The Perils of Climate Risk

The Perils of Climate Risk:

The People and the Science

Edited by

Carole LeBlanc

Cambridge Scholars Publishing

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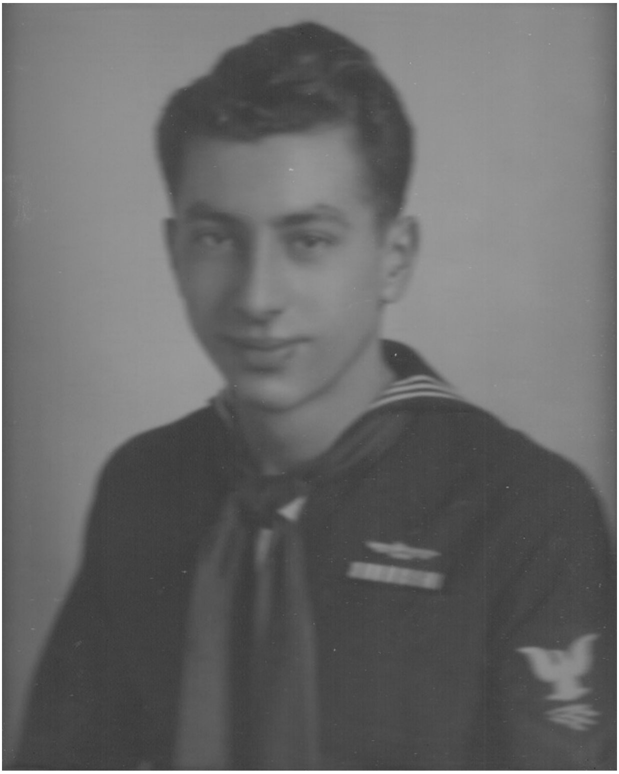
In Memoriam



I am told that my father, Clarence Andrew Fraughton, was not quite 18 years old when he enlisted in the United States (U.S.) Navy following the Japanese invasion of Pearl Harbor that ushered the U.S. into World War II. He served as a submariner, quipping years later that,

> "The line to get into the Air Force was just too long."

Such are the young decisions that shape the rest of our lives. He was a 'radar man' back in the day when the exposure effects of things like radiation were hardly known. And so it was that when he returned home (submarine service was then the most dangerous duty in the military, with casualty rates around 20 percent), he was anxious to start a family.

That is the beginning of my story, as I am the oldest of three daughters. While I am sure he wanted a son, I benefited from his advice long before the current women's movement: that in our country, I could accomplish anything, be anyone, if only I was willing to work hard. In chapter three, *Putting Women in Power* of **Demystifying Climate Risk Volume I: Environmental, Health, and Societal Impacts** (LeBlanc, C. ed., Cambridge Scholars Publishing, 2017), Maggie Roth wrote:

> "…women are under-represented at all levels of the STEM[1] career pipeline, from interest and intent of majoring in a STEM field in college to having a career in a STEM field, such as clean energy…"

I would be less than truthful if I said that being the first or only woman in certain professional settings wasn't daunting, or even frightening, at times. But his counsel never left me. Amazing, the power of a father's influence on a little girl.

Thanks, Dad.

[1] STEM, or Science, Technology, Engineering, and Mathematics is the term that groups these academic disciplines together. The term is particularly useful in addressing related educational policies and curriculum choices to improve competitiveness, having implications for workforce development and other issues of national and international importance. The acronym arose after an interagency meeting at the U.S. National Science Foundation (NSF) chaired by NSF Director Rita Colwell. One of the first NSF projects to use the acronym was STEMTEC, the Science, Technology, Engineering and Math Teacher Education Collaborative at the University of Massachusetts Amherst in 1998.

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PREFACE

This book constitutes the findings of the second in a series of three workshops on climate risk. The workshops were held in Maine, a New England state in the northeast section of the United States (U.S.) known for its environmental beauty bordering Canada.

