Aquanomic$

The economics of water risk and future resilience

→ ghd.com/aquanomics

Table of contents

“The water sector has the opportunity to lead change, embracing new technologies, approaches and solutions to optimise assets.”

Foreword

The Intergovernmental Panel on Climate Change (IPCC) recently revealed that over half of all natural disasters since the 1970s have involved water. As the climate crisis intensifies, the threat posed to people by changes in water systems will only grow. As well as affecting livelihoods, social systems and individuals, these changes can also have a huge impact on economies. Data from the Emergency Event Database (EM-DAT) revealed that drought, floods and storms led to global economic losses of approximately $224.2 billion in 2021, compared to the 2001 to 2020 annual average of $117.8 billion.

Aquanomics uses a bespoke model to project the future economic impact of water risk in seven countries representing a diverse range of climates: Australia, Canada, China, the Philippines, the United Arab Emirates, the United Kingdom and the United States. It reveals droughts, floods and storms could result in a total loss of **$5.6 trillion to GDP across these countries between 2022 and 2050**. This risk will not be spread evenly across countries, and some sectors will be hit harder than others.

To address this huge challenge, more directed investment, focused innovation, and integrated water management is needed in our global water systems and bringing communities along on this journey is key. The water sector has the opportunity to lead change, embracing new technologies, approaches and solutions to optimise assets. Recognising the role of water as a connector between sectors – that is, as central to the development of a circular economy and a critical element of every business and supply chain on the planet – will also be part of the solution. We've seen governments already taking action to mitigate water risk, but more needs to be done.

We need to reorient our relationship with water. It's time to move away from viewing it as a commodity to be controlled, instead recognising its intrinsic value; water is part of a natural cycle, the balance of which must be restored and maintained if we are to live sustainably and prosperously. At GHD, we are focused on working with stakeholders to develop and implement integrated solutions to this challenge. This means understanding and optimising the infrastructure already in place and collaborating with our clients and industry peers to consider different kinds of assets that work in harmony with communities and nature.

The water industry must take an agile approach, regenerating systems, and building resilience over time, while involving communities at every stage. This will require radical collaboration across industry and innovative policy solutions from government. Truly resilient water infrastructure will require close partnerships between the public and private sector to tackle this together – across borders, at a global level, as well as within countries and communities. We need to consider water by catchments, not by political or artificial boundaries.

By focusing on economic impacts, as we have done with this study, we aim to help identify and unlock the social and environmental benefits of tackling water risk head-on. As well as highlighting risk, this study explores some of the ways in which our focus countries can adapt to change and build resilience in their water systems. With water risk on the rise, we need to move to a proactive, holistic and inclusive approach in understanding and addressing fast-developing challenges.

Rod Naylor
Global Leader, Future of Water, GHD

[1] Unless otherwise stated, all figures are in US dollars

About Aquanomics

Aquanomics: The economics of water risk and future resilience utilised a three-phase methodology to estimate the direct losses, sector losses and GDP losses that will be attributed to water risk (droughts, floods and storms) between 2022 and 2050. The study focuses on seven key countries across GHD's footprint - Australia, Canada, China, the Philippines, the UAE, the UK and the US - and three US regions - Northeastern US, Southeastern US and Southwestern US.

Phase 1: Projecting direct water risk losses at key dates between 2022 and 2050

We used data from the global insurance sector to project the potential direct losses attributed to water risk (droughts, floods and storms) across our 10 focus geographies. This data is derived from Ortec Finance's climate PREDICT model[2] and includes both insured and uninsured losses. It is reported in currency terms (USD).

Phase 2: Estimating future losses from water risk by sector between 2022 and 2050

We conducted a review of relevant literature into the effects of drought, flooding and water-related storm damage on five economic sectors. This was based on a total review of 19 research papers and focused on the agriculture; banking and insurance; energy and utilities; fast-moving consumer goods (FMCG) and retail; and manufacturing and distribution sectors.

Phase 3: Modelling wider economic impact of water losses at key dates between 2022 and 2050

We then inputted the water risk loss data from stages 1 and 2 (estimated direct sector losses) into the E3ME economic model[3] as 'shocks' to ascertain the total economic impact of water risk across the 10 focus geographies.
These impacts included:

- **Direct effects:** from direct losses to different sectors and households (using data from Phase 2).
- **Indirect effects:** adjustments to price (including energy price) and government spending, as well as investment impacts caused by the capacity shocks.
- **Wider effects:** impacts on supply chains, international competitiveness, employment, income, and consumption.

The outputs of the model are then reported in currency terms (total GDP USD losses between 2022 and 2050), a percentage of annual GDP and output at a sector level.

Global climate change assumptions

As global warming intensifies, extreme weather events are expected to increase, resulting in greater water risk to countries and regions. The figures in this study assume a 2° C rise in global temperatures in line with the 'absolute cap' in global warming agreed by governments in the 2015 Paris Agreement (a threshold beyond which climate impacts become increasingly extreme).

Credits

Research design and concept development by Man Bites Dog and GHD. Economic modelling conducted by Cambridge Econometrics. Additional qualitative research into the environmental and social impact of water risk provided by Dr. Ania Grobicki, former Deputy Director of External Affairs at the Green Climate Fund and Executive Secretary of the Global Water Partnership.

See page 40 for full methodology.

---

[2] Ortec Finance Climate PREDICT model quantifies the increase in frequency as well as impact (direct financial losses) of extreme eather risk per type of event (e.g. droughts, storms, floods) per different climate scenarios. Find out more: https://www.ortecfinance.com/en/insights/product/climate-predict

[3] The E3ME model is a dynamic computer-based macroeconomic model of the world's economic and energy systems and the environment. Find out more: www.e3me.com

Global Aquanomics

→ From risk to resilience

The global water cycle is the most important component of our natural ecosystems – yet rising CO2 levels are causing it to change at an alarming rate. Weather patterns are changing, resulting in increasingly frequent and extreme water-related disasters. Rainfall events are becoming shorter and more intense, increasing storm and flood risks worldwide, while longer, hotter drought periods and associated wildfires are causing more damage to agriculture, buildings, infrastructure, and habitats. This rising variability means that using historical weather patterns to predict future conditions is becoming more unreliable.

Natural assets, which sustain and control the water cycle, are being lost at a rapid rate. Underground aquifers worldwide are being drawn down so that water has to be pumped from deeper levels, and the resulting water quality degradation is increasing the need for desalination. At the same time, large areas of forest and wetland continue to be cleared and drained, while rivers are modified for hydropower, irrigation, and water supply.

The social impact of water-related disasters on people and communities can be dramatic, especially for the poorest and most vulnerable members of the population. Levels of exposure and vulnerability can vary enormously between – and within – countries, depending upon location and income. Recent research from the Emergency Event Database (EM-DAT) revealed, in 2021, drought, flood and storm disasters affected close to 100 million people globally, through factors such as displacement, economic damage, food insecurity and injury[4]. Although this number was below the 2001-2020 average, 2021 was marked by an increased number of disaster events and extensive economic losses.

In 2021, drought affected over 50 million people, floods affected some 30 million people, and storms affected 17.6 million people worldwide.

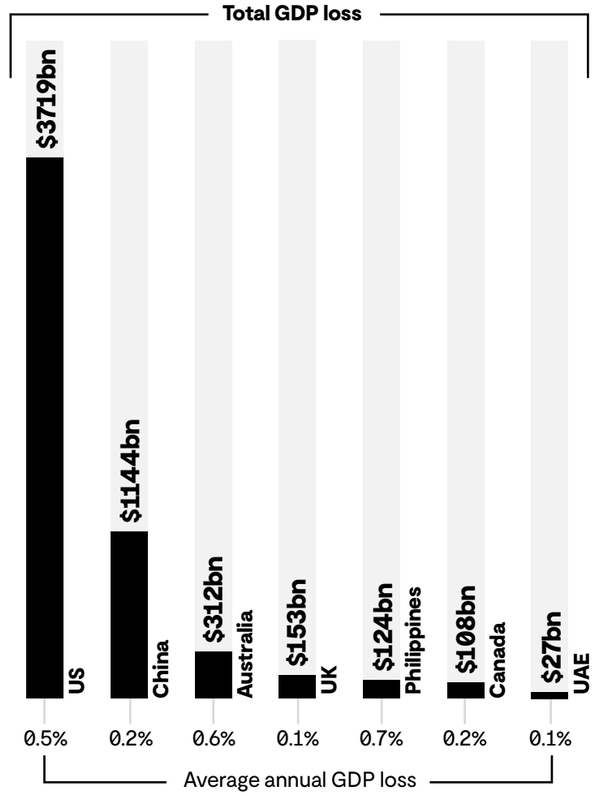
Aquanomics across the globe

The economic risk of water by region

Our Aquanomics model estimates droughts, floods and storms could result in a total loss of **almost $5.6 trillion to GDP for our eight focus countries between 2022 and 2050** – more than the combined annual GDP of the UK and Germany. While the economic shock of water risk will accelerate throughout the century, it is a pressing concern this decade: between now and 2030, water risk could cost global economies an estimated total of $1.3 trillion.

