

World Water Resources

Nilgun B. Harmancioglu
Dogan Altinbilek *Editors*

Water Resources of Turkey

 Springer

World Water Resources

Volume 2

Series Editor

Vijay P. Singh, Texas A&M University, College Station, TX, USA

This series aims to publish books, monographs and contributed volumes on water resources in the world, with particular focus per volume on water resources of a particular country or region. With the freshwater supplies becoming an increasingly important and scarce commodity, it is important to have under one cover up to date literature published on water resources and their management, e.g. lessons learnt or details from one river basin may be quite useful for other basins. Also, it is important that national and international river basins are managed, keeping each country's interest and environment in mind. The need for dialog is being heightened by climate change and global warming. It is hoped that the Series will make a contribution to this dialog. The volumes in the series ideally would follow a "Three Part" approach as outlined below: In the chapters in the first Part *Sources of Freshwater* would be covered, like water resources of river basins; water resources of lake basins, including surface water and under river flow; groundwater; desalination; and snow cover/ice caps. In the second Part the chapters would include topics like: *Water Use and Consumption*, e.g. irrigation, industrial, domestic, recreational etc. In the third Part in different chapters more miscellaneous items can be covered like impacts of anthropogenic effects on water resources; impact of global warming and climate change on water resources; river basin management; river compacts and treaties; lake basin management; national development and water resources management; peace and water resources; economics of water resources development; water resources and civilization; politics and water resources; water-energy-food nexus; water security and sustainability; large water resources projects; ancient water works; and challenges for the future. Authored and edited volumes are welcomed to the series. Editor or co-editors would solicit colleagues to write chapters that make up the edited book. For an edited book, it is anticipated that there would be about 12–15 chapters in a book of about 300 pages. Books in the Series could also be authored by one person or several co-authors without inviting others to prepare separate chapters. The volumes in the Series would tend to follow the "Three Part" approach as outlined above. Topics that are of current interest can be added as well.

Readership

Readers would be university researchers, governmental agencies, NGOs, research institutes, and industry. It is also envisaged that conservation groups and those interested in water resources management would find some of the books of great interest. Comments or suggestions for future volumes are welcomed.

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More information about this series at <http://www.springer.com/series/15410>

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The Ataturk Dam on the Euphrates River, was built as the major dam of the Southeastern Anatolia Project with 85 million m³ embankment, creating a reservoir of 48 km³, with installed capacity of 2400 MW. It generates hydroelectric energy up to 9 TWh/y. The dam is functional since 1992 and is widely considered to be not only the largest dam in Turkey, but also one of the largest in the world (Photo by Prof. Dr. Unal Ozis)

Foreword

In world geography, Turkey occupies a unique place connecting Europe and the Middle East. It has varied landscape and varied climate, which, in turn, reflect diverse space-time characteristics of its water resources. These diverse characteristics present a challenge and an opportunity to policy makers, the agencies responsible for water resource management, the agricultural sector involved in growing crops, the energy sector involved in generating hydropower, the municipalities responsible for water supply, the departments of tourism involved in providing recreational facilities, as well as those involved in environmental and ecosystem management. Further, because of its situation, Turkey has a number of transboundary river basins, which compound the aforementioned challenge and opportunity. A comprehensive treatise dealing with a broad range of water resource issues pertaining to Turkey has long been desired, and the need for such a treatise has increased under the specter of climate change and global warming and the transformation of the country from a water-rich nation to a not-so-water-rich nation, facing frequent water scarcity because of a growing population, rising standard of living, increasing demand for water, and less-than-proper water management. This book, edited by Professors Harmancioglu and Altinbilek, meets this long-felt need.

Beginning with a discussion of the factors that shape Turkey's water resources and their availability and distribution, the book, encompassing 17 chapters, provides a detailed treatment of water use and consumption, as well as management, legislation, sustainability and security, climate change, ancient water works, and future outlook. The book contains a wealth of information, reflecting the vast and rich experiences of not only the editors but also the chapter contributors.

There is much to learn from this book which more than meets the objectives of the World Water Resources book series. It shows how water management strategies can be developed in concert with legal, institutional, economic, and capacity development requirements. These strategies enhance sustainability and water security and promote the water-food-energy nexus. The material presented in the various chapters is equally relevant to many countries in the world—a point for launching the book series.

Both Professors Harmancioglu and Altinbilek deserve a lot of applause and ought to be congratulated for preparing this treatise, which will be of enormous value to the people of Turkey and will also enrich the water resource literature.

