Risks to Water Resources

Prepared by the IAA’s Resource and Environment Working Group

WEBINAR
14 December 2020
Resource and Environment Working Group (REWG)

• **Purpose:** To serve as a working group within the IAA devoted to resource and environment issues that have relevance to and/or affect the work of actuaries in their various areas of practice, are relevant to the subject of actuarial science, or to which the actuarial profession may be able to contribute

• **Past papers:**
  – Climate Change, Insurance and Vulnerable Populations (2020)
  – Flood risks (2019)
  – Decarbonization (2018)
  – Climate change and mortality (2017)

• **Works in progress:**
  – Disclosure for pension plans
  – Climate Change Risks – a chapter for the IAA Risk Book
Based on the REWG paper entitled “Risks to water Resources”

The main purpose of the paper is to start a conversation on water resource risk, first among actuaries and then within the broader scientific and public policy communities.

Actuaries need to be informed about broader societal issues such as this one, as water resource risks affect a wide range of perils commonly insured. And, once informed, actuaries will be in a better position to make a positive contribution to policy development.

Can be accessed on IAA Website (www.actuaries.org)

Select: Publications → Papers
Today’s presenters

**Moderator:** Micheline Dionne (Canada)

**Speaker:** Dale Hall (USA)

**Speaker:** Stephen Lowe (USA)

**Speaker:** Rade Musulin (Australia)

Risks to Water Resources | 14 December 2020
Introduction

Why is water resource risk an important topic?
Purpose of the paper
Resource and environmental risks

Plastic pollution  Wheat rust  Antibiotic resistant bugs

Deforestation  Smoke pollution from bushfires

Clockwise from top: Blue Ocean, Western Australia government, NC State University, Sri Lankan Foundation, the Conversation
Why water resources?

- Water is critical to survival
- Systems, both natural and man-made, are under significant stress
- Water shortages can lead to significant disruptions in economies, societies, and political systems
- The World Health Organization has published a hierarchy of water needs and estimated the amounts that would be required in an emergency

Source: How Much Water is Needed in Emergencies? World Health Organization
Purpose of this paper

- Risks need to be better understood, so that they can be more effectively prioritized and managed:
  - Prevention efforts pre-event
  - Mitigation efforts post-event
- The main goal is to start a conversation, among actuaries first, then among the broader scientific and policy communities
- It is an opportunity to apply risk management capabilities of actuaries to a new problem
- It serves as a reminder that there is more to resource and environment issues than global warming and climate change, though water risk is an excellent example of the interaction of climate and other risks
Risk Management

Risk identification – a register for water resource risk
Risk assessment – classifying the risk impacts
The water goes elsewhere; the supply becomes insufficient
  – The pattern of rainfall and snowfall could change, for example due to global warming
  – A supply problem in an adjacent region could put pressure on demand

Water is there, but the delivery system is significantly disrupted
  – Dams break, emptying the reservoir, for example due to an earthquake
  – Aqueducts collapse, disrupting delivery

Water is there, but it is not potable
  – High levels of industrial pollution, such as lead, could be found
  – Flooding can cause fresh water and sewage to be mixed
### Example of a generalized risk register

