few days. The government preferred to call these two actions "water restriction" rather than using the term "rationing". These semantic strategies aimed to poorly inform the people and seek to minimize negative perception among the population.

During the crisis, educational actions undertaken by SABESP were very limited. There was no guidance on ways to save water, no explanation about techniques for reusing of water or the possibilities regarding the collecting of rainwater. Being SABESP, there was the impression that SABESP feared that after the crisis consumption would remain low, damaging its profits. This situation had already occurred at the beginning of this century, when there was a need to ration the use of electric energy. At that time, as the population learned to save energy, the billing of electricity generation and distribution companies remained low even after the power rationing was ended.

This concern with billing was evident when the tariff policy applied to large consumers, such as industries, universities and shopping centers, was analyzed. To prevent these organizations from using water wells as an alternative, SABESP offered a reduced tariff as long as these organizations-maintained consumption above a certain level (negotiated case by case).

The most effective action was the development of a bonus policy for those who conserve water. This practice took as reference the average consumption of each residence. If consumption were lower than this average, the tariff per cubic meter would be lower. On the other hand, there was

a tariff increase for consumers who did not reduce their consumption. But this practice of granting price reduction as an incentive to more moderate use was ended when the government considered that the crisis was over in early 2015. In this context, preventive and adaptive management should have been done once it was diagnosed the water vulnerability of the region.

“The most effective action was the development of a bonus policy for those who conserve water.”

However, the focus given by public officials for this situation ignored the collaborative and integrated management of urban water sources and participatory governance, prioritizing emergency works to interconnect the supply systems and disregarding social and environmental issues, in particular the environmental licensing process (Jacobi et al., 2015). Some measures were taken with adequate environmental licensing and with no public debate due to the need to solve the problem in an immediate engineering approach.

Therefore, there was political incoherence in the process because there was lack of transparency in the communication of the measures regarding the crisis for the population as well as centralization in decision-making. The constant negatives of the State Government related to the gravity of the crisis, hindered the involvement of civil society to confront it, as it also served as a justification for initiatives arising from different articulations of NGOs and community organizations as well as the water basin committee not to be considered. The Crisis Committee created by the central government practically had no meetings and did not produce the expected outcomes when of its creation: development of a contingency plan as well as a communication plan to keep population informed about the situation and measures to be taken (Jacobi et al., 2015).

By analyzing the crisis from a historical perspective, it is to be observed the prevalence of a refractory position of the state government to accept the crisis. The daily bulletins on the existing volume of water in reservoirs were constantly questioned and at a certain moment of the crisis in April 2015 the Public Prosecution at Federal and State level determined that the effective volume of water of the Cantareira reservoir should be disclosed. It was necessary its intervention in order to the State Government took the necessary measures to confront the water crisis, as the lack of communication and dialogue, as well as the lack of proposals and information that could contribute to a debate between the different stakeholders and water users of the Cantareira System, that led to the depletion of water resources of the main reservoir of the region.

Various non-governmental organizations developed activities, actions, initiatives and projects to inform the population, focusing the actions of public officials and working cohesively

for water governance with a focus on the new culture of care for water (Aliança pela Água, 2015). The movements and articulations of NGOs developed strategies to denounce the crisis and exerted pressure towards authorities to allow the participation of civil society with propositions and solutions, to guarantee equity in access to water and expand the channels of mobilization. And it is relevant to stress that during the debates that took place during the crisis, it was verified that SABESP, did not carry out between 2008 and 2013 the necessary foreseen investments in public works to increase water supply.

The possibility of an extremely critical situation was already anticipated for at least a decade by specialists in the field, especially in São Paulo, pointing that upcoming shortage of water to a level that consumption would exceed water availability. In São Paulo, during the crisis of 2014-2015, the decreases in rainfall in the southeastern region of Brazil presented a predictable scenario of water scarcity in 2015. But it is important to note that in addition to the difficulties related to hydrological cycles and water availability, there are still human-made factors that interfere with the quality and quantity of the resource: inland sewage disposal, the effects of climate change on water production and the lack of investments in water storage and distribution infrastructure.

Although the focus of the news on the water crisis is the lack of rainfall, it can be observed that the denial of the possible crisis, the critical situation and the delays in proposing effective measures to minimize it, revealed governance problems.

The lack of governance of the water management system was already signaled envisaged by specialists since the end of the 80's, as recommendations were made to increase water availability in the region and less dependency of water import from neighboring watersheds.

In 2004, the Department of Water and Electric Energy –DAEE – responsible for the management of water resources and coordinator of the integrated system of the State of São Paulo recommended a set of actions to increase water availability.

10

Conclusion

The analysis of São Paulo's Performance on SDG 6 (clean water and sanitation) reveals important aspects of and challenges for sustainable water governance. On the one hand, according to IBGE data Brazil's most populous State virtually achieved universal access to drinking water (99.9%) and to managed sanitation services (96.5%) (SDG targets 6.1 and 6.2, respectively), according to the latest data available (2016 and 2013, respectively). Nevertheless, the analysis would benefit from more updated data, as these numbers are expected to vary over time, depending on the population growth and the respective provision of services and infrastructure. On the other hand, São Paulo faces three main challenges for sustainable water governance.

“Performance assessment of Sustainable Development Goals, through its advantages and limitations, is a useful exercise to guide water governance and decision-making processes anywhere.”

First, only 64% of wastewater are safely treated (indicator 6.3.1). In a State where more than 45 million people live, this is worrisome and certainly impactful in environmental and socioeconomic terms. Second, and most likely a consequence of the former, only 47% of São Paulo's bodies of water were classified as excellent or good in terms of ambient water quality (indicator 6.3.2). Finally, although ranking among the most effective States in Brazil in water withdrawal (indicator 6.4.2), it is critical to emphasize another worrisome scenario: there is no State in Brazil where the average of loss of distribution is below 30%. Given the recurring problems with water shortages in the country and particularly in São Paulo, these numbers deserve special attention and concern.

As far as indicators 6.4.1, 6.5.1, 6.6.1 and 6.B.1 are concerned, no conclusive analysis is possible due to the lack of systematic and consolidated data. In any case, the numbers presented by São Paulo's 2016-2019 Multiannual Plan, official reports as well

as the discussions promoted by academics and civil society actors reveal a scenario of progress in some aspects (e.g. reduction of Atlantic Rainforest deforestation) and limitations and controversy in others (e.g. lack of data, transparency and room for participation in decision-making processes).

Last but not least, this paper corroborates with civil society's 2018 Spotlight Report for the 2030 Agenda claims for integrated implementation of water resources management at the national and subnational levels in Brazil with more transparency and through participatory processes (c.f. GTSC para Agenda 2030, 2018, pp. 31-32). To this end, governance structures must be adapted to local conditions and needs

(UN Water, 2013) and public management should benefit from the efforts towards adapting the global goals and targets for sustainable development to their respective contexts by considering their indicators in multiannual plans and strategic planning (Rosa dos Santos et al., 2018).

In a nutshell, this goal-based performance analysis unearths relevant aspects and challenges for water governance in São Paulo, including in terms of indicators establishment and availability of data. In fact, performance assessment of Sustainable Development Goals, through its advantages and limitations, is a useful exercise to guide water governance and decision-making processes anywhere. Accordingly, we expect that the governance aspects highlighted in this paper inspire further research on water governance and integrated approaches for water management and sustainable development.

Acknowledgment

This work is financed by FAPESP - The São Paulo Research Foundation, grants 2015/03804-9 for Pedro Roberto Jacobi and 2018/2018/06685-9 for Pedro Henrique C. Torres

References

- Aliança pela Água. <https://www.aliancapelaagua.com.br/> (accessed September, 2018).
- Agência Nacional de Águas. (2017). *Atlas Esgotos: Despoluição de Bacias Hidrográficas*. Retrieved from Secretaria Nacional de Saneamento Ambiental website: <http://atlasesgotos.ana.gov.br/>.
- CETESB. (2018). *Qualidade das águas interiores no estado de São Paulo 2017*. Retrieved from CETESB – Companhia Ambiental do Estado de São Paulo website: <https://cetesb.sp.gov.br/aguas-interiores/publicacoes-e-relatorios/>.
- Comissão Nacional ODS Brasil. (2017). *Comissão Nacional para os ODS: Plano de Ação 2017 – 2019*. Brasília.
- Côrtes, P., Torrente, M., Filho, A., Ruiz, M., Dias, A. & Rodrigues, R. (2015). Crise de abastecimento de água em São Paulo e falta de planejamento estratégico. *Estudos Avançados*, 29(84), pp. 7-26.
- Coutinho, R., Kraenkel, R. & Prado, P. (2015). Catastrophic Regime Shift in Water Reservoirs and São Paulo Water Supply Crisis. *PLoS ONE*, 10(9) <https://doi.org/10.1371/journal.pone.0138278>.
- EMPLASA, www.emplasa.sp.gov.br – (accessed September, 2018).
- Governo do Estado de São Paulo. (2015a). *Plano Plurianual 2016 - 2019: Volume I*. Lei 16.082, de 28 de dezembro de 2015.
- _____. (2015b). *Plano Plurianual 2016 - 2019: Volume II*. Lei 16.082, de 28 de dezembro de 2015.
- GTSC para Agenda 2030. (2018). *Relatório Luz da Agenda 2030 de Desenvolvimento Sustentável: Síntese II*. Retrieved from Grupo de Trabalho da Sociedade Civil para Agenda 2030 website: <https://gtagenda2030.org.br/biblioteca/relatorios-luz/>.
- Heijden, J. (2018). City and subnational governance: high ambitions, innovative instruments and polycentric collaborations? In Andrew Jordan, Dave Huitema, Harro van Asselt Johanna Forster. (eds.) *Governing climate change: polycentricity in action?* Cambridge, UK: Cambridge Univ. Press, pp. 81-96.
- IBGE. Indicadores ODS - IBGE: Objetivo 6 - Água Potável e Saneamento. Retrieved from <https://indicadoresods.ibge.gov.br/objetivo/objetivo?n=6>.
- IPEA. (2018). *ODS – Metas Nacionais dos Objetivos de Desenvolvimento Sustentável: Proposta de adequação*. Agenda 2030.
- Jacobi, P., Cibim, J. & Souza Leão, R. (2015). Crise hídrica na Macrometrópole Paulista e respostas da sociedade civil. *Estudos Avançados*, 29(84), pp. 27–42.
- Kanie, N., Bernstein, S., Biermann, F. & Haas, P. (2017). Introduction: Global Governance through Goal Setting. In *Governing Through Goals: Sustainable Development Goals as Governance Innovation*, pp. 1–28. Cambridge, Massachusetts: The MIT Press.
- Lynn, L., Heinrich, C. & Hill, C. (2000). Studying governance and public management: why? How? In Heinrich, C. & Lynn, L. *Governance and Performance: new perspective*, pp. 1-33. Georgetown University Press, Washington D.C.
- Ministério das Cidades. (2018). *Diagnóstico dos Serviços de Água e Esgotos – 2016: Sistema Nacional de Informações sobre Saneamento – SNIS*. Retrieved from Ministério das Cidades website: <http://www.snis.gov.br/diagnostico-agua-e-esgotos/diagnostico-ae-2016>.
- Pintér, L., Kok, M. & Almassy, D. (2017). Measuring Progress in Achieving the Sustainable Development Goals. In *Governing Through Goals: Sustainable Development Goals as Governance Innovation*, pp. 99–134. Cambridge, Massachusetts: The MIT Press.
- PNUD. (2016). *Roteiro para a Localização dos Objetivos de Desenvolvimento Sustentável: Implementação e Acompanhamento no nível subnacional*. Retrieved from Programa das Nações Unidas para o Desenvolvimento no Brasil (PNUD) website: <http://www.br.undp.org/content/brazil/pt/home/library/ods/roteiro-para-a-localizacao-dos-objetivos-de-desenvolvimento-sust.html>.
- Rodrigues, C. & Villela, F. (2015). Disponibilidade e escassez de água na Grande São Paulo: elementos-chave para compreender a origem da atual crise de abastecimento. *Geosp – Espaço e Tempo (Online)*, 19(3), pp. 399-421.
- Rosa dos Santos, G., Lizete Farias, A., Nogueira Soares, D., Franca Freitas, D., Vasquez Arroyo, E., Issao Kuwajima, J., Augusto Bronzatto, L., Simões Cucio, M. & Rodrigues Fachine, V. (2018). *Elementos essenciais e diretrizes para o aperfeiçoamento de políticas públicas e atendimento ao ODS 6: Texto preliminar escrito como subsídio ao debate ao segundo seminário do projeto para realização de estudos e proposição de medidas para implantação e monitoramento do Objetivo de Desenvolvimento Sustentável (ODS) nº 6 - Água e Saneamento, firmado entre a Agência Nacional de Águas-ANA, o Instituto de Pesquisa Econômica Aplicada-IPEA, o Centro Internacional de Políticas para o Crescimento Inclusivo-IPC-IG e o Programa das Nações Unidas para o Desenvolvimento-PNUD*.
- Santos, C., Satyamurty, P., Gomes, O. & Silva, L. (2012). Variability of extreme climate indices at Rio claro, São Paulo, Brazil. *Revista Brasileira de Meteorologia*, 27(4), pp. 395-400.

- SABESP. (2013). Relatório interno sobre produção diária de água entre 2004 e 2012 para a Região Metropolitana de São Paulo, SABESP, São Paulo.
- Sachs, J. (2012). From Millennium Development Goals to Sustainable Development Goals. *The Lancet*, 379(9832).
- Silva Dias, M., Dias, J., Carvalho, L., Freitas, E. & Silva Dias, P. (2013). Changes in extreme daily rainfall for São Paulo, Brazil. *Climatic Change*, 116(3-4), pp. 705-722.
- SOS Mata Atlântica. & INPE. (2018). *Atlas dos Remanescentes Florestais da Mata Atlântica: Período 2016-2017*. Relatório Técnico. Retrieved from Fundação SOS Mata Atlântica e Instituto Nacional de Pesquisas Espaciais website: <https://www.sosma.org.br/projeto/atlas-da-mata-atlantica/dados-mais-recentes/>.
- Torres, P., Jacobi, P., Barbi, F. & Goncalves, L. (2019). Governança e Planejamento Ambiental: adaptação e políticas públicas na Macrometrópole Paulista. Rio de Janeiro: Letra Capital.
- Torres, P., Ramos, R. & Gonçalves, L. (2019). Conflitos ambientais na Macrometrópole Paulista: Paranapiacaba e São Sebastião. *Revista Ambiente & Sociedade*, vol. 23.
- UN General Assembly. (2001). *Road map towards the implementation of the United Nations Millennium Declaration: Report of the Secretary-General* (No. A/56/326).
- _____. (2012). *The future we want* (No. A/RES/66/288).
- _____. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development* (No. A/RES/70/1).
- UN Water. (2013). *Water Security and the Global Water Agenda: A UN-Water Analytical Brief*. Retrieved from <http://www.unwater.org/publications/water-security-global-water-agenda/>.
- UNESCO-IHP. (2012a). Strategic Plan of the Eight Phase of IHP (IHP-VIII, 2014-2021). Paris, France: UNESCO-IHP. Available at <http://unesdoc.unesco.org/images/0021/002164/216434E.pdf>.
- _____. (2012b). Final Report. 20th Session of the Intergovernmental Council. Paris. 4-7 June, 2012. Paris, France: UNESCO-IHP. Available at <https://unesdoc.unesco.org/ark:/48223/pf0000217383>.
- United Nations. Sustainable Development Goal 6. Sustainable Development Knowledge Platform. Retrieved from <https://sustainabledevelopment.un.org/sdg6>.
- United Nations. (2017). *Progress towards the Sustainable Development Goals: Report of the Secretary-General* (No. E/2017/66).
- Warner, J. (2005). Multi-Stakeholder Platforms: integrating society in water resource management? *Ambiente e Sociedade*, 8(2), Campinas. pp. 9-28.
- Young, O. (2009). Governance for sustainable development in a world of rising interdependences. In Delmas, M. & Young, O. (eds.) *Governance for the Environment: New perspectives*, pp.12-40. Cambridge University Press.

Website accessed:

- <http://programademetas.prefeitura.sp.gov.br/>.
- IBGE: <https://indicadoresods.ibge.gov.br/objetivo/objetivo?n=6> .
- SEADE: http://www.projetos.seade.gov.br/wireframe/ods/#ods6_meta_61_page .
- Observatório do Futuro (TCESP): <https://www4.tce.sp.gov.br/observatorio/#section-team>.
- Global Targets and Indicators for SDG 6: <https://sustainabledevelopment.un.org/sdg6> .
- UN Stats - SDG 6 (Clean Water and Sanitation): <https://unstats.un.org/sdgs/report/2017/goal-06/>.

