

FLOODS IN A CHANGING CLIMATE  
RISK MANAGEMENT

气候变化背景下的  
洪水风险管理

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## 内 容 简 介

气候变化及其日趋显著的影响已成为全球共同关注与应对的重大问题。在气候变化背景下,洪水与洪灾表现出更大的不确定性,迫切需要将系统方法引入洪水风险管理,为解决防灾、减灾、应急响应与灾后重建中跨学科的一系列复杂难题,提供更为适合的分析工具。本书深入浅出讲解了洪水风险管理的基本理念,论述了气候变化对洪水风险特性的影响,探讨了应对气候变化的洪水风险管理决策过程与有效措施;进而基于系统理论与案例分析详细介绍了概率法与模糊集方法在洪水风险管理中的应用,展望了未来适应气候变化的洪水风险管理前景。本译著为相关领域科研、管理人员和大专院校师生提供了中英对照的读本,具有良好的学习与借鉴价值。

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*What is the appropriate behavior for a man or a woman in the midst of this world, where each person is clinging to his piece of debris? What's the proper salutation between people as they pass each other in this flood?*

Buddha (c. 563-483 BC)

*There is a tide in the affairs of men, which, taken at the flood, leads on to fortune... we must take the current when it serves, or lose our ventures.*

William Shakespeare (1564—1616)

*There can be no vulnerability without risk; there can be no community without vulnerability; there can be no peace, and ultimately no life, without community.*

M. Scott Peck (1936—2005)

*Decision is a risk rooted in the courage of being free.*

Paul Tillich (1886—1965)

在这人人都执着于自身肉体的俗世当中,对一个男人或女人来说,什么是适当的行为? 在自顾不暇的危急时刻,还能在意什么呢?

——释迦牟尼(公元前 563—公元前 483)

人生潮起潮落,唯乘高潮顺势而进者,方可抵达成功的彼岸,……我们必须把握现时的机会,否则全部的冒险都将前功尽弃。

——威廉·莎士比亚(1564—1616)

没有风险就无所谓脆弱,没有脆弱就不会有团结,没有团结就不会有和平,且最终导致人类失去安宁的生活。

——M. 斯科特·派克(1936—2005)

风险决策源于追求自由的勇气。

——保罗·田立克(1886—1965)

## 译著序言 | Foreword

新世纪以来,全球年均地表气温屡创新高,根据世界气象组织的报告,2016年平均气温为有气象记录以来最高的一年,气候温暖化的趋势已成不争事实。全球增温既加速了两级冰川融化与海平面的上升,又影响到大气环流运动、水汽循环与降水的时空分布,使得极端天气事件与水旱灾害的发生具有更大的不确定性。这种不确定性的加大,一方面意味着水灾风险的上升,使得人们对已建、在建与规划中待建的水利工程体系有效性产生疑问,对如何应对气候变化、满足全社会随经济发展而日益提高的水安全保障需求提出了更严峻的挑战;另一方面也意味着潜在的机遇,不仅成为人类研发全球观测体系、深入探索自然演变规律的巨大动力,而且对摒弃危害生态环境的粗放发展模式,加强人类适应气候变化与实施洪水风险管理的能力建设,亦起到积极的促进作用。可以说,有关应对与适应气候变化的研究与实践,必将成为人类社会贯穿整个 21 世纪的关注热点。

面对气候变化背景下洪灾频发、损失加重的趋势,综合考虑与灾害相关的经济、社会与环境因素,系统辨析洪水风险增长的自然成因、人为成因以及两者的交互作用,为决策者制定更为理性的发展规划和更为有效的防灾、减灾方案提供科学的依据,降低因不确定性增大而产生的决策风险,就成为保障可持续发展的必然需求。Slobodan P. Simonovic 教授这本专著的主要目标是将系统方法引入洪水风险管理,以解决跨学科领域的复杂问题,促使不确定性的负面影响向有利面转化。其可贵之处在于以人类关于可能性的认知(基础牢靠、不牢靠和无基础)和关于结果的认知(连续的、离散的和不理想的结果)为基础,阐明了概率分析、模糊集与情景分析等方法在洪水风险管理中对应风险、不确定性、模糊和未知等不同特性问题的适用范围;从系统的角度进一步提出了适应性的风险管理概念,以便能够在关键时刻了解、适应、防止、辨识和应对新的、未知的各种威胁;基于对主观与客观不确定性的统筹考虑,论述了综合洪水风险管理的理念,并通过风险信息的交流将风险估算、风险管理和决策过程联系起来。作者将模拟、优化和多目标分析等方法介绍到基于风险的洪水管理之中,不仅提供了相应的案例,而且编制了计算程序并以文本形式发布在网站上([www.cambridge.org/simonovic](http://www.cambridge.org/simonovic)),以便于广大读者学习和应用专著中介绍的各种系统方法。