<table>
<thead>
<tr>
<th>Principal Risk Type</th>
<th>Risk Event</th>
<th>Direct Impact</th>
<th>Following Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural and Human causes</td>
<td>Reservoirs are depleted due to hydrological changes caused by climate change, which causes rain and snow to decline in region, and evaporation to rise, leading to drought conditions.</td>
<td>Region becomes uninhabitable without potable water supply; alternative freshwater solutions (desalination plants, etc.) take too long, cost too much</td>
<td>Property in region becomes worthless; people are forced to migrate elsewhere, without the financial means to do so; regional economy is disrupted while being relieved; morbidity and mortality rates; social and political unrest as migrants struggle with relocation</td>
</tr>
<tr>
<td>Human causes</td>
<td>Failure of a neighboring region’s water system necessitates sharing of water supply; new aqueducts are constructed to share one region’s water with another region.</td>
<td>Region suffers water shortages, and strict rationing becomes necessary. It takes years to fully address the shortage</td>
<td>Population, business and tourism all decline as region becomes “not the place to live, work and visit”; political unrest pits region against its neighbors</td>
</tr>
<tr>
<td>Natural causes</td>
<td>A significant earthquake or other major ground motion event causes aqueducts and pipes to break, causing shutdown of delivery system; land subsidence causes shifts in elevations, rendering gravity-based water flows inoperative.</td>
<td>Region is without drinkable water supply while emergency repairs are undertaken; damage is significant, such that it takes months to bring the system back online</td>
<td>Region is forced to declare a “holiday”, encouraging residents to go elsewhere temporarily while repairs are undertaken; federal program provides lost wages to those who cannot work; workers living outside affected area; bring water to work with them every day; disruption to regional economy could be minor or significant</td>
</tr>
<tr>
<td>Human causes</td>
<td>Terrorists use nuclear bomb or massive conventional explosive to destroy reservoir dams and aqueducts, rendering the delivery system inoperable.</td>
<td>Region is without drinkable water supply while emergency repairs are undertaken; damage is massive, such that it takes roughly a year to bring the system back online</td>
<td>Property values in region decline significantly, rise in unaffected areas, as many residents leave and do not come back; infrastructure in region becomes unfearable; infrastructure outside affected area is overwhelmed; morbidity and mortality rates; disruption to regional economy is significant, as workforce is disrupted</td>
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<td>Terrorists destroy underground water delivery pipes, leading to temporary shutdown of affected parts of system.</td>
<td>Region is without drinkable water supply while emergency repairs are undertaken; damage is manageable, such that it takes only one month to bring the system back online</td>
<td>Region is forced to declare a “holiday”, encouraging residents to do elsewhere temporarily while repairs are undertaken; federal program provides lost wages to those who cannot work; workers living outside affected area; bring water to work with them every day; disruption to regional economy is minor</td>
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<td>Human causes</td>
<td>Maintenance of system is inadequate, neglected system deteriorates, leading to widespread water leakage and ultimately a significant system failure.</td>
<td>Region is without drinkable water supply whenever emergency repairs are required; damage is manageable but frequent, such that outages last a few days or perhaps a week</td>
<td>Region’s water supply system is characterized as that of a “third-world country”; outages are frequent and public is outraged; residents and businesses move elsewhere; region enters permanent decline, as population, property values and social order declines</td>
</tr>
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<td>Natural and Human causes</td>
<td>Terrorists poison the water, either in the reservoirs or in the aqueducts and pipelines, leading to emergency shutdown of system while water purification steps are undertaken.</td>
<td>Region is without drinkable water supply for perhaps a week, while water purification is undertaken; prior to its identification a large number of people are sickened or die from drinking contaminated water</td>
<td>Lack of water for a week is a manageable program, assuming the public listens to officials and stops drinking the water; however, people are afraid to drink the water afterward due to the significant loss of life; business and population declines; tourism takes a major hit</td>
</tr>
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<td>Human causes</td>
<td>Industrial or agricultural pollution contaminates aquifers, making water undrinkable.</td>
<td>Water must be boiled or purified by other means by residents, while solution at the source is developed and implemented; crisis situation lasts perhaps for one month</td>
<td>Population, business and tourism all decline as region becomes “not the place to live, work and visit”; significant numbers of people are sickened because they do not take proper purification steps</td>
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**Example of a generalized risk register**
We classified the risk along four dimensions

- **Likelihood**
  - Imminent, Probable, Unlikely, Very Unlikely, Speculative

- **Scope of Impact**
  - Local, Regional, Global

- **Extent of Impact**
  - Disruptive, Endurable, Crushing, Existential

- **Controllability**
  - Preventable to Unpreventable, Mitigable to Unmitigable
The New York City Water System