This water risk is spread unevenly across the globe. The Philippines, Australia and the US are projected to experience an average economic decline of between 0.5% and 0.7% in annual GDP in the years up to 2050. For the UAE and the UK, despite having very different economies and water risk exposure, it is estimated the average yearly impact to GDP will be just 0.1%.

Total GDP loss in billions



Data shown is average annual % GDP loss betweeen 2022 and 2050 by country

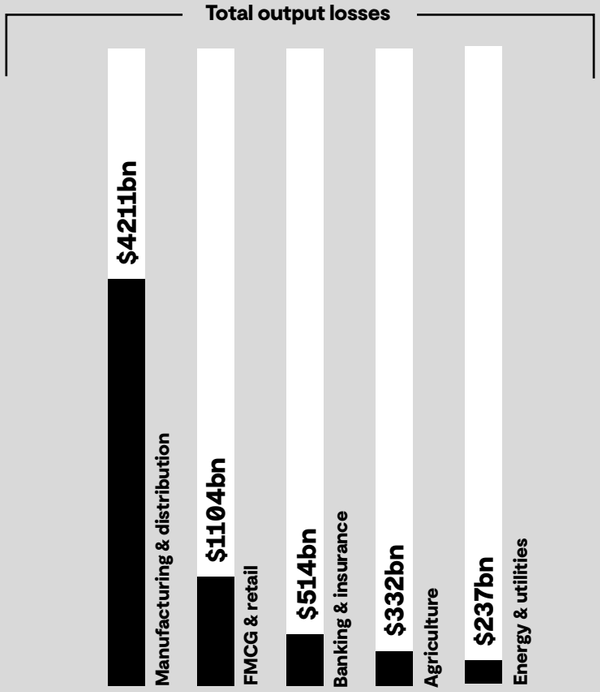
Aquanomics by sector

The economic risk of water at a sector level

All businesses are dependent on water; no matter their size or sector, they require water to function. This makes water a connector between sectors, crucial to enabling circular economies and global supply chains. It also means no sector is protected against operational disruption in the face of droughts, floods and storms.

Our Aquanomics model reveals the impact of water risk on five critical sectors within the global economy: agriculture; banking and insurance; energy and utilities; FMCG and retail; and manufacturing and distribution. While these sectors are diverse, with very different types and levels of water risk, they are all expected to face significant output losses in the years up to 2050.

Total output losses by sector



Data shows total sector output losses in USD (billions) between 2022 – 2050

Agriculture

Agriculture is the world's thirstiest industry – accounting for approximately 70% of global freshwater withdrawals. Our Aquanomics model estimates the sector could lose $332bn in economic output between 2022 and 2050.

Water risk in the agricultural sector

Droughts have devastating effects on crop cultivation and livestock farming, while flooding and storms can damage infrastructure, crop lands, livestock shelter and farming equipment. Water-related disasters can also have a long-term impact on the productivity of agricultural land. Disruption to food production can impact imports and exports, which can affect global food security as well as impacting health and social equity within countries.

Banking and insurance

As a proportion of overall output, the banking and insurance sector has a more optimistic outlook compared to the other sectors. However, our Aquanomics model projects it could still incur losses of $514bn between 2022 and 2050.

Water risk in the banking and insurance sector

These losses will primarily come from the indirect wider disruption caused by droughts, floods and storms, such as reductions in productivity and economic activity in the aftermath of these events. Additional long-term impacts include the disruption of trade, increased insurance payouts and the disruption of vital infrastructure.

Energy and utilities

The energy-water nexus means the availability of water resources can directly affect the productivity of energy systems, and vice-versa. Our Aquanomics model projects total output losses of $237bn to the energy and utilities sector by 2050.

Water risk in the energy and utilities sector

Restricted access to water can limit energy production due to the shutdown of powerplants (such as hydro and nuclear), while flooding and storms can result in direct damage to energy and water infrastructure, as well as limiting solar power production.

Fast moving consumer goods (FMCG) and retail

The FMCG and retail sector is heavily reliant on water infrastructure throughout its interconnected and complex supply chains. Our Aquanomics model predicts the sector could face total output losses of just over $1.1tn by 2050 due to water risk.

Water risk in the FMCG and retail sector

Water-related disasters can cause direct damage to infrastructure and assets, including buildings, inventory and machinery. It can also cause disruptions to supply chains through transport infrastructure such as roads and railways and compounding delays in global shipping caused by geopolitical uncertainties.

Manufacturing and distribution

Our Aquanomics model predicts the manufacturing and distribution sector will be the most heavily affected by increasing water risk – facing total output losses of just over $4.2tn by 2050.

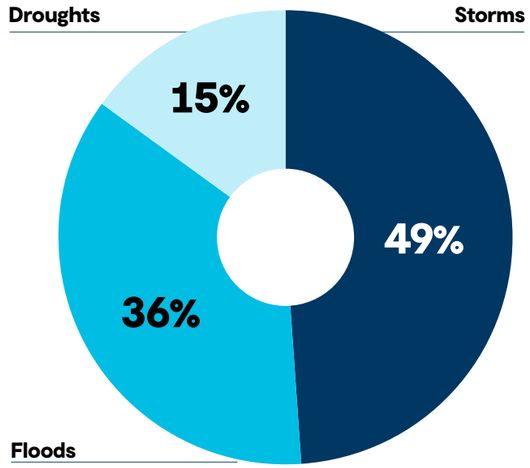
Water risk in the manufacturing and distribution sector

Manufacturing plays a fundamental role in the supply chains of all other sectors. Water scarcity can restrict industrial production processes, while flooding and storms can cause direct damage to assets (buildings, inventory and machinery) and energy supply. Water risk also impacts distribution; for example, extreme drought can cause disruption to waterborne transportation while flooding and storms can disrupt road and rail infrastructure.

Direct losses attributed to floods, droughts and storms

The wider GDP and sector losses projected within this study are calculated using the direct losses attributed to floods, droughts and storms. Across the 10 focus geographies in this study, storms are likely to cause the largest direct losses to economies, followed by floods and then droughts.

Direct losses by event type



Data showing direct losses by 2050 by weather event type

Building future water resilience

What steps can be taken to boost water resilience across the globe?

The diversity of water risk that exists across the globe means there is no one-size-fits-all solution for improving water resilience. Resilience in a region that is facing severe water scarcity can mean a very different thing when compared to a region where the greatest risk is posed by an over-abundance. Despite this, taking a long-term strategic view of the management of water assets and focusing on a few universal principles will help ensure resilience is improved across the globe.

01

With the climate crisis increasing the frequency of extreme weather events, building resilience is no longer a case of implementing costly, large-scale infrastructure interventions and expecting them to be effective for the next century. The industry needs to be able to rapidly adapt to evolving risk; it is about optimising assets and leveraging nature-based solutions that can be implemented quickly and efficiently for maximum effect.

02

Adopting a circular economy approach to water management is crucial. Focusing on water recycling and working within nature's cycle can not only improve the long-term sustainability of water infrastructure but reduce costs as well. Nature-based solutions often do not demand huge capital upfront and can achieve the same results as more traditional forms of water infrastructure.

03

Embracing advanced digital solutions and data to improve the management and efficiency of the water cycle will also play a major role in mitigating risk. Smart devices and sensors enable utilities to monitor the resilience of their assets in real-time – enabling more effective maintenance – and predictive modelling will allow water supply clients to be proactive toward climate stress, helping them make better-informed decisions about where to direct future investment.