Notes

1. Brazil's official monitoring agency is IBGE. Under the website <https://ods.ibge.gov.br> is possible to follow the updates. More details on the official data and methodology on the website. Civil Society just release a book with an alternative measuring of the goals <https://gtagenda2030.org.br/category/relatorio-luz/>.
2. *Programa 3913, Planejamento e Administração dos Recursos Hídricos* (R\$ 73.781.866,-) and *Programa 3934, Planejamento, Formulação e Implementação da Política de Recursos Hídricos* (R\$ 723.629.970,-).
3. *Programa 2511, Habitação sustentável e recuperação ambiental da Serra do Mar e Litoral Paulista* (R\$ 1.764.105.059,-); *Programa 2618, Conservação ambiental e restauração ecológica* (R\$ 1.402.786.610,-); *Programa 2619, Redução da vulnerabilidade ambiental e mudanças climáticas* (R\$ 149.248.515,-).



IV

Water Security and Technology





7

Dimensions of Water Security in the Global Context of Sustainable Development

Petra Schneider and Tamara Avellán

Petra Schneider, University of Applied Sciences Magdeburg-Stendal.

e-mail: petra.schneiderk@hs-magdeburg.de

Tamara Avellán, United Nations University, Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES).

e-mail: avellan@unu.edu

Abstract

The contribution discusses the transdisciplinary dimensions of water security in the framework of global change syndromes according to Schellnhuber et al. (1997), as there are: Utilization Syndromes (Sahel, Overexploitation, Rural Exodus, Dust Bowl, Katanga, Mass Tourism, Scorched Earth), Development Syndromes (Aral Sea, Green Revolution, Asian Tiger, Favela, Urban Sprawl, Disaster), and Sink Syndromes (Smokestack, Waste Dumping, Contaminated Land). Through case studies, illustrated with a cause-and-effect analysis the drivers and pressures on water resources for the global change syndromes are described, and their resulting impacts in relation to the UN Sustainable Development Goals (SDGs), also known as Agenda 2030. In addition, we show the responses while focusing on success stories of dealing with global change syndromes. In the water-related transdisciplinary context of SDG6, the proposed topic relates further to the SDGs 1, 2, 3, 4, 7, 8, 9, 11, 12, 13, 14, 15 and 16. The syndrome approach forces systems thinking to analyze the interlinkages between sectors and approaches, and as such is a feasible teaching tool for the assessment and implementation of a Nexus approach, supporting strongly SDG17 – partnership for the goals. The results shall support to disseminate information on water security and the SDGs, providing the water community with illustrative material, which can be used also for teaching purposes on different educational levels.

Keywords

Global change syndromes, planetary boundaries, global water security

01

Introduction

With the 2030 Agenda for Sustainable Development, the international community expresses its conviction that global challenges can only be solved together. The Agenda lays the foundation for shaping global economic progress in harmony with social justice and within the Earth's ecological boundaries.

At the heart of the agenda is an ambitious catalog of 17 Sustainable Development Goals (SDGs) (United Nations, 2015a). The Agenda 2030 represents a new global understanding of transforming economies towards sustainable development, for example through responsible consumption and production patterns and clean and affordable energy. It becomes clear that climate policy, sustainable development and poverty reduction are inextricably interwoven.

The importance of water to the international community is made clear by the inclusion of the ambitious target 6: “Ensure availability and sustainable management of water and sanitation for all by 2030.” (United Nations, 2015a). The Human Right to Water and Sanitation (HRWS) was already recognised by the UN in 2010 (United Nations General Assembly, 2010), and later on highlighted as separate but equal in 2015 (United Nations, 2015b).

“Worldwide, around 4 billion people, or two-thirds of the world’s population, do not have enough water for at least one month a year, so they suffer severe water scarcity, which is divided into two aspects: shortage and stress.”

1.1. Dimensions of Water Security

Water security was defined as “the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks” (Grey & Sadoff, 2007). The further development of the characterization by the UN-Water Task Force on Water Security (2013) lead to the following definition: “The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability”.

Worldwide, around 4 billion people, or two-thirds of the world's population, do not have enough water for at least one month a year, so they suffer severe water scarcity, which is divided into two aspects: shortage and stress (Kummu et al., 2016) (See Figure 7-1). According to Kummu et al. (2016) water shortage refers to the impact of low water availability per person, while water stress refers to the impact of high water use (either withdrawals or consumption) relative to water availability. The population under water scarcity increased from 0.24 billion (14% of global population) in the 1900s to 3.8 billion (58%) in the 2000s (Kummu et al., 2016). 1.8 to 2.9 billion people suffer from severe water shortages for 4 to 6 months a year, and about 0.5 billion people year-round (Mekonnen & Hoekstra, 2016).



Figure 7-1 Overview of the dimensions of water stress (World Resources Institute, 2013)



Figure 7-2 Estimates of how the different control variables for seven planetary boundaries have changed from 1950 to present (Source Stockholm Resilience Centre, 2013). The green shaded polygon represents the safe operating space (Source Steffen et al., 2015)

In the frame of the SDGs, water security plays a fundamental role for several related SDGs, particularly SDGs 1 (No Poverty), 2 (Zero hunger), 3 (Good Health and Well-Being for People), 4 (Quality Education), 7 (Affordable and Clean Energy), 8 (Decent work and economic growth), 9 (Industry, innovation and infrastructure), 11 (sustainable cities and communities), 12 (Responsible consumption and production), 13 (Climate action), 14 (Life below water), 15 (Life on Land), and 16 (Peace, justice and strong institutions). The opposite of water security, water stress can be caused by natural factors, such as floods and droughts, or be due to water scarcity that arises with rivaling water demands, and can also occur when there is reduced access to drinking water or access to poor water quality (UNESCO, 2015). Water stress is thus influenced by various global change factors such as population growth, urbanization and economic growth, and climate change.

1.2. Global Change and Planetary Boundaries

Global Change is a process that transforms the operational mode of the planetary ecosystem, thereby generating cascades of significant (and possible irreversible) impacts on a majority of individuals in present and future generations (WBGU, 1994). In this regard, the global change process is closely linked with the concept of planetary boundaries of the Stockholm Resilience Centre (Rockström et al., 2009). These boundaries define the safe operating space for humanity with respect to the earth's system and are associated with the planet's biophysical subsystems or processes (Rockström et al., 2009) (See Figure 7-2). Even if some of the limits that have not yet been surpassed globally, some already exceed regional tolerance limits, such as water consumption in the western US, as well as in parts of southern Europe, Asia and the Middle East.

1.3. Global Change Syndromes

The word “syndrome” stems from ancient Greek and refers to a confluence of various factors. In the medical field, syndromes are complex clinical pictures. The syndrome approach is a method for considering problems in the environmental, economic, social and cultural fields, which are divided into different syndromes (WBGU, 1994, 1996; Schellnhuber et al., 1997). The basic hypothesis of the syndrome concept is the assumption that global change can be traced back to a manageable number of typical patterns or trends of causal relationships at the human-environment interface (WBGU, 1994, 1996; Schellnhuber et al., 1997). The trends or symptoms (Harenberg, 2011) of global change denote highly complex natural and anthropogenic processes and describe the most important developments in global change as qualitative elements. As such, the syndrome concept has four goals:

- Systematic, functionally oriented overview of the processes of global change on different spatial and temporal scales;
- Identification of non-sustainable developments of development patterns in order to determine the guidelines for a “sustainable development”;
- Contribution to the operationalization of the sustainability concept;
- Identification of the decomposition of global change into functional patterns.

The syndrome concept is a heuristic approach, which, however, intuitively does justice to the complexity of human-environment interactions within global change. Syndromes or “(global) clinical pictures” (WBGU, 1996) involve different interacting symptoms that explain mechanisms of change (feedback effect, synergetic effect, and symbioses) (Schindler, 2005). Syndromes thus represent characteristic, generalized constellations of symptoms and interactions (Cassel-Gintz & Bahr, 2008). However, individual symptoms can be part of different syndromes (Schindler, 2005).

In the process of syndrome identification, generalizations regarding the interactions between the individual symptoms are possible (e.g. “the more intensive the agriculture, the higher the soil degradation”) (Cassel-Gintz & Bahr, 2008). Each syndrome involves a fixed core mechanism (certain interactions between symptoms). In addition, however, it remains regionally flexible, since other symptoms can occur depending on the circumstances (Schindler, 2005). The identified syndromes were classified by the WBGU into the three groups, namely: “use” (with a total of 7 syndromes), “development”

“The syndrome approach is a method for considering problems in the environmental, economic, social and cultural fields, which are divided into different syndromes.”

Syndrome	Explanation	Example
Sahel-Syndrome	agricultural overuse of marginal habitats	Sahel Zone
Rural Exodus	environmental degradation through the abandonment of traditional forms of land use	Western Africa
Depletion- (or overexploitation) Syndrome	depletion of natural ecosystems	deforestation of tropical rain forests, for example, in Brazil
Dust-Bowl-Syndrome	temporary industrial cultivation of soil and water	Mid-West of the USA, Western Europe
Katanga-Syndrome	environmental degradation through destruction of non-renewable resources	Raw Material Mining (Diamond Mines), Mining
Mass Tourism -Syndrome	development and damage of natural areas for recuperation reasons and tourism	Mallorca, Tenerife
Scorched-Earth-Syndrome	environmental destruction through military use	Vietnam War

Table 7-1 Use Syndromes (Schellnhuber et al., 1997)

Syndrome	Explanation	Example
Aral Sea-Syndrome	environmental damage due to intentional nature-design for large projects	Aral Sea, Three-Gorges-Barrage, Lake Chad
Green-Revolution-Syndrome	environmental degradation through the expansion of habitat-strange agricultural production methods	Green Revolution in India or China, Green Houses
Small-Tiger-Syndrome	neglect of ecological standards in the course of highly dynamic economic growth	Indonesia, Vietnam
Favela-Syndrome	environmental degradation through unregulated urbanisation	Marginal Towns in Mega Cities
Urban Sprawl Syndrome	landscape damage through planned expansions of cities and infrastructures	Suburbanisation in North America or Europe
Disaster-Syndrome	singular, human caused environmental catastrophes with long-term effects	Tailings Pond Spills, Chernobyl, Fukushima

Table 7-2 Development Syndromes (Schellnhuber et al., 1997)

Syndrome	Explanation	Example
Smokestack-Syndrome	environmental degradation through long range diffuse distribution of most durable agents	Ozone Layer
Landfill-Syndrome	environmental consumption through regulated and unregulated dumping of human waste	Landfills on the Outskirts of Large Cities
Contaminated Sites -Syndrome	local contamination of environment commodities from industrial production facilities	Western and Eastern Europe, for instance Manchester-Liverpool-Birmingham,

Table 7-3 Sink Syndromes (Schellnhuber et al., 1997)

(with a total of 6 syndromes) and “sink” (with a total of 3 syndromes) (WBGU, 1996; Schellnhuber et al., 1997).

The syndrome group “use”, which describes syndromes as a result of an unadjusted use of natural resources as production factors, is assigned seven different syndromes (See Table 7-1).

Another six syndromes are assigned to the syndrome group “development”, which includes human-environment problems resulting from non-sustainable developmental processes (See Table 7-2).

The remaining three syndromes are assigned to the group “sinks”, which addresses environmental degradation through unadjusted civilization disposal (See Table 7-3).

1.4. Cause-and-Effect Analysis

The Cause-and-Effect Analysis is a diagram-based technique to identify likely causes of problems (Ishikawa, 1968; 1990). Although it was originally developed as a quality control tool, the technique is feasible also for purposes, like:

- Discovering the root cause of a problem.
- Uncovering bottlenecks in a process.
- Identifying where and why a process is not working.

An Ishikawa diagram is a particular type of Cause-and-Effect Analysis which works through the visualization of categories of the potential causes of a problem in order to identify their root causes (Ishikawa, 1968; 1990). It covers the categories “Equipment”, “Process”, “People”, “Materials”, “Environment”, and “Management”. The syndromes described in the earlier section are to a large extent ‘problems’. Ishikawa diagrams may help in visualizing the causes of syndromes by splitting up the problem into several categories.

1.5. Scope of this article

The scope of this contribution is to assess water security in the framework of global change syndromes according to Schellnhuber et al. (1997) by means of a cause-and-effect analysis (Ishikawa-Diagrams) to highlight the drivers and pressures on water resources, and the resulting impacts in relation to the SDGs. Case studies of water-security related syndromes are used to illustrate the current global situation of stressed Planetary Boundaries. The contribution also highlights success stories and their contributions to the implementation of the SDGs. Success stories indicate options to take measures for improvement of water stress.

02

Methodology

The focus of the analysis was laid on global syndromes with a particular impact on assessing water stress to achieve water security. With its four dimensions – water availability/water scarcity, accessibility, quality and environmental flows – water stress was used to assess relevant syndromes.

For each syndrome that relates to a dimension of water stress, we undertook a cause-and-effect analysis by an empirical key driver analysis (KDA) which allows to identify what features or aspects have the biggest impact on an outcome variable (Alberts & Dorofee, 2009). We then used a case study for each syndrome to illustrate the cause-and-effect analysis and success stories to show how to overcome the impacts.

03

Results: Correlating Water Related Global Change Syndromes and Agenda 2030

Use syndromes depend strongly on population growth, and the related resource consumption for economic development. Underlining the interrelation, we selected the Sahel syndrome, which forces rural exodus. People seek a better life (Favela syndrome) and leave their homes (Rural exodus syndrome) to improve their economic situation. When societies start to develop, they use resources for urbanization (Katanga syndrome, Aral Sea syndrome), drive agricultural (Green revolution syndrome) and industrial development (Smokestack syndrome). Usually, the development activities cause severe environmental impacts and societal challenges which call urgently for a sustainable development approach as outlined in the Agenda 2030.

We selected the following syndromes for further cause-and-effect analysis, because the WBGU (1996) showed that these had significant water shortage effects and negative impacts on water resources:

1. Use Syndromes
 - a. Sahel syndrome,
 - b. Rural exodus syndrome,
 - c. Katanga syndrome,
2. Development Syndromes
 - a. Aral Sea syndrome,
 - b. Favela syndrome,
3. Sink Syndromes
 - a. Smokestack syndrome.

3.1. Cause-and-effect Analysis for Use Syndromes and Respective Cases

Use syndromes are based on the use and consumption of natural resources, as expressed for instance through the Water-Energy-Food Nexus. There are sectoral demands on the available water resources which in practice are often not equivalent with the available resources. In terms of water resources, Use syndromes lead to the depletion of water resources from water shortages all the way to water scarcity (See Table 7-4 for the water stress relevant Use syndromes).

3.1.1. Sahel Syndrome

The Sahel-Syndrome refers to Agricultural overexploitation of marginalized sites. This is the exceedance of the ecological carrying capacity in regions that are of limited agricultural use. Symptoms include destabilization of ecosystems, loss of biodiversity, soil degradation, higher risk of drought due to deforestation, desertification, food security threats, marginalization, and rural exodus. The results of the Ishikawa diagram are shown in Figure 7-3.

Marginal land is land that is of little agricultural value because crops produced from the area would be worth less than any rent paid for access to the area (Baumol & Blinder, 2011). Peterson & Galbraith (1932) considered that the term marginal is often used in a subjective sense for less-than-ideal lands, in this way being fundamentally an economic term. There are several types of reasons for land being marginal, for poor water supply, poor soil quality, pollution from previous industrial activities, terrain challenges such as excessive slope, or excessive distance from means of transportation (Pimentel, 2012).

Syndrome	Explanation	Relation to water stress
Sahel-Syndrome	agricultural overuse of marginal habitats	leads to a reduction of water resources and water availability, driver for drought, often related to poor water supply, driver of climate change
Rural-Exodus-Syndrome	environmental degradation through the abandonment of traditional land use forms	traditional water management structures which are based on family structures (water collection and distribution) are abandoned and might be replaced after a while replaced through industrial structures
Katanga-Syndrome	environmental degradation through destruction of non-renewable resources	freshwater shortage, runoff, pollution of rivers, destruction of river beds, contamination and qualitative freshwater scarcity

Table 7-4 Selected Use syndromes and their relation to water stress

3.1.1.1. Case Study: Chingaza National Park in Colombia

An example of the Sahel syndrome which is quite well documented is the Chingaza National Park in the mountains of Colombia, which provides the freshwater sources for the capital Bogotá. The region is formed by the Páramo, an Andes ecosystem above the continuous forest line with harsh climate and ecological conditions. The Chingaza National Park is located in the Eastern Andes, in the departments of Cundinamarca and Meta of Colombia, at altitudes between 800 and 4,020m above sea level NN, with the largest part of the area at altitudes over 3,300m above sea level (Lora, 1999). The park is protected since 1977. Water represents the most important ecosystem service as about 70% of the water needs of the capital city of Bogotá and its surroundings come from the park area. The area is only marginally suited for agriculture.

The ecosystem services of the Chingaza National Park are threatened by natural factors, such as natural fires and weather phenomena such as El Niño, which cause precipitation and drought. With global warming and agriculture, the spread of herbivorous insects in the national park is favored (→ loss of fauna, effects of invasive fauna and flora). The plant species Espeletia, which plays an important role in the water balance of the area, is at risk (→ loss of fauna, water resources depletion due to reduced groundwater recharge, driver of climate change).