As a recently retired chemist and policy advisor to U.S. and state governments, the original intent of the first workshop was to ensure that the knowledge and wisdom gained by my contemporaries was shared with the next generation of students and professionals. Some of that work concerned implementing the Montreal Protocol, the international treaty that successfully restored earth's ozone layer over a quarter of a century, and still protects our planet's atmosphere to this very day. It seemed reasonable that the 'lessons learned' from that experience would be helpful to today's younger scientists and public policy wonks, now focused on another atmospheric threat: climate change.

Only weeks after the first workshop, the 2016 U.S. presidential election was held. Now it would no longer be just a matter of sharing technical expertise. Now the focus would necessarily shift from mentoring, to protecting scientific integrity, and sometimes even to protecting scientists themselves:

Silencing Science: An Insider's Take on the Trump Administration's Efforts to Undermine Federal Climate Policy was a March 15, 2018 event hosted by Maine Audubon. It featured Maine native, Joel Clement[1], former director of the U.S. Interior Department's Office of Policy Analysis. Clement's July 19, 2017 Washington Post opinion editorial reads, in part:

> "I am not a member of the deep state. I am not big government. I am a scientist, a policy expert, a civil servant and a worried citizen. Reluctantly, as of today, I am also a whistleblower on an administration that chooses silence over science…On June 15, I was one of about 50 senior department employees who received letters informing us of involuntary reassignments... I believe I was retaliated against for speaking out publicly about the dangers that climate change poses to Alaska Native communities. During the months preceding my reassignment, I raised the issue with White House officials,

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[1] Joel Clement is currently a senior fellow with the Center for Science and Democracy at the Union of Concerned Scientists (see Table 12.2).

> senior Interior officials and the international community, most recently at a UN <United Nations> conference in June. It is clear to me that the administration was so uncomfortable with this work, and my disclosures, that I was reassigned with the intent to coerce me into leaving the federal government…Let's be honest: The Trump administration didn't think my years of science and policy experience were better suited to accounts receivable…Trump and Zinke[2] might kick me out of my office, but they can't keep me from speaking out."

Truthfully, these are trying times. Speaking of truth:

> "I am the way and the truth and the life."
>
> King James Version, chapter 14, verse 6

Of all the nouns, in all the languages that Jesus could have chosen to describe himself, he chose these three. And 'truth' is right in the middle of them. Most historians agree that Jesus probably spoke Aramaic, the common language of Judea in the first century. While there may be different ancient words with different shades of meaning for the English word, 'truth', this humbles me and gives me pause. Might it also serve to strengthen all scientists in our current pursuit of 'truth'?

Shortly before his death on August 25, 2018, a U.S. senator penned these farewell words to the American people:

> "Do not despair of our present difficulties but believe always in the promise and greatness of America, because *nothing is inevitable here* <emphasis added>. Americans never quit. We never surrender. We never hide from history. We make history."[3]
>
> John McCain

A prisoner of war in North Vietnam for 5½ years, McCain lived there longer than at any other address in the U.S. up to that time in his life. *Tortured to the point where he would never again be able to lift his arms up*

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[2] A Trump nominee in late 2016, Interior Secretary Ryan Zinke moved to open coastal waters and public lands for oil and gas leasing, and recommended shrinking up to four national monuments. He resigned December 15, 2018 amid allegations of unrelated misconduct.

[3] For Senator McCain's entire statement, see: https://www.cnn.com/2018/08/27/politics/john-mccain-farewell-statement/index.html.

over his head, he would still insist in his final public statement that he considered himself to be the luckiest person on earth.

Certainly, whatever problems we face today we can conquer, provided we face them together.

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The editor thanks all participants to the 2nd Annual International Technical Workshop on Climate Risk, whether remote or in person. A special thanks to Sam Higuchi of the United States (U.S.) National Aeronautics and Space Administration (NASA) for his leadership in the workshop's content. Recognition is owed to Sam's co-workers from Leidos, in particular, Erik Tucker and Kim Gotwals, for their assistance in running the workshop.