Distinguished Professor, Regents
Professor, Caroline & William N Lehrer
Distinguished Chair in Water
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College Station, Texas, USA

Vijay P. Singh

Preface

Environmental and water crises dominate the present world we live in. Pollution is observed at varying degrees of intensity in almost all natural resources. The quality of surface and ground waters is continuously degrading to limit their use. Similarly, land resources are exposed to problems of soil erosion, deforestation, urban sprawl, and desertification in many parts of the world. Another problem in particular regions is air pollution, which has already reached life- and health-threatening levels. All these adverse conditions have eventually endangered physical habitat for biodiversity. There are also some recent problems to aggravate the situation, i.e. climate change and its possible effects on various components of the environment. Certainly, environmental degradation not only endangers nature, but it also has serious social and economic implications. An important feature of the above problems is that they are experienced globally; that is, all countries experience one or more of these adverse conditions at different degrees of severity and coverage. The same is valid for water resources so that it is important to work out commonalities and differing aspects of world water resources.

Springer has initiated a new book series entitled *World Water Resources*, edited by Professor Vijay P. Singh from Texas A&M University, USA. The reason for starting the book series was to have a comprehensive understanding of water resources of different countries and how these countries are planning and managing their water resources. With the freshwater supplies becoming an increasingly important and scarce commodity, it is important to have under one cover up-to-date literature published on world water resources and their management. Lessons learned from one river basin may be quite useful for other basins. Since many countries share their resources with each other, it is deemed useful to have an unbiased assessment of these resources, which will help resolve legal issues arising from mutual conflicts. That means national and international basins must be managed, keeping each country's interest and environment in mind.

This book is proposed as one of the first volumes to contribute to the above book series and provides an in-depth description of water resources in Turkey. Turkey has a unique geographical location in the world, extending in part from Europe to the

Mediterranean and further to the Middle East. This means that its water resources also reflect diverse characteristics under varying geography, topography, hydrology, geology, and climate among its water basins. Furthermore, due to its geographical location, Turkey has a significant number of transboundary river basins as an upstream and downstream country and has to share her water resources with her neighbors, an issue that sometimes may lead to water conflicts.

Turkey is also an interesting example as a developing country that tries to adapt to universal water management strategies but with legal, institutional, economic, and capacity development drawbacks. The country has long remained as a water-rich country, but the situation is now reversed to problems of water scarcity due to increasing population, inefficient use of the resource, impacts of climate change, and environmental degradation.

The book is designed in three parts, as required for the book series. The first part is devoted to physical features shaping the country's water resources, e.g., geography, topography, geology, hydrology, meteorology, climate, and the similar. The second part focuses on water use and consumption comprising the three major uses of water in Turkey, which relate to the domestic (drinking and industrial), agriculture (irrigation), and water power (hydroelectric energy) sectors. The third part of the book addresses the so-called miscellaneous issues, but all of which are highly significant in terms of water management. These issues, in particular, are river basin management, water-related legislation, sustainability and water security issues, impacts of global warming and climate change, ancient water works, and challenges for the future. A special section is devoted to transboundary river basins in Turkey as a significant portion of the water resources is transboundary and deserves special attention with regard to political conflicts and peace in the region.

The above three parts are addressed via 17 chapters, including the introductory chapter (Chap. 1), which provides a summary of each section. Chapters 2 and 3 reflect an interesting feature of water resource systems and structures in Turkey, that is, one may encounter in the country both the world's most ancient water works (Chap. 2) and the modern advanced systems developed during the Republican era (Chap. 3), which are unique in many ways. Chapters 4, 5, 6, 7, and 8 present an in-depth description of the physical features of water resources in the country, including a comprehensive chapter on Turkey's climate. The following three chapters constitute the second part of the book, i.e., water use and consumption. Three areas, agriculture (Chap. 9), water power (Chap. 10), and domestic/industrial water (Chap. 11), are considered in these chapters as the major water-consuming sectors. The third part of the book starts with Chap. 12 on transboundary river basins in Turkey. Transboundary and/or boundary-forming rivers have a significant contribution to the overall water potential of Turkey; they also play an important role with respect to the possible mutual conflicts among riparian countries and peace in the region. Chapter 13 addresses the practices of river basin management in Turkey, the importance of which is recognized only within the last decade. The major issues that

influence water management are discussed in Chap. 14 on the expected impacts of climate change and Chap. 15 on the Turkish legislation relevant to water resources. Chapter 16 basically complements Chap. 13 to elaborate further on water management through discussing concepts of sustainability, water security, water allocation, and the water-food-energy nexus. The last chapter, Chap. 17, is basically a wrap-up of current problems regarding water resources and management in Turkey and discusses challenges for the future in the light of these problems.