The ecosystem is also threatened by anthropological influences: Runaway dogs that endanger the fauna of the area (→ loss of fauna); the construction of roads, pipelines, dams, shelters (→ loss of land resources, higher risk of drought due to deforestation, higher flood risk due to land sealing); mining and deforestation (→ loss of vegetation, driver of climate change).

Agriculture has the most intense influence, even though the area is not very fertile (→ changed succession patterns). Monoculture areas reduce natural barriers to wildfires as the natural variety of the plant structure is which can reduce the risk of fire is altered (→ changed succession patterns, increase of the drought risk). In an intact Páramo, the natural vegetation of the region (Morales et al., 2007), there are plant structures that survive these fires due to their structure and root system (Bedoya Zuluaga, 2014). The creation of grazing land, however, destroys the Páramo and encourages the spread of certain herbs and grasses (→ loss of vegetation) encouraging the spread of wildfires.

3.1.1.2. Is there a success story?

In the face of the endangered water resources, the water supplier has undertaken efforts to better protect the water resources in the Chingaza National Park to avoid qualitative and quantitative water shortage. Generally, there are various mechanisms for financing the protection of ecosystems. One of them is the Payment for Ecosystem Services (PES). The principle is based on transferring the payment of benefits in the form of money from the users of the ecosystem services to the suppliers and compensating them for their efforts to protect ecosystems (Secretariat of the Convention on Biological Diversity, 2010). The payments create the motivation for behavioral change to protect ecosystems. This principle works particularly well with water supply, since water consumption usually already has financial structures in place (user fees or government investment) (Secretariat of the Convention on Biological Diversity, 2010).

In Colombia, since 2008, PES has been used by the Bogotá Water Fund to protect the water resources of the capital, Bogotá. The Nature Conservancy (TNC) has formed the Water Fund with partner organizations, local authorities

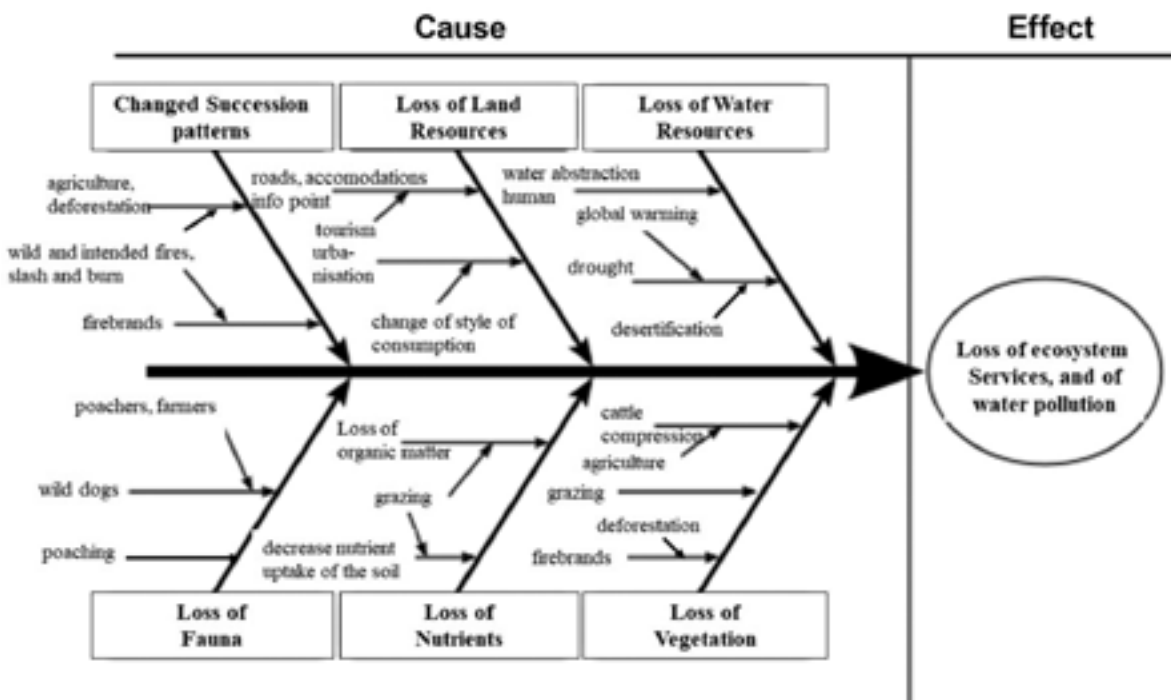


Figure 7-3 Cause-and-effect analysis of the Sahel syndrome

and companies to improve water quality (Secretariat of the Convention on Biological Diversity, 2010). This financial protection mechanism works by compensating the landowner, as for example, in the Bogotá River catchment for their efforts to protect forests and soil (Bogotá Water Fund). Compensation in the form of cash payments is realized through a fund financed by public and private sector funds (Bogotá Water Fund). The water prices of the residents are not affected by this. Potable water quality and quantity are expected to be improved through the protection of the Páramo, thus significantly reducing water treatment costs by 88 billion pesos over a stretch of ten years (Bogotá Water Fund) through optimization of the treatment processes.

3.1.2. Rural Exodus Syndrome

The Rural exodus syndrome refers to Environmental degradation through the abandonment of traditional land use forms. Traditional, formerly sustainable forms of agriculture cannot be maintained due to high work intensity and emigration of mostly young, male populations. The symptoms here are genetic erosion, soil erosion, rural depopulation, endangering food security, lack of water management and marginalization. The results of the Ishikawa diagram are shown in Figure 7-4.

3.1.2.1. Case Study: Rural-urban migration in Uganda

By 2030 at the latest, the UN estimates, that more Africans will live in cities than in the countryside (United Nations, Department of Economic and Social Affairs, Population Division, 2014) producing more and higher polluted wastewater (Mateo-Sagasta et al., 2015) (→ urbanization and changed lifestyle, urban sprawl). With an annual population growth of 3.3%, Uganda is one of the fastest growing countries in Africa, and worldwide (United Nations, 2018). In 2017, 85% of the

41.45 million people living in Uganda did so in the countryside (Destatis, 2018). In rural areas, on average, three quarters of household income comes from agriculture (Kasirye, 2013). To escape from poverty is one of the main motivation for rural exodus in Uganda, as the income conditions in the urban centers are better, as shown in Figure 7-5.

Small farmers dominate the agricultural sector, over 90% of the products are grown on farms with less than two hectares (Government of the Republic of Uganda, Ministry of Agriculture, Animal Industry and Fisheries, 2009). Small farmers often lack knowledge about sustainable and profitable methods of cultivating and livestock farming as well as the marketing of products (→ insufficient technical knowledge and equipment). Micro-credit to start small businesses is hardly accessible to the rural population (Seibel & Almeyda, 2002; Mpuga, 2004; The World Bank, Financial and Private Sector Development, Africa Region, 2009). The soil is degraded and the effects of climate change are noticeable, so that the young population migrates (→ land degradation). About 20% of the population lives below the poverty line (The World Bank Group, 2016).

3.1.2.2. Is there a success story?

Throughout Africa, eco-villages projects have been created where people gather to change their social and environmental situation. Whether they create jobs and training opportunities for women and young people on their own initiative; whether they organize tree planting, a well or toilet constructions in slums and villages, or care for street children; whether they defend nature on the edge of national parks: they create alternatives to escape from the big city, but also from poverty in their villages. A number of eco-villages projects were founded also in Uganda, with one example given in Figure 7-6.

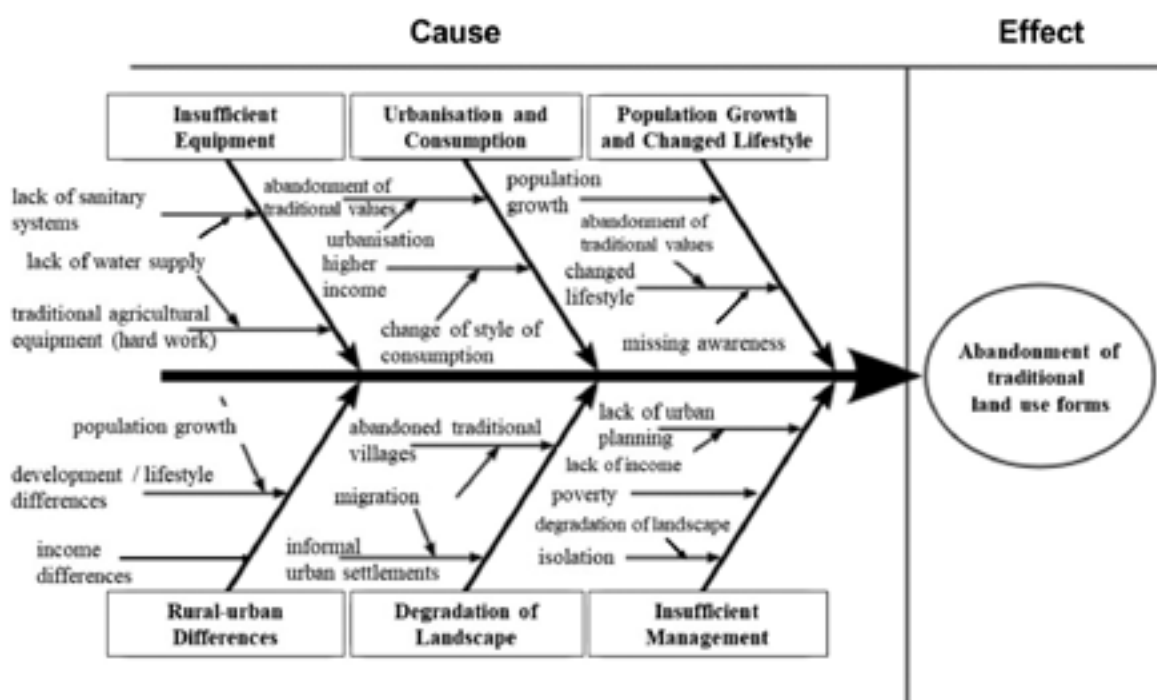


Figure 7-4 Cause-and-effect analysis for the Rural Exodus Syndrome

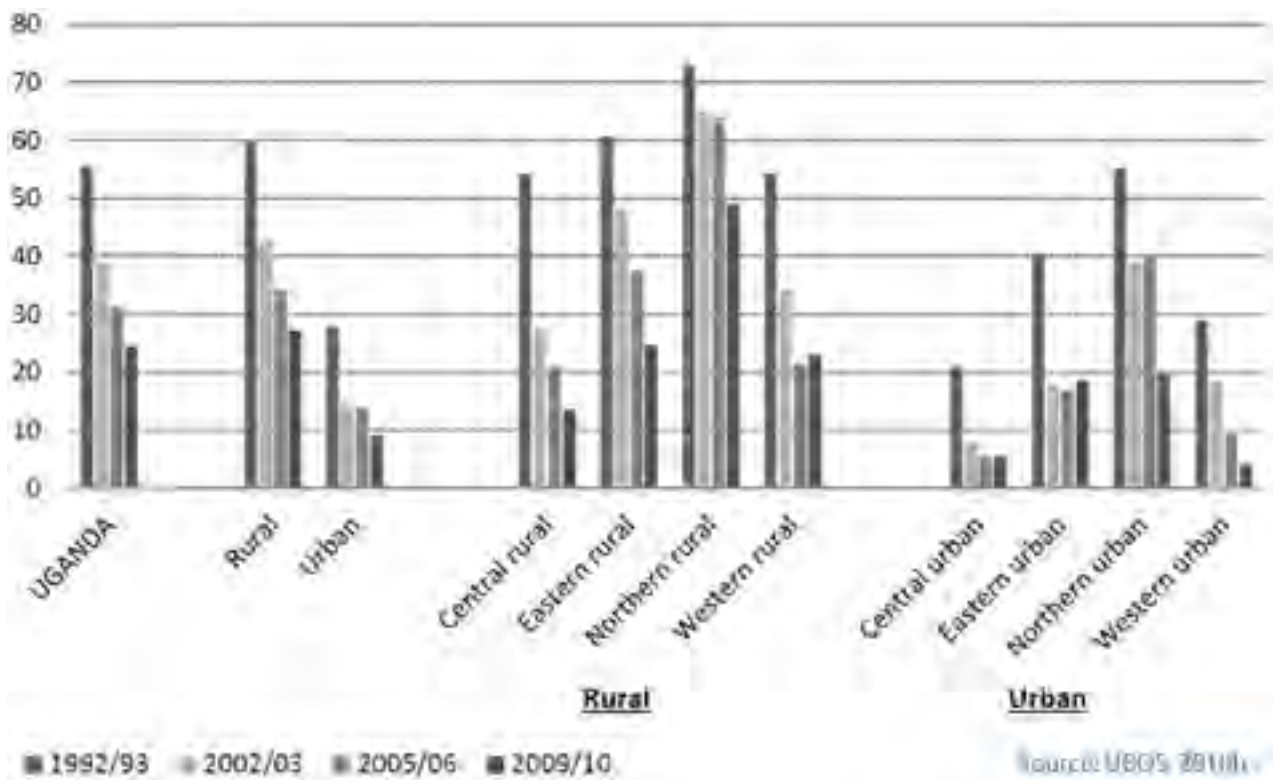


Figure 7-5 Rural and urban poverty headcount trends, national and regional, 1992-1993 to 2009-2010, in % (Mukwaya et al., 2012)

Through the improvement of farming methods and more versatile products, through higher yields, through sustainable agriculture and the approaches to establish a joint market for selling artisanal products, many families or young people have been able to resist the trend to move to urban centers (Dorosh & Thurlow, 2012). Through this approach, water and land resources are being preserved, additional income for the local inhabitants is generated as well as a perspective for the long term. The Kibale Association for Rural and Environmental Development (KAFRED) outlined how tourism has changed the Bigodi community (Bigodi Tourism, 2017):

- employment of 17 teachers, 8 guides, 3 cooks, 4 security guards and 3 cleaners, teachers and guides receive training

and capacity building.

- prices in Bigodi are 30% higher in Bigodi than in neighboring villages that have no tourist trade.
- the number of permanent houses has increased from 2 in 1992 to 7 in 1995, being more than 30 nowadays.
- about 95% of wetlands visitors are foreigners, creating other business opportunities such as hotels and lodges run by local people and which employ local staff.

Furthermore, KAFRED funded a community project for water security. Community water kiosks have been set up to serve at least 300 people, leading to a reduction of the water prices from UGS 800 to UGS 200 per 20 L can. This success story reflects the SDGs 1, 2, 3, 4, 6, 11, 13, and 15.



Figure 7-6 Impression of the Uganda eco-village in the Bigodi Wetlands Sanctuary in the Kibale region, established in 1992, providing nature and cultural village walks

3.1.3. Katanga Syndrome

The Katanga-Syndrome refers to Environmental degradation through the depletion of non-renewable resources. The above- and belowground mining of non-regenerative resources damages the environment partly irreversibly by toxicity or morphological and energetic consequences. The symptoms included are the loss of biodiversity, local air pollution, freshwater shortage, runoff, pollution of rivers, destruction of river beds, soil degradation, contamination, and environmental damage. The results of the Ishikawa Diagram are shown in Figure 7-7.

3.1.3.1. Case Study: Lusatian Mining District in Germany

Even though the Katanga-Syndrome is named after a mining region in Congo, the case study refers to a mining region in Eastern Germany, the lignite mining area in Lusatia, an area bordering Poland. Prior to the industrialization in the region, lignite from numerous small artisanal mines was extracted and used as domestic fuel or agricultural fertilizer. In 1998, approx. 80,000 ha of arable and forested land were affected by mining activities in the Lusatian area (Hüttel, 1998; Krümmelbein et al., 2012).

In Lusatia, brown coal was found in the area of Lauchhammer in 1789 and a first lignite mine was cut there in 1815 (Heitmann et al., 2010). The fuel demand of the cloth and glassworks factories in the 1860s was the trigger for the establishment of several mining operations in Upper Lusatia. Since the end of the 1850s lignite was blackened and briquetted. After 1870 in the Lusatian district, the lignite mining took structure determining dimensions, through two processing plants, which processed coal of seventeen mines and in 1989 promoted about 1/6 of the lignite world production (Heitmann et al., 2010). By this, once the largest brown coal refining company in the world, the number of

inhabitants in the formerly small town Hoyerswerda increased within three decades from less than 10,000 to finally over 70,000 people. One of the most fundamental consequences of lignite mining was the relocation of the affected people associated with the depletion of mining sites (→ insufficient management). A total of 136 Lusatian towns have partially or completely disappeared; >25,000 people lost their homes (source: Museum Archive of missing places, Forst, Lower Lusatia; Heitmann et al., 2010).

Connected to the lignite mining activities come huge environmental impacts caused by the mass movement and the dewatering of the mining area (Krümmelbein et al., 2012). Groundwater was pumped through well galleries to lower the groundwater level for several kilometers around the mines (→ insufficient management). Land subsidence due to groundwater extraction caused stability problems to buildings (→ land degradation and deforestation). Air pollution due to dust and sulphide dioxide was immense (→ emissions to water, soil and air; qualitative freshwater scarcity). The number of children suffering from bronchitis in the mining area increased from 228 (1974) to 342 (1989, annual average) (Heitmann et al., 2010). Figure 7-8 provides an impression of the former lignite mining area in the Lusatia region in 1980.