Stephen Lowe
New York City – a highly developed water system

- Provides 1.2 billion gallons of water per day
- Reservoirs are filled by watershed of over 1-million acres
- Three major aqueducts carry water to gravity to the city
- Water is distributed by 6,800 miles of water mains
NYC – risk prevention and mitigation activities

- New York engages in substantial risk prevention and risk mitigation activities
  - Development in watershed is restricted
  - A dedicated police force of 200 protects the system
  - Tunnel 3 adds redundancy
  - 95% of the water is delivered by gravity; no need for electricity
  - 965 water sampling stations; 50 stations sampled every day
  - $240 million earmarked to address leakage over five years
## Risk assessment summary for New York

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<tr>
<td>Water goes elsewhere</td>
<td>Natural and human causes</td>
<td>Reservoirs are depleted due to hydrological changes caused by climate change, which causes rain and snow fall to decline in regions, and evaporation to rise, leading to drought conditions</td>
<td>Speculative; Rain and snow fall are unlikely to decline materially in this region of the country</td>
<td>Regional, but with international follow-on impacts</td>
<td>Existential</td>
<td>Preventable but unmitigable</td>
</tr>
<tr>
<td>Human causes</td>
<td>Failure of a neighboring region’s water system necessitates sharing of water supply. New aqueducts are constructed to share one region’s water with another region</td>
<td>Very unlikely; Adjacent cities have good water supplies</td>
<td>Regional across multiple regions; international follow-on effects</td>
<td>Disruptive</td>
<td>Preventable and mitigable</td>
<td></td>
</tr>
<tr>
<td>Water is there, but delivery system is disrupted</td>
<td>Natural causes</td>
<td>A significant earthquake or other major ground motion event causes aqueducts and pipes to break, causing shutdown of delivery system</td>
<td>Speculative; This is not an earthquake-prone area, nor is it subject to land subsidence</td>
<td>Regional across multiple regions; international follow-on effects</td>
<td>Existential</td>
<td>Unpreventable and unmitigable</td>
</tr>
<tr>
<td>Human causes</td>
<td>Terrorists use nuclear bomb or massive conventional explosive to destroy reservoir dams and aqueducts, rendering the delivery system impossible</td>
<td>Unlikely; The system is well-protected, but a successful attack can’t be ruled out</td>
<td>Regional but with international follow-on impacts</td>
<td>Existential</td>
<td>Preventable and mitigable</td>
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<td>Human causes</td>
<td>Terrorists destroy underground water delivery pipes, leading to temporary shutdown of affected parts of system</td>
<td>Unlikely</td>
<td>Regional, but with international follow-on impacts</td>
<td>Endurable</td>
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### Human causes

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<td>Water is there, but becomes undrinkable</td>
<td>Human causes</td>
<td>Terrorists poison the water, either in the reservoirs or in the aqueducts and pipelines, leading to emergency shutdown of system while water purification steps are undertaken</td>
<td>Unlikely; The system is relatively well-maintained and leakage is measured</td>
<td>Regional</td>
<td>Endurable</td>
<td>Preventable but unmitigable</td>
</tr>
<tr>
<td>Industrial or agricultural pollution contaminates aquifer, making water undrinkable</td>
<td>Industrial causes</td>
<td>Speculative; Development in the water supply region is managed</td>
<td>Regional, but with international follow-on impacts</td>
<td>Disruptive</td>
<td>Preventable by unmitigable</td>
<td></td>
</tr>
</tbody>
</table>
The Mexico City Water System

Dale Hall
Mexico City – a developed system under stress

- Most populated area in the Western Hemisphere; population over 20 million
  Water flows from aquifer under the city and from distant lakes via pipeline
- Land subsidence has undermined gravity-based flows, increasing need for pumping stations
- Rainfall is limited to a four-month rainy season
- Demand exceeds supply; the aquifer is being depleted
- Infrastructure is deteriorating; 40% waste due to leakage
- Some families spend 20% of income on private water delivery
• Additional water supplies are being identified and pipelines extended
• Pumping infrastructure is being added as further subsidence occurs
• 2009 water sustainability program
  – Prevent floods from inundating system
  – Treat all wastewater
  – Reduce over-utilization of ground water
Mexico City – significant risks