“Access to safe, affordable and reliable water is a fundamental human right and plays an increasingly crucial role in every part of the global economy, and yet it is one of our most undervalued resources. The water sector faces the twin issues of increasing requirements for water (both residential and commercial) and a potential reduction in supply due to climate change. The way in which the industry responds to these threats will be one of the most important challenges of the coming decades.”

Rod Naylor
Global Leader, Future of Water
GHD

Aquanomics regional **spotlights**

- Australia
- Canada
- China
- The Philippines
- The UAE
- The UK
- The US (overall)
- Northeastern US
- Southeastern US
- Southwestern US

Australia

Land of droughts and flooding rains

Our Aquanomics model projects that droughts, floods, and storms could result in a total loss of **$312 billion** to Australia's GDP between 2022 and 2050 – almost one third of Australia's GDP in 2020. Storms are expected to have the greatest direct impact on the economy **($70 billion)**, followed by floods **($44 billion)** and droughts **($28 billion)**.

As a land of 'droughts and flooding rains', Australia has more experience than most in the battle against water risk. Australia is the driest of all inhabited continents, experiencing varied and volatile weather patterns across the country. Australia's east coast has experienced record rains and flooding in 2022; by the end of the first week in March, Southern Queensland and northern New South Wales had each received more than a year's worth of rainfall in a week, leaving thousands displaced and destroying property, livestock and transport infrastructure.

The agricultural industry will have to improve productivity more than previously planned.

Water risk in Australia

After more than 60,000 years of stewardship by Indigenous Peoples, the country's fragile ecosystems reflect remarkable adaptation to dry conditions. However, post-industrial era climate variability is straining aquatic ecosystems and other living systems with profound consequences. For example, between December 2018 and January 2019, a combination of drought and harmful algal blooms resulted in the death of hundreds of thousands, possibly millions, of fish in the Murray-Darling Basin. Disruption to these systems due to contamination and the risk of too much or too little water, exacerbated by climate change, is putting pressure on communities and livelihoods hardest hit by exposure.

Australia's agricultural sector will feel the most significant economic impact of climate change, with projected annual output losses of 5% by 2030 and 8% by 2050 – the largest in percentage terms in the entire study. Overall, water risk could result in the sector suffering $150 billion in total output losses between 2022 and 2050. These potential losses could mean the industry will have to improve productivity more than previously planned in order to achieve the Government's ambition of growing Australian agriculture to AUD$100 billion by 2030.

Australia's Aquanomics data dashboard

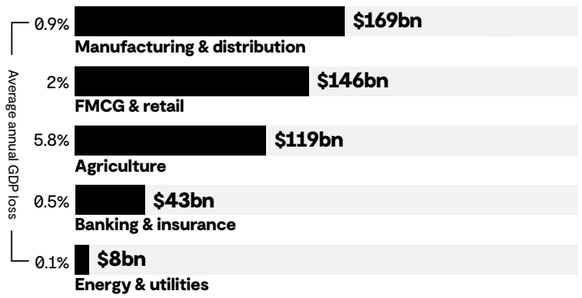
$312 billion

Total GDP loss between 2022 and 2050

0.6%

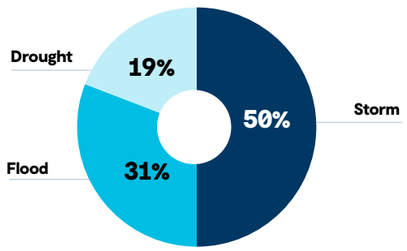
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

With a growing population and increasing demand for water, the adoption of a circular economy approach by the Australian water industry is crucial to optimising resources and mitigating risk. At GHD, we are supporting this mission, helping water authorities design out waste and pollution and regenerate natural systems.

Increasing supplies of manufactured water through water reuse and recycling offers a reliable source of water that is not climate-dependent. For Australia's coastal cities – where 80% of the country's population is concentrated – desalination will be crucial in easing water stress. Inland, wastewater treatment and recycling will become more important. These processes make purified recycled water available to power stations, industry, and agriculture for indirect potable reuse.

In rural farming communities, where it is often impossible to manufacture the enormous quantities of water needed, the answer lies in the modernisation of inefficient systems. With irrigated agriculture currently using approximately three quarters of Australia's natural water supply, upgrading to smarter irrigation systems will be central to mitigating the threat posed to the industry by water risk. Embracing sensible renewal and replacement programs and predictive digital solutions – like flood modelling and real-time monitoring systems – will also help to plan for future risk. There are already some great examples of where this has been successfully implemented such as the Murrumbidgee Irrigation Scheme.

The Government has a key role to play in managing the transition to new methods of water management. Investment programs, such as the National Water Grid Fund, are the first step, but infrastructure can only be part of the solution; moving to a circular economy means fundamental changes to deeply held attitudes around water management.

Lindsey Brown
Australian
Water Market Leader
GHD

Canada

A land of extremes

Our Aquanomics model projects that droughts, floods and storms could result in a total loss of **$108 billion** to Canadian GDP between 2022 and 2050 – an average of **0.2%** of GDP per annum. Canada's large land mass – combined with low population density – contributes to water risk having less of an impact than many of the other countries in the study, but there are still risks. Flooding alone is expected to cost the Canadian economy over **$30 billion** in the years leading up to 2050, making up almost half of the country's estimated total direct losses.

***Canada's large land mass – combined with low population density – contributes to water risk having less of an impact than many of the other countries.**

Water risk in Canada

Canada is a country of physical extremes and contrasts. Many of this vast country's enormous forests, rivers, lakes and wetlands remain in relatively pristine condition due to the low population density and its high-water availability, although the Arctic region is changing rapidly due to the high rate of warming and melting permafrost. The Great Lakes region – which holds over 20% of the Earth's surface fresh water – has been intensively managed over time in a collaborative way between Canada and the US.

Despite high levels of insurance and excellent disaster risk reduction systems in place, the Canadian population is still vulnerable to water-related hazards. The 2021 British Columbia floods saw the city of Vancouver cut off when the transport corridor linking it to the rest of the country was flooded out. For the First Nations, issues of inequitable access to clean, safe drinking water are an urgent priority.

Canada's Aquanomics data dashboard

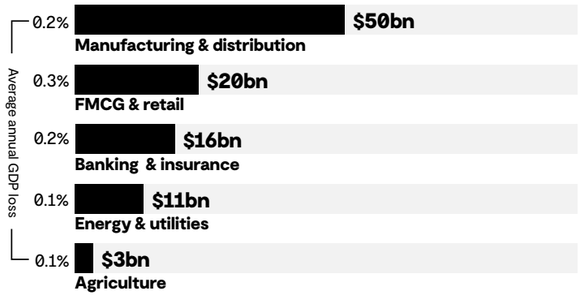
$108 billion

Total GDP loss between 2022 and 2050

0.2%

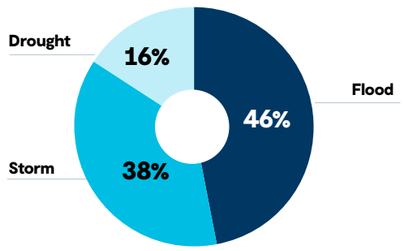
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

Canada may not be a water-stressed country, but it is a country of extremes, and these extremes are getting more pronounced. With the Canadian government estimating the country is warming at double the global mean rate, a growing number of municipalities have declared climate emergencies and are implementing policies to boost resiliency. It is up to the engineering community to help clients adopt a risk-based management approach to plan for increasing variability.

Effective risk management means squeezing the maximum amount of value from assets – ideally replacing them just in time. The City of Toronto is currently losing 103 million litres of water per day due to ageing pipes. To help mitigate this sort of wastage, we need to make better use of the growing volume of data being generated to enable predictive monitoring and maintenance of assets.

GHD's recent project with the City of Calgary and the Calgary Airport Authority developed a data study to determine the impacts of climate change. The analysis revealed that, although the amount of precipitation is going to stay the same, that precipitation will change and become more extreme. The city has begun using this data to inform infrastructure design, operational planning and community decision-making to eventually build more climate-resilient infrastructure.