The mass transfer of billions of tons of soil led to the devastation of nature and a disturbed water balance. Weathering and oxidation of geogenic sulphide minerals in the coal layer take place when they are exposed to air during excavation (Krümmelbein et al., 2012) (→ handling mining substances). This process causes acid mine drainage (AMD), that is the release of acidity, iron and sulphate, an impact that continues even after the closure of the lignite mine (→ insufficient equipment). AMD of lignite mining sites often contains high concentrations of iron and heavy metals (Vanberk & Wisotzky, 1995).

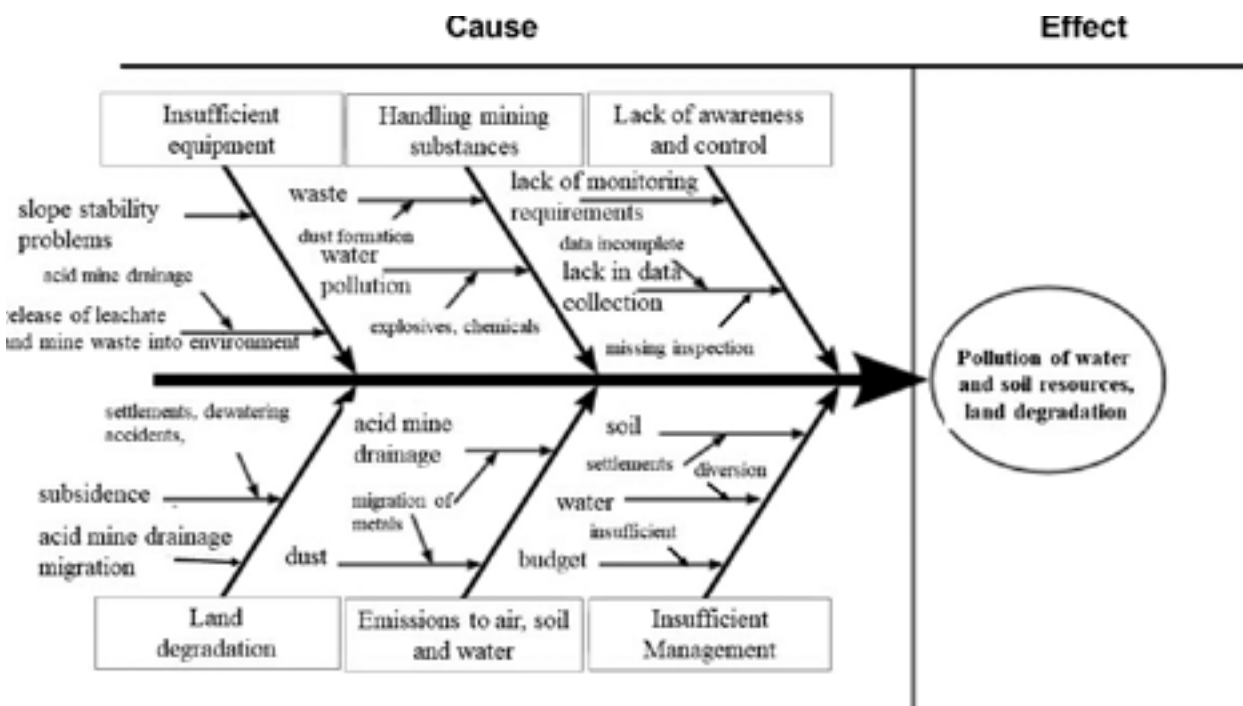


Figure 7-7 Cause-and-effect analysis for the Katanga syndrome



Figure 7-8 Former lignite mining area in the Lusatia region in 1980 (Source Welt Journal)

3.1.3.2. Is there a success story?

Lusatia (former) lignite mining became a success story after the year 2000, particularly in terms of water. The Lusatian Lakeland is becoming an artificial lake district in Lusatia (Richter, 2008; Diesing & Weiß, 2009). Due to the flooding of the abandoned lignite mines of the Lusatian lignite mining area, Europe's largest artificial water landscape and Germany's fourth largest lake district is to be created by 2025. The new lake district, the so called Lusatian Lakeland, is largely made up of former open cast lignite mines, which are flooded.

Some of the emerging lakes have already reached their final water level, others will be completely flooded in a few years. The total extent of Europe's future largest artificial lake district is about 80km from west to east, and from north to south (depending on the demarcation) between 32 and 40km (Richter, 2008; Diesing & Weiß, 2009). Figure 7-9 provides

an impression of the Lusatian Lakeland and the connecting navigable channels. The Lusatian Lakeland has a special significance for the tourist development of Lower Lusatia with approx. 7,000 ha of water (Richter, 2008; Diesing & Weiß, 2009). The plan is to make the lake landscape a nationally important water landscape with an attractive character, representing a modern example of Green and Blue Infrastructure.

Extensive investment in infrastructure is needed for this purpose: making bathing beaches, marinas, bases for water skiing, jet skiing, camping, gastronomy, etc. The individual lakes have been connected with channels to allow faster flooding. The connecting channels are navigable for use in water sports and water tourism (Richter, 2008; Diesing & Weiß, 2009), creating completely new job opportunities for a region which suffered decades from environmental damage. The Lusatian Lakeland represents a success story with reference to the SDGs 3, 6, 9, 11, 13, 14, and 15.



Figure 7-9 Impression of the Lusatian Lakeland and the connecting channels

3.2. Development Syndromes

The Development syndromes refer to human-environment problems resulting from non-sustainable developmental processes that lead to degradation processes which interact with socio-economic developments. In terms of water resources, this concerns phenomena like water resources consumption (particularly of fossil water resources), pollution and overexploitation leading to water scarcity and water stress (See Table 7-5). Also, the global water grabbing problem (in conjunction with land grabbing) is a symptom which reflects the global problems in terms of water and food security.

3.2.1. Aral Sea syndrome

The Aral Sea syndrome refers to Environmental damage through targeted natural space design in the framework of major projects. This is a failed large-scale and planned transformation of natural areas with high capital investment, where the effects of a lack of understanding of the system are ignored. Examples are dams or irrigation projects. The cluster of symptoms consists of a loss of biodiversity, local to global climate change, lack of freshwater supply, soil degradation, forced displacement of local populations, and the threat of inter-state conflict (e.g. water). The results of the Ishikawa Diagram are shown in Figure 7-10.

Syndrome	Explanation	Relation to water stress
Aral Sea-Syndrome	environmental damage due to intentional nature-design for large projects	local to global climate change, drought, lack of freshwater supply, qualitative and quantitative freshwater scarcity, driver of climate change
Favela-Syndrome	environmental degradation through unregulated urbanisation	due to informal settling, there is no waste water network, no waste water collection, which results in the pollution of rivers and ground water resources, causing qualitative freshwater scarcity, higher risk of flooding due to deforestation and river embankment destabilisation

Table 7-5 Selected Development syndromes and their relation to water stress

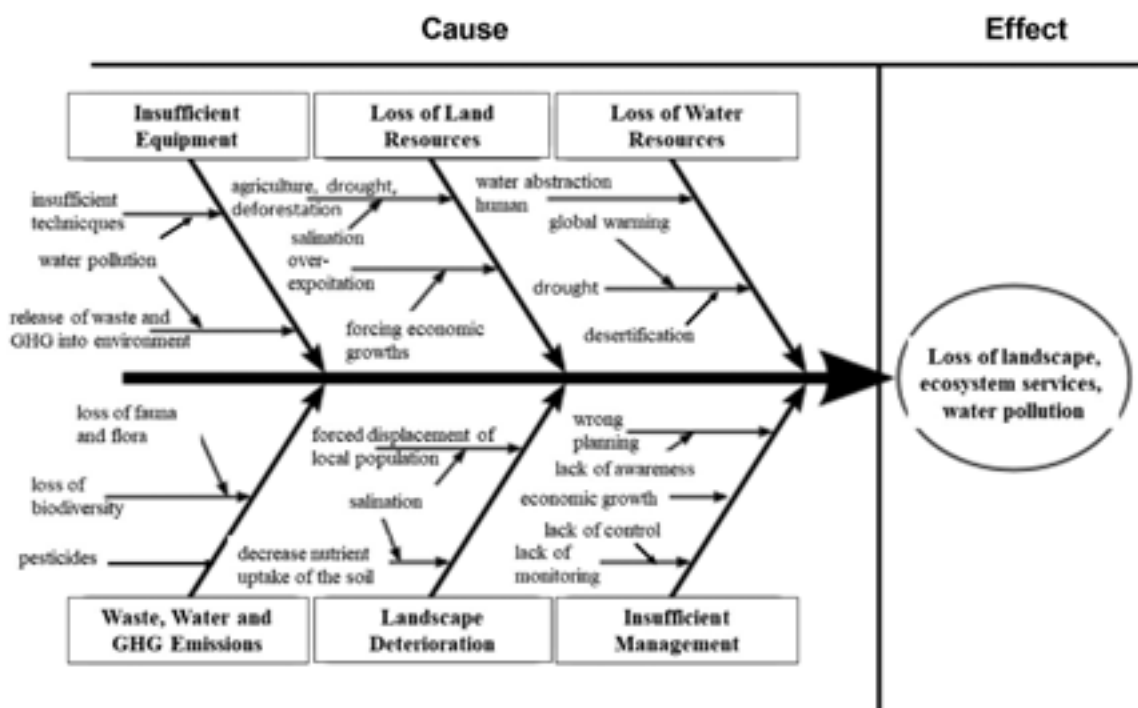


Figure 7-10 Cause-and-effect analysis for the Aral Sea Syndrome

3.2.1.1. Case Study: The Aral Sea

The decline of the water levels of the Aral Sea is recognized as one of the biggest catastrophes which happened to the water resources in the past century, and it is still ongoing. The Aral Sea was a large salt lake in Central Asia, within the following countries: Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, and Turkmenistan, all being parts of the former Soviet Union. The main tributaries are the rivers Amu Darya (coming from the south) and Syr Darya (from the east). With its original size of around 68,000km², the Aral Sea used to be the fourth largest inland lake in the world. In the early 1960s, the Soviet government decided the two rivers would be diverted to irrigate the desert, in an attempt to grow rice, melons, cereals, and cotton (Gaybullaev et al., 2013) (→ water resources overexploitation). Subsequently, at the turn of the 20th to the 21st century the Aral Sea dried up and only a few small bodies of water remain due desertification/desiccation (Luxner & Drake, 2015) (→ drought). Since then, the remains have formed the Northern Aral Sea, the Western Aral Sea, the Barsakelmes Lake between them and the Aralkum desert. Figure 7-11 provides information about the desiccation of the Aral Sea (Luxner & Drake, 2015).

While the cotton crop fields in Kazakhstan and Uzbekistan covered 50,000 ha in 1884, the production increased to 2.9 Mio ha in the 1950s, and further to 7.2 Mio ha in 1989 (Giese

“The Development syndromes refer to human-environment problems resulting from non-sustainable developmental processes that lead to degradation processes which interact with socio-economic developments.”

et al., 1998). Nowadays, more than 8 Mio ha of land are irrigated (Unger-Shayesteh et al., 2013), and around 22 Mio people depend on irrigated agriculture (→ water resources overexploitation). From the 1960s to 1997, the water level dropped 18 meters from 53m to 35m, and the lake's area dropped 44.3% to 29,630km² (Giese et al., 1998). The volume of water was reduced by 90% and at the same time the salinity quadrupled (→ loss of water resources, qualitative freshwater scarcity). The crisis of the Aral Sea continues and the trend has not receded or reversed, even though there are discussions about several solutions on restoration of the lake and reducing the water losses in the catchment. The fundamental approach to a rehabilitation of at least part of the water resources would be the establishment of a transboundary water management system, which is respecting the catchment's hydrological limits. This would also mean for all pivotal states to reduce their water consumption.

3.2.1.2. Is there a success story?

Even though the chance to restore the Western Aral Sea is very low, there is hope for the Small Aral Sea. To save at least the smaller (northern) part of the Aral Sea, Kazakhstan built the Kokaral Dam in 2003-2005 to hold back the water. In addition to this dam construction, measures were also taken to improve the irrigation systems along the Syr Darya, which flows into the northern part of the lake (Bekchanov



Figure 7-11 Desiccation of the Aral Sea (Luxner & Drake, 2015)

et al., 2015). In the process, canals were repaired and partly the embankments were reinforced with concrete. This should provide additional water to be directed into the lake.

As a result, by 2006, the lake level increased by 3 meters (Micklin, 2007), the area increased by 900km² and the volume by 11km³, the salinity dropped significantly. Since the Northern Aral Sea has an outflow, the concentration of toxins also dropped: they were flushed into the Western Aral Sea. In some places, the coastline has shifted more than 75km. The Kazakh government hopes that the Aral Sea will largely recover through further improvements in irrigation systems (Micklin, 2007; Micklin et al., 2014; Xu, 2017). The waterline in the Northern Aral Sea has stabilized again in 2009 at a height of 43m. The water surface of the northern part has grown by more than 30%, to now about 3,300km², the volume is 27km³. The salinity there is again below 1.5%, compared to 4% at the end of the 1990s; the fish stocks have recovered (Micklin et al., 2014).

The disadvantage of the project is that the dehydration of the southern part is accelerated: the water that replenishes the northern part of the lake is missing in the south. The dam project reduced the total water intake in the southern half by about one third. This can only be regulated by transboundary cooperation and respective agreements. The Aral Sea syndrome is a common example for the need of the implementation of the SDGs, particularly to create sustainable development in line with SDGs 1, 2, 3, 6, 11, 13, 14, 15, and 16.

3.2.2. Favela Syndrome

Favela Syndrome refers to Environmental degradation through uncontrolled (informal) urbanization. High

population growth and development problems in rural areas are driving a process of unplanned, informal urbanization, especially in the form of slums. The results of the Ishikawa Diagram are shown in Figure 7-12.

It is followed by congestion, infrastructure and environmental problems as well as segregation phenomena. A planning of the settlement processes is no longer sustainable. Symptoms include air pollution, soil erosion, water pollution, waste accumulation, noise, population growth, rural exodus, acute health hazards, marginalization, administrative failures, lack of basic infrastructure and congested transport infrastructure.

3.2.2.1. Case Study: Greater Jakarta (Jabodetabek), Indonesia

With more than 13 Mio inhabitants, Jakarta is by far the most populated city in Indonesia. Jakarta is the capital and thus the political center of the country (→ urban sprawl and land consumption). More than 30 cities in Indonesia have a population of more than 1 Mio. Greater Jakarta (Jabodetabek) has a population of 28 million (→ urbanization and changed lifestyle, deforestation, sealing of land). Nearly 20% of the GDP is generated in the metropolis.

At eight meters above sea level Jakarta has always been vulnerable to flooding. For instance, in February 2007, almost 70% of the urban area was temporarily under water (→ sealed retention spaces, increase of flood risk). The violent monsoons made over 300,000 people homeless. Rapid urbanization and population growth is the main reason for the emergence of informal settlements in Jakarta (Alzamil, 2017). First and foremost, the floods hit the poor who build their huts on the fallow land along the rivers and canals.

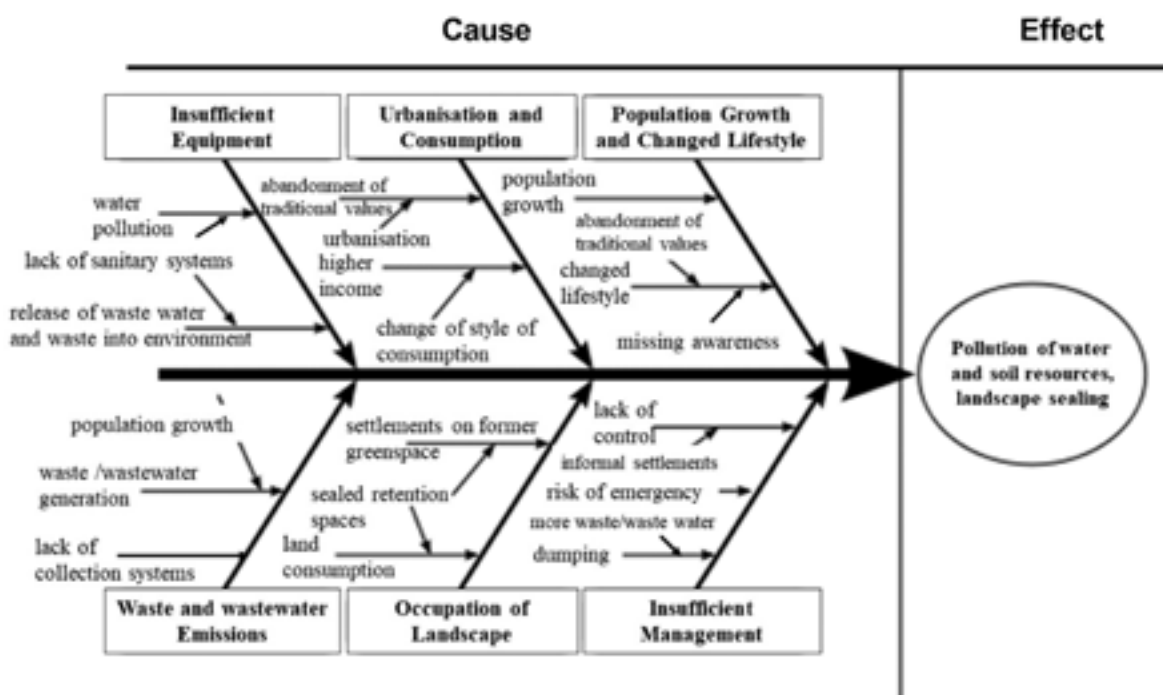


Figure 7-12 Cause-and-effect analysis for the Favela Syndrome

There is a shortage of space in Jakarta (→ urbanization and occupation of landscape, flood risk due to river embankment destabilization and sealing). Figure 7-13 shows the stages of urban development in Jakarta (Baker, 2012).