The editor also thanks Cambridge Scholars Publishing for their support. Following the workshop in October 2017, a number of climate change developments occurred in 2018. These included some very important scientific reports with political and policy ramifications that necessitated postponing the publishing deadline to cover the issues sufficiently. Almost immediately thereafter, the U.S. government was partially shut-down, requiring another delay. I am most grateful for the publisher's patience.

Neighbors Megan Walsh and Ed Rogowski, both of whom are teachers, provided personal and moral support, as did my friend and cousin, Robert Stelin. Contributing author Phil Barnes shared ideas about the book's title. Colleagues and students at the University of New England in Biddeford, Maine, U.S. were likewise instrumental in making this book possible. Without them, it would have been unfeasible to focus on the possibility of a promising future, in light of the current dire climate data reported herein.

INTRODUCTION

Demystifying Climate Risk: Volumes I and II (LeBlanc, C. ed., Cambridge Scholars Publishing, 2017), published following the 2016 Annual International Technical Workshop on Climate Risk, focused on environmental, health, and societal implications; and industry and infrastructure implications, respectively. Both books conclude with the statement:

> "It is our <the workshop participants'> intention to continue the theme of systems thinking as an essential approach to addressing the multitude of challenges posed by climate change."

In, *Tools for Systems Thinkers: The 6 Fundamental Concepts of Systems Thinking* (2017)[1], Dr. Leyla Acaroglu[2] identifies the following essential elements to systems thinking:

1. Interconnectedness;
2. Synthesis;
3. Emergence;
4. Feedback loops;
5. Causality; and
6. Systems mapping.

The publication of this book, **The Perils of Climate Risk: The People and the Science**, follows the 2017 Annual International Technical Workshop on Climate Risk and a plethora of climate change developments in 2018. These developments included some very important scientific reports with political and policy ramifications that are examined here.

Based on participants' expertise, the book begins by covering related scientific topics, such as the assessment of climate change science itself, and tracking global changes in greenhouse gas (GHG) concentrations. Technical tools are described, including: (1) engineering designs to control water after

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[1] https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a.

[2] Dr. Acaroglu was named the 2016 Champion of the Earth by the United Nations Environment Programme (UNEP).

intense rainfall; (2) a pollution prevention (P2) options analysis system; and (3) the manufacture of pharmaceuticals involving catalysis to reduce the use of toxins.

The next section focuses on the human side of climate change. For example, climate change impacts on public health, and the role of indigenous peoples in dealing with climate change impacts. Other chapters discuss the influence of maritime ports on climate change, and the economics of climate action.

Significantly, and in keeping with the 'systems approach', one author contributes to both the scientific (e.g., theoretical) and societal (e.g., applied) sections regarding climate risk management. The book's twelve contributors hail from government, business, and academia, including a Nobel Peace Prize recipient and Fulbright Scholars. In all chapters, the editor strove to maintain the authentic voice of each of the contributing authors. Acronyms are defined within each of the chapters, so that the reader does not have to consult a glossary or preceding parts of the book.

From December 22, 2018 to January 25, 2019, the United States (U.S.) government was partially shut down, the longest in history. Some of the book's contributing authors were either affected government employees (who should be paid their back salaries upon reinstatement) or government-contracted employees (who will most likely not be paid their missing salaries). Realizing that these colleagues may not even to able to read their emails, I still sent them a message which read in part:

> "In anticipation for the government's return to work, allow me to thank former co-workers for how much I value your efforts in helping to keep our environment safer, on behalf of humans and other creatures! Now, as a private citizen, it is even more clear to me how important your work is. Again, thank you so much. I hope that you were able to enjoy the Holiday Season as much as possible."

After the elections for the U.S. House of Representatives on November 6, 2018, the select committee on climate change, eliminated in 2010, was expected to be revived. The purpose of the committee would be to:

> "Prepare the way with evidence <for energy conservation and other climate change mitigation legislation>. It <the committee> was clearly still needed to educate the public about the impact of more frequent extreme weather events."
>
> Speaker of the House, Nancy Pelosi

Depending on your point of view, this is either an exciting or a terrifying time to be a climate scientist. If you are fortunate enough to have a healthy sense of humor, perchance it is both.