The reader may find some commonalities between the chapters since many aspects of water resources cannot be separated by clear-cut lines but are components of the same water continuum (e.g., features like hydrology and water potential, groundwater and precipitation, climate and precipitation). Likewise, figures given for the same entities may vary slightly from chapter to chapter, depending on possible discordances between the derivations of these figures by different authors. However, these variations are minor and do not affect the overall level of the entities.

No book has been published as yet in Turkey to cover all aspects of water resources in the country, related problems, and water management issues as comprehensive as in this volume. Thus, the presented work will be, in a way, a useful “reference book” or a guide for all members of water communities in the country, including authorities, institutions, water users, academicians, and all other professionals. It is believed that the international water community will also welcome this volume as it demonstrates a multifaceted example of water developments and associated problems in a typical developing country under water stress. Water professionals, practitioners, managers, governmental authorities, and scientists at the international level are expected to benefit from the book in terms of working out commonalities and differing aspects of world water resources. Information and lessons derived from this example will be useful for basins and their management problems in other countries. In particular, Turkey’s unique geographical position linking Europe and Asia and the presence of significant transboundary river basins will be important factors in arousing international interest in the volume.

It must be mentioned here that the authors contributing to this book are eminent professors and government authorities, renowned in their area of expertise both in Turkey and on the international platform. The editors would like to express their deep appreciation to all the contributors of the book, who have generously devoted their efforts and time toward the realization of this volume.

The editors extend their special thanks to the key editor of the book series *World Water Resources*, Professor Vijay P. Singh of Texas A&M University, USA, and to Mrs. Petra van Steenberg, executive editor of Springer Earth Sciences, Geography and Environment, for inviting them to prepare this book. Their valuable roles and support in initiating and realizing the present volume are gratefully acknowledged. Special thanks go to our colleagues Drs. Filiz Barbaros and Cem P. Cetinkaya, who committed themselves to scrupulous editing of the book throughout all stages of the work.

Finally, we would like to dedicate this book to the Republic of Turkey and to all those who have contributed to the development of water resources in the country. We expect that the work will shed light to future water developments and help water professionals and authorities recognize both the country's strenghts to build on and the expected water problems that are ever growing.

Buca, Izmir, Turkey
Cankaya, Ankara, Turkey

Nilgun B. Harmancioglu
Dogan Altinbilek

29.10.2018

95th Anniversary of the Foundation of the Republic of Turkey

To the Memory of Prof. Dr. Orhan Uslu

At the time when the production process of this book started, we were deeply saddened to learn that Prof. Dr. Orhan Uslu, one of the principal contributors to this work, unexpectedly passed away. His loss left us with the most heartfelt sorrow but we have found solace in having had the opportunity to have worked with him in his last work. It was an honor to have known such a great person and scientist. His memory will always be with us as we read this book and regret that he did not have time to see it published.

We would like to express our sincere condolences to his family and to the national/international academia. May he rest in peace.

05.12.2018

Nilgun B. Harmancioglu
Dogan Altinbilek
Editors
on behalf of all authors of this book

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Prof. Dr. Nilgun B. Harmancioglu is a professor of hydrology and water resources, who carried out teaching and research activities at the DEU Faculty of Engineering between 1976 and 2017 (formerly Aegean University between 1976 and 1982). She received her BSc in civil engineering in 1973, her MSc in water resources engineering in 1976, and her PhD in hydrology and water resources in 1981. She was promoted to full professorship in 1992 at the DEU Faculty of Engineering, Civil Engineering Department.

She carried out her postdoctoral studies first at Ecole Nationale Supérieure des Mines de Paris, Centre d'Informatique Géologique, Laboratoire d'Hydrogéologie Mathématique Paris, (1980–1981), and then at George Washington University, School of Engineering and Applied Science, International Water Resources Institute (1984–1986), where she also worked as a research associate.

Dr. Harmancioglu's basic areas of research are water resource management, simulation of hydrologic

processes, and information theory as applied to water resources. She has about 350 publications in the relevant areas, 70% of which are in English. She published and edited 4 books published by Springer and has contributed to several international conferences and symposia as a codirector, lecturer, and member of organization committees. She conducted various research projects funded by NATO, IWMI, the British Council, EU Framework Programs, the State Planning Agency, DEU, and TUBITAK (Scientific and Technical Research Council of Turkey). She also acted as a member of the Theme Advisory Board for the UNESCO IHP-VI Program between 2002 and 2007.

She was awarded by EWRA (European Water Resources Association) in 2015 as a distinguished member for her sustained and remarkable contributions to the scientific field of water resource management and for her continuous service to society.