In 2002, just 92% of households in Jakarta had access to water within a maximum of 200m. Around 50% of households had drinking water within the building (→ urbanization). About 8% were dependent on private water vendors and usually had to pay a multiple of the city water price. Almost 60% of the houses and other housing units were connected to the sewage system, almost 100% to the power supply. The average private water consumption rate for Jakarta was 161L/cap*d in 2002. In informal settlements and slums this consumption is much lower and there is a lack of sanitary systems (→ water

pollution). Only 16% of wastewater was disposed of safely in 2002 (United Nations Department of Economics and Social Affairs/Population Division, 2006; United Nations Human Settlements Programme, 2003, 2005).

3.2.2.2. Is there a success story?

The Indonesian government has made attempts to mitigate the greatest challenge of this urban transformation for affordable adequate housing, self-help houses, and the 1 Million Houses Program (Friedrich Ebert Stiftung, 2017). In 2014, the government set the target of “100 – 0 – 100”. This means 100% access to sanitation, zero slums and 100% potable water networks by 2019. The city designed a Smart City urban development concept, which implies the use of network connectivity for e-governance, communication,

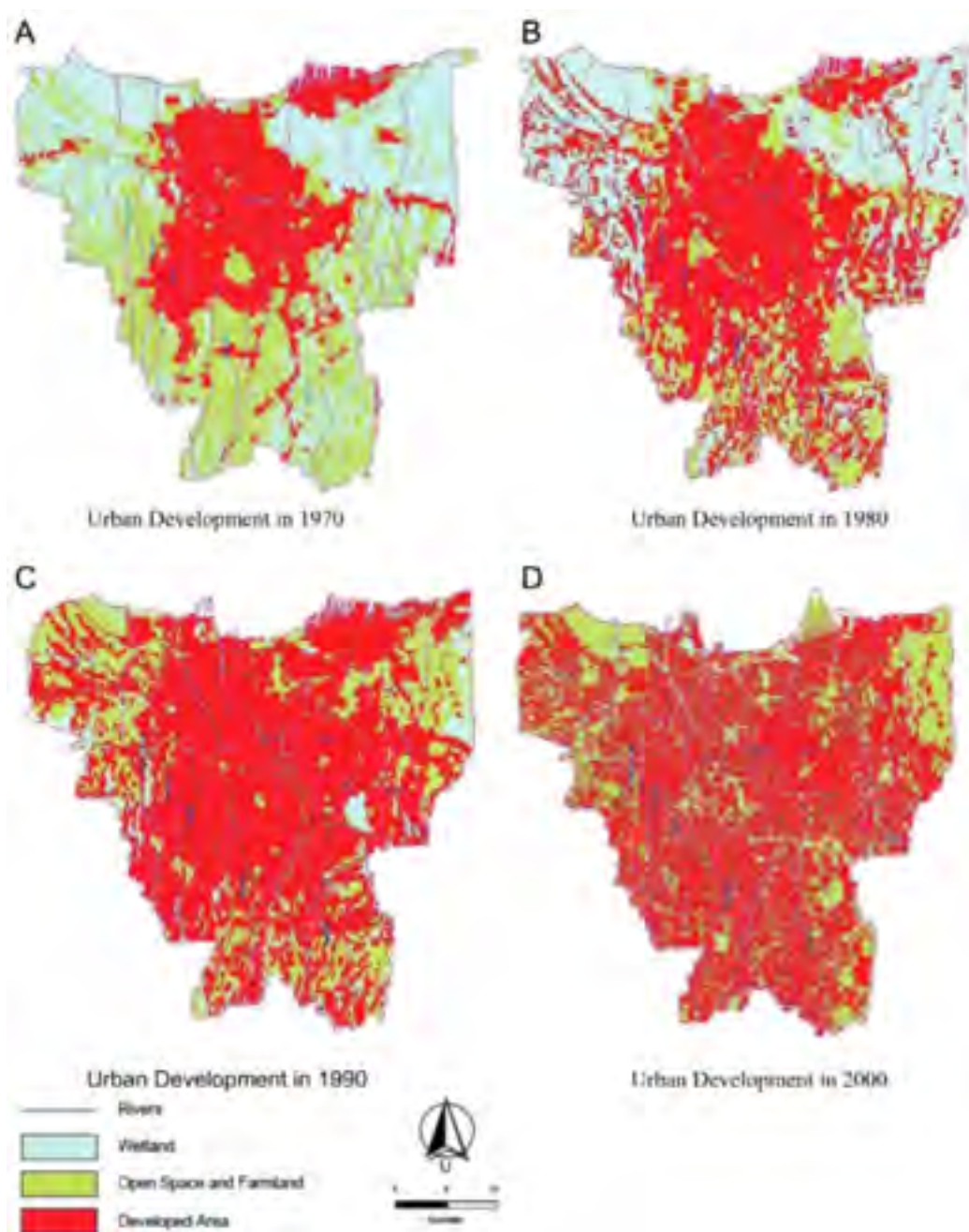


Figure 7-13 The stages of urban development in Jakarta (Baker, 2012)

collaboration, urban planning and other activities, The Jakarta provincial government opened a Smart City unit in 2014 that focuses on collecting big data and analysing it to drive the city’s decision-making (Friedrich Ebert Stiftung, 2017). The basic characteristics of the integrated urban development concept is a holistic strategy and the involvement of all administrative departments, as well as the external actors as businesses, culture, and local citizens (Friedrich Ebert Stiftung, 2017). Jakarta might not be a success story yet, but respective plans have been made to become one in the future as it acts in line with the SDGs 1, 2, 3, 6, 9, 11, 13, 14, and 15.

emissions after disposal into the water and into the air cause environmentally harmful long-term effects. The symptoms are extensive and include biodiversity loss, eutrophication of ecosystems, thinning of the stratospheric ozone layer, increased irradiation of UVB on the ground, enhancement of the greenhouse effect, regional and global climate change, sea level rise, acid rain and contamination of soils and groundwater with consequences for drinking water resources as emissions are widely distributed. They can then descend over more than 1,000km from the emission site as acid rain. The results of the Ishikawa Diagram are shown in Figure 7-14.

3.3. Sink Syndromes

The sink syndrome addresses environmental degradation through unadjusted civilization disposal causing environmental pollution and qualitative water shortage. Particularly during industrialization, pollutants are wide spread and might migrate long distances via the air and water path. The sink syndromes refer to the ‘pollutant source – migration path – receptor / sink’ model and concerns metals and industrial pollutants.

3.3.1. Smokestack syndrome

The smokestack syndrome refers to Environmental degradation through widespread diffuse distribution of mostly long-lived active substances. Substance

“The sink syndrome addresses environmental degradation through unadjusted civilization disposal causing environmental pollution and qualitative water shortage.”

3.3.1.1. Case Study: China

The growing air pollution caused by the rapid economic growth is causing increasing acid rain in China polluting also surface and groundwater (→ qualitative freshwater scarcity). Despite all efforts, the situation is “out of control” as pointed out by Wang Jian from the State Environmental Agency after completing a five-year study (China Daily). More than 265 cities in China are affected by acid rain. The economic damage was estimated at 110 bn yuan (10 bn euros) annually, or 2 to 3% of the GDP. The increasing number of cars, growing consumption of coal and excessive fertilizer use play a strong role in polluting the country, among them also acid rain (→ landscape deterioration, deforestation). Growing demand for coal, which is the main energy source in China, and the large number of small power plants, are the main reasons for the rapid increase in SO₂ emissions. The highest volume of

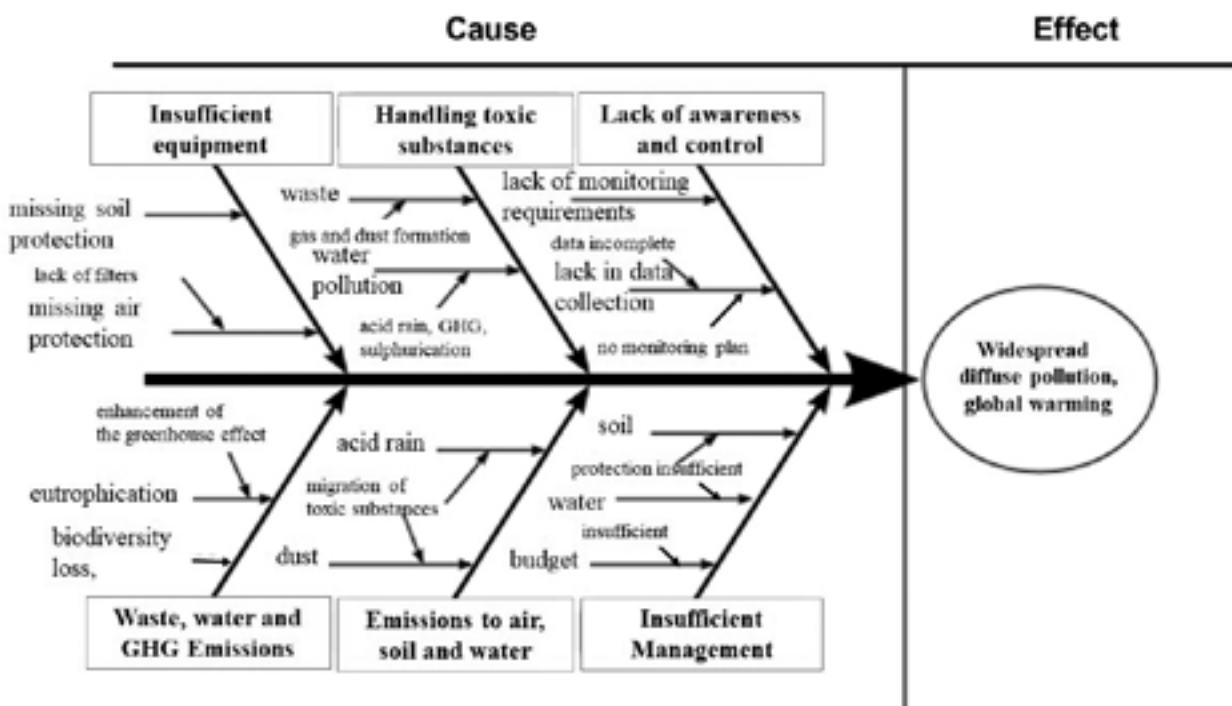
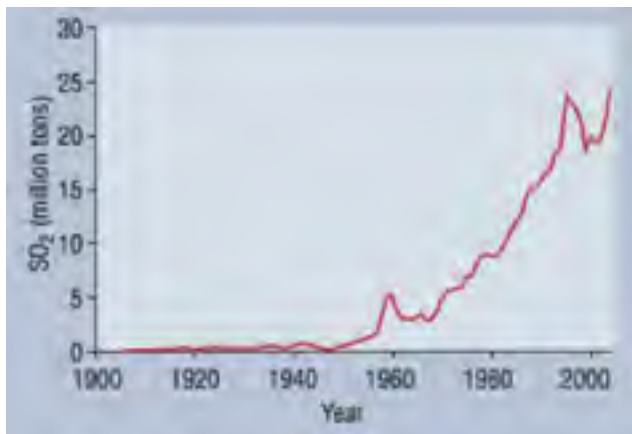


Figure 7-14 Cause-and-effect analysis for the Smokestack syndrome

Syndrome	Explanation	Relation to water stress
Smokestack-Syndrome	environmental degradation through long range diffuse distribution of durable agents	the diffuse pollution causes acid rain, resulting in pollution of fresh and groundwater resources, acidification of soils and depletion of biodiversity, higher risk of flooding due to deforestation, qualitative freshwater scarcity

Table 7-6 Sink syndromes and their water stress impacts

coal in the world is mined and consumed in China, whose coal is particularly sulphurous. According to Larsson et al. (2006), China's economic growth resulted in increasing sulfur dioxide (SO₂) levels and acid rain particularly in the southern provinces (Figure 7-15). Spatial and temporal distribution maps of average annual precipitation pH in China (Lei et al., 2016).



Environmental impacts of acid rain were documented in the publication of Bhargava and Bhargava, (2013), and it can be summarized that acid rain affects every part of an ecosystem, particularly vulnerable to acid rain are aquatic ecosystems (→ qualitative freshwater scarcity). Leaching soils with acid rain resolves metals and generates polluted water, which in turn negatively impacts aquatic flora and fauna in lakes and rivers (→ loss of biodiversity, deforestation). Biomagnification can occur; in which acidic chemicals are passed from organism to organism (Bhargava & Bhargava, 2013). Larssen et al. (2006) highlighted the effects around Chongqing caused by extreme SO₂ concentrations in rain and mist (Bian & Yu, 1992).

3.3.1.2. Is there a success story?

In Europe, air pollution from sulfur dioxide has fallen by three quarters since 1980, to the largest extent in Germany. In the 1970s, air pollution had reached its peak in Europe. Acid rain led to the degradation of forests. Smog also made people sick, and life expectancy declined. In particular, the requirement that coal-fired power plants must install desulphurisation plants has lowered SO₂ emissions.

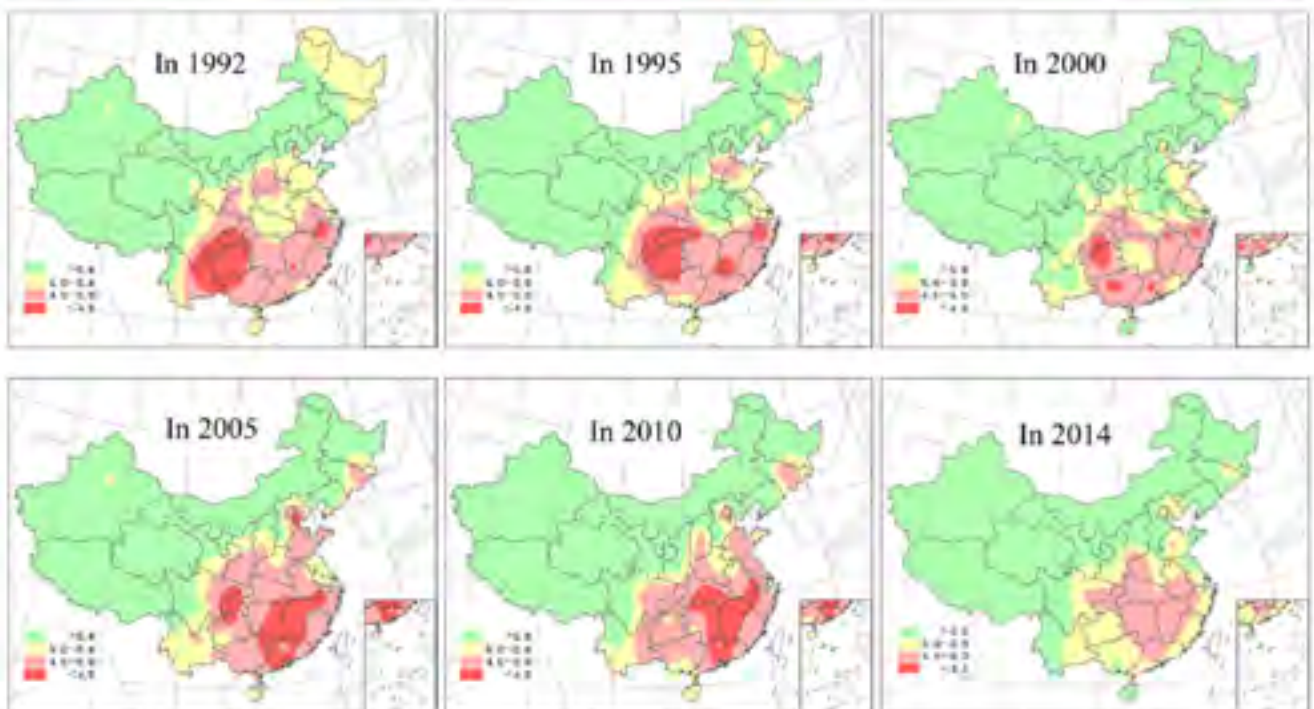


Figure 7-15 Graph showing the historical evolution of SO₂ emissions (Larssen et al., 2006), and Spatial and temporal distribution maps of average annual precipitation pH in China (Lei et al., 2016)

The decline of the Eastern European industry following the fall of the Berlin Wall also contributed significantly to the decline in the harmful gas. Even after a good three decades, there are streams and rivers in Germany that are still slowly recovering from the effects of acid rain (Bayerisches Landesamt für Umwelt, 2015). Their pH levels are still very low and the levels of leached aluminum are so high that they harm aquatic organisms. In 1991, 25% of all trees had significant damage, compared to 20% in 1996 (Bundesrat, 1996; Federal Ministry of Food, Agriculture and Consumer Protection of Germany, 2011). The experience from Germany, particularly the Harz and Ore Mountains show, that a recovery of nature after elimination of the emission sources is feasible, even it will take decades (Bittersohl et al., 2014). Globally speaking, the smokestack syndrome will remain a challenging topic within the next decades as it is strongly related to industrialization. The scope and challenge is to drive the industrialization in line with SDGs 2, 3, 6, 13, 14, and 15.