我国目前仍处于快速发展的城镇化进程之中,在人类活动加剧与自然环境演变的双重影响下,洪水风险的增长态势更为复杂;我国政府积极推进从控制洪水向洪水管理的转变,任务也更为艰巨。本译著的出版,不仅有助于洪水风险管理基础理念的普及和先进风险分析手段的推广,而且,其理论与方法在我国的应用中都存在显著的创新与提升空间,这对广大青年读者尤其具有了更强的吸引力。我相信,本译著的发行,会对我国推进适应气候变化与洪水风险管理的研究产生持久的影响。

鉴于该书在风险管理理论与数学方法上有一定的深度和难度,且某些专业词汇在国内尚无统一的译法,为了减少阅读中的误解,译著特意争取了英文原著的版权,采用了中英对照的发行模式,使读者有机会从英文原文中去探究作者的本意,译者的这一点用心,也是值得特别称道的。

中国工程院院士:

Handwritten signature of Zhang Jianyun in black ink.

## 译者的话 | Preface

洪水灾害千百年来一直困扰着世界各地的人们。2000—2010年期间所有灾害损失中，有过半的损失是由水文地质灾害——主要是洪水和泥石流——造成的。据统计，2000—2010年全球洪灾年均损失高达200亿美元。Slobodan P. Simonovic先生编著的这本关于洪水风险管理的书，介绍了许多减轻洪水影响的方法和途径，特别是针对那些易于遭受洪水灾害的地区和居民。目前，随着空前规模的人类活动不断加剧，温室气体的浓度显著攀升，并正在影响着地球气候的变化。随着全球变暖，强降雨事件将更为频繁，这从物理机制上意味着将会有更多的洪水事件发生，尤其是针对弱势群体，洪水的不良影响将会明显增大，因此要求采取防范行动的呼声也随之高涨。本书的重要性就在于及时向人们介绍如何针对未来气候变化开展洪水风险评估，并据此及早制定更为有效的应对措施。

作者基于全球观测和众多学者的研究成果，系统阐述了气候变化背景下全球洪水风险的演变机理与趋向，探讨了针对气候变化的洪水风险评估理论与方法，并以众多典型案例分类说明了不同评估方法的适用性与可行性，进而有针对性地介绍了许多减轻洪水风险的途径和适应性措施。全书视野开阔，内容丰富，案例深入浅出，对于了解该领域国际前沿动向和开展洪水风险管理的研究与实践具有很好的参考价值。

全书共分6章。第1章(韩松译)介绍了洪灾给人类带来的巨大危害，而且危害程度越来越高。进入新千年，气候变化对全球的影响重大且广泛。人口增加、城市化等人为因素是造成气候变化的根本原因。而气候变化又改变了洪水的物理特性。作者认为洪灾损失是地球物理系统、人类系统和建造物系统及其多个子系统间相互作用的结果。开展洪水可持续发展的目标是减少洪水发生的概率和可能造成的影响，而制定洪水风险管理计划是最有效率的方法。

第2章(郭重汕译)详细论述气候变化和洪水风险的关系。作者首先分析了洪水的成因与类型，以及流域形态、林地砍伐、农田排水和城市化等对洪水物理特性的影响。随后，从气候变化和气候变异两个方面，基于对全球尺度、地区尺度和流域尺度的监测数据分析，进一步阐释了极端温度、极端降水和季风降雨对洪水发生过程的影响及未来变化趋势。最后，作者介绍了面对气候变化这一全球性挑战的两种途径——减缓与适应。

