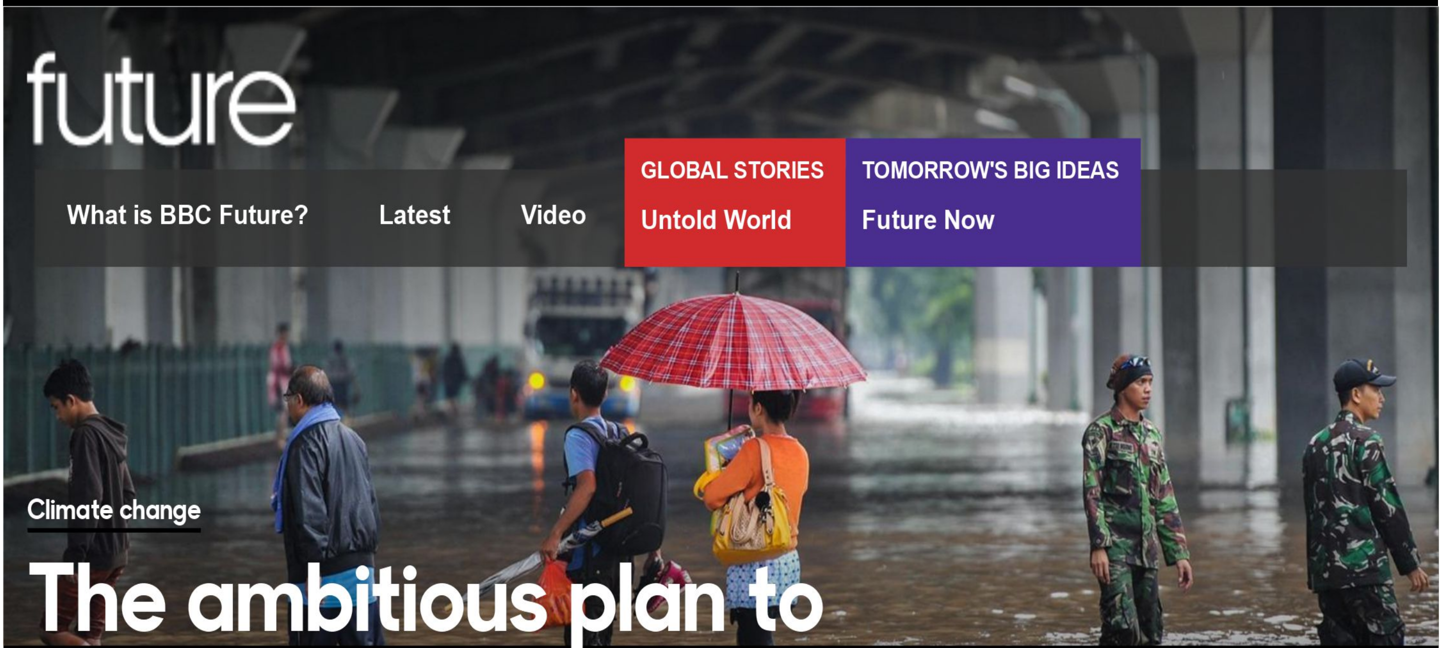
BBC

future

What is BBC Future? Latest Video GLOBAL STORIES Untold World TOMORROW'S BIG IDEAS Future Now



Climate change

The ambitious plan to stop the ground from sinking

Our thirst for drinking water is causing severe subsidence in many areas around the world, putting them at risk of flooding. But some communities are trying to solve the problem.

By Amanda Ruggeri
1 December 2017

From Miami to Jakarta, coastal communities around the world are battling the effects of sea level rise.

But in some places, the problem is exacerbated by another phenomenon: the land is falling.

The Indonesian capital, for example, is sinking up to 17cm (6.7 inches) per year. “That’s an issue, because they’re right at sea level,” says Michelle Sneed, a land subsidence specialist at the **US Geological Survey** (USGS). “They have this added pressure of increased flooding and sea level rise. They built seawalls. But the city is subsiding so quickly that, at high tides, water just pours over.”

A man rides his motorcycle along a flooded street in Jakarta, a city facing the twin challenges of sea level rise and subsidence (Credit: Alamy)

Partly because of examples like Jakarta, subsidence often gets misinterpreted by climate change sceptics, who argue this phenomenon alone explains increased flooding in coastal areas. The reality is more challenging. Both sea level rise and subsidence are happening at once. But while sea level rise is a global issue caused by the warming of the oceans and melting of the world’s ice caps, land subsidence is a local problem, affecting some communities but not others.

In coastal areas unlucky enough to be hit by both phenomena, the risk of flooding can be severe. And although inland communities are unlikely to suffer much from sea level rise, many, including Mexico City and California’s San Joaquin Valley, are grappling with the challenges posed by sinking land instead.