“If the 17 goals are to be achieved this, together with the impact of global trends such as climate change, will increase competition for the use of water, energy and land resources. Nexus thinking can help assess interlinkages and derive adequate, networked problem resolution through coordinated governance and governance.”

04

Conclusion

Water is essential for the lives of humans, animals and plants as well as for all types of social and economic development. Already today, about four billion people suffer from water shortages for at least one month each year. By 2030, the demand for water could increase by 40%, adding to the pressure on the resource.

With the 2030 Agenda for Sustainable Development, the United Nations has formulated an ambitious program. If the 17 goals - and in particular the objectives of food security (SDG 2), water security (SDG 6), energy security (SDG 7), combating climate change (SDG 13) and protection of land ecosystems (SDG 15) - are to be achieved this, together with the impact of global trends such as climate change, will increase competition for the use of water, energy and land resources.

To tackle these networked supply risks, isolated sectoral policies competing for the same natural resources are not the solution but often the problem. Nexus thinking can help assess interlinkages and derive adequate, networked problem resolution through coordinated governance and governance. The syndrome approach forces systems thinking to analyze the interlinkages between sectors and approaches, and as such is a feasible teaching tool for the assessment and implementation of a Nexus approach, supporting strongly SDG17 – partnership for the goals.

References

- Alberts, C. & Dorofee, A. (2009, April). A Framework for Categorizing Key Drivers of Risk, Technical Report, Software Engineering Institute, Carnegie Mellon University, CMU/SEI-2009-TR-007, ESC-TR-2009-007.
- Alzamil, W. (2017). The urban features of informal settlements in Jakarta, Indonesia, *Data in Brief*, Elsevier, 15, pp. 993-999.
- Baker, J. (2012). *Climate Change, Disaster Risk, and the Urban Poor: cities Building Resilience for a Changing World*: World Bank Publications.
- Baumol, W. & Blinder, A. (2011). *Economics: Principles and Policy*. Cengage Learning. ISBN: 978-0538453677.
- Bayerisches Landesamt für Umwelt. (2015). *Entwicklungen, Trends und Perspektiven: 25 Jahre Versauerungsmonitoring in Bayern*, available online: <http://www.lfu.bayern.de>.
- Bedoya Zuluaga, J. (2014). *La auto-organización de comunidades vegetales de páramo luego de un disturbio por fuego: Una herramienta para la restauración ecológica*. Universidad tecnológica de Pereira, facultad de ciencias ambientales, maestría en ecotecnología, Pereira 2014.
- Bekchanov, M., Ringler, C., Bhaduri, A. & Jeuland, M. (2015). Optimizing irrigation efficiency improvements in the Aral Sea Basin, *WaterResources and Economics* 2015, <http://dx.doi.org/10.1016/j.wre.2015.08.003i>.
- Bhargava, S. & Bhargava, S. (2013). Ecological consequences of the Acid rain, *Journal of Applied Chemistry*, 5(4), pp. 19-24.
- Bian, Y. & Yu, S. (1992). Forest Decline in Nanshan, China, *Forest ecology management*, 51, pp. 53-59.
- Bigodi Tourism. (2017). 'Home of the Great Blue Turaco', available online: <https://bigoditourism.com/>, (accessed on 25 September 2018).
- Bittersohl, J., W. Walther. & Meesenburg, H. (2014). Gewässerversauerung durch Säuredeposition in Deutschland – Entwicklung und aktueller Stand. – *Hydrologie und Wasserbewirtschaftung* 58 (5), pp. 260-273. DOI: 10.5675/HyWa_2014,5_1.
- Bundesrat. (1996). *Waldzustandsbericht der Bundesregierung 1996*, Drucksache 899/96, available online: dipbt.bundestag.de/dip21/brd/1996/D899+96.pdf.
- Cassel-Gintz, M. & Bahr, M. (2008). Syndrome globalen Wandels. In: *Praxis Geographie*. 6/2008.
- Chuying, C. (1985). Effects of acid rain on Pinus massoniana forests in the region of Chongqing. Presentation to the China-US Workshop on Air Pollution Ecological Effects. Nanjing, China.
- De Haan, G., Giesel, K. & Rode, H. (2002). *Umweltbildung in Deutschland. Stand und Trends im außerschulischen Bereich*. Berlin: Springer.
- De Haan, G. (2002). Was ist Bildung für Nachhaltigkeit? In: F. Brickwedde, U. Peters: *Umweltkommunikation. Vom Wissen zum Handeln*. Berlin 2002, S. 259-267, ISBN 978-3-503-06682-7.
- Destatis Statistisches Bundesamt. (2018). *Uganda Statistisches Länderprofil Ausgabe 06/2018*.
- Dianqu, Z. & Jiling, X. (1988). Chapter 10 Acidification in Southwestern China, In: *Acidification in Tropical Countries*, Wiley, pp. 317- 345.
- Diesing, F. & Weiß, S. (eds.). (2009). *Seenland Leipzig & Lausitz: Das Reisemagazin für Urlaub am Wasser*, SD Media Services, Berlin 2009. ISBN: 978-3-9812026-7-0.
- Dorosh, P. & Thurlow, J. (2012). Agglomeration, Growth and Regional Equity: An Analysis of Agriculture- versus Urban-led Development in Uganda, *Journal of African Economies* 21(1), pp. 94-123.
- El Espectador. (2014). Guacheneque y Chingaza, las fábricas de agua dulce de Bogotá. *Jorunal article* available online; <http://blogs.elespectador.com/elrio/2014/07/25/guacheneque-y-chingaza-las-fabricas-de-agua-dulce-de-bogota/>, article in the Blog El Espectador (25.07.2014), (accessed 12th september 2016).
- Fairless, D. (2007). Northern Aral Sea recovering, Kazakhstan plans second phase of project. *Nature*. DOI:10.1038/news070409-8.
- Farmingfirst. (2017). It Is Time for Brazil's Second Green Revolution, available online: <https://farmingfirst.org/2017/11/it-is-time-for-brazils-second-green-revolution/>. (accessed 1 July, 2018).
- Federal Ministry of Food, Agriculture and Consumer Protection of Germany. (2011). *German forests - Nature and economic factor*, Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), available online: <https://www.bmel.de>.
- Friedrich Ebert Stiftung. (2017). *Jakarta: an adventure in urban planning*, available online: <https://www.fes-connect.org/in-pipeline/jakarta-an-adventure-in-urban-planning/>. (accessed 1 July, 2017).
- Gaybullaev, B., Su-Chin Chen & Yi-Ming Kuo. (2013). Water Volume and Salinity Forecasts of the Small Aral Sea for the Years 2025, *Journal of Chinese Soil and Water Conservation*, 44(3), pp. 265-270.
- Giese, E., Bahro, G. & Betke, D. (1998). *Umweltzerstörungen in Trockengebieten Zentralasiens (West- und Ost-Turkestan). Ursachen, Auswirkungen, Maßnahmen*. S. 59.
- Government of the Republic of Uganda, Ministry of Agriculture, Animal Industry and Fisheries. (2009). *Uganda National Rice Development Strategy (UNRDS), 2nd draft*, available online: www.agriculturego.ug, Entebbe, Uganda.
- Grey, D. & Sadoff, C. (2007). Sink or Swim? Water security for growth and development. *Water Policy*, 9(6), pp. 545-571.
- Harenberg, D. (2011). Syndrome globalen Wandels als überfachliches Unterrichtsprinzip. Available online: www.transfer-21.de/daten/texte/SyndromtextHarenberg.pdf. (accessed on 28 June, 2018).
- Heitmann, C., Fiedler, M. & Müller, S. (2010). Entstehung, Entwicklung und Bedeutung der Lausitzer und mitteldeutschen Braunkohlenindustrie im Spiegel ihrer Überlieferung im Bergarchiv Freiberg, *Archiv und Wirtschaft* · 43. Jahrgang · 2010 · Heft 1.

- Hüttl, R. (1998). Ecology of post strip-mining landscapes in Lusatia, Germany. *Environmental Science & Policy*, 1, pp. 129-135.
- Ishikawa, K. (1968). *Guide to Quality Control*. Tokyo JUSE.
- _____. (1990). *Introduction to Quality Control*, p. 448. ISBN: 4-906224-61-X OCLC 61341428.
- Jordan, H.-P. & Vulpius, R. (1993). Umweltauswirkungen des Braunkohlenbergbaus in der Lausitz, in Strottop, U. (Ed.), *Zeitraum Braunkohle*, Essen.
- Kasirye, I. (2013). Constraints to Agricultural Technology Adoption in Uganda: Evidence from the 2005/06-2009/10 Uganda National Panel Survey, The Economic Policy Research Centre (EPRC) Uganda, available online: <https://ageconsearch.umn.edu/bitstream/159669/2/series102.pdf>.
- Kummu, M., Guillaume, J., Moel, H., Eisner, S., Flörke, M., Porkka, M., Siebert, S., Veldkamp, T. & Ward, P. (2016). The world's road to water scarcity: shortage and stress in the 20th century and pathways towards sustainability. *Scientific Reports*, 6, 38495. DOI:10.1038/srep38495.
- Krümmelbein, J., Bens, O., Raab, T. & Naeth, M. (2012). A history of lignite coal mining and reclamation practices in Lusatia, eastern Germany, *Canadian Journal of Soil Science*, 92, pp. 53-66. DOI:10.4141/CJSS2010-063.
- Larssen, T., Lydersen, E., Tang, D., He, Y., Gao, J., Liu, H., Duan, L., Seip, H., Vogt, R., Mulder, J., Shao, M., Wang, Y., Shang, H., Zhang, X., Solberg, S., Aas, W., Okland, T., Eilertsen, O., Angell, V., Li, Q., Zhao, D., Xiang, R., Xiao, J. & Luo, J. (2006). 'Acid rain in China' – *Environmentl Science and Technology*, 40(2), pp. 418-425.
- Lei Duan, Qian Yu, Qiang Zhang, Zifa Wang, Yuepeng Pan, Thorjörn Larssen, Jie Tang, Jan Mulder, Acid deposition in Asia: Emissions, deposition, and ecosystem effects, *Atmospheric Environment*, Volume 146, 2016, Pages 55-69, ISSN 1352-2310, <https://doi.org/10.1016/j.atmosenv.2016.07.018>.
- Lora, C. (1999). El Parque Nacional Natural Chingaza. s. p. In: I Simposio taller de investigación para la región del PNN Chingaza (1999). Ministerio del Medio Ambiente – Unidad Administrativa Especial del Sistema de Parques Nacionales Naturales, Fundación Natura, Wildlife Conservation Society, Bogotá.
- Luxner, L. & Drake, C. (2015). Reviving the North Aral Sea. *Aramco World*, September/October 2015, Vol. 66, No. 5, ISSN 1530-5821. Available online: <http://www.aramcoworld.com/Articles/September-2015/Reviving-the-North-Aral-Sea?page=3>, accessed 27.01.2018.
- Mateo-Sagasta, J., Raschid-Sally, L. & Thebo, A. (2015). Global Wastewater and Sludge Production, Treatment and Use, in: P. Drechsel et al. (eds.), *Wastewater*, © Springer Science+Business Media Dordrecht 2015. DOI: 10.1007/978-94-017-9545-6_2.
- Mekonnen, M. & Hoekstra, A. (2016). Four billion people facing severe water scarcity. *Science Advances*, 2. DOI:10.1126/sciadv.1500323.
- Morales, M., Otero, J., van der Hammen, T., Torres, A., Cadena, C., Pedraza, C., Rodriguez, N., Franco, C., Betancourth, J., Olaya, E., Posada, E. & Cardenas, L. (2007). Atlas de páramos de Colombia.: Complejo de Chingaza, pp. 92-95. Impreso en Bogotá, D. C., 1. Auflage (2007), Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. ISBN: 958-8151-91-5.
- Micklin, P. (2007). The Aral Sea Disaster. *Annual Review of Earth and Planetary Sciences*, 35, pp. 47-72. DOI: 10.1146/annurev.earth.35.031306.140120.
- Micklin, P., Nikolay, A. & Plotnikov, I. (eds.). (2014). *The Aral Sea. The Devastation and Partial Rehabilitation of a Great Lake*, Springer-Verlag Berlin Heidelberg. DOI: 10.1007/978-3-642-02356-9.
- Mpuga, P. (2004). Demand for Credit in Rural Uganda: Who Cares for the Peasants?, A paper presented at the Conference on Growth, Poverty Reduction and Human Development in Africa Centre for the Study of African Economies, available online: <https://pdfs.semanticscholar.org/d10b/e2947e8a4c338ab3f1d0c07265b7aac1ea4a.pdf>.
- Mukwaya, P., Bamutaze, Y., Mugarura, S. & Benson, T. (2012). Rural-Urban Transformation in Uganda, Uganda Support Program, contribution to the joint IFPRI and University of Ghana conference on "Understanding Economic Transformation in Sub-Saharan Africa", Accra, Ghana, 10-11 May 2011.
- Neue Zürcher Zeitung. (2010). Ausgetrocknet und versteppt: Der Aralsee von 1960 bis 2008 Heute bekommt der Kleine Aral dank einem Damm wieder Frischwasser. In: *Neue Zürcher Zeitung*.
- Peterson, GM. & Galbraith, J. (1932). "The concept of marginal land". *Journal of Farm Economics*, 14(2), pp. 295-310.
- Pimentel, D. (2012). *Global Economic and Environmental Aspects of Biofuels*, p. 92.
- Potsdam Institut für Klimafolgenforschung. (2015). Vier von neun „planetaren Grenzen“ bereits überschritten, available online: <https://www.pik-potsdam.de/aktuelles/pressemitteilungen/vier-von-neun-planetaren-grenzen201d-bereits-ueberschritten>. (accessed 27 January, 2018).
- Richter, T. (2008). *Lausitzer Seenland - Ein Wasserparadies im Werden*, Agrimedia, Edition Limosa, Clenze 2008. ISBN: 978-3-86037-341-5.
- Rigotto, R., Paixão e Vasconcelos, D. & Melo Rocha, M. (2014). Pesticide use in Brazil and problems for public health, *Cad. Saúde Pública*, 30(7). Rio de Janeiro. <http://dx.doi.org/10.1590/0102-311XPE020714>.
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E., Lenton, T., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., de Wit, C., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R., Fabry, V., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J. (2009, September 24). A safe operating space for humanity. *Nature*, 461, pp. 472-475.
- Schellnhuber, H., Block, A., Cassel-Gintz, M., Kropp, J., Lammel, G., Lass, W., Lienenkamp, R., loose, C., Lüdecke, M.K.B., Moldenhauer, O., Petschel-Held, G., Plöchl, M. & Reusswig, F. (1997). Syndromes of Global Change. *GIA*, 6(1), pp. 19-34.