- Introduction of pumping stations increases reliance on electricity
- Subsidence is likely to continue; ever-increasing need for pumping
- Climate change may lower rainfall levels in region
- Significant risk of water supply depletion; region could become uninhabitable
- Repairs to reduce leakage may be beyond budget
## Risk assessment summary for Mexico City

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<td>Water goes elsewhere</td>
<td>Natural and human causes</td>
<td>Reservoirs are depleted due to hydrological changes caused by climate change, which causes rain and snowfall to decline in region, and evaporation to rise, leading to drought conditions</td>
<td>Unlikely, Climate change likely to affect region, with longer, hotter dry seasons, Impact on aquifer is uncertain</td>
<td>Regional</td>
<td>Existential</td>
<td>Unpreventable and unmitigable</td>
</tr>
<tr>
<td>Human causes</td>
<td>Population growth and continuing development of tourism strongly increase demand for water</td>
<td>Likely and happening today</td>
<td>Regional</td>
<td>Disruptive</td>
<td>Preventable and mitigable</td>
<td></td>
</tr>
<tr>
<td>Water is there, but delivery system is disrupted</td>
<td>Natural causes</td>
<td>A significant earthquake or ongoing land subsidence causes aqueducts and pipes to break and gravity to overwhelm pumping stations, causing failure of delivery system</td>
<td>Speculative</td>
<td>Regional</td>
<td>Existential</td>
<td>Unpreventable and unmitigable</td>
</tr>
<tr>
<td>Human causes</td>
<td>Terrorist activity damages or destroys secondary water source of dams and aqueducts, rendering the delivery system inoperable</td>
<td>Unlikely, but with international follow-on impacts</td>
<td>Regional, but disruptive</td>
<td>Population may need to be relocated</td>
<td>Preventable and mitigable</td>
<td></td>
</tr>
<tr>
<td>Maintenance of system is inadequate, neglected, system deteriorates, leading to widespread or significant system failure</td>
<td>Unlikely</td>
<td>Regional</td>
<td>Disruptive</td>
<td>Preventable and mitigable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water is there, but becomes undrinkable</td>
<td>Human causes</td>
<td>Severe flood fills lake bed areas and inundates water maintenance system operations</td>
<td>Speculative</td>
<td>Regional</td>
<td>Endurable</td>
<td>Preventable and mitigable</td>
</tr>
<tr>
<td>Intermingling of water and sewage occurs, making water undrinkable</td>
<td>Speculative</td>
<td>Regional</td>
<td>Disruptive</td>
<td>Preventable and mitigable</td>
<td></td>
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The Water System in India

Rade Musulin
India – a rapidly developing country under stress (I)

- On track to become the most populous country in the world, over 1.3 billion people
- While the country receives significant rain and snowfall, water supplies are stressed:
  - Seasonality of precipitation
  - Inadequate infrastructure
  - Poor sanitation in many places
  - Depletion of groundwater supplies (up to 40% of supply from groundwater)
- Dependence on snowmelt runoff from Himalayan region exposes the country to future challenges in a warming climate
- Tropical cyclones pose problems with too much water, particularly in the Northeast, exposing many to physical risk
- World Bank: 21% of India’s communicable diseases are linked to unsafe water
India – a rapidly developing country under stress (II)

Figure 6: Baseline water stress in India\textsuperscript{14,15,16}

Ratio of total withdrawals and total flow (2010)

\textbf{Facts: Water supply is limited, quality is poor}

- \textit{600 million people} face high-to-extreme water stress.
- 75% of households do not have drinking water on premise. \textit{84%} rural households do not have piped water access.
- 70% of our water is contaminated; India is currently ranked 120 among 122 countries in the water quality index.
India – risk prevention and mitigation activities