第3章(王妍炜译)首先详述了适应一词的含义，适应气候变化的内容以及适应性、敏感性、强韧性等名词的概念。作者强调适应气候变化是为降低社会对气候系统变化的脆弱性而对行为或经济结构作出的各种调整。这种调整可以是自发的，也可以是计划的。洪水风险管理是灾害管理的一种，是互动式的决策过程，包括灾害的预防、响应与恢复。而适应性洪水风险管理是将适应性管理与洪水风险管理的方法合二为一，是一种应对洪水复杂性的系统方法。本章详细介绍了洪水管理措施中解决不确定性的概率方法和模糊集方法，及各自的适用范围和优缺点。随后，以加拿大安大略省London市为例，说明如何对气候变化导



致的市政基础设施洪水风险进行自上而下的评价。

第4章(张诚,韩松译,冶运涛、秦涛参与校稿工作)作者介绍了在洪水风险分析中使用概率法的详细做法。首先介绍了概率的数学定义、风险类型、风险标准、概率风险模型建立的步骤。详细说明了洪水风险管理概率工具在实践中的应用,包括蒙特卡洛模拟、进化优化算法、概率多目标规划等,每种工具都引用若干案例说明具体建模步骤及难点的处理办法,并编制了计算程序,发布在相关网站上,便于读者学习和使用。

第5章(朱瑶译)探讨了气候变化条件下模糊集理论在处理洪水风险管理各种不确定性中的应用。相对于概率论方法,模糊集方法更能解决气候变化条件下的不确定性问题。作者详细介绍了模糊风险的定义与模糊风险指标,以及风险管理中使用模糊集的三种工具:模糊模拟、模糊优化和模糊多目标分析。最后通过实际案例对三种工具的建模步骤和难点进行了详细说明,并编制了计算程序,发布在相关网站上。

第6章(朱瑶译)是对全书内容的总结。作者首先总结了气候变化与洪水风险之间的关联关系,气候变化影响范围大而深远,使洪水风险存在更多不确定性。本书提出的交互式洪水风险管理方法为政策制定者对气候变化影响作出判断和制定对策提供了实用指南。使用模糊集方法解决洪水风险管理是本书的创新性观点。

本书的翻译、出版得到了中国水利水电科学研究院程晓陶教授和彭静教授的大力支持。在本书的翻译过程中,程晓陶教授对全书译稿进行了悉心的指导,并对全文进行了审校。张建立教授和万洪涛教授为本书提出了宝贵意见。朱瑶博士对全书进行了统稿。本书出版得到“十二五”科技支撑项目(2012BAC21B02)“太湖流域洪水风险演变及适应技术集成与应用”和国家自然科学基金青年基金(41401045)“水文过程对弯曲型河道横向植被格局累积影响及调控方法”的资助。在此一并表示衷心感谢。

由于译者水平有限,在翻译过程中难免出现纰漏之处,对译文有疑义的地方,读者可对照英文原文理解作者的本意,并欢迎批评指正。

译者

中国水利水电科学研究院

2016年5月

# 序言 | Foreword

## Foreword I

Almost every day, many people are affected by flooding. In 2011, cyclones and heavy monsoon rains triggered unusually severe seasonal flooding across Southeast Asia, affecting many nations including Thailand. The major floods in Bangkok had, by mid-December, killed at least 675 people and caused major economic impacts. In the fall 2011, there were also floods in Colombia, Australia, Kenya, and other places. Hydrologic disasters, dominantly floods but also including wet mass movements (mud slides), are responsible for just more than half of all the disasters in the period 2000—2010. During this period, these events killed, on average, more than 5,000 people per year with the total affected being about 100 million people. The total affected is the sum of injured, homeless, and people requiring immediate assistance during a period of emergency. Annual damage costs are about US \$20 billion.

M. Wahlstrom, the United Nations Assistant Secretary-General for Disaster Risk Reduction, stated, “Over the last two decades (1988—2007), 76% of all disaster events were hydrological, meteorological or climatological in nature; these accounted for 45% of the deaths and 79% of the economic losses caused by natural hazards.” She concluded her statement with: “The real tragedy is that many of these deaths can be avoided.” This book on flood risk management, by Professor Slobodan Simonovic, is about actions that can be taken to anticipate and prevent or mitigate harms that may be avoidable and reduce the number of deaths and lower the socio-economic impacts.