- Schindler, J. (2005). *Syndromansatz - Ein praktisches Instrument für die Geographiedidaktik*. Praxis Neue Kulturgeographie. LIT Verlag, Münster.
- Science for Environment Policy. (2016). No net land take by 2050? Future Brief 14. Produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol. Available at: <http://ec.europa.eu/science-environment-policy>.
- Seibel, H.-D. & Almeyda, G. (2002). Women And Men In Rural Microfinance: The Case Of Uganda, Working Paper, No. 2002, 4, Universität zu Köln, Arbeitsstelle für Entwicklungsländerforschung (AEF), Köln, available online: https://www.econstor.eu/bitstream/10419/23705/1/2002-4_UG_Microfinance.pdf.
- Steffen, W., Richardson, K., Rockström, J., Cornell, S., Fetzer, I., Bennett, E., Biggs, R., Carpenter, S., de Vries, W., de Wit, C., Folke, C., Gerten, D., Heinke, J., Mace, G., Persson, L., Ramanathan, V., Reyers, B. & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, 347. DOI:10.1126/science.1259855.
- The Republic of Uganda. (2017). State of Uganda Population Report 2017 - Theme: Transforming Uganda's Economy: Opportunities to Harness the Demographic Dividend for Sustainable Development. National Population Council Statistics House, Plot 9, Colville Street, P.O. Box 2666, Kampala, Uganda. available online: <http://library.health.go.ug/sites/default/files/resources/State%20of%20Uganda%20Population%20Report%202017.pdf>.
- The World Bank Group. (2016). The Uganda Poverty Assessment Report 2016 Farms, cities and good fortune: assessing poverty reduction in Uganda from 2006 to 2013, Report No. ACS18391. available online: <http://pubdocs.worldbank.org/en/381951474255092375/pdf/Uganda-Poverty-Assessment-Report-2016.pdf>.
- The World Bank. (2009, December). Making Finance Work for Uganda. available online: siteresources.worldbank.org/.../Resources/Making_Finance_Work_for_Uganda.pdf.
- United Nations, Department of Economic and Social Affairs, Population Division. (2014). *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)*, United Nations. ISBN: 978-92-1-151517-6.
- United Nations. (2018). *World Economic Situation and Prospects 2018*, United Nations publication, Sales No. E.18.II.C.2, New York. ISBN: 978-92-1-109177-9, eISBN: 978-92-1-362882-9.
- United Nations Educational, Scientific and Cultural Organization (UNESCO). (2009). IWRM Guidelines at River Basin Level—Part 2-1: The Guidelines for IWRM Coordination. Available online: <http://unesdoc.unesco.org/images/0018/001864/186418e.pdf>, accessed 10 January 2017.
- _____. (2010). *Sharing Water, Sharing Benefits: Working towards Effective Transboundary Water Resources Management, A Graduate / Professional Skills-Building Workbook*. Compiled and edited by Prof. Aaron T. Wolf.
- _____. (2015). *The Un World Water Development Report 2015, Water for a Sustainable World*. available online: <https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1711&menu=35>, accessed 25 September 2018.
- United Nations Department of Economics and Social Affairs /Population Division. (2006). *World Urbanization Prospects: The 2005 Revision*.
- United Nations General Assembly. (2010). Resolution A/RES/64/292. <http://daccess-ods.un.org/access.nsf/Get?Open&DS=A/RES/64/292&Lang=E>.
- United Nations Human Settlements Programme. (2003). *The Challenge of Slums, Global Report On Human Settlements 2003*.
- _____. (2005). *Financing Urban Shelter, Global Report On Human Settlements 2005*.
- UN-Water. (2013). *Water Security and the Global Water Agenda – A UN-Water Analytical Brief*, Available at <http://www.unwater.org/publications/water-security-global-water-agenda/>, accessed 3 November 2017.
- Unger-Shayesteh, K., Vorogushyn, S., Farinotti, D., Gafurov, A., Duethmann, D., Mandychew, A. & Merz, B. (2013). What do we know about past changes in the water cycle of Central Asian headwaters? A review, *Global and Planetary Change* 110, pp. 4–25. <https://doi.org/10.1016/j.gloplacha.2013.02.004>.
- United Nations. (2015a). *Transforming our world: the 2030 Agenda for Sustainable Development*, United Nations - Sustainable Development knowledge platform, 25.09.2015.
- _____. (2015b). General Assembly resolution 7/169, The human rights to safe drinking water and sanitation, (18 November 2015). available from <http://www.endwaterpoverty.org/sites/endwaterpoverty.org/files/The%20Human%20Rights%20To%20Water%20And%20Sanitation%20UN%20resolution.pdf>.
- Vanberk, W. & Wisotzky, F. (1995). Sulfide oxidation in brown coal overburden and chemical modeling of reactions in aquifers influenced by sulphide oxidation. *Environmental Geology*, 26(3), pp. 192-196.
- Vargas Rios, O. & Pedraza, P. (2004). Parque Nacional Natural Chingaza; Localización Y Ambiente Físico Del Parque Nacional Natural Chingaza S. 24 - 34; Vegetación S. 123 - 134. Impresión: Gente Nueva Editorial, 1. Edition (2004). ISBN: 958-33-6824-5.
- Weltagrarbericht. (2018). 30 Jahre Agrarökologie und das „Null Hunger“-Programm in Brasilien. available online: <https://www.weltagrarbericht.de/leuchttuerme/agraroekologie-in-brasilien.html>, accessed 02.07.2018.
- WBGU. (1994). *World in Transition: Basic Structure of Global People-Environment Interactions*, Bonn, 1994. Based on: German Advisory Council on Global Change, *Economica*, Annual Report 1993.
- _____. (1996). *World in Transition: Ways towards Global Environmental Solutions*, Berlin, 1996. Based on: German Advisory Council on Global Change, *Springer*, Annual Report 1995.
- Xu, H. (2017). The Study on Eco-environmental Issue of Aral Sea from the Perspective of Sustainable Development of Silk Road Economic Belt. *IOP Conference Series: Earth and Environmental Science*, 57, 012060. DOI:10.1088/1755-1315/57/1/012060



8

Microscopic Impurities in Drinking Water and Solutions

YoungDug Kim and Kihyeok Jeong

YoungDug Kim, The Wave Talk Inc.

e-mail: ceo@thewavetalk.com

Kihyeok Jeong, The Wave Talk Inc.

e-mail: kihyeok-jeong@thewavetalk.com

Abstract

Microscopic impurities such as bacteria or microplastics have been a major threat for our society, causing numerous outbreaks and following economic loss. Current methods such as particle counter or agar culturing are used, but these methods have their own shortcomings and cannot perfectly detect drinking water contamination. Most of all, all the methods used require sampling of drinking water, which makes it hard to cope with the disaster. We propose our new solution, consisting of laser and our newly developed optic sensor, or so-called TWT sensor. This solution uses time-reversal mirror effect and light scattering to detect microscopic debris floating around the water.

In this paper, we will briefly introduce how microscopic impurities can be serious issue in water safety and what solutions are out there in the market. We will introduce features of each solutions and difficulties using each method. Then we introduce our new solution and its principle, and the significance it could have compared to conventional methods. We close this paper with the application of the sensor, showing its impact to water security.

Keywords

Microscopic impurities, water safety, laser sensor, drinking water

01

Introduction

1.1. Problems Caused by Microscopic Impurities

On March 1993, Milwaukee experienced the largest documented water outbreak in US history. Caused by *Cryptosporidium parvum*, the chlorine-resistant parasite, the outbreak affected over 400,000 people, which was 25 percent of Milwaukee's population back then. according to a study by the US Centers for Disease Control and Prevention, the outbreak resulted in over \$96 million in economic losses including healthcare costs and productivity losses, with mortality of 69 deaths (Corso et al., 2003). Although the turbidity levels of treated water in the Howard Avenue Water Purification Plant, one of two water treatment plants in Milwaukee, showed well above normal, it couldn't detect the contamination made by *Cryptosporidium* protozoans (Mac Kenzie et al., 1994).

The tragedy of Milwaukee, 1993 gives us two major implications. First, preexisting technologies has limitations for detecting microscopic impurities such as bacteria, microplastics, fungi, etc. Current impurity detecting technologies include flow cytometry, particle counting, agar culturing, and real-time PCR. However, limitations exist in those technologies in detectable particle size, number of particles, and time required for inspection. Milwaukee's outbreak exemplifies this blind spot of current inspection technology, as the turbidity level failed to predict the existence of the parasite.

What's even more is that small microscopic impurity, the size of impurity being several micrometers, can cause considerable damages to both economy and lives. From 1971 to 2006, total 833 waterborne disease outbreaks (WBDO) were reported, with 577,991 cases of illness, and 106 deaths. 36.6% of total 833 outbreaks were reported to be caused by bacteria and parasites, both being microbiome impurities with the size of several micrometers (Craun et al., 2010). The economic loss caused by WBDOs are costly in both morbidity and mortality as well as causing financial loss (Harrington et al., 1989).

In this paper we propose new possible solution for detecting microscopic impurities. We first discuss what limitations do current technologies have in terms of cost, inspection time, detectable particle size and number of particles. Then we suggest new solution for inspecting drinking waters, which utilizes laser technology. Details of technology will not be discussed due to confidentiality issues. The paper closes with applications of this novel technology and expected effects on water safety issues.

02

Preexisting Solutions

Current solutions for detecting microscopic impurities include flow cytometry, particle counter, agar culturing, and real-time PCR. Flow cytometry is a laser based biophysical technology used for cell counting by suspending cells in a stream of fluid and passing them through an electronic detection apparatus. Particle counter is an instrument that detects and counts physical particles based on light scattering or direct imaging. Agar culturing is a method used to detect microbiomes by letting them reproduce in predetermined culture medium and counting colonies formed. Finally, real-time PCR (polymerase chain reaction) is a laboratory technique of molecular biology monitoring the amplification of a targeted DNA molecule during the inspection. These four means are major methods used in drinking water and beverage industries. In this section, we provide brief introduction on each technique and discuss about their limitations.

2.1. Flow Cytometry

Flow cytometry is a technique based on laser or impedance, mostly employed in cell counting or cell sorting. Flow cytometry analyzes the expression of cell surface and molecules inside the cell and distinguishes different cell types in a heterogeneous cell population, thus analyzing cell size and volume, as well as assessing the purity of isolated subpopulation.

Flow cytometry is predominantly used to measure fluorescence intensity produced by molecules that bind to cells or specific cell-associated molecules such as propidium iodide binding to DNA or fluorescence-labeled antibodies.

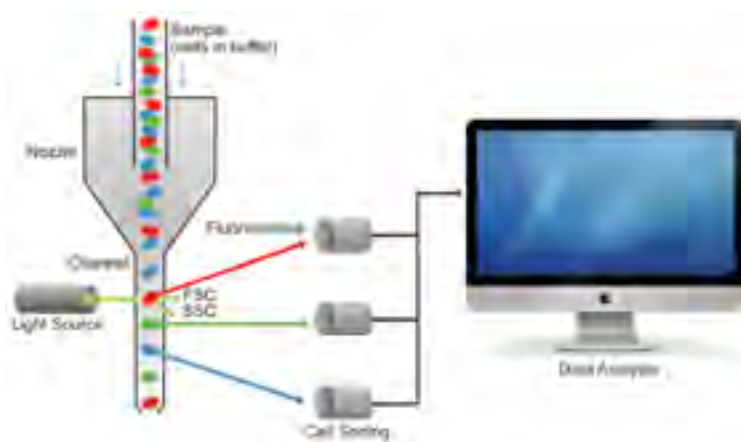


Figure 8-1 Diagram of Flow Cytometry



Figure 8-2 BD FACSCalibur™, an Example of Flow Cytometer

Therefore, prior to the analysis, flow cytometry involves single-cell suspension from cell culture or tissue samples. After the suspension, the cells are then incubated in tubes or microtiter plates with unlabeled or fluorochrome-labeled antibodies and analyzed on the flow cytometer.

When prepared samples are run through the cytometer, sheath fluid is run to hydrodynamically focus them through a small nozzle, taking the cells past the laser light one at a time (Figure 8-1). Light scattered from the cells or particles is detected as they go through the laser beam. Fluorescence detectors measure the fluorescence emitted from positively stained cells or particles.

Flow cytometry allows simultaneous multiparametric analysis of cells up to thousands of particles per second. It is routinely used in the clinical diagnosis or other applications in basic research. Despite its capacity of analyzing thousands of particles, however, flow cytometry has its weakness that it requires sampling. This makes this technique time-consuming for analyzing drinking waters as it involves taking sample

from water and then coming back to the lab. In addition, flow cytometry requires pre-processing of cell suspending and staining to make specimens detectable. Also, the detection of impurity is limited to micro-organisms and cannot detect non-organisms such as microplastics or glass. These shortcomings make it vulnerable to water pollutions and makes such technique inadequate for inspection of drinking water inspection.

2.2. Particle Counter

Particle counter, or particle counting is a method that detects and counts physical particles. The method is based upon optical technology. A high intensity light source, typically a halogen light or laser, is used to illuminate the particle as it passes through the detection chamber. Three different optical principles are used for particle counting: light scattering, direct imaging, or light obscuration.

The particle counter utilizes either of these three principles, but as light obscuration method is mostly used for inspecting fluids in hydraulic systems, usually light scattering or direct imaging is used for health-related concerns.

Light scattering method is based upon the amount of light that is deflected (i.e. light scattering) by a particle passing through the detection area of the particle counter. The redirected light from scattering is detected by a photo detector. This method is capable of detecting smaller-sized particles. Typical detection sensitivity of the light scattering method is 0.05 micrometer or larger.

Direct imaging is a technique that uses the light, either a halogen or laser, to illuminate a cell where particles are passing through, while a high definition, high magnification camera records passing particles. Recorded video is then analyzed by computer software to measure particle attributes.

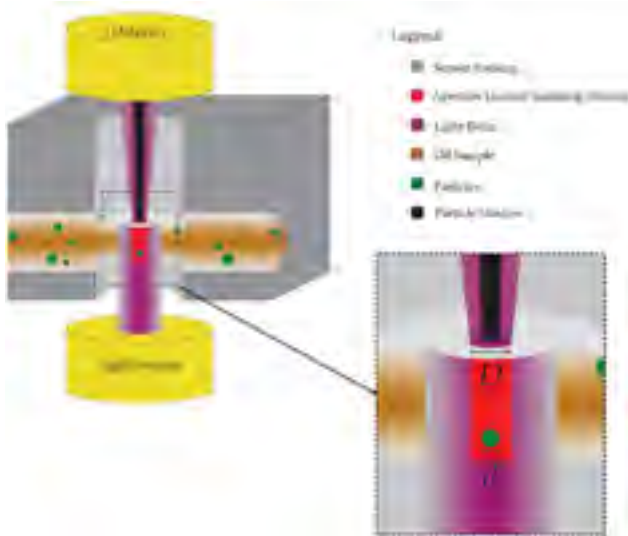


Figure 8-3 Diagram of Particle Counter

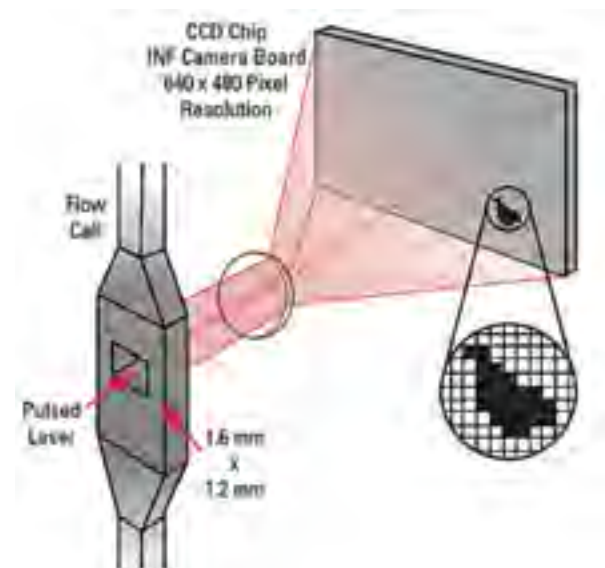


Figure 8-4 An Illustration of Direct Imaging

The particle counter can count 100,000 particles per 1mL of liquid, and both organic and inorganic particles as small as 0.1 to 10 micrometers. The particle counting method, however, also needs sampling process, as particle counter available in market is intended for laboratory use. This also makes it vulnerable to cope with water contamination, as the need for sampling means more time consumed. Also, although the number of particles countable with the apparatus meets up the “golden standard” for hygiene issues in drinking water, the capability whether it can assess drinkability is questionable, as even a little amount of bacteria or other impurities can cause serious health problems.

2.3. Agar Culturing and Real-time PCR

For detecting micro-organisms in particular liquid, a sample is spread on agar plate, a Petri dish containing solid growth medium, and cultivated enough to be seen with bare eye. This method is called agar culturing.

Several methods are available for plating out cells. One technique is streaking, which is a method that a drop of the culture on the end of a thin, sterile loop of wire is streaked across the surface of the agar plate, leaving organisms behind. Individual colonies will grow on the streaked area, the number being the same as the number deposited. Another way is the spot analysis. This is often used to check the viability of cells and performed with pinners. Third technique is using sterile glass beads for plating out cells. In this technique cells are grown in a liquid culture of which a small volume is pipetted on the agar plate and then spread out using the beads. The last is replicate plating.

Once plated, individual micro-organisms placed will grow into individual colonies, each a clone genetically identical to their own ancestor organisms. Therefore, the plate can be used to estimate the concentration of organisms in a liquid culture using a colony counter.

Another microbiological method is real-time PCR. PCR, or polymerase chain reaction, is a molecular biology technique to amplify a few copies of a segment of DNA into thousands to millions of copies. Real-time PCR monitors the amplification of targeted DNA molecules during the PCR process. Detection of micro-organisms is enabled by the inclusion of fluorescent dyes in reaction, so that particular organism can be distinguished and identified.

Like particle counter, both of these techniques can only detect organic, which leaves out inorganic debris floating around the water. Also, agar culturing costs 48 hours to cultivate organisms into visible colonies. Therefore, even though agar culturing can provide highly precise results it makes vulnerable for coping with the contamination, or even more vulnerable than other methods mentioned. Furthermore, the cost for both methods are high, both the cost for apparatus and experts needed for the technique.

03

Seeking New Solutions

Utilizing laser scattering, we sought for new solution that can address both accuracy and cost issues.