• Major commitment by the Indian government to recognizing and measuring the problem, including the creation of the water management index
• Aggressive programs to improve sanitation, by building infrastructure and installing 90 million toilets
• 90% of urban population now has access to water and “basic sanitation”
• Water use tariffs to encourage conservation
• Controlling excessive use of antibiotics in agriculture and healthcare
• Nonetheless, extensive use of antibiotics is contributing to a global problem with “super-bugs”, an example of where water issues in one place can contribute to risk exposure elsewhere
### Risk assessment summary for India

#### Natural and human causes

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<tbody>
<tr>
<td>Water supply and amount</td>
<td>Natural causes</td>
<td>Water supplies become more erratic due to hydrological changes caused by climate change, which causes delays in the onset of the monsoon, declining snowfall in northern mountains, increased intensity of rainfall, and more intense tropical cyclones</td>
<td>Imminent. Extreme precipitation, floods</td>
<td>National</td>
<td>Highly disruptive</td>
<td>Unpreventable and mitigable</td>
</tr>
<tr>
<td>Human causes</td>
<td>Population growth, development, and growing middle class increase demand for water</td>
<td>Certain and happening now</td>
<td>National</td>
<td>Highly disruptive</td>
<td>Unpreventable and mitigable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Growth of middle-class changes demand for types of food, shifting to more meat, poultry, and dairy. This may create stresses on water supplies in locations which produce these foodstuffs</td>
<td>Likely</td>
<td>National</td>
<td>Somewhat disruptive</td>
<td>Preventable and mitigable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased flood risk from climate change (e.g. extreme cyclones, melting snowpack, and higher rainfall intensity) damages water supply delivery systems such as reservoirs, dams, and pumping stations</td>
<td>Speculative</td>
<td>Regional across multiple regions; international follow-on effects</td>
<td>Existential</td>
<td>Preventable and mitigable</td>
<td></td>
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<td></td>
<td>Excessive reliance on groundwater depletes aquifers</td>
<td>Likely within five years</td>
<td>Major cities nationwide</td>
<td>Highly disruptive</td>
<td>Unpreventable and mitigable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor systems for measuring water use lead to many people not paying tariffs, thus removing an economic incentive to conserve water</td>
<td>Exists now</td>
<td>Regional</td>
<td>Endurable but inefficient</td>
<td>Preventable and mitigable</td>
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<td>Poor sanitation leads to contamination of water supplies, increasing disease risk</td>
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<td>National</td>
<td>Highly disruptive</td>
<td>Preventable and mitigable</td>
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<td>Increased disease from unclean water leads to excessive use of antibiotics for humans and agriculture, contributing to risk of &quot;superbugs&quot; and/or global pandemic</td>
<td>Speculative</td>
<td>International</td>
<td>Catastrophic</td>
<td>Preventable and mitigable</td>
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#### Water supply and amount

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<td>Building of dams, for example on upper Ganges, damages water supplies downstream near Kolkata or in Bangladesh</td>
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#### Water is there, but delivery system is disrupted

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Broad Conclusions
Implications for Actuaries
We face a looming water crisis, potentially of existential proportions, in some parts of the world
  – Supplies running out
  – Water becoming non-potable
• Significant disparities across systems
• Not simply a “wealthy versus poor” country issue, as the US Midwest and California have issues
• Significant population migrations seem inevitable
• Antibiotic resistance is a global problem born from water resource issues
Real estate prices could change dramatically; business activity could be disrupted, affecting equity markets and credit quality; these have implications for asset values.

Agriculture insurers need to recognize the issues; historical variations in crop yields may no longer be predictive.

Life insurers face risk concentration issues, future mortality could also be affected.

Health care costs could spiral to the extent that poor water quality increases morbidity.

Property insurers may encounter business interruption claims; declines in property values create moral hazard; civil unrest is possible.

Social security and pension plans could be affected by disruption in economy.

Insurance prices probably do not appropriately consider water resource risks and costs.
Next steps

• Get more actuaries involved to extend and expand the analysis
• Seek opportunities for collaboration with experts
• Work towards a system of ongoing assessments, around a common risk framework, across most water resource systems
Questions and Discussion
Thank you