You might also like:
- ***Miami’s fight against rising seas***
- ***Could we tap water from thin air?***
- ***The frozen danger hidden under US soil***

But there is good news. While most scientists agree that rising sea levels only can be mitigated by lowering carbon emissions, which will require global consensus, communities can take control of their own land subsidence.

"If water is high because of sea level rise, then you have to address the entire world," says University of Utrecht geologist and subsidence researcher Gilles Erkens. "In some ways, that makes it easier to address land subsidence, because you only have to look at a local area."

> *If water is high because of sea level rise, then you have to address the entire world. In some ways, that makes it easier to address land subsidence – Gilles Erkens*

Some cities, including **Shanghai** and **Tokyo**, have already solved the problem. Other communities, like the Hampton Roads area of eastern Virginia, are now coming up with their own creative solutions.

If you're surprised to hear that subsidence is a localised (or solvable) problem, you may be thinking of one kind of vertical land motion: **global isostatic adjustment** (GIA). A hangover from the last Ice Age that occurred around 12,000 years ago, GIA is the rebound of Northern Hemisphere land after it was freed of the weight of billions of tonnes of ice. While the areas once under the now-melted ice are rising, those on the edges are falling in response.

Imagine poking a balloon with your finger. You'd create an indent, as well as a bulge around your fingertip. When you release your finger – much like melting the ice – the indent bounces back while the bulge goes down. In North America, the spot with the indent is Canada and Alaska, while the bulge is the mid-Atlantic.

Stretch that millisecond-long experiment over millennia and you have something similar to what is happening to the Earth right now. But as you might expect, GIA is a relatively slow process and should not be confused with the more dramatic subsidence affecting some communities.

When subsidence is this dramatic, it isn't due to global isostatic adjustment (Credit: Alamy)

"If a localised area is seeing its land sinking significantly, it's not because of global isostatic adjustment," says NOAA's Philippe Hensel. "At a maximum, global isostatic adjustment is going to be pretty minor."

The most significant increase in height due to GIA, in places like Alaska and Canada, is nearly 10mm per year, says Hensel. But those areas that are moving downwards because of GIA are falling by a maximum of 1mm or 2mm annually.

Water slide

For most communities around the world, therefore, the reason for significant subsidence is something entirely man-made: groundwater extraction.

"Everything you extract from the underground results in subsidence," says geologist Simone Fiaschi, who studies subsidence at the University of Padova. "You remove something from the layers the terrain is made of, so the ground starts to collapse."

That means other types of extraction, such as removing methane gas or oil, can also produce the same effect. But groundwater, one of the most important sources of fresh water supplies in the world, is usually the culprit. In India, **the world's largest user of groundwater**, 85% of drinking water comes from the ground; in Europe, **75% of the population** gets drinking water from groundwater.

> *In many parts of the world, the ground is being emptied of water faster than it has time to recharge – which can cause the soil to compact*

And then there are all of the other uses. In the US, for example, **irrigation for agriculture** accounted for the withdrawal of 225 million cubic metres (49.5 billion gallons) of groundwater per day in 2010 – 60% of the total removed from the ground. That's enough water to fill up an empty Lake Tahoe, California's largest lake by volume, in less than two years.

Groundwater is supposed to replenish itself naturally from rain and snowfall seeping through the rock. In many parts of the world, though, the ground is being emptied of water faster than it has time to recharge. This can lead to **depletion of the water table** and dwindling water supplies – but also can cause the soil to compact so that the layers on top drop, sometimes significantly.

Mexico City, for example, depends upon a local aquifer for about half of its potable water. Thanks to a combination of the city's vast population of 21 million people and inefficient water use – 42% is lost to leakages – the aquifer is being overdrawn. At this rate, it will be empty within 50 years, says Arnoldo Matus Kramer, the city's chief resilience officer. In the meantime, parts of the city are sinking by 30cm (12 inches) per year.

Some of Mexico City's neighbourhoods are sinking by up to 30cm (12 inches) per year (Credit: Alamy)

As a result, the city is trapped in a vicious cycle where subsidence damages the water pipe infrastructure and makes it more difficult to maintain, which leads to more leaks and more water being withdrawn. And as well as making the city more vulnerable to water shortages, subsidence also may have made some buildings more vulnerable to Mexico City's recent **earthquake**, says Kramer.

Exactly how much of the world is affected by subsidence is hard to say. "We're still trying to get the data for places around the world," says Erkens. "For many places, we don't know exactly what's happening, which also hampers our options for dealing with the challenges."

Still, from the data available, scientists agree that they've seen something promising.

> *Stopping groundwater pumping can halt subsidence – and even help the land rebound*

Stopping groundwater pumping can halt subsidence – and even help the land rebound.