Dr. Harmancioglu was the director of SUMER (DEU Water Resources Management Research & Application Center) between 2001 and 2017. She is currently the scientific director of EA-TEK, International R&D, Engineering, Software and Consultancy Company, located at the Technopark of Dokuz Eylul University, to continue her research and project activities.



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Hydraulic Works (DSI), which is the major government agency in Turkey responsible for water resource development, including water supply to large cities. During 2005–2009, Prof. Altinbilek was appointed as president of Energy Group at IC Holding, Ankara, Turkey, and also as chairman of the board of AES-IC Ictas Energy Production Company.

He served as a governor (2006–2018) and Vice President (2012–2018) of World Water Council (WWC). Prof. Dogan Altinbilek was also an honorary member and the President (2013–2015) of International Water Resources Association (IWRA). Prof. Altinbilek also served as the President (2004–2008) and Honorary Member of International Hydropower Association (IHA).

Chapter 1

Introduction



Nilgun B. Harmancioglu

Abstract Springer has initiated a new book series entitled World Water Resources, which aims to develop a comprehensive understanding of water resources of different countries and how these countries are planning and managing their water resources. This book is proposed as one of the first volumes to contribute to the above book series and provides an in-depth description of water resources in Turkey. The book is designed in three parts. The first part is devoted to physical features shaping the country's water resources; the second part focuses on water use and consumption, including domestic, agricultural (irrigation), and hydroelectric energy production uses. The third part of the book addresses the so-called miscellaneous issues, e.g., river basin management, water-related legislation, sustainability and water security issues, impacts of global warming and climate change, ancient water works, transboundary basins, and challenges for the future. The three basic parts of the book mentioned above are covered via 16 chapters, each of which gives a comprehensive description of the various features of water resources in Turkey. This introductory chapter is intended to shortly summarize the contents of these chapters so that it will be easier for the reader to select sections of interest.

Keywords Turkey · Water resources · Water resources systems · Basin management · Water security · Transboundary river basins

We live in an age of environmental alertness. Almost all natural resources are attacked by pollution at varying degrees of intensity. The quality of surface and ground waters is continuously degrading. The situation is similar for land resources with problems of soil erosion, deforestation, and desertification in many parts of the world. Air pollution has already reached life and health threatening levels in particular regions. These problems have eventually endangered physical habitat for biodiversity. Further difficulties are expected due to the possible effects of climate

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change on various components of the environment. All these adverse developments are induced by diverse human activities as well as by natural occurrences. The result is that environmental degradation not only endangers nature, but it also has serious social and economic implications. An important feature of the above problems is that we live them globally; that is, all countries experience one or more of these adverse conditions at different degrees of severity and coverage.

The global nature of the present environmental crisis, including water and its central role in the environment, has essentially been the major motive in initiating the new book series on “World Water Resources” by Springer. The basic idea behind this initiative is to work out commonalities and differing aspects of world water resources by dedicating each volume in the series to a different country. Regarding water resources, the book series will be a valuable source of information sharing at basin, national and international scales. Information and lessons learned on a river basin from a particular country may be useful for basins in other countries. At the national scale, the series foresees a comprehensive understanding of water resources of different countries and of how these countries are planning and managing their water resources. At the international scale, since many countries share their resources with each other in transboundary or international basins, it is deemed useful to have an unbiased assessment of these resources, which will also help resolve legal issues arising from mutual conflicts. There are other recent global issues to be addressed under the same cover, such as global climate change, water management, sustainability and water security, water-energy-food nexus, politics and water resources, and economic development.

This book is proposed as a volume to contribute to the above book series and provides an in-depth description of water resources in Turkey. Turkey has a unique geographical location in the world, extending in-part from Europe to the Mediterranean and further to the Middle East (Fig. 1.1). This means that its water resources



Fig. 1.1 Geographical map of Turkey and her neighbors

also reflect diverse characteristics under varying geography, topography, hydrology, geology, and climate among its water basins. Furthermore, due to its geographical location, Turkey has a significant number of transboundary river basins and has to share her water resources with her neighbors, an issue that sometimes may lead to water conflicts.

In view of the above-mentioned global environmental (water) crisis most countries experience today, it must be stated that Turkey is also a country currently under water stress although it was considered as being water-rich in the past. Countries regarded as being rich in water resources have 8–10 thousand m³ water per capita per year; and, on the basis of international standards and indices, the annual threshold value for water scarcity is stated as 1700 m³ per capita per year. The recent reports by state authorities reveal that the available water per capita in Turkey is in the order of 1400 m³. It is predicted that the population of Turkey will increase to 100 million in 2040 so that this value will reduce to 1120 m³. Thus, Turkey will experience a more enhanced water stress in the future, coupled with increases in relevant environmental problems. At this stage, it is important that prompt and sound actions are taken to reassess the prevailing water problems and to develop more effective policies for the planning and management of available water resources in the country. These issues are discussed in depth in the following chapters of this book.