From my perspective, there are three classes, critical to human health and happiness, that will always require our political attention:

- Children, including education;
- Animals, both wild and domestic; and
- The natural environment.

As different as these categories appear to be, they have one thing in common: they cannot vote! Consequently, they require our constant vigilance, similar to the battle for civil rights.

The natural environment is obviously the focal point of this book. After years of environmental abuse and neglect, much legislative progress was made circa 1970; the U.S. Clean Air Act, the U.S. Clean Water Act: you name it; we protected it. Laws like these have made considerable and long-lasting improvements to both public health and the environment. The mistake that my generation made is that we thought we had won the battle. But legislation like the U.S. Toxic Substances Control Act (TSCA), while visionary at its origin, remains woefully outdated today.

Everything we needed to know, the extent and the consequences of unfettered climate change, was determined by the 1970s:

> "In 1974, the <U.S.> C.I.A. <Central Intelligence Agency> issued a classified report on the carbon-dioxide problem. It concluded that climate change had begun around 1960 and had 'already caused major economic problems throughout the world.' The future economic and political impacts would be 'almost beyond comprehension.' Yet emissions continued to rise, and at this rate, MacDonald[3] warned, they could see a snowless New England, the swamping of major coastal cities, as much as a 40 percent decline in national wheat production, the forced migration of about one-quarter of the world's population. Not within centuries within their own lifetimes."
>
> Nathaniel Rich[4]

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[3] Gordon MacDonald, an American geophysicist (1929-2002).

[4] From, *Losing Earth: The Decade We Almost Stopped Climate Change*, which appeared as the only story in the August 2018 edition of the New York Times Magazine. https://www.nytimes.com/interactive/2018/08/01/magazine/climate-change-losing-earth.html. The reporting was supported by the Pulitzer Center: http://pulitzercenter.org/.

Still, new books on climate change abound, do they not? So why add another one to the list? Perhaps the author of chapter eight, *Traditional Knowledge and Climate Change Challenges: Anambra State, Nigeria Case Study*, says it best:

> "But despite over 40 years and about 900 environmental treaties in force, human-induced environmental change is pushing the earth system towards a critical tipping point which may be irreversible, unless urgent steps are taken to avert the disaster."
>
> Chizoba Chinweze

The solution remains the same as it was in the 1970s: sound, science-based public policy. The difference today, I fear, is that policies, even when legislated, are not enforced. The possible reasons for this are considered in the book's final chapter dealing with ethical and governance issues. Neither of these issues was addressed in the first two volumes leading up to this book.

Finally, it is hoped that the book's conclusion will bring the role of environmental stewardship into further clarity for the reader.

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Chapter Summaries

The science

Chapter One: *Assessing the Science of Climate Change*, by Dr. Don Wuebbles, provides an update to the understanding of climate change based on the latest authoritative assessment: Volume I of the 4th National Climate Assessment, also known as the Climate Science Special Report (CSSR). Focused on the U.S., the report reveals the climate knowledge gained since the publication of the third assessment in 2014. These findings, along with other research, include: (1) 2016 was the warmest year on record to date, with global temperatures expected to continue to rise; (2) heavy precipitation is increasing in intensity and frequency across the U.S.; (3) heat waves have become more frequent while cold waves have become less frequent in the country; (4) record-setting warm years are expected to continue in the U.S.; (5) earlier spring snowmelt and reduced snowpack are affecting water resources in the western states, increasing the possibility of serious drought before this century's end; (6) the increase in the number of large forest fires in the western states and Alaska since 1980 is expected to continue; (7) higher atmospheric water vapor concentrations, resulting from rising temperatures, will likely impact flooding events, particularly along the West Coast; (8) a hurricane's precipitation rate, intensity and/or frequency, depending on the storm's location in the Atlantic or Pacific Ocean, will increase; and (9) sea level rise (as much as 8 feet by the year 2100) will continue throughout the world – as the incidence of daily tidal flooding is accelerating in more than 25 Atlantic and Gulf Coast cities – and with higher-than-global-averages possible along the East and Gulf Coasts. It is extremely likely that human activity is the dominant cause of the observed warming for the period of 1951-2010, the contributions of natural forcing and internal variability being minor for the same time frame. The atmospheric carbon dioxide (CO_2) concentration is now over 400 parts per million (ppm), a level not seen for three million years, when the Earth was much warmer and sea levels higher. If carbon emissions continue to rise, human-caused changes to climate will result in even more, and perhaps irreversible, damage to, for example, human health, water, energy, transportation, agriculture, forests, and ecosystems. Dr. Wuebbles ends on a positive note, stating that we are more than capable as a species to reduce emissions by mitigation and to adapt to the changes already taking place.