Although the impacts of a flood are usually less than an earthquake, floods occur more often. Meteorological events, such as storms, the next most common, occur less than half as often. Both are part of what we can call the climate system, and this book is addressing flood risk management in the context of climate change. In 2009, world leaders at the United Nations Climate Change Conference agreed to the Copenhagen Accord, which states in the opening paragraph: “We underline that climate change is one of the greatest challenges of our time... . We recognize the critical impacts of climate change and the potential impacts of response measures on countries particularly vulnerable to its adverse

## 序一

洪水几乎每天都在困扰着人们。2011年,台风与季风暴雨引发了罕见的季节性大洪水,影响了泰国在内的多个东南亚国家。截止到2011年12月中旬,曼谷大洪水造成了至少675人死亡并使当地经济受到重创。2011年秋天,哥伦比亚、澳大利亚、肯尼亚等多个国家和地区也遭受了洪水的袭击。2000—2010年期间所有灾害损失中,有过半的损失是由水文地质灾害——主要是洪水和泥石流——造成的。与此同时,洪水和泥石流导致平均每年大约有1亿人受灾、超过5000人死亡。在洪灾期间,还有很多人受伤,无家可归,急需救助。据统计,2000—2010年间,洪灾造成的年均损失高达200亿美元。

联合国秘书长助理、负责降低灾害风险工作的M. Wahlstrom女士在演讲中说道:“过去20年里(1988—2007)的所有灾害事件中,有76%是水文、气象或气候等自然灾害,45%的因灾死亡人口和79%的因灾经济损失是由这几类自然灾害造成的。”她在发言中这样总结:“真正的悲剧在于这些伤亡中许多是可以避免的。”Slobodan Simonovic教授编著的这本关于洪水风险管理的书,介绍了许多实际可行的防灾减灾措施,这些措施可用于避免和减少因灾死亡人数、降低灾害对社会经济造成的影响。

通常情况下,尽管一场洪水没有地震影响大,但洪水发生得更为频繁。气象事件中,风暴发生的频率居次,但其发生的次数不及洪灾的一半。暴风雨、洪水与风暴都是气候系统的组成部分,而本书旨在阐述气候变化背景下的洪水风险管理。2009年,在联合国气候变化大会上,与会各国首脑签署了哥本哈根协议,公开发表声明称:“我们强调,气候变化是我们这个时代最大的挑战之一……我们认识到气候变化所带来的严重影响,以及应对措施对各国的潜在影响,

effects and stress the need to establish a comprehensive adaptation programme including international support. ” Since climate change adaptation is “the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities,” this book deals with how to moderate harm or specifically reduce flooding risk. Chapter 6 specifically addresses future perspectives in a changing climate.

In November 2011, governments approved the Summary for Policy Makers of the Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. The Summary for Policy Makers includes the statement: “A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events.” The Special Report specifically concluded: “It is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe.” The Special Report states that the changes in projected precipitation and temperature changes imply possible changes in floods, but notes that there is low confidence in projections of changes in fluvial floods due to the limited evidence and because the causes of regional changes are complex. This book is addressing those relationships so with further studies based on these principles the evidence should become clearer in the future.

This book provides methods and approaches to reduce the impacts of floods that have for millennia been affecting people around the world and usually most on those most vulnerable. Now through the actions of people collectively, and specifically mostly those in developing countries, the atmospheric greenhouse gas concentrations have increased and are changing the climate. With that climate change there will be more intense precipitation events and warmer temperatures which based on physical logic implies more flooding events. Hence, the impacts on the vulnerable will increase more and raise the need for actions. Among those actions needed is the reduction of risk of flooding and that is the topic addressed in this important and timely book.

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尤其是对那些易于受其负面影响的国家。我们强调要建立一个全面的适应计划,包括国际社会的支持。”适应气候变化就是“自然或人类系统为应对实际的或预期可能的气候变化及其影响所作出的一系列调整,这些调整能够减少人员伤亡或者创造出有利的机会。”正因如此,本书介绍了如何减少人员伤亡,特别是如何降低洪水风险的方法。本书的第6章展望了气候变化下的前景。