The overall picture of Turkey's water resources structure, including the sources, developments and management of water, is highly complex and again unique in a number of ways, ranging from historical to present day features. Thus, only a book as comprehensive as this volume can "almost fully" cover the diverse characteristics of water resources in the country. The book is designed in three parts. The first part is devoted to physical features shaping the country's water resources, e.g. geography, topography, geology, hydrology, meteorology, climate, and the similar. Thus, sources of freshwater, surface water, groundwater, river basins, lakes, coastal waters, water quality, and wetlands are described in this first part. Given that the source is identified with its many features, the second part focuses on water use and consumption. Three major water uses of water in Turkey relate to domestic (domestic and industrial), agriculture (irrigation), and water power (hydroelectric energy). Within the last decade, preservation of environmental (ecological) integrity has assumed the second priority among the above water uses after provision of domestic water. The third part of the book addresses the so-called miscellaneous issues, but all of which are highly significant in terms of water management. These issues, in particular, are river basin management, water-related legislation, sustainability and water security issues, impacts of global warming and climate change, ancient water works, and challenges for the future. A special section is devoted to transboundary river basins in Turkey as a significant portion of the water resources are transboundary and deserve special attention with regard to political conflicts and peace in the region. The three basic parts of the book mentioned above are covered via 16 chapters, each of which gives a comprehensive description of the various features of water resources in Turkey. This introductory chapter is intended to shortly summarize the contents of these chapters so that it will be easier for the reader to select sections of interest.

An interesting feature of water resources systems and structures in Turkey is that one may encounter both the world's most ancient water works and the modern advanced systems, which are unique in many ways. Turkey is particularly known for her historical attractions in the tourism sector. The same is true for the water sector; that is, the country is renowned for her outstanding remnants of numerous ancient water works from a four-millenia-long period, some of which are still in operation. These historical works are rich in kind to encompass various types of water structures. Geographically, they extend all over the country, indicating the various civilizations who realized them. Chapter 2 of this book presents many examples of these ancient structures in colorful photos.

After the foundation of the Turkish Republic in 1923, Turkey started both to assess the availability of her water resources for various purposes and to harness the potential through concentrating on development plans and projects. The first projects, mostly dams, date back to the 1930s and were realized under financial constraints and significant data limitations. These projects were certainly coupled with the establishment of water-related institutions and authorities. In the following years, water resources systems and structures flourished in Turkish river basins for purposes of irrigation, domestic water supply, power generation, flood control, and other purposes. The last three to four decades have witnessed large scale and unique development plans and systems, including water transfer among basins and even transport to neighboring water scarce regions. These new developments are covered in Chap. 3, providing interesting examples of the advanced modern projects in Turkish river basins.

The next five chapters relate to the first part of the book, i.e., the description of the physical features (geography, topography, geology, hydrology, meteorology, climate, and the similar) that constitute the driving forces or sources producing the overall picture of water resources in Turkey. It will be observed in all these chapters that the above mentioned physical features are marked by significant diversity, leading also to diverse characteristics of water resources in Turkey. The final output of these chapters will be the delineation of the water potential in the country, derived as the most recent figures presented so far.

Chapter 4 focuses on the comprehensive analysis of Turkey's climate, including the current aridity and drought conditions, by implementing a contemporary physical geographical, hydro-climatological and meteorological approach. The chapter covers a description of variable climatic conditions across all the geographical regions of the country. It discloses that "*the southern and western portions (Marmara, Aegean, Mediterranean and South-eastern Anatolia regions) of Turkey are characterized mainly with the dry summer sub-tropical Mediterranean climate*", and further that "*All of these regions are also influenced by mid-to-high degree drought probability and drought risk, while the Black Sea Region is characterized with a mid-latitude temperate climate with a low-level drought probability and risk.*" The climate of Turkey is marked by diversity since it is affected by the transition zone of various atmospheric disturbances and weather types. The complexity of the topography, land-sea interactions and many other influences aggravate this diversity. The chapter also discusses climate-induced soil properties and land degradation and,

thus, relates to the topic of desertification as one of the significant problems in Turkey.