Funding is available for these projects through the Investing in Canada plan. Launched in 2016, the Canadian government committed over CAD$180 billion to improve ageing infrastructure across the country. This includes funding to increase water infrastructure resilience, but further investment is needed too.

Don Holland
Canada Water Business Group Leader
GHD

China

Continued investment

Although China has a similar land mass to other regions in the study, its high population and large economy would suggest that water risk will have a bigger impact. However, the region's significant investment in infrastructure means that the predicted average yearly GDP loss from droughts, floods and storms is just **0.2%**.

Although the average annual GDP impact of water risk is small, in real terms, the total losses are huge between 2022 and 2050 with China projected to lose over **$1.1 trillion** in GDP over that period. The country's mighty manufacturing and distribution sector is set to be worst hit, losing nearly **$1.7 trillion** to water-related natural disasters over the course of the next 30 years.

The country's mighty manufacturing and distribution sector is set to be worst hit.

Water risk in China

China is a highly diverse country, both in geography and ethnography, bringing a high degree of vulnerability to climatic hazards. The country's historic exposure to massive flooding in its two major river basins (the Yellow and the Yangtze), as well as in smaller catchments, has led to a focus on developing water infrastructure and canalising rivers to reduce the impact of flood disasters since ancient times. More recently, China has redefined itself as an "ecological civilisation" with priorities including reducing water pollution, protecting wetlands and building "sponge cities" that absorb water, while continuing to build water infrastructure apace.

Large inter-basin water transfer projects and the creation of a national water grid build resilience against drought in water-scarce regions of China. However, floods remain the major water-related threat with 14.5 million people affected and displaced in 2021, while the mortality rate was relatively low (352 people) due to improvements in early warning systems and emergency services. Poor rural households in China are disproportionately affected by floods.

However, the region has invested a significant amount in projects to build resilience, such as the Three Gorges Dam and the South-to-North Water Diversion project. Between 2008 and 2019 there was a spectacular seven-fold increase in annual expenditure on water infrastructure projects. And, in January 2022 the Chinese government announced plans to further expand water investment during the 14th Five-Year Plan period (2021-2025).

China's Aquanomics data dashboard

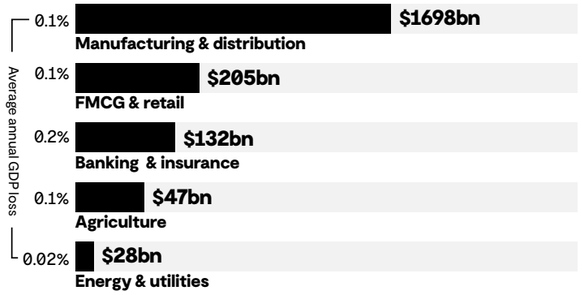
$1.1 trillion

Total GDP loss between 2022 and 2050

0.2%

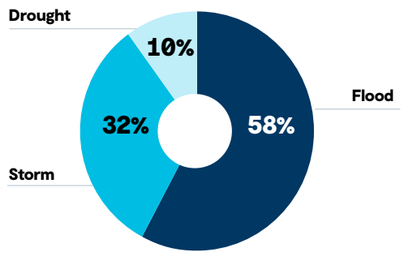
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

China's resiliency to past water risks has been primarily defined by their bold investments into greater infrastructure developments both in rural and urban areas. However, the number of summer floods in the southern regions of China's manufacturing hub is predicted to increase as climate challenges worsen.

China has begun to combine the successes of traditional and technological approaches to mitigating the effects of flash floods through an Asian Development Bank project, which utilises a community-level mobile app-enabled emergency response that collects and monitors measurements of rainfall remotely while making use of alarm systems to alert residents for evacuation in the Shewei and Kongmu river basins.

Given the scale of the water risk in China, it is crucial that the Chinese government, with support from international development organisations and neighbouring countries, invests in greater preventive infrastructure through a combination of dry and wet floodproofing measures that would allow for floods to be diverted wherever possible, while at the same time developing infrastructure that can withstand frequent flood threats.

Philippines

Water, water everywhere

Our Aquanomics model projects that droughts, floods and storms could result in a total loss of **$124 billion** to the Philippines's GDP between 2022 and 2050. The Philippines is ranked as the fourth most affected country in the world for water-related disasters, with approximately 20 typhoons entering the country each year, often bringing torrential rain and flooding. Our data shows that floods and tropical storms are predicted to amount to over **90%** of direct losses (around **$89 billion**) between 2022 and 2050

The Philippines is ranked as the fourth most affected country in the world for water-related disasters.

Water risk in the Philippines

The Philippines is a tropical archipelago with more than 7,000 islands. Its extraordinary biodiversity is still preserved on many of the smaller islands, however over 70% of its forest cover was lost over the last century. Levels of water pollution are locally very high in many places due to a lack of wastewater treatment, affecting the health of communities and ecosystems.

Major infrastructure and population centres are located on the coastal plains, exposing them to flooding and storm events. In 2013, Typhoon Haiyan (known locally as Yolanda) killed 6,300 people and left 28,689 injured, 1.6 million homeless and more than six million displaced. Typhoon Rai in 2021 displaced 10.6 million people, yet the death toll was 457 people, showing the value of the early warning systems and other disaster risk reduction measures put in place.

Although a minority have many options for avoiding these risks, adaptation options are limited for the majority of citizens, due to their lack of resources. Despite the devastation bought about by frequent natural disasters, inadequate and intermittent water supply remains a challenge across the country; around one in ten Filipinos do not have access to improved water sources, with poorer communities being disproportionately affected.

The Philippines's Aquanomics data dashboard

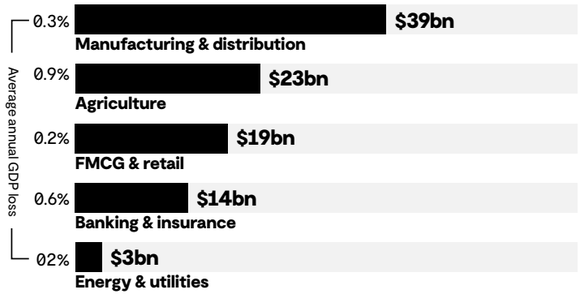
$124 billion

Total GDP loss between 2022 and 2050

0.7%

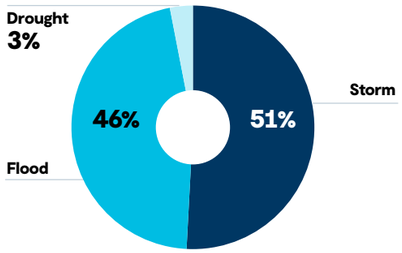
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

The Philippines is one of the world's fastest growing emerging markets in terms of population, urbanisation and industrialisation. With the population expected to increase by around 50% by 2050, prioritising ongoing investment in water infrastructure will be crucial over the coming decades.

Water supply and sanitation services are a key focus, with three million Filipino citizens currently relying on unsafe water sources, and seven million lacking access to improved sanitation. The Philippine Water Supply and Sanitation Master Plan calls for a total investment of around 1.1 trillion pesos to achieve universal access to water and sanitation for all Filipinos by 2030. GHD partners with the country's major water utility providers to achieve universal access to safe, sufficient, and sustainable water supply.

When it comes to flood management, investment needs to be targeted to building infrastructure in the right areas and working with nature to channel water away. This means carrying out flood studies and building infrastructure out of flood zones where possible, but this can be challenging when retrofitting solutions in densely populated urban areas.

Darren Shrives
Philippines General Manager
GHD

UAE

Turning risk into opportunity

Even though drought conditions are the baseline, and floods and storms are currently very rare, our Aquanomics model projects that the UAE will still face a degree of water risk (albeit low when compared to other countries and regions within this study). The country is expected to face a **$27 billion** total GDP loss between 2022 and 2050 due to changing droughts, floods, and storm conditions. The main sector-level threat to the UAE falls on its growing agricultural sector, which is projected to experience output losses of **0.5%** year-on-year due to water risk.

Due to its climate and developed economy, the UAE already has a highly advanced standard of water infrastructure across its regions, but the anticipated changing climate conditions – will require this baseline to be further transformed.

