Foreword

One of the major questions that faces the world at the beginning of this century is the threat to our water resources, both in terms of quantity and of quality. There are today 6.2 billion inhabitants on Earth, 14% of whom are already suffering from hunger, a number that has unfortunately been increasing for the last five years, and 20% of whom lack an adequate drinking water supply. In 2050, there will most likely be 9 billion people. To provide food and an adequate domestic water supply to that many people, with their evolving diets, we will need roughly 75% more water than we use today[†], mostly for agriculture, at the same time as we will need to safeguard a biodiverse and healthy series of natural ecosystems, indispensable for the ecological equilibrium of the planet.

In addition, our current urban life, our industrial activity and our agricultural practices increasingly generate sources of contaminants that are spread in the atmosphere, in surface water, on soils and in groundwater, threatening water quality.

Finally, these threats must be examined in the context of climate variability, which most likely will be enhanced by impending climate changes, as indicated by the recent *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change released on 29 January 2007[‡]. Not only will more water be needed, but it will have to be available even during droughts. The world has always experienced great climate variability, such as the seven years of fat cows and lean cows in the Bible. For instance, some archaeological studies conducted simultaneously in Greece and China seem to show that a major drought occurred in these two countries around AD 400; in 1876–1878, and in 1898–1900, there were severe droughts simultaneously in Brazil, China, India and Ethiopia, causing dramatic famines[§]. In 1998, following a strong El Niño event, there were large deficits in the grain production in China and Indonesia. These two countries were able to import food from the world stocks, and no major consequences were felt, but the global food stocks fell to a very low level. It is

[†] See, for example, *Les Eaux Continentales*, coordinated by G. de Marsily, EDP Sciences, Paris, 2006; M. Griffon, *Nourrir la Planète*, Odile Jacob, Paris, 2006; International Water Management Institute, *Water for Food, Water For Life: The Comprehensive Assessment of Water Management in Agriculture*, Colombo, Sri Lanka, report to be published 2007.

[‡] Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007.

[§] See, for example, A. Sen and J. Drèze, *Omnibus*, Oxford University Press, New Delhi, 1999; M. Davis, *Late Victorian Holocausts, El Niño Famines and the Making of the Third World*, Verso, London, 2001 (also available in French: *Génocides Tropicaux*, La Découverte, Paris, 2003 and 2006).

most likely that such events will occur again and severely affect water resources simultaneously across different continents.

As emphasised by the Stern Report released on 30 October 2006[¶], taking action now to combat climate change is of utmost importance, if severe economical and social crises in the course of this century are to be avoided. But this applies also to the protection of the environment and the management of water resources, as shown, for example, by the Millennium Ecosystem Assessment Report[‖].

This book addresses one of the central issues of these concerns: the science and policy of groundwater resource management. Groundwater is and will indeed be a major world resource for both irrigation and domestic use. Aquifers supply, in fact, about one-fourth of the flow of all the rivers in the world, about 90% of it in the low-flow season, about 75% of the drinking water supply in Europe, about 50% worldwide and a majority of the irrigation water in the world; aquifers are also the major natural means of storing water during wet years and make it available during droughts. Finally, almost 20% of the world freshwater reserves are contained in the aquifers, while surface waters only contribute 0.5%; the remaining 80% are the continental ice sheets, not readily usable. Managing and protecting our groundwater resources is thus a very urgent and important task. By contrast, aquifers, because they are not visible and their functioning in general poorly understood, are currently very poorly managed worldwide, or rather not managed at all, and often exploited at the highest possible level without a thought spared for their protection.

In fact, very little time is left to learn how our aquifer systems operate, what their reserves are and how to protect and to manage them in order to be able to meet tomorrow's challenges. This book is thus a timely contribution to this endeavour. With the 2000 Water Framework Directive[**], the European Community took the lead in Europe in addressing the issue of re-establishing the ecological and chemical quality of our continental waters, and with the new daughter directive on groundwater[††], adopted on 12 December 2006, the European Community is again setting out the framework for the management of groundwater in Europe.

Philippe Quevauviller, who was the leader at the European Commission for the development of the daughter directive on groundwater, was in an ideal position to assemble the necessary multidisciplinary team of specialists who have contributed to this book. Groundwater is indeed a topic that requires the interaction of many disciplines for its management: geologists, hydrologists, geochemists, geobiologists, agronomists and farming experts, health specialists,

[¶] www.sternreview.org.uk.

[‖] Millennium Ecosystem Assessment, *Ecosystems and Human Well-being: Synthesis*, Island Press, World Resources Institute, Washington, DC, 2005 (www.maweb.org).

[**] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Official Journal of the European Communities, L 327, 22.12.2000.

[††] Directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration, L 372, 12.12.2006.

economists, law-makers, social scientists, *etc*. About 70 such experts from 13 European countries have contributed to this book, with one author from the US Environmental Protection Agency giving some perspectives on groundwater protection in the USA.

With eleven different sections, the book in a coordinated fashion covers most of the topics of importance in the management of groundwater, both from the technical side and the management aspect. Bringing together often opposite views of aquifer management, that of the scientist and that of the policy maker, is a rare achievement, for which the authors and the editor must be congratulated. Science–policy integration, regulatory frameworks and stakeholder involvement are covered at the same time as groundwater characterisation, monitoring, risk assessment, remediation, modelling and management at the basin scale.

The book ends with a remarkable concluding section on further policy and research objectives that need to be addressed in the coming few years, in order to put Europe at the forefront of groundwater resource management, and to meet the social, economic and ecological challenges of our water supply in the 21st century.

Ghislain de Marsily
French Academy of Sciences and University Paris VI, Paris, France