2011年11月,各国政府批准通过了“为政府间气候变化专门委员会的政策制定者提交关于《管理极端事件与灾害风险,推进适应气候变化行动专题报告》”。《报告》向决策者声明:“变化中的气候导致极端天气气候事件在频次、强度、空间规模、持续过程和发生时间上的变化,并引发一些前所未有的极端天气气候事件。”专题报告的结论直言:“21世纪全球许多地区强降雨的频数或强降水占总降水量的比例很可能增加。”该报告指出,降雨和气温的预期变化意味着洪水可能发生的变化。但值得注意的是,由于区域变化成因的复杂性以及缺乏足够的证据,有关江河洪水的预测可信度较低。本书是基于这些信念通过进一步的研究来理清那些关系,这样,今后的证据将变得更为清晰。

洪水灾害千百年来一直困扰着世界各地的人们,本书介绍了许多减少洪水影响的方法和途径,特别是针对那些易于遭受洪水灾害的地区和居民。目前,由于大规模的人类活动,尤其是大多在发展中国家的活动,温室气体的浓度不断增加,并改变着地球的气候。随着气候变化,全球变暖,强降雨事件将发生得更为频繁,这从物理机制上就意味着将会有更多的洪水事件发生。因此,洪水对弱势群体的影响将会增大,要求采取行动的呼声也随之提高。本书的重要性就在于及时地向人们介绍在所需采取的行动中如何减轻洪水的风险。

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## Foreword II

Climate change is undoubtedly one of the most pressing issues facing society today and the potential impacts of climate change are currently a prime concern for water resource professionals. The possible impacts of climate change have the potential to dramatically alter the temporal and spatial distribution and availability of water on the Earth's surface with consequences that could be disastrous. Furthermore, climate change could, paradoxically, lead to both more frequent and severe drought conditions and flooding events that are of greater frequency and magnitude. In this book, Professor Slobodan Simonovic addresses the potential impacts of increases in flood event magnitude and frequency through a comprehensive analysis of the interplay between climate change and flooding conditions with a particular focus on the role of the management of flood risk.

Professor Simonovic has had a distinguished career as a water professional, consultant, educator, and researcher. I first met Slobodan more than 25 years ago when we were both faculty members at the University of Manitoba in Winnipeg, Manitoba, Canada. Through collaboration on research and consulting projects I came to appreciate the wealth of knowledge that he brings to his professional activities. Towards the end of our time in Winnipeg, we were both involved in different aspects of the Red River Flood of 1997, the so-called "Flood of the Century", in the Red River valley, a flood-prone area of Canada and the United States. Slobodan's involvement with this major flood event, and its aftermath, is but one of many examples of the practical expertise that he brings to the writing of this important and timely book. We frequently hear reports in the media of devastating flooding events, in various parts of the world, of seemingly unprecedented scope, geographic extent, and magnitude. There often follows natural speculation that the occurrence of such a flooding event, or events, must be further evidence of the impacts of climate change. This book helps to make sense of these events and provides the water professional with important tools to cope with the impacts of increases in the frequency and magnitude of flooding events and the associated societal consequences.

In this book, Professor Simonovic considers not just what the impacts of climate change may be on water, and flooding in particular, but also looks at flood risk management, which can be usefully applied, as he suggests, as an effective form of climate change adaptation. Climate change adaptation through flood risk management is one of several themes that tie the parts of this book together. The book consists of four parts. The first part, entitled "Setting

## 序二

毋庸置疑,气候变化是当今社会面临的最紧迫问题之一,其潜在影响是水资源领域专业人员关注的重点。气候变化还可能影响地表水的时空分布与可利用性,其后果可能是灾难性的。此外,气候变化还可能导致更为频繁、更为严重的水旱灾害。在本书中,西蒙诺维奇教授从洪水风险管理的角度,通过气候变化与洪水孕灾环境之间复杂相互关系的综合分析,论述了气候变化对增加洪水灾害程度和频数的潜在影响。

Simonovic 教授是著名的水问题专家、顾问、教育家和研究者。我第一次见到他是在 25 年前,那时我们都在加拿大马尼托巴省温尼伯的 Manitoba 大学当老师。在合作研究和项目咨询中,我逐渐为他丰富渊博的专业知识所折服。在温尼伯合作的后期,我们二人从不同的角度对 1997 年 Red 河大洪水进行了研究。那场发生在 Red 河河谷的“世纪洪水”,其影响范围涉及美国与加拿大部分地区。他非常关注这场大洪水以及其造成的后果,这是他许多实践经验中的案例之一,并写进了这本正合时宜的书中。我们经常听到媒体有关世界各地发生毁灭性大洪水的报道,影响范围、量级都达到了前所未有的规模。随后,总会有人出来推测,这一洪水事件的发生,正是气候变化影响的新证据。本书有助于理解这些洪水事件发生的原委,并从专业的角度为应对愈发严重的洪水灾害及其带来的社会影响提供了指导。