Water risk in the UAE

This cluster of Emirates contains a unique water risk profile across both the deserts and in the developed city oases. Apart from a few sparse wetland areas, the UAE's meagre water resources consist mainly of groundwater eked out by the expensive and energy-intensive desalination process. Rising temperatures and a greater frequency and voracity of dust storms are the major climate threats to the UAE and its ecosystems. Despite the baseline challenges, potable water is comparatively cheap, which facilitates one of the world's highest water usage rates per capita.

In recognition of these trends, the UAE Water Security Strategy 2036 was launched in 2017 and aims to boost sustainability and achieve a strategic set of water security goals. Due to its naturally inhospitable climate and developed economy, the UAE already has a highly advanced standard of water infrastructure across its regions, but the anticipated changing climate conditions – and ultimately ageing assets – will require this baseline to be further transformed to meet the desired future goals.

The UAE's Aquanomics data dashboard

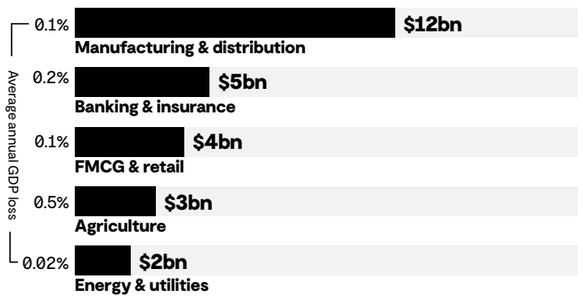
$27 billion

Total GDP loss between 2022 and 2050

0.1%

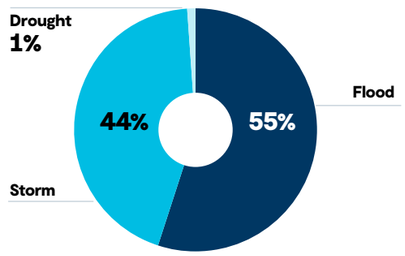
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

As one of the most water-scarce countries in the word, the UAE has become dependent on desalination to mitigate risk, with 42% of its potable water supply coming from the thermal desalination of seawater. But these processes come at a high economic and environmental price, and – looking to a future increasingly affected by the global climate crisis – this critical infrastructure is also at risk from rising sea levels.

The UAE needs less and better desalination, which will ultimately enhance water processes and mitigate severe environmental impacts. Applying a long-term perspective and increasing the use of innovative technologies such as water recycling and the use of renewable energy for desalination will be key to building resiliency in the country and enable targeted demand management. The strategic use of precious groundwater resources will also be crucial, particularly for the agricultural sector.

Currently, a large proportion of the UAE's infrastructure projects are funded by the region's oil and gas exports. But this industry is undergoing a huge transition, and appropriate long-term planning is needed to set the country up for a sustainable future. Sustainable transition needs to be a focus across the broad spectrum – and water should not be immune from that.

Andrew Saunders
UAE Transport & Infrastructure Market Leader
GHD

UK

Long-term flood risk

Our Aquanomics model projects that, in total, the UK could face a loss of **$153 billion** to GDP due to water risk between the years 2022 to 2050. It also estimates that it will lose over **$100 billion** over that period as a direct result of water risk, with flooding making up approximately **45%** of that total. That said, all things being equal, the model also projects that the global threat of droughts, floods and storms could lead to the UK's agricultural sector increasing its output slightly by 2050 to make up for other countries' reduction in output.

The global threat of droughts, floods and storms could lead to the UK's agricultural sector increasing its output.

Water risk in the UK

With a temperate climate, the UK faces relatively low levels of water risk. Resilience is high, and most people are protected from loss of their existing homes, assets and livelihoods through insurance. But, while the majority of the population has low rates of exposure and vulnerability to hazards such as droughts, floods and storms, there are pockets of the country that are disproportionately affected.

Climate change, population growth and the protection of delicate environments are leading to water shortages in parts of the Southeast. More than half the region's water comes from underground aquifers that rely on sufficient winter rainfall to meet rising water demands in spring and summer. Climate change will have a big impact on the variability and volume of rainfall, making long term planning with any certainty harder. The Southeast region typically experiences more droughts than any other region in the UK and the predicted hotter, drier summers will put even more pressure on homes, business, and the natural environment.

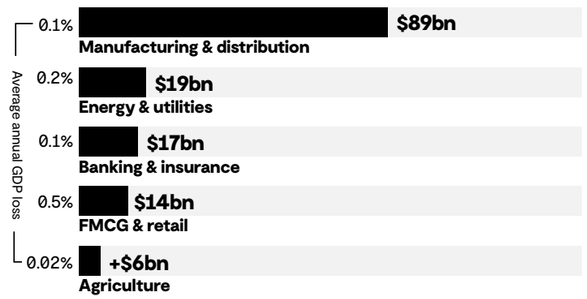
The UK's Aquanomics data dashboard

$153 billion

Total GDP loss between 2022 and 2050

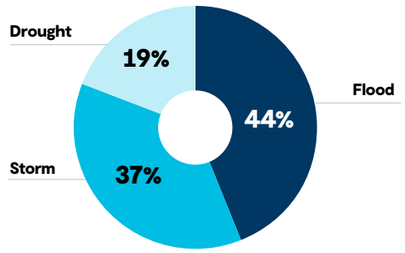
0.1%
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

In contrast, heavy rainfall across large swathes of the UK leads to flooding as rivers and sewers are unable to take away water quickly enough. Homes and businesses where sewer capacity is inadequate for the huge volumes, or where built on floodplains and vulnerable parts of the coastline, face increasing risks due to flooding and land erosion, with increasing social and economic pressures to relocate. Effective early warning systems and emergency services help to ensure that the risk of mortality and illness as a result of storms and floods remains low for the vast majority of the population.

The Water Services Regulation Authority, or Ofwat – the economic regulator of the privatised water sector in England and Wales – has pledged a spending package of £51 billion for 2020-2025. A quarter of this, £13 billion, is for new and improved services to help tackle challenges outside of day-to-day operations. This includes £1 billion to reduce the impact of future flooding and almost £500 million to help solve long-term drought resilience challenges. The Environment Agency has also promised investment of £5.2 billion to create around 2,000 new flood and coastal defences to better protect 336,000 properties in England by 2027, alongside support to help communities back on their feet more quickly after flooding.

Building future water resilience

The UK population is forecast to reach 75 million by 2050, with most of the rise expected to occur in areas already experiencing water stress. On a warming planet, extreme and irregular weather events such as floods and drought are expected to become more frequent, and the ecological health of our rivers is declining.

Building resilience and adaptability into our systems that collect, treat, store, and distribute water must be addressed now. Strategic water planning that ensures affordability, resilience and sustainability for the public, industry and the natural environment is urgently needed, but the scale and complexity present a real challenge for government, regulators, and water companies.

Effective infrastructure is critical for sustained economic growth and adequate well-being, but current investment levels are insufficient to repair our ageing water systems, expand systems to accommodate urban growth, meet stricter environmental regulations or adequately adapt to climate change.

The UK Government's proposed legislation (in the Environment Bill) provisions on nature – including biodiversity net gain, local nature recovery strategies and protected site strategies – are complimenting the drive to use natural systems to slow storm flows, store water and cleanse runoff. Green bonds or debt raised specifically for environmental purposes are being used to finance related investment.

Water intensive sectors such as energy, agriculture and manufacturing tend to pursue individual plans, however collaboration across these parties would enable more efficient water use. Bringing together water stakeholders is critical to meet increasing demand for water while maintaining a sustainable, vibrant and resilient environment that can respond to the major impacts that climate change is having on this vital resource. Circular economy approaches are now in the spotlight to help, but it is abundantly clear that the urgency to adapt and transform in the face of immediate and future challenges has intensified to a new level.

John Hensman
UK Water Market Leader
GHD

US (overall)

Infrastructure investment signals a new era

Our Aquanomics model projects water risk could result in a total loss of **$3.7 trillion** to US GDP between 2022 and 2050. For comparison, the recently passed Infrastructure Investment and Jobs Act includes approximately $1.2 trillion in spending on upgrading the nation's physical and infrastructure systems, with a package that includes transportation, broadband access, clean water and electric grid renewal. When it comes to direct losses, storms are predicted to account for **over half** of the overall damage ($1.4 trillion) followed by floods ($645 billion) and droughts ($432 billion). Manufacturing and distribution could suffer total output losses of **$2.2 trillion** by 2050 – but that only works out to **0.7%** of its average yearly loss. The agriculture industry, on the other hand – the most water-intensive industry – faces losses of **$143 billion** by 2050, but this is an average output loss of **1.2%** each year.