Chapter Two: *Tracking Global Changes in Greenhouse Gas Concentrations*, by Dr. Steve Montzka, provides a thorough explanation of how and why the U.S. National Oceanic and Atmospheric Administration (NOAA) tracks greenhouse gas (GHG) concentrations. The paper communicates NOAA's findings in tracking changes in global atmospheric concentrations of long-lived GHGs (LLGHGs) and the underlying implications of these measured changes. While the main contributors to Earth's greenhouse effects are: (1) water vapor (50%); (2) clouds (25%); (3) carbon dioxide, CO_2 (20%); and (4) methane, nitrous oxide, halocarbons, ozone, etc. (5%), many human activities lead to the emission of LLGHGs (for example, the burning of fossil fuels emits CO_2). As a result, atmospheric concentrations of these gases are elevated substantially above natural levels. Consequently, NOAA overseas a global air sampling network. Based in Boulder, Colorado, U.S., NOAA's Global Monitoring Division (GMD) maintains a vast cooperative air sampling network of nearly 90 sites around the world, from the northern tip of Alaska to the Gobi Desert in Mongolia and even to the snowy desolate landscape of the Antarctic South Pole. Depending on the site, measurements are taken of the most abundant GHGs (CO_2, CH_4, and N_2O) and long-lived halocarbons[5] that are also potent GHGs. GMD's goal is to map LLGHG concentrations throughout the lower atmosphere of the entire world. Once a week, sampling flasks are filled and sent to the Boulder facility where they are analyzed on several instruments for the measurement of over 40 long-lived chemicals. The focus is on long-lived gases, i.e., gases having lifetimes of approximately one year or longer, as they are the largest contributors to climate warming today whose impacts will be felt for decades, even centuries, after being emitted. The ability of a trace gas (that is, atmospheric gases other than nitrogen, oxygen, and argon) to influence climate depends on its: (1) efficiency for absorbing available heat energy; (2) concentration; and (3) persistence. The effect of a trace gas on the energy balance of Earth's climate system can be expressed as a *radiative forcing* (warming influence), and serves as an index of the significance of the factor as a potential climate change mechanism. Analysis of measured global atmospheric concentrations reveals that CO_2 accounts for (1) two-thirds of the current atmospheric radiative forcing from all LLGHGs and (2) more than 80% of the increase in radiative forcing over the past 5 years from all LLGHGs. Furthermore, *the overall increase in radiative forcing from 2015 to 2016 was the second largest annual increase on record.* NOAA's Annual Greenhouse Gas Index (AGGI) is a measure of the climate-warming influence of long-lived trace gases and how that influence has changed since the Industrial Revolution. Its value in a given year reflects the warming influence (or radiative forcing) in that year relative to 1990, based on

[5] Halocarbons are chemicals in which one or more carbon atoms are linked with one or more halogen atoms: fluorine, chlorine, bromine or iodine.