在本书中,Simonovic 教授不仅分析了气候变化对水、特别是洪水可能产生的影响,还着重介绍了洪水风险管理在应对气候变化中的应用。正如他所建议的,这将是很有有效的应对措施。通过洪水风险管理适应气候变化是本书的若干主题之一,也是贯穿全文的主线。本书共有 4 个部分。第一部分为基本理论,主要介绍洪水风险管理的基本理念以及气候变化与

the Stage”, deals with the central topic of flood risk management and introduces climate change and the interplay between climate change and flood risk management. An important and interesting section in this part is the very detailed case study of climate change impacts on municipal infrastructure within the City of London, Ontario, Canada. This extensive example application very nicely draws together the common intertwining threads of floods, risk, and climate change within a real-world application. The research described in this section of the book is one of the strengths of this publication. The second and third parts of the book deal with flood risk management from the perspective of a probabilistic and a fuzzy set approach, respectively. In both of these parts, flood risk management is introduced from a systems analysis context; systems analysis is another common and unifying theme for much of the material in this book. The final part of the book looks at “Future Perspectives” and again provides an essential link between the potential impacts of climate change and flood risk management with a particular focus on the importance of both of these issues to the public and also the overarching need to effectively communicate climate change impacts and flood risk management issues to the general public. These are again topics with which Professor Simonovic has considerable experience.

This is an important book that will be of interest to water professionals, policy makers, researchers, and others concerned with the potential impacts of climate change on flooding events and on flood risk management.

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洪水风险管理之间的相互影响。书中重要而有趣的一节是关于气候变化影响加拿大安大略省 London 市市政基础设施的详细案例研究。此案例将洪水、风险和气候很好地联系在一起。这一部分研究成果也是本书重点之一。本书的第二部分和第三部分分别基于概率论和模糊集理论探讨了洪水风险管理。这两部分均采用系统分析方法来介绍洪水风险管理的内容；系统分析是本书中处理大量资料的另一个常用方法。本书的最后一部分是“未来的前景”，重申了气候变化的潜在影响与洪水风险管理之间的必然联系，特别是要与公众进行有效的沟通，使他们了解洪水风险管理对应对气候变化的重要性。这些观点都是 Simonovic 教授基于多年工作经验总结提炼出来的。

本书对于从事与水相关的专业人士、政策制定者、研究人员以及其他关心气候变化对洪水影响和洪水风险管理影响的人士来说，都将会有很大的帮助。

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## 前言 | Preface

I have stated many times that I am one of the lucky few who have the opportunity to work all their professional lives in an area that they enjoy. The most enjoyable activity for me is to integrate knowledge from different fields into an approach for solving complex problems that include uncertainty. My work has brought me into contact with many people, responsible professionals, talented engineers, capable managers, and dedicated politicians. In my capacity as an academic I have also had an opportunity to work with young talented people—the future of our workforce. I learned a lot from all of them. I learned many things about the profession, I learned a lot about different cultures, and most importantly I learned about life. Thank you.

My interest in risk and flooding as a natural disaster grew from my main area of expertise—water resources systems management. From the early days of my professional career I was involved with floods and flood management, first from an engineering point of view and then later from a management point of view. Flood problems along the Morava, Sava, and Danube rivers in my country of origin—Serbia—were among the first professional challenges I had to deal with after graduation. In 1997, I was teaching at the University of Manitoba and living in Winnipeg. That was the year of the “Flood of the Century.” The governments of Canada and the USA have agreed that steps must be taken to reduce the impact of future flooding on the Red River. In June 1997, they asked the International Joint Commission (IJC) to analyze the causes and effects of the Red River flood of that year. The IJC appointed the International Red River Basin Task Force to examine a range of alternatives to prevent or reduce future flood damage. I was appointed to the task force and the subsequent experience changed my life.