Storms are predicted to account for over half of the overall damage.

Water risk in the US

The United States is a highly diverse landscape, ranging from tropical conditions in the South to arctic and alpine conditions in Alaska and across the Rocky Mountains – this not only brings varying challenges for industry, supply chain and energy supply, but also means that water risk type varies greatly by location. Across the country, climate change is resulting in more frequent heat waves, extreme precipitation, larger wildfires, and water scarcity. When combined with outdated infrastructure, these catastrophes pose a significant threat to the economy and the wellbeing of its people.

This diversity also extends to the management of water, which is largely devolved to the state level. Individual states have substantial authority to establish and implement laws, policies and programs on water, appropriate to local needs. However, no single governmental level has complete authority over water management and rights: policies must be coordinated among all levels of government, as well as administrative commissions and independent regional agencies.

Collaboration to manage river basins and aquifers for water security becomes more complex, and many interstate water disputes are settled in the courts of law. However, widespread disasters can be declared at the federal level and thereby trigger federal funds for disaster relief. Coastal, riverine and urban flooding affects both communities and ecosystems. For instance, the Mississippi River Basin is the largest drainage system in the country, encompassing 31 of the 50 states.

US's Aquanomics data dashboard

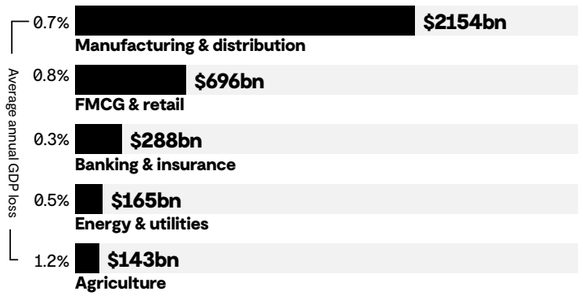
$3.7 trillion

Total GDP loss between 2022 and 2050

0.5%

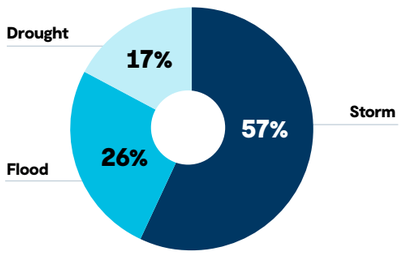
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

The Infrastructure Investment and Jobs Act (IIJA) provides a much-needed injection of funding for the water sector, which has long been starved of the capital needed to maintain vital infrastructure.

Building future water resilience across the US will require solutions as diverse as the types of water risk the country faces. Managing water scarcity caused by drought in California will require an entirely different approach to mitigating the worst impact of storm surges in the Gulf of Mexico. In the Northeast, flooding is the biggest problem, although replacing lead pipes in the drinking water system is also a key priority. In the Southeast, flooding and coastal protection top the agenda. For these regions, a focus on flood mitigation should be at the centre of any water resilience strategy.

However, what unites all these regions is the need to adopt innovative new solutions and technology – which the US has in abundance – and to pursue an approach of radical collaboration between all stakeholders.

Don Holland
Americas Water Market Leader
GHD

Northeastern US

States included:

- New York
- Pennsylvania
- Maryland
- Delaware
- New Jersey

Northeastern US

Ageing assets due for an upgrade

With estimated total GDP losses of over **$700 billion** between 2022 and 2050, our Aquanomics model projects that the states that make up the Northeastern region of the US face a significant economic hit. The region also could face direct losses of **$434 billion** in the years leading up to 2050, with well over half of that figure ($288 billion) attributed to flooding.

In percentage terms, it is the region's FMCG and retail and agriculture sectors that could be particularly affected, with projected annual output losses of nearly **3%**. However, the Northeastern US's huge financial sector (incorporating the financial hubs of New York City and Delaware) is predicted to be relatively unscathed with projected output losses of just **0.1%**.

Building future water resilience

The Northeastern US is a water-rich environment with advanced systems to manage flood risk and potential storm damage. However, water quality remains an issue in some areas due to ageing infrastructure, which will require significant investment to rectify over the coming decades.

The Northeastern region of the US faces a significant economic hit.

Water risk in the Northeastern US

The Northeastern region is characterised by a fairly diverse climate, with bitterly cold winters often bringing extreme weather in the form of ice storms and snowstorms (including the infamous 'nor'easters' – massive storms blowing from the northeast) and semi-humid summers, especially to the south. The region suffers from ageing infrastructure, with much of it having been constructed over a century ago. Many older cities' sewer and stormwater systems simply cannot handle the volume of water produced by heavy storms, and many areas have toxic lead pipes supplying drinking water, which need to be replaced.

However, the exposure and vulnerability of the population are relatively low due to effective and widespread early warning systems. While Hurricane Ida caused a huge amount of economic disaster losses in the Northeastern US (over $18 billion) due to flash flooding and tornados, the number of fatalities was relatively low. Emergency situations may lead to the temporary displacement or evacuation of large numbers of people; however, most are able to return home and rebuild due to high levels of insurance cover and federal support, as was notably the case following Hurricane Sandy in 2011.

The Northeastern US's Aquanomics data dashboard

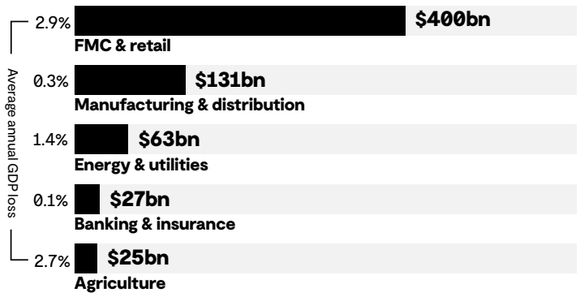
$718 billion

Total GDP loss between 2022 and 2050

0.6%

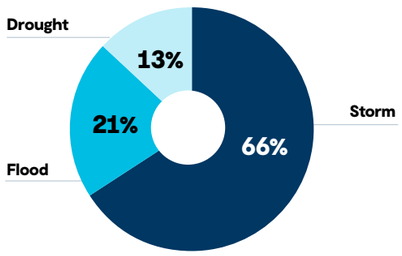
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Mark Abbott
Regional Water Market Lead, East
GHD

Southeastern US

States included:

- Florida
- Georgia
- Virginia

Southeastern US

Facing stormy weather

Our Aquanomics model projects that the Southeastern region of the US could face total GDP losses of over **$400 billion** between 2022 and 2050 due to droughts, floods and storms – representing an average annual loss of **0.5%** to the economy.

At **$176 billion**, the greatest estimated direct losses faced by the Southeastern states in the years between 2022 and 2050 is from storms – accounting for over 70% of total direct losses. In terms of industry, the region's FMCG and retail sector will be hit hardest; it is projected that the sector will lose **$227 billion** due to water risk by 2050, representing an average annual output loss of **1.9%**.

Rapid urbanisation and growing, shifting populations are putting pressure on water supplies and water quality.

Water risk in the Southeastern US

The Southeastern US generally receives a lot of rain and is considered water rich. The region is also home to iconic wetlands and water environments including the Everglades in Florida. However, rapid urbanisation and shifting populations are putting pressure on water supplies and water quality. This is likely to be compounded by increasing coastal flooding threats. Not only does this pose a threat to communities, limiting safe water supply, but to fragile aquatic ecosystems and agriculture.

In 2017, Hurricane Irma – and the ensuing heavy rains and storm surges – caused widespread destruction across the Southeast. The disaster resulted in over one hundred fatalities and an estimated $50 billion in damage – making it the fifth-costliest hurricane to hit the mainland US sinch 1900. Due to the increasing number of storms and hurricanes, flood protection is a high priority.