The sensor, or TWT sensor, as we named it, can detect the presence as well as the mass (per ml) of bacteria by analyzing the reflected or transmitted light. Bacteria are continuously monitored and detected instantly through mobile phone for single users at home. For food production industries, the sensor can be installed within the production lines at the view point (for visual inspection). Unlike conventional inspection methods that require sampling, it is a fully automatic method that does not require human operation after installation.

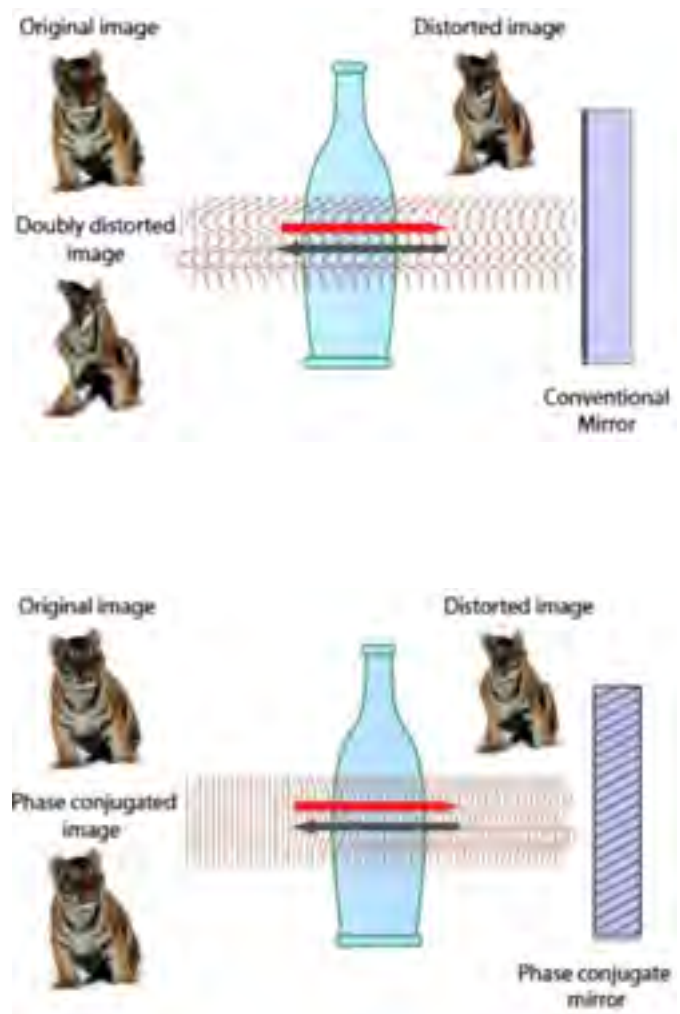


Figure 8-5 An Explanation of Time-Reversal Mirror Effect

3.1. Principle & How system works

Our technology is inspired from Time-Reversal Mirror effect, which is an effect that the phase of light scattered by certain media is reversed into the phase before scattering, when a light is reflected by the Time-Reversal Mirror. The phase, or waveform, of light changes whenever it's either reflected by mirror or scattered by certain object. However, when light is reflected by Time-Reversal Mirror the properties of reflected light is identical to the light prior to scattering or reflection. Utilizing this principle, our sensor detects impurities in fluids (e.g. gas, liquid) by penetrating laser through the fluid and analyzing the reflected light.

Laser speckle imaging has been introduced to monitor moving particles in optically

“Unlike conventional inspection methods that require sampling, it is a fully automatic method that does not require human operation after installation.”

inhomogeneous media by analyzing time-varying laser speckle patterns. Light impinging on turbid media such as biological tissues experiences multiple light scattering, and scattered light produces laser speckle patterns by light interference. Because of the deterministic nature of multiple light scattering, scattered light from a static turbid medium generates a constant laser speckle pattern. However, if scatters are spontaneously moving inside a turbid medium, time-varying speckle patterns are produced, from which information of the moving scatters can be retrieved.

Our solution consists of a light source, mainly laser, and TWT sensor. This system can be installed in any facilities where water or other homogeneous liquid is in. When a laser is lit

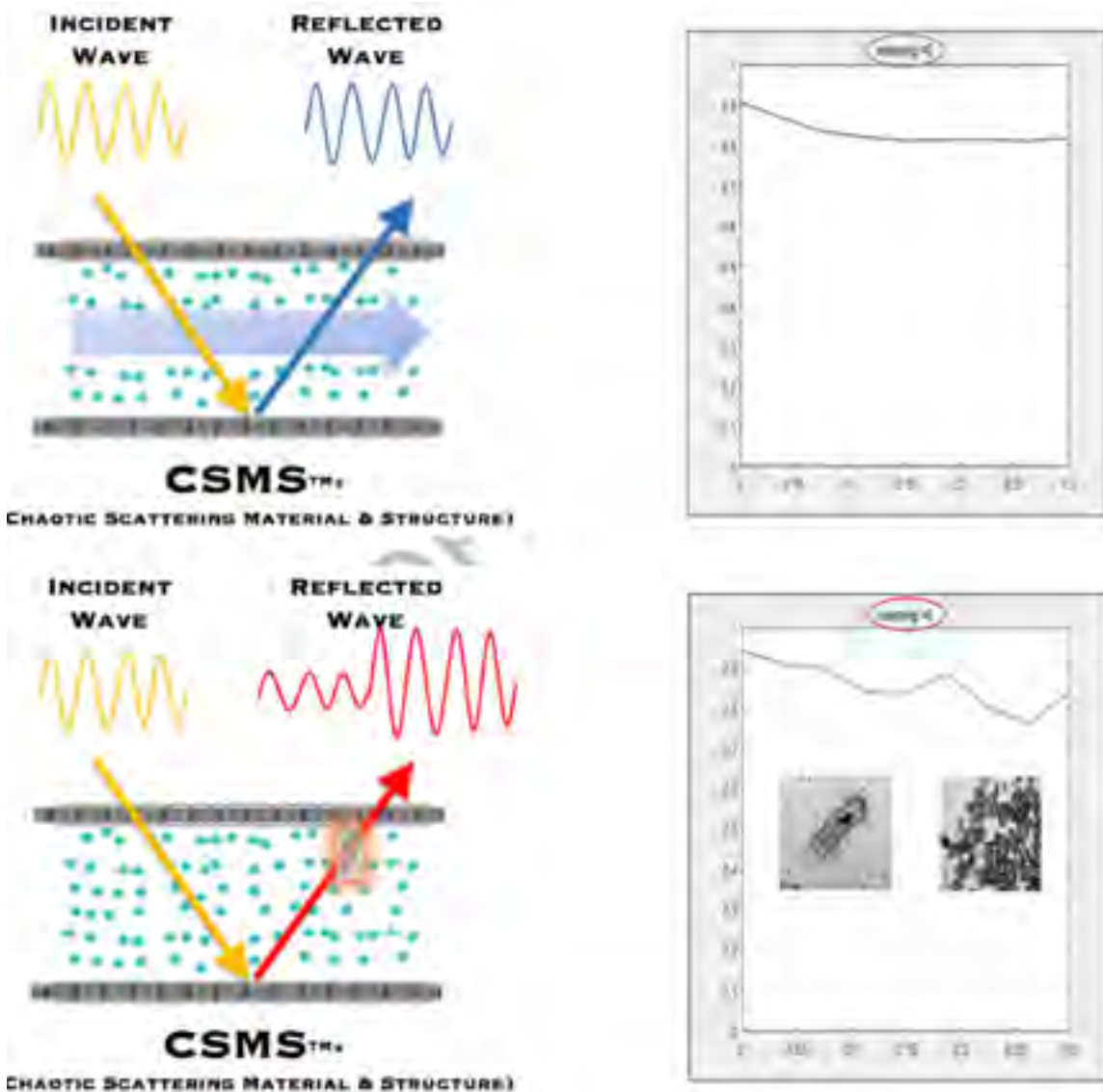


Figure 8-6 Principle of TWT Sensor

inside the water, it encounters water molecules and is scattered in a complicated pattern. Nevertheless, the speckle from the scattered laser is identical to the laser prior to scattering. However, if there are microscopic impurities in the water, the laser speckle generated changes with time. Through correlation analysis by TWT sensor, the system analyzes the difference among the images taken with time difference. The whole process takes less than one second and is effective for detecting any form of debris bigger than 0.3 micrometers.

3.2. Benefits

As mentioned, current solution for microscopic impurities, particle counter, flow cytometry, agar culturing and real-time PCR, require sampling and take relatively much time. Especially, agar culturing, the most frequently used method, requires two days including bacteria culturing. This means if drinking water is contaminated, the result can be known after two days, which means two days of unnecessary morbidity, mortality, and financial loss. Our solution, being able to detect impurity larger than 0.3 micrometer in less than one second, can dramatically save time. If the system is connected to the Internet, the process can be automated, reducing even more time. This can effectively prevent possible outbreaks, or financial loss for water providers.

“This system, utilizing TWT sensor, has a lot of potential for solving state-of-the-art water security issues, especially when it comes to water hygiene.”

The fact that our solution doesn't require sampling also enables total inspection for drinking water. Especially for pipelines, it is important to identify which part of facility has caused contamination. The sensor can be installed in each different parts of facility, so that the whole water processing facility can be monitored. This will enable rapid and precise after treatment after the contamination.

Moreover, the cost for this solution is relatively low. PCR and agar culturing require experts, and the need for experts produces more cost. Particle counter and flow cytometry may not need expert as the previous two methods, but the cost for the apparatus is high, ranging from 10,000 to 20,000 USD. Our system, however, has relatively low, as the system only consists of light source and newly developed TWT sensor. The simplicity of the system makes it affordable for various applications, ranging from industrial system to hand-held device.

3.3. Applications

This system, utilizing TWT sensor, has a lot of potential for solving state-of-the-art water security issues, especially when it comes to water hygiene. First, TWT sensor can be used in water reservoirs to monitor possible water contaminants. This can either be a water pipeline providing drinking water or water tank preserving water for various uses. Embedding TWT sensor in the infrastructure of the city will greatly enhance water security, as TWT



Figure 8-7 An Ecology of TWT Sensor System

sensor can detect microscopic impurity in less than one second. Also, TWT sensor can be connected wirelessly, so information on water hygiene can be instantly checked via mobile applications.

Recently, we installed TWT sensor on Suji Purification Plant as a part of K-Water Test Bed Operation Management Program. We will be testing TWT sensor's feasibility in actual water plant for further implementation in smart cities. Although the performance seems to be fair, further data collection will be needed to perfectly realize the system. Nevertheless, this installation will be the start of the enhancement of water security in whole city and whole nation.

TWT sensor can also be applied to product inspection in beverage production line. Given that even small contamination of beverage can cause catastrophic impact, whole inspection of beverages produced is crucial for maintaining water security. Current inspection is done by sampling method, a method which takes sample from production line and sets it in an oven for 48 hours in order to cultivate possible microorganisms inside and visualize it as a colony. This makes the company vulnerable to cope with possible outbreak as well as causing considerable economic damage. TWT sensor, with its ability to rapidly check the product and share the result ubiquitously, shortens the inspection time to less than one second and enables real-time whole inspection. Also, it can be installed in any point of production line, so the company can track the cause when the contamination happens. This system is currently implemented in one of the Korea's largest drinking water company, and every bottled water are examined by TWT sensor to safely deliver drinking water to people.

04

Conclusion

This paper has suggested our new solution for microscopic impurities in drinking water and compared it with current solutions. Microscopic impurities such as bacteria or microplastics in drinking water can cause serious problems, as we can see in the case of Milwaukee, 1993. Current solutions frequently used are flow cytometry, particle counter, agar culturing and real-time PCR.

“This solution has benefits in not only shortening inspection time but lowering cost while providing precise detecting method at the same time.”

However, each solution has its shortcomings, especially the fact all these methods require sampling flowing water. Our solution, consisting of laser and our special sensor, makes the inspection real time by directly installing the apparatus to water pipeline and dramatically shortening inspection time. This solution has benefits in not only shortening inspection time but lowering cost while providing precise detecting method at the same time. This solution can be applied to various products and occasions, but further research and development is needed to further diversify product lines.

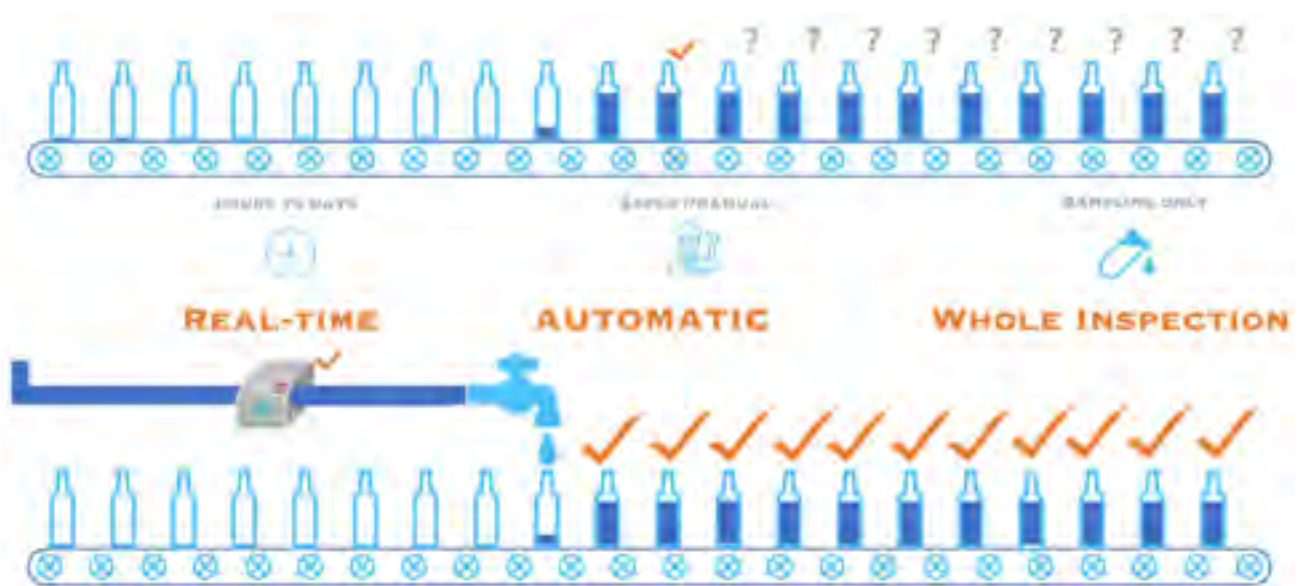


Figure 8-8 Diagram of Whole Inspection System Using TWT Sensor

References

- Corso, P., Kramer, M., Blair, K., Addiss, D., Davis, J. & Haddix, A. (2003). Costs of Illness in the 1993 Waterborne Cryptosporidium Outbreak, Milwaukee, Wisconsin. *Emerging Infectious Diseases*, 9(4), pp. 426-431. DOI:10.3201/eid0904.020417.
- Craun, G., Brunkard, J., Yoder, J., Roberts, V., Carpenter, J., Wade, T., Calderon, R., Roberts, J., Beach, M. & Roy, S. (2010). Causes of Outbreaks Associated with Drinking Water in the United States from 1971 to 2006. *Clinical Microbiology Reviews*, 23(3), pp. 507-528. DOI:10.1128/cmr.00077-09.
- Mac Kenzie, W., Hoxie, N., Proctor, M., Gradus, M., Blair, K., Peterson, D., Kazmierczak, J., Addiss, D., Fox, K. & Rose, J. (1994, July). A massive outbreak in Milwaukee of cryptosporidium infection transmitted through the public water supply. *The New England Journal of Medicine*, 331(3), pp. 161-167. DOI:10.1056/nejm199407213310304. PMID 7818640.
- Harrington, W., Krupnick, A. & Spofford, W. (1989). The economic losses of a waterborne disease outbreak. *Journal of Urban Economics*, 25(1), pp. 116-137. DOI:10.1016/0094-1190(89)90048-x.



The 'Global Water Security Issues (GWSI) Case Studies' is the publication of the International Water Security and Sustainable Management (i-WSSM).

The GWSI Case Studies seeks to demonstrate that water has a central role in all aspects of economic development and social welfare, and that concerted action via a collective approach of the water-using sectors is needed to ensure water's many benefits are maximized and shared equitably and that water-related development goals are achieved.

While this publication is factual, containing the most current information available concerning the state of knowledge on water security in the perspective of sustainable development and covering the most recent developments that affect it, this publication also provides decision-makers with concrete examples of approaches and potential responses for addressing water security-related challenges from the perspectives of both the sustainable development goals (SDGs) and a broader political and sectoral scope, which covers development, governance, environment, capacity-building, institutional reform and technology.

It is hoped that this publication will be a reference source on water security as it covers diverse aspects of human development and the cases and solutions introduced in the GWSI Case Studies can be invaluable for decision-makers, their advisors and anyone interested in – and concerned about – water security, and that this case studies will reach an ever-widening audience that includes actors outside the 'water box' who make or influence broad socio-economic policies that can affect water security.



United Nations
Educational, Scientific and
Cultural Organization



International Centre for
Water Security and
Sustainable Management



This publication is
partially financed
by Asia Water Council.