My work has taken me all over the world. I have had an opportunity to see flood problems in the developed and developing world, in small villages and large urban centers. Projects I have been involved with range in scale from the local to the international. I have discussed flooding issues with farmers of the Siyu area in China as well as the Minister for Irrigation and Water Resources of Egypt. I hope that my professional expertise continues to contribute to the solution of some of these problems. It definitely inspires me to continue to work with greater effort and more dedication.

我经常说我很幸运，能够有机会把职业作为自己的爱好，并乐在其中。最让我感到享受的事情就是整合不同领域的知识，从中找到求解复杂不确定性问题的方法。由于工作原因，我得以有机会接触很多人——认真负责的教授，才华横溢的工程师，精明能干的管理人员以及富有奉献精神的政治家。作为一名学者，我也有机会与许多青年才俊一起工作，他们是未来的动力。从我所遇到的人那里学到了很多东西，学到了专业知识，学到了不同的文化，最重要的是我明白了人生的意义。非常感谢你们。

我对洪水灾害与风险的兴趣衍生于我的主要专业领域——水资源系统管理。我在职业生涯的早期就涉及洪水及洪水管理的问题，最初是从工程的角度，而后转向了管理的视点。大学毕业后，我最早不得不应对的专业挑战中，就有我的祖国塞尔维亚的 Morava 河、Sava 河以及多瑙河沿岸的洪水问题。1997 年，当那场“世纪洪水”发生时，我正居住在温尼伯市，并在 Manitoba 大学任教。洪水过后，加拿大和美国政府一致认为必须采取措施以减轻未来 Red 河水患的影响。1997 年 6 月，两国政府要求国际联合委员会 (IJC) 分析当年 Red 河大洪水的成因及其影响。IJC 指定国际 Red 河流域特别小组开展了一系列的研究，提出预防和减轻未来洪灾损失的应对措施。我应招加入特别小组，这段经历彻底改变了我的生活。

由于工作原因，我有机会到访过世界各地，看到发达国家和发展中国家的各种洪水问题，从小村庄到大都市。我参与过的项目涉及广泛，从区域课题到国际项目。我与中国四湖地区的农民以及埃及水利部长都讨论过洪水问题。我希望我的专业知识继续为解决其中的一些问题作出贡献，这定将激励我以更大的努力和更多的奉献不断工作下去。

For more than 35 years of personal research, consulting, teaching, involvement in policy, implementation of projects, and presentation of experiences through the pages of many professional journals, I have worked hard to raise awareness of the importance of uncertainty-objective and subjective-in the solution of complex problems. The main thrust of my work is the use of a systems approach in dealing with complexity. I have accumulated tremendous experience over the years. In that time I realized that there is an opportunity to contribute to the area of flood risk management by transferring some of the knowledge and experience from the implementation of systems thinking and systems tools to various steps of the flood risk management cycle. Writing this book offered me a moment of reflection, and it elaborates on lessons learned from the past to develop ideas for the future.

35年来,我一直从事研究、咨询和教学工作,也参与了政策制定及工程实施,并在许多专业期刊上发表过学术论文。我一直努力工作,致力于在解决复杂问题的过程中提高对不确定性问题的认识(包括主观不确定性和客观不确定性)。我工作的重点是运用系统论方法解决复杂性的问题,多年来已积累了许多经验。于是,我希望能有一个机会为洪水风险管理领域做贡献,将相关的知识和经验——从系统思维和系统工具的实现,到洪水风险管理全过程的各个环节——介绍给世人。本书的写作,也给了我一个反思的契机,从以往教训的剖析中获得未来发展的理念——前事不忘,后事之师。



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The support of my family, Dijana, Damjan, and Tanja, was of the utmost importance in the development of this book. They provide a very large part of my motivation, my goals, my energy, and my spirit. Without the endless encouragement, criticism, advice, and support of my wife Tanja this book would never have been completed.