The diversity in Turkey's climate is directly reflected in the hydrologic characteristics of freshwaters as detailed in Chap. 5 on surface water. Surface water resources of Turkey are divided between 25 river basins, each with its own hydrological and hydro-meteorological character. The share of surface waters in these basins contribute to 80% of the total water potential of the country. Chapter 5 presents in detail the characteristics of each river basin, including lakes, by disclosing their drainage areas, input precipitation, and average flow conditions. This information is derived from data provided by the prevailing hydrometric gauging network in Turkey, which is also described as to its assets and limitations. The chapter further focuses on streamflow maxima and minima in the river basins since, due to the heterogeneity of hydro-meteorological conditions in the country, some regions are flood-prone while others can be affected by extreme droughts. The trend analyses mentioned in the chapter finally conclude that extremes in surface flows will become more pronounced with larger maxima and lower minima than those observed in the past.

A comprehensive evaluation of groundwater in Turkey is presented in Chap. 6. A significant portion of the streamflow of major rivers is supplied by groundwater through springs and base flow. The aquifers in the country are grouped into four categories as the alluvial deposits/gravel aquifers, karstic aquifers, volcanic rock aquifers, and the fractured bedrock aquifers. The available groundwater potential provided by these aquifers is about 15 km^3 , accounting approximately to 18% of the total water resources potential of Turkey. Groundwater is basically used in irrigation, domestic and industrial water supply, where irrigation consumes about approximately two-thirds of the total amount of groundwater used. It is depicted in the chapter that *“the share of the groundwater resources in sectoral water allocation has increased from 8.5 billion m^3/year in 1995 to about 15 billion m^3/year in 2014”* and further *“that the groundwater resources supply about 25% of the total water use in 2004 and about 30% in 2008”*. The apparent overexploitation of groundwater resources and the accruing decrease of springs and/or spring flows show the inevitable result that the groundwater resources are under severe natural and/or anthropogenic stresses in Turkey.

Following the description of freshwaters and groundwater in quantitative terms in the preceding chapters, Chap. 7 presents an assessment of water quality in Turkish waters and the related pollution problems. It is stressed in the chapter that increases in production and consumption have caused serious pressures on water resources and the environment in Turkey. These problems are due to population increase, inland migration from rural to urban areas, industrialization, agriculture, expansion of tourism, and increases in economic activities and resource depletion. The work discusses the current status of water quality of inland and coastal waters (river, lake, groundwater and marine pollution) in Turkey, along with the associated legislation. Current wastewater management schemes and efforts towards the improvement of the pollution situation (surface water and groundwater pollution, lake pollution, marine pollution and removal of sludge), using available treatment and disposal

technologies, are also considered in depth. The chapter concludes that, although environmental loads have increased several hundred times in the last 50–60 years, Turkey has shown a fast and consistent response to the situation as sufficient expertise, funds, regulations, and responsible governmental agencies have developed.

The first part of the book concludes with Chap. 8, which presents the overall results for the water potential of Turkey. The chapter is based on a very recent study carried out by the former Ministry of Forestry and Water and the related institutions (State Hydraulic Works, Meteorological Services, and the Directorate General of Water Management). The work comprises a compilation and review of the available data on precipitation, evapotranspiration, groundwater and surface flows between 1981 and 2010, and the main factors affecting Turkey's water potential. The computed values for the water resources potential in each of the 25 river basins in the country are disclosed together with the country's total water potential, which was derived by a water balance approach. The chapter further presents recent information on maximum and minimum values of the hydrologic and meteorological components of the water cycle, using the period between 1981 and 2010 as the reference years.

The following three chapters constitute the second part of the book, i.e. water use and consumption. Three sectors, agriculture, domestic/industrial water and water power, are considered in these chapters as the major water consuming sectors. Chapter 9 focuses on irrigated agriculture and states that irrigation is a must in almost all basins since the spatial and temporal distribution of input precipitation is highly variable across the country. The total irrigable area in Turkey is 25.85 million hectares (Mha), of which 22.6 Mha land can be economically and technically irrigable under present conditions. However, only 8.5 Mha area is expected to be equipped with irrigation schemes by DSI (the State Hydraulic Works) by the year 2023, which is the centennial of the foundation of the Turkish Republic. Irrigation is the largest water consuming sector in Turkey and uses about 74% of the total water potential of Turkey. However, the share of water use for irrigation is projected to be reduced to 64% by 2023. The chapter gives information on the institutional framework in irrigation developments and discusses irrigation practices in each of the 25 river basins of the country. It also introduces large scale regional development projects including irrigation investments. Among these, the *Southeastern Anatolia Project (GAP)* deserves special attention as it is considered as one of the biggest integrated development projects in the world, comprising several aspects such as irrigation, flood control, environment, hydropower generation, education, health, industry, etc.