The Southeastern US's Aquanomics data dashboard

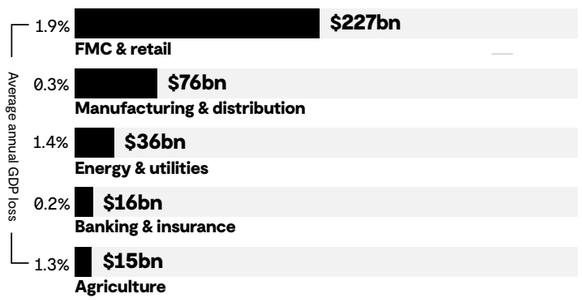
$406 billion

Total GDP loss between 2022 and 2050

0.5%

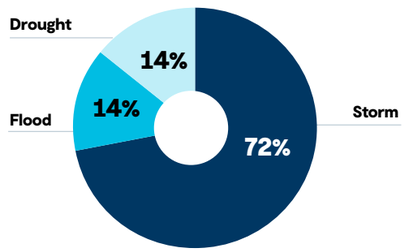
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

Building future water resilience

Water issues in the Southeast are complex and interconnected systems with diverse sets of stakeholders. Initiatives like resiliency are dictated by a myriad of considerations, impacted by growth, land use and environmental management. Because of these relationships, planning for water resilience in the Southeast is not simple nor straightforward. Organisations require new innovative approaches that help understand and navigate the process of building capacity to function in the face of water-related stresses to allow cities and citizens to survive and thrive. Digital solutions will be required to prioritise efforts and action, bring clarity to the vision of resilience, centralise knowledge and data, and leverage existing sensors and telemetry already embedded in systems and environments of these organisations.

With the climate crisis increasing the frequency of extreme weather events, the water sector and local municipalities must ensure the long-term resiliency of water infrastructure. Taking stock of the current state of coastal water infrastructure and assessing which areas are vulnerable to flooding or storm surges should be the start of any water resiliency strategy. With this insight, recommendations for improvements can be made including "dry flood proofing" – reinforcing the structure to withstand floods – or "wet flood proofing" – allowing flood water to enter the building but protecting the contents of the building from water damage.

Real-time data analysis can also provide municipalities across Florida, Louisiana, Georgia and Virginia with improved flood risk intelligence. Combined with real-world network controls like valves and sluice gates, this is one of the most effective ways to improve the water resiliency in a region – such as Southeastern US – that is subject to extensive flood and storm damage.

Freddie Guerra
Digital North America Water Market Leader
GHD

Southwestern US

States included:

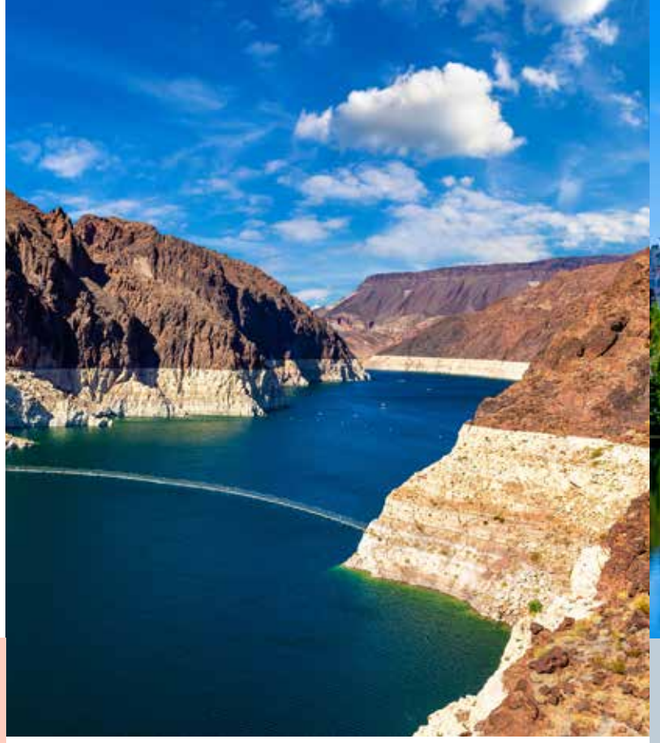
- California
- Nevada
- Arizona
- Texas

Southwestern US

Home of the megadrought

In less than 30 years (2022 to 2050), the Southwestern US is projected to face a total loss of over **$1.4 trillion** to GDP due to water risk. This means not only is the Southwest expected to face a greater economic hit than the other US regions in our study, but also than every country in the study, apart from the US overall. The region is particularly at risk from droughts, which account for **$178 billion** of estimated direct losses. On a sector level, the Southwestern US's FMCG and retail sector could be particularly exposed, with a projected average annual output loss of 3.5% – representing total output losses of **$819 billion** by 2050.

.



The Southwest is currently experiencing a megadrought.

Water risk in the Southwestern US

Although our Aquanomics model estimates that storms and floods will take a higher toll in terms of direct losses, the social and environmental impacts of drought are more widespread. The Southwestern US is the hottest and driest region, where the availability of water has defined its landscapes, people and economy. Its magnificent yet arid landscapes and ecosystems are increasingly under threat from water scarcity, compounded by a growing population and ageing infrastructure.

Forested areas are subject to massive wildfires as the region continues to dry. Iconic rivers such as the Colorado River and the Rio Grande – shared with Mexico – are retreating as water overuse and drought take their toll. As of June 2022, water levels in Lake Mead were at their lowest since the Hoover Dam was built in the 1930s. Groundwater levels are also dropping, forcing a move across the region towards increasing levels of water management and conservation.

The Southwest is currently experiencing a megadrought (a drought lasting two decades or more) – the longest and most severe experienced by the region in 1,200 years. This is bringing disruption to agricultural production and affecting homes and businesses, with the poorest members of the population being the most vulnerable to loss of employment and lack of water supply.