atmospheric changes since 1750. *The value for the AGGI in 2017 of 1.41 means that the warming influence from human-derived emissions of LLGHGs has increased by 41% since 1990.* Radiative forcing provides an estimate of the warming influence supplied by a LLGHG at a point in time as a result of emissions in the past. It does not indicate how the warming influence from these gases will change in the future. The future of climate warming will reflect both the persistence of GHGs in the atmosphere today (their lifetimes) as well as the magnitude and persistence of current GHG emissions. As a result of the magnitude and changes noted in the recent past for LLGHGs emissions, total radiative forcing from these gases has steadily increased over time. Stabilizing climate will only be achieved by decreasing emissions of these gases to the point where radiative forcing stops increasing or even decreases. Given the dominant role of CO_2 in total radiative forcing and its recent increase, and in total GHG emission, any attempt to stabilize climate will need to focus on CO_2 emissions. Specifically, *CO_2 emissions need to decrease by 80% to stop the increase in its concentration and its associated radiative forcing.* But climate responds to overall radiative forcing, not just the forcing associated with one or two gases. These results indicate that anthropogenic (i.e., human-caused) warming by LLGHGs still continues to increase for several years after various emission reduction scenarios are phased in gradually. Since the 1990s and the passage of the Kyoto Protocol[6]: *(1) LLGHG emissions have instead increased by 24%; and (2) CO_2 emissions have increased by about 60%.* NOAA GMD's global atmospheric observations of LLGHGs are therefore invaluable to: (1) provide a measure of GHG emissions which enables identification of mitigation opportunities on global as well as local scales; and (2) enable an assessment of efforts to stabilize climate warming on global scales.

Chapter Three: *A "4th Wave" Perspective on Climate Risk Management*, by Sam Higuchi, documents the historical nature of the environmental movement by trends or "waves". The first three waves were characterized by conservation, regulation, and sustainable development, respectively. According to Richard MacLean, Director of Richard MacLean & Associates, LLC[7], the movement has now entered a fourth wave focusing on resources or, more precisely, "strategic resources positioning". Nationally, there is strong evidence for this with Executive Order (EO)

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[6] An international treaty which extended the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that committed state parties to reduce LLGHG emissions. The U.S. is a signatory to the treaty.

[7] https://rmacleanllc.com/.

13806, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States* and EO 13817, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, both signed in 2017. Internationally, the evidence is provided by the European Union (EU) publications: *Critical Raw Materials and the Circular Economy* and *Raw Materials Information System (RMIS).* The emphasis on resources can easily be translated to materials usage. This includes: (1) decarbonization – using less carbon-based fuels for energy in manufacturing products (mitigates climate change by reducing GHG emissions); (2) dematerialization – reducing the use of scarce materials/minerals in manufacturing products (conserves limited resources and decreases GHG emissions by eliminating the energy required to extract critical materials/minerals); and (3) detoxification – eliminating toxic material-chemicals in manufacturing products (reduces the release of toxic by-products, ozone depleting substances (ODSs), GHGs, etc., and resultant environmental contamination)[8]. Collectively, decarbonization, dematerialization and detoxification are elements of sustainable materials management (SMM). The scarcity of critical materials/minerals has been characterized as a "ticking time bomb" in the SMM paradigm. PricewaterhouseCoopers (PwC) defines scarcity-based manufacturing disruptions in three dimensions: (1) physical – due to natural disasters (hurricanes, et al.); (2) economic – due to price volatility, for example; and (3) geopolitical – due to export controls, conflict zones, etc. Moreover, materials are interconnected to water and energy, such that a direct impact on one will eventually impact the others, leading to potential supply chain disruptions. Consequently, businesses as well as nations must manage risks relative to SMM to maintain a competitive advantage. The author describes a number of climate risk frameworks originating from the concept of enterprise risk management (ERM). Three ERM components are important to manage climate-related risks: (1) event identification (e.g., extreme weather); (2) risk assessment; and (3) risk response. Linking these frameworks together creates a useful network to incorporate climate risk management into a financial-accounting approach. Two Australian publications are recommended*: Climate Change Adaptation in Industry and Business: A framework for best practice in financial risk assessment, governance and disclosure* and *Managing the Risks from Climate Change: An adaptation checklist for business*. Existing U.S. federal statutes can be

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[8] For more information on the topic of Toxics Use Reduction (TUR), see chapter five, *Pollution Prevention Options Analysis System* by J. Marshall and chapter five, *Cleaning Solvents: How to Choose A Safer One* by J. Marshall in **Demystifying Climate Risk Volume II: Industrial and Infrastructure Implications** (LeBlanc, C. ed., Cambridge Scholars Publishing, 2017).