在多方人士的共同努力下,本书得以出版发行。在此,我首先要感谢联合国教科文组织国际水文计划署和水科学部,特别感谢 Siegfried Demuth 和 Biljana Radojevic 对本书出版给予的大力支持。本书中的大部分内容来源于世界各地,由我的老师、学生还有同事们提供的,是他们让我懂得了更多的知识。我要特别感谢参与本书编写的学生们,按照编写章节的顺序,他们是:参与第3章编写工作的 Hyung-III Eum, Dragan Sredojevic, Lisa Bowering-Taylor, Angela Peck; 参与编写第4章和第5章工作的 Dejan Vucetic; 参与第5章编写工作的 Ozren Despic, Ibrahim El-Baroudi, Taslima Akter 和 Mike Bender。此外,还要特别感谢开发计算程序的 Veerakcudy Rajasekaram。

感谢家人给予我的支持, Dijana, Damjan 和 Tanja 对于我能够完成本书是至关重要的。正是他们给予我动力和能力,鼓舞了我的精神,使得我能够实现我的目标。如果没有我的妻子 Tanja 给我莫大的鼓励和支持、一直以来的批评和建议,我是无法完成本书的编写工作的。



## 术语 | Definitions

**Uncertainty**: lack of certainty; a state of having limited knowledge where it is impossible to exactly describe the existing state or future outcome; more than one possible outcome. Sometimes the implications of uncertainty involve risk—a significant potential unwelcome effect of system performance. For example, if you do not know whether it will rain tomorrow, then you have a state of uncertainty. If you apply probabilities to the possible outcomes using weather forecasts, you have quantified the uncertainty. Suppose you quantify your uncertainty as a 90% chance of sunshine. If you are planning a major, costly, outdoor event for tomorrow then you have risk, since there is a 10% chance of rain and rain would be undesirable. Furthermore, if this is a business event and you would lose \$100,000 if it rains, then you have quantified the risk (a 10% chance of losing \$100,000).

Vagueness or ambiguity is sometimes described as “secondorder uncertainty,” where there is uncertainty even about the definitions of uncertain states or outcomes. The difference here is that this uncertainty is about human definitions and concepts, not an objective fact of nature. It has been argued that ambiguity, however, is always avoidable while uncertainty (of the “first order”) is not necessarily avoidable.

Uncertainty may be purely a consequence of a lack of knowledge of obtainable facts. That is, you may be uncertain about whether a new dyke design will work, but this uncertainty can be removed with further analysis and experimentation.

There are other taxonomies of uncertainties and decisions that include a broader sense of uncertainty and how it should be approached from an ethics perspective (Tannert *et al.*, 2007). Figure 1 shows the taxonomy of uncertainties and decisions according to Tannert *et al.*

The first form of uncertainty in this scheme is objective uncertainty, which can be further divided into epistemological uncertainty and ontological uncertainty. The former is caused by gaps in knowledge that can be closed by research. In this case, research becomes a moral duty that is required to avoid dangers or risks, to realize possible

**不确定性**: 确定性不足; 利用有限的知识, 不可能准确描述当前状态或未来结果; 可能的结果多于一个。有时不确定性的含义包含风险, 即对系统运行存在重大潜在负面影响。例如, 你不知道明天是否下雨, 那么你就处于一个不确定的状态。如果你利用天气预报对可能的后果进行概率分析, 那么你就对不确定性作了量化。比如, 猜测晴天的概率为 90%, 就是量化了你的不确定性。如果你正策划明天一次重要的、预算昂贵的户外活动, 那么你就有了风险, 即遭遇下雨的可能性为 10%。如果这是一次商业交易, 下雨就意味着你将损失 10 万美元, 那么你就已对风险进行了量化, 即损失 10 万美元的概率为 10%。

模棱两可或含糊不清, 有时被表述为“二阶不确定性”, 这种情况下, 不确定性的存在甚至关系到不确定状态或后果的定义。所不同的是, 此处的不确定性是指人们关于定义或概念的不确定性, 而不是客观事物本身的不确定性。然而, 一直在争论的是, 模棱两可(二阶不确定性)总是可以回避的, 而一阶不确定性却不一定可避免。

不确定性可能就是客观事物认识不足造成的。也就是说, 你可能不确定新设计的堤防工程能否发挥正常功效, 但是这种不确定性可以通过进一步的分析和实验来消除。

不确定性和决策也有其他的分类方法, 包括一个更广义的不确定性以及如何从道德伦理的角度来释义不确定性(Tannert 等, 2007)。根据 Tannert 等人的论述, 图 1 给出了不确定性和决策的分类方法。

在这个体系图中, 不确定性的第一种形式为客观不确定性, 客观不确定性进一步被分为认识论的不确定性和存在论的不确定性。前者是由知识上的差距造成的, 可以通过研究来弥补。在这种情况下, 研究成为一种道德义务, 帮助人们避免危险或规避风险,