Chapter 10 is devoted to water power and hydroelectric potential of Turkey. The primary energy resources of Turkey are quite limited; therefore Turkey has to develop her water power potential to produce electrical energy. The hydroelectric energy production of Turkey was only 1 TWh/year in 1960 but increased to about 75 TWh/year in 2017, which is equal to half of the economically feasible hydroelectric potential of the country. The total installed capacity of hydroelectric power plants was 0.4 GW in 1960 and increased to 27.3 GW in 2017, thus nearly 70 times in

57 years. The economically feasible hydroelectric potential of Turkey is in the order of 150 TWh/year. Turkey anticipates to harness the remaining part of this potential so that several hundreds of major hydroelectric power plants have still to be developed in the near future. The total installed capacity of all types of electricity generating plants in Turkey was around 73 GW in 2015. The total installed capacity of hydroelectric power plants is 26 GW, and its share in the total power generation is 35%. The water power potential of Turkey is basically harnessed by power plants located at the toe of dams along the middle stretches of the rivers and by high-head diversion plants at the higher stretches of the rivers. The chapter presents several examples of the existing water power schemes in the country, detailing the various structures (dams, conduits, diversions, etc.) involved in the systems in colorful photographs.

Urban and industrial water use and management in Turkey is considered in Chap. 11, using available data related to sectoral uses, constraints and a realization of envisaged targets up to the present. Water supply and sanitation sector is discussed on the basis of the existing regulatory system, particularly in relation to the EU legislation as part of Turkey's accession process to the EU. The sectoral analysis presented in the chapter covers such issues as drinking water production and its use by households and the public sector, industries connected to the public water supply system, self-supplied industries, and pollution generated by municipal and industrial water consumption and its disposal. The first part of the chapter focuses on water uses in the urban and industrial sector, water supply and treatment, sewerage, wastewater treatment and disposal. A general description of the existing institutional structure related to water and sewerage administrations in Turkey is covered in the second section.

The third part of the book starts with Chap. 12 on transboundary river basins in Turkey. Transboundary and/or boundary-forming rivers contribute about 70 km³/year or 40% to the gross surface water potential originating in Turkey. Their basins cover an area of 250,000 km² or roughly one third of the land surface of Turkey. The largest is the Euphrates-Tigris Basin, which represents about four fifths of the water potential of transboundary rivers in Turkey. The rest is contributed by the basins Orontes, Kura-Araks, Chorokhi, Maritza, and a few other quite small basins. The chapter presents detailed information on these basins as to their potential, development, existing water structures, and the amounts of water potential shared by each riparian country. Often, downstream riparian countries are concerned about the development of land and water resources in Turkey as they anticipate decreases in the quantity of waters that flows into their territories in addition to possible deterioration in quality of the water. These concerns are particularly related to the implementation of the Southeastern Anatolia Project in the Euphrates-Tigris Basin, where Turkey is the upstream riparian in both main subbasins. Concerns over water quantity also stem from water scarcity in the Middle East, which is expected to get worse through the impacts of climate change. However, Turkey claims that water resources developments in the country comply with the UN principles of equitable and reasonable use and further that dams in Turkey provide significant benefits to

downstream countries, such as flood mitigation, sediment retention, and temporary low flow augmentation.

Chapter 13 addresses the issue of river basin management in Turkey. The water community recognized the significance of the concept of river basin management only within the last 2 decades. However, as a European Union (EU) candidate country, Turkey has taken significant steps towards the implementation of EU norms and requirements on river basin management. Still, there is yet no management plan that is practiced fully in Turkish river basins due to a number of problems. These problems relate basically to institutional structures, water management based on administrative boundaries, insufficient databases, poor monitoring and surveillance, capacity building, and insufficient sanctions and policies. In particular, there is no national Water Law yet finalized in the country. It still remains at the draft scale. Despite these deficiencies, River Basin Management Plans (RBMPs) are prepared in accordance with the EU Water Frame Directive (WFD) for 25 river basins in the country to achieve “good status” by 2036 in all water environments. To this end, the previously completed Basin Protection Action Plans (BPAPs) are transformed into RBMPs.

Chapter 14 essentially follows Chap. 4 on Climate of Turkey but, this time, focuses on the expected impacts of climate change over the country. The work covers projections of future climate conditions by using regional climate model simulations. To this end, changes in seasonal precipitation climatology, extreme weather conditions, and aridity conditions of Turkey are assessed for the 30 years between 2021 and 2050, based on the reference period of 1971–2000. The majority of geographical regions in Turkey are characterized by semi-arid climate conditions. Only the northeastern and the western parts (some parts) of the Black Sea region appear to be hyper-humid areas. The climate projections realized indicate a strong decrease in precipitation for almost all areas, but an increase in the intensity of drought conditions. Accordingly, more arid conditions are expected in the region for the near future. This means that Turkey will become significantly vulnerable to climate change, particularly to increased droughts.