used to implement a similar financial-accounting framework, that is, statutes requiring a federal agency to: (1) safeguard its assets; (2) manage high-risk management challenges; (3) apply climate science research findings pursuant to its statutory duties under the federal agency's Authorization Act; and (4) apply climate science research findings pursuant to its statutory duties under a federal agency's duty to comply with federal laws. Linking these four statutory groups together likewise creates a networked financial-accounting framework for climate-related risk management. In summary, Mr. Higuchi presents several viable frameworks, including those with a solid financial basis, to help protect assets and supply chains from the risks associated with climate change for both business and government.

Chapter Four: *Adjusting Precipitation Intensity-Duration-Frequency (IDF) Curves in Engineering Design*, by Mark Klingenstein, examines why the adoption of climate-adjusted IDF curves may be appropriate for public agencies. In a previous paper, the author provided the following description of IDF curves:

> "An individual IDF curve presents rainfall intensity/duration combinations having a single specified return frequency. A series of <IDF> curves is therefore used to provide intensity/duration data for a range of specified return frequencies at a given location".[9]

Climate-adjusted IDF curves take into account the changes between IDF curves of the current climate and those of a projected future climate. In this paper, the author investigates the degree to which climate-adjusted IDF curves have been incorporated in the U.S. at the federal, state and municipal levels. He reports that:

- The Department of Transportation (DOT)'s Federal Highway Administration (FHWA) – recognizes the potential impact of climate change on transportation systems, including on the drainage systems serving those systems, and facilitates such climate-impact activities by considering them eligible for federal funding. While the FHWA does not mandate the use of climate change adjusted IDF data, FHWA indirectly encourages investigation of its applicability by

[9] *Climate Change Adjustment Of Intensity-Duration-Frequency Curves by M. Klingenstein*, **Demystifying Climate Risk Volume II: Industry and Infrastructure Implications** (LeBlanc, C. ed., Cambridge Scholars Publishing, 2017).

individual agencies with the development of the *U.S. DOT CMIP Climate Data Processing Tool*.

- State DOTs – a number of these agencies are investing energy and resources into the issue of climate change, and its impact on transportation infrastructure. However, none have determined that the use of climate adjusted IDF information is appropriate. Upon examination of states' DOT websites, California, Illinois, North Carolina, and Vermont address climate change in their hydraulic design manuals. Mr. Klingenstein provides a detailed explanation of each of these states' approaches.
- U.S. municipalities – while a significant number of large U.S. cities have ongoing/developing climate change action plans, only one city, New York City (NYC), was found to have developed or be developing climate change-adjusted IDF curves for the design of storm drainage systems. After much debate, the Mayor's Office of Recovery and Resiliency released a document in April 2017, the *Preliminary Climate Resiliency Design Guidelines, Version 1.0*, that provides design criteria adjustments to address increasing high temperatures, increased intense precipitation, and sea level rise. For increasing intense precipitation, the guidelines provide adjusted IDF curves for 5-year, 50-year and 100-year events, based upon the New York City Panel on Climate Change (NPCC) impact prediction modeling analyses. As climate science progresses, the guideline is expected to be further refined.

The study concludes that U.S. adoption of climate-adjusted IDF curves is limited, but that Canadian counterparts have apparently made more progress, perhaps because of the creation of an infrastructure vulnerability committee in that country. Welland, Ontario, Canada is a case in point: in order to ensure that new infrastructure would perform as designed for its entire service life, the city undertook an assessment utilizing data from the World Climate Research Programme. Published in 2012, it is unclear how much of the assessment's recommendations have been implemented at this time.

Chapter Five: *Pollution Prevention Options Analysis System*, by Dr. Jason Marshall, details the recent progress made in the field of alternatives assessment: "<the> process for comparing alternatives, usually to a chemical of concern, and identifying those that are safer".[10] In the mid-

[10] https://www.turi.org/Our_Work/Research/Alternatives_Assessment/Alternatives_Assessment_Guidance.