Cities have proven it before. After decades of groundwater extraction in Tokyo, the land began to sink more and more, peaking in 1968 at 24cm (9 inches) per year. At around the same time groundwater pumping in the city also reached a high of 1.5 million cubic meters (329 million gallons) per day. In response, Tokyo's government passed laws limiting pumping. By the early 2000s, **the city's subsidence slowed to 1cm** (0.4 inches) a year.

Much of San Joaquin Valley's agriculture has shifted to water-intensive permanent crops like vineyards, worsening its subsidence (Credit: Alamy)

But halting pumping requires changing the main source of a city's water. And for some areas, that may not be possible. The San Joaquin Valley, which spreads across some 25,900 square km (10,000 square miles) in the centre of California, relies on groundwater for its main industry – agriculture. Exacerbated by the recent drought, **parts of the region have begun to sink by up to 60cm (2ft)** per year.

"That's among the very fastest in the world," says the USGS's Sneed, who is based in California. Worsening the problem has been a recent change toward more water-intensive practices as agriculture has shifted from rotation crops like tomatoes and peppers to permanent crops like orchards and vineyards.

Although subsidence here isn't causing flooding, it's still undermining the area's infrastructure. One example is its massive canal system, which it uses to move water around the area. Parts of the valley are subsiding at different rates, causing the gravity-reliant canal system to fail. As a result, California legislators signed a law in 2014 to ensure that groundwater use doesn't cause unreasonable land subsidence.

Since its construction, this bridge over a canal in San Joaquin Valley has sunk about 1 metre (4ft) as the land has subsided (Credit: Alamy)

How that will be done, though, has yet to be determined. Relying on alternative water sources seems unlikely, according to Sneed, as California doesn't have much capacity for further reservoirs.

"I think they're starting to realise what a monumental task it will be," Sneed says. "Locals are going to have make some very hard choices that they haven't had to make before on how they use their land."

Pumped up

One way cities like Shanghai have tackled the problem is by not only limiting pumping, but by recharging their aquifers. An even more creative solution, though, is being developed in Virginia.

There, the southern part of the Chesapeake Bay region, known as Hampton Roads, is threatened by three different forces. This is an area at the edge of the now-melted ice –

“

At about 2.8mm per year,

the single biggest contributor to flooding in Hampton Roads is groundwater pumping

so while GIA here is around 1mm per year, that rate of drop is still among the fastest in the world. The second problem is sea level rise, contributing around another 2mm per year.

But at about 2.8mm per year, **the single biggest contributor is groundwater pumping** from the massive Potomac aquifer.

In an area this flat, those millimetres add up. The area suffers **frequent flooding**, as well as saltwater intrusion into both the aquifer and into delicate wetlands that are in danger of being inundated.

Ted Henifin is the general manager of the Hampton Roads Sanitation District. A few years ago, his team started to wonder if there was a better use for the wastewater that they were processing and dumping into the mouth of the Chesapeake. "It's not like the water we put back into the waterways is used by anyone else, or even needed," he says.

So what if they could use the water for something of value? That train of thought led to an innovative new project called **Swift**. Instead of dumping the water, the project will treat the wastewater – which totals some 682,000 cubic metres (150 million gallons) each day – to standards that will meet that of drinking water. It will also be given the exact same profile, including the salinity, as the groundwater. Once it's been processed, the water will be pumped back into the aquifer.

Flooding is worsening in the Hampton Roads area of Virginia, including at homes like this one (Credit:

Alamy)

The project is still starting out, with the goal of getting permits in 2019 and injecting 45,500-91,000 cubic metres (10-20 million gallons) a day by 2023. But the models have already found that adding the water can increase pressures as far as Maryland and North Carolina.

"With the total aquifer compaction that would have been seen without our project, if we continue with the permitted withdrawals that we've got to the end of a 50-year period, there's a total compaction, in the worst areas, of about 2ft (61cm)," says Henifin. "If the same model is run with our water going in, we eliminate that entirely."

If the project works, the plan is to scale up to full capacity, 545,000 cubic metres (120 million gallons) a day, by 2030 – and then replicate the programme in wastewater treatment plants across other counties.

> *This idea may be the only one we've come up with that may buy some time for our region – Ted Henifin*

David Nelms, a USGS scientist who has been involved in the project, cautions that it may not be a panacea. As elsewhere, the ground here is layered with both clay and sand. Extraction over the last century has compacted both layers. When water is injected, though, it will 'pump up' only the sand. The clay remains compacted. "You will never get that back," says Nelms. "That's permanent. But [the project's] sites are scattered and the geology is different in each one of them, so you should expect different responses in different places."

Land subsidence may be a complicated problem. But with projects like Swift aimed at tackling it, there may be reason for optimism – not only to fix subsidence, but to mitigate its twin challenge of sea level rise. "In terms of can we do something about sea level in our lifetime, this idea may be the only one we've come up with that may buy some time for our region," Henifin says.