Chapter 15 addresses one of the crucial issues in Turkey, i.e. legislation relevant to water resources. Institutional and legal problems have long hindered the proper management of these resources since institutions and legislation have gone through many changes and amendments in time. Laws governing the use and management of water failed to keep up with the increasing water demand and decreasing water supply. At present, the national Water Law is still in draft form, but many new primary and secondary water legislations in the domestic water, irrigation, hydro-power, and the environment sectors have been issued. This chapter describes the principal water legislation in Turkey, along with institutional changes that have taken place due to domestic and regional political issues. Turkey’s transboundary water policy is also discussed on the basis of related basic principles and prevailing practices.

Sustainability and water security issues considered in Chapter 16 basically complement Chapter 13 on river basin management. Sustainability is a long renowned concept in Turkey, but it is not fully understood as to its linkages with

developmental targets and water management. The same is true for the fundamental basis of water security. The problem has been that every sector, every authority, or every individual evaluated sustainability through his/her own window. Mostly, the term has been associated with efforts on preventing long term adverse effects of development on the environment. In the water sector, this definition was directly associated with water quality. As noted above, the difficulty has been to comprehend the link between sustainability, water resources, and development. Water security is a newer concept in Turkey, and it has been only 4–5 years since water authorities came to recognize it as a requirement. Studies on these issues long remained at academic level, and the early institutional responses were quite slow. The chapter discusses the above problems and presents examples of the few studies carried out on sustainability and water security.

The last chapter, Chap. 17, is basically a wrap-up of current problems regarding water resources and management in Turkey and discusses challenges for the future in the light of these problems. It also discloses how water communities in the country react to these challenges and plan new targets for the future. The most challenging issue appears to be water scarcity resulting from fast increases in population, urbanization, industrialization, agriculture, expansion of tourism, and increases in economic activities, and resource depletion. Turkey is also an interesting example as a developing country that tries to adapt to universal water management strategies but with legal, institutional, economic and capacity development problems. The country has long remained as a water-rich country but the situation is now reversed to problems of water scarcity due to increasing population, inefficient use of the resource, impacts of climate change and environmental degradation.

In Turkey, no book has been published as yet to cover all aspects of water resources in the country, related problems, and water management issues as comprehensive as this volume. Thus, the presented work will be, in a way, a useful “handbook” or a guide for all members of water communities in the country, including authorities, institutions, water users, academicians, and all other professionals. It is believed that the international water community will also welcome this volume as it demonstrates a multifaceted example of water developments and associated problems in a typical developing country. Information and lessons derived from this example will be useful for basins and their management problems in other countries. In particular, Turkey’s unique geographical position linking Europe and Asia and the presence of significant transboundary river basins will be important factors in arousing international interest in the volume.

Chapter 2

Water Works of Ancient Civilizations



Unal Ozis, Ahmet Alkan, and Yalcin Ozdemir

Abstract Turkey is renowned for her outstanding remnants of ancient water works and is thus one of the foremost open-air museums of the world with regard to hydraulic structures in the world. Numerous ancient water works from a four-millenia-long period are still in operation after several centuries or even several millennia. These historical works are rich in kind to encompass dams, irrigation canals, masonry conduits, aqueduct-bridges, tunnels, water collection works, water conveyance systems, pipes, inverted siphons and water mills. Geographically, they extend all over the country, indicating the various civilizations who realized them. They date back to the second millenium BC, the Hittite civilization in Central Anatolia; to the first half of the first millenium BC, the Urartu civilization in Eastern Anatolia; to the second half of the first millenium BC and the first millenium AD, the Hellenistic, Roman and Byzantine civilizations in Western and Southern Anatolia; to the eleventh up to the fourteenth centuries, the Seljukide civilization in Central and Eastern Anatolia; to the fourteenth up to the early twentieth centuries, the Ottoman civilization in Turkey. Some of these ancient water works were given as interesting examples in relevant books; several of them were dealt with more detail in other specific publications, journals and proceedings.

Keywords Turkey · Civilization · Ancient · Water · Hydraulic · Dam · Conduit · Tunnel · Aqueduct · Bridge · Canal · Pipe

2.1 Introduction

Turkey is one of the foremost open-air museums of the world with regard to historical water works for the last 4000 years (Fig. 2.1). Numerous ancient water works from this four-millenia-long period are still in operation after several centuries or even several millennia.

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