The Southwestern US's Aquanomics data dashboard

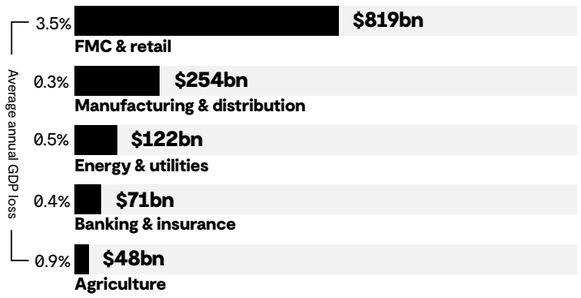
$1.4 trillion

Total GDP loss between 2022 and 2050

0.8%

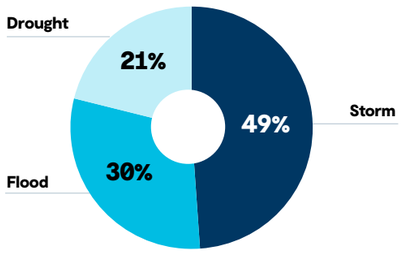
Average annual GDP loss

Total output losses by sector



Data showing total sector output losses in USD (billions) between 2022 – 2050

Direct losses by event type



Data showing direct losses by weather event type between 2022 – 2050

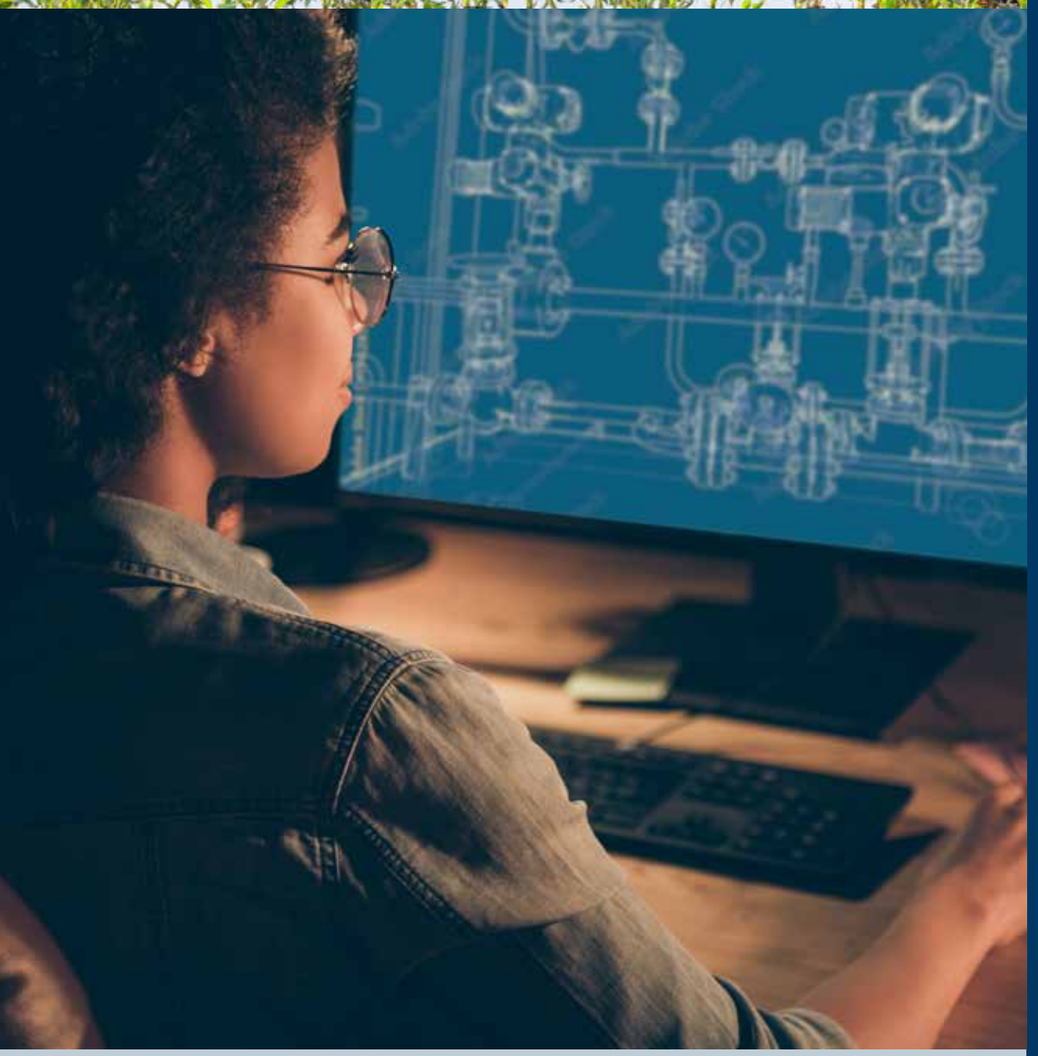
The Southwestern US is on the frontline of international drought pressures and, as the local population continues to increase and the demand for water rises, there is an urgent need for new water sources.

With groundwater resources depleting, and PFAS and other emerging contaminants threatening the quality of these supplies in areas such as Southern California, water conservation, reuse and recycling must step in to fill the gap. The Southwestern region has long been at the forefront of drought mitigation innovation, with the largest, most technologically advanced and energy-efficient seawater desalination facility in the US being opened in California in 2015. Utilising wastewater and stormwater through methods such as indirect and direct potable reuse will also be essential for building resiliency across the region.

Digital solutions that incorporate data, advanced analytics, and intelligent asset management are opening up new ways to combat water risk. Utilities and governments are already using GIS mapping processes and digital tracking systems to increase the capability of groundwater systems to stop depletion and degradation.

Ultimately, what is needed is close partnerships between policymakers and industry to deliver an Integrated Water Management (IWM) approach. This must consider the entire water cycle, identifying a mix of solutions and bringing maximum benefit at an affordable cost to both consumers and commercial water users across the Southwestern US.

Mark Donovan
North American Water Treatment and Desalination Lead
GHD



Methodology

The economics of water risk and future resilience utilised a three-phased methodology to estimate the direct losses, sector losses and GDP losses that will be attributed to water risk (droughts, floods and storms) between 2022 and 2050. The study focuses on seven key countries across GHD's footprint – Australia, Canada, China, the Philippines, the UAE, the UK and the US – and three US regions – Northeastern US, Southeastern US and Southwestern US. This study has focused predominantly on countries within the developed world to show that they – alongside the developing world – will be affected by water risk.

Phase

01

Projecting direct water risk losses at key dates

Global insurance data was used to project the potential direct losses attributed to water risk (droughts, floods and storms) across the 11 geographies. This data is derived from Ortec Finance's climate PREDICT model[6] which itself comprises several databases including the UN World Urbanization Program, NASA's Socioeconomic Data and Applications Center (SEDAC), National Centers for Environmental Information's NOAA climate data, and Munich Re disaster/loss data. This is reported as the total direct losses between the years 2022-2050 and in currency terms (USD) by water risk type for each region.

6 Ortec Finance Climate PREDICT model quantifies the increase in frequency as well as impact (direct financial losses) of extreme weather risk per type of event (i.e. droughts, storms, floods) per different climate scenarios. Find out more: https://www.ortecfinance.com/en/insights/product/climate-predict

Phase

02

Estimating future losses from water risk by sector

We conducted a review of relevant literature into the effects of drought, flooding and water-related storm damage on five economic sectors. This was based on a total review of 19 research papers which provided model inputs into the impact of water risk by sector. The findings from the literature review were adjusted to reflect the sectoral composition of the selected regions.

Focus sectors

Agriculture

- Crop and animal production, hunting and related service activities

Banking and insurance

- Financial service activities, except insurance and pension funding
- Insurance, reinsurance and pension funding, except compulsory social security
- Activities auxiliary to financial services and insurance activities

Fast Moving Consumer Goods (FMCG) and Retail

- Manufacture of food, beverage, and tobacco products
- Manufacture of basic pharmaceutical products and pharmaceutical preparations
- Retail trade

Energy and Utilities ('Energy'; includes Coal; Oil & Gas; Electricity; Gas Supply; Water Supply)

- Mining of coal and lignite
- Extraction of crude petroleum and natural gas
- Manufacture of coke and refined petroleum products
- Electricity, gas, steam and air conditioning supply
- Water supply, sewerage, waste management and remediation activities

Manufacturing and Distribution (includes all Manufacturing subsectors; Distribution)

- All manufacturing subsectors
- Wholesale trade

Phase

03

Modelling wider economic impact of water losses at key dates between 2022 and 2050

The water risk loss data from stages 1 and 2 (estimated direct sector losses) was inputted into the E3ME economic model[7] as 'shocks' to ascertain the total economic impact of water risk across the 11 focus geographies.

These impacts include:

- Direct effects – from direct losses to different sectors and households (using data from Phase 2)
- Indirect effects – adjustments to price (including energy price) and government spending, as well as investment impacts caused by the capacity shocks
- Wider effects – impacts on supply chains, international competitiveness, employment, income, and consumption

These impacts were then combined and reported in currency terms (total GDP USD losses between 2022 and 2050) and a percentage of annual GDP.

Global heating assumptions

As global heating intensifies, extreme weather events are expected to increase, resulting in greater water risk to countries and regions. Unless otherwise stated, the figures in this study assume a 2-degree rise in global temperatures in line with the 'absolute cap' in global heating agreed by governments in the 2015 Paris Agreement.

Credits

Research design and concept development by GHD and Man Bites Dog. Economic modelling conducted by Cambridge Econometrics. Additional qualitative research into the environmental and social impact of water risk provided by Dr. Ania Grobicki, former Deputy Director of External Affairs at the Green Climate Fund and Executive Secretary of the Global Water Partnership.

7 The E3ME model is a dynamic computer-based macroeconomic model of the world's economic and energy systems and the environment. Find out more: www.e3me.com

Floods

Storms

Droughts

Floods

Storms

Droughts

Floods

Storms

Droughts

Floods

Storms

Droughts

Floods

Storms

Droughts

Floods

Contact us

Helping you respond to a rapidly changing world

Together with our clients, we're collaborating on new solutions that will deliver more for our communities in an ever-changing world. We call this Future of Water – it's our commitment to help you pre-empt and prepare for what's next.

Rod Naylor

Global Leader, Future of Water,
GHD

E: Rod.Naylor@ghd.com

About GHD

GHD recognises and understands the world is constantly changing. We are committed to solving the world's biggest challenges in the areas of water, energy and urbanisation.

We are a global professional services company that leads through engineering, construction and architectural expertise. Our forward-looking, innovative approaches connect and sustain communities around the world. Delivering extraordinary social and economic outcomes, we are focused on building lasting relationships with our partners and clients.

Established in 1928, we remain wholly owned by our people. We are 10,000+ diverse and skilled individuals connected by over 200 offices, across five continents – Asia, Australia, Europe, North and South America, and the Pacific region.

→ ghd.com/aquanomics