



For centuries, the Netherlands has suffered from catastrophic floods. As the rest of the world now reckons with the same fate, the Dutch are sharing—and selling—what they've learned.

By Jeff Chu
Photographs by Mishu de Klerk

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The Waterborne House
Architect Hsiao Othuis
astride a floating villa
he designed in the village
of Rotterdam



HUIB DE VRIEND WAS 5 YEARS OLD WHEN THE GREAT FLOOD OF 1953 HIT. IT WAS A CHILLY SATURDAY NIGHT,

and the local radio stations had gone off the air at their usual hour near bedtime, just before the full force of the storm blew in. What shook young Huib more than the whistle of the wind or the thrum of the rain was the panic in his grandmother's voice. "She was yelling, 'The water is coming! The water is coming!'" he recalls. That was when he knew something was wrong. His grandmother was usually a voice of calm in the family.

They fled to the attic. Huib's father ventured down to the ground floor, which had filled like a bathtub, to raid the pantry for provisions. A few days later, soldiers arrived in dinghies to help the de Vriendts evacuate to their local church, which was built on the village high ground; not long after, they were moved by rail to a town 10 miles away, where Huib attended kindergarten for several weeks before his family was allowed to return home. "Only later did I realize that my grandmother belonged to the generations with an inherited fear of water," he says. "She never even learned to swim. It was not normal to swim. So you can imagine that even a meter of water was enough to make them nervous."

The de Vriendts survived, but more than 1,300 other compatriots did not. Three hundred thousand Dutch were left homeless, and one-tenth of the nation's farmland flooded. The famously pragmatic Queen Juliana, who had banned her subjects from bowing and curtsying to her, pulled on rubber boots to join the relief effort. "God," she declared, "now calls upon our powers of resilience."

In the Netherlands, that resilience ultimately meant far more than a respect for the Dutch. For Huib, the de Vriendt grew up to become a coastal and fluvial morphologist, a kind of scientist that studies the dynamics of shores and rivers. Though he insists the floodwaters did not set his career path, he acknowledges that "you don't forget

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something like that." (He also learned to swim.) He meanwhile became part of a growing army of engineers, designers, and scientists who since 1953 have made it their life's mission to work with water, as the Netherlands built itself into the world's premier laboratory for how to tame the rivers and the sea. Today, the country's ideas and expertise may be its most valuable export. "Retreat is not an option, though we know it's dangerous. The only option is to protect ourselves," says Free University of Amsterdam professor Jeroen Aerts, the world's foremost expert in flood-risk management. "If we invest right now in innovative measures, we can avoid a lot of damage in the future."

Visitors who come to the Netherlands in the hopes of seeing a floodproof system of flood control that they can easily duplicate back in their home countries are bound to be disappointed. The Dutch have learned the hard way that no single solution will suffice. Their rebuilding efforts since 1953 have evolved away from post-disaster clichés—We'll show the storm who's boss!—to something far more sophisticated. What you see there now, especially what has been built in the past few years, is indeed the architecture of the future, as the fight against rising tides goes global. But it's also the attitude of the future. The Dutch have lately been working with nature instead of battling it, lowering barriers against the water instead of raising them. They're harnessing the power of the cloud—enormous amounts of data and cutting-edge computer modeling—to predict the consequences of the clouds. They're building seawalls so beautiful you wouldn't recognize them, and as discovered, the most important lessons they are trying to impart might not be about dikes and dunes at all.

Nearly half of the world's population lives within 60 miles of the sea, and hundreds of millions more reside in river valleys. In Hong Kong and Singapore, New York and Shanghai, thousands of acres of new waterland have been created through the magic of land reclamation—and then stacked with luxury condos and gleaming office towers. Yet the risk of coastal living has grown in lockstep with that land's soaring

value. Seas are rising. And land is sinking. The soil under Jakarta, Indonesia, is collapsing 4 inches a year.

As scientists predict a wetter, stormier future for much of the planet, the Dutch have become a nationwide consulting company, fanning across the world to talk about water. They are working on water-related projects from the Mississippi to the Mekong, and their thinking was a cornerstone of New York's \$40 billion post-Hurricane Sandy protection plan (see page 104). "We are branding this knowledge around the globe, and we are benefiting from it," says Piet Dircke, who is widely known as the "water guru" at the Amsterdam-based engineering and consulting firm Arcadis. "You don't need too many Dutch," he says, "but a few can help you a little bit." Dircke is a jovial evangelist for better water management, who speaks of dikes with a passion usually reserved for football teams and refers to New Orleans's revamped levees as "absolutely fabulous!" He spends about 200 days a year away from home, and his recent itinerary reflects the demand for Dutch help: Bangkok, Jakarta, Ho Chi Minh City, Dhaka, Shanghai, New York, New Orleans, Los Angeles, San Francisco.

When Dircke started at Arcadis 20 years ago, it was mainly a Dutch company—"95% of our business was Dutch," he says. Last year, just 12% of the firm's \$5.5 billion in revenue came from the Netherlands; the U.S. was by far its largest market. Arcadis is working with the Army Corps of Engineers on wetlands reclamation in the Mississippi Delta. It is helping to restore the Los Angeles River's natural flow. And it did hydrological modeling work for the Bloomberg administration on Jamaica Bay in New York, helping it lead to more post-Sandy flood-protection business. "If I were a New Yorker, I would be very excited," he says. "How fantastically interesting!" And for the Dutch, how fantastically lucrative. It's undeniable, says Matthijs van Leden, an executive at the

THE DUTCH NOW CONSULT EVERYWHERE FROM BANGKOK TO JAKARTA, FROM DHAKA TO NEW YORK. THE SURGE IN GLOBAL DISASTERS HAS MEANT A SURGE IN DUTCH BUSINESS.

CARVING A NEW CHANNEL FOR THE RIVER WAAL WILL TRANSFORM THE CITY OF NIJMEGEN—AND MAKE IT SAFER.

A RIVER RUNS THROUGH IT



The River Waal has brought trade and wealth to 2,008-year-old Nijmegen, the most ancient city in the Netherlands. But it also presents danger. Nijmegen sits at a flood-prone river bend that is one of the narrowest in the nation. In 1995, tens of thousands of residents were forced to evacuate after heavy rain and snow upstream in the Alps swelled the Waal.

The Challenge
Sixteen miles upstream, a dam burst, sending a surge of water hurtling toward Nijmegen. The surge was 10 feet high and 100 feet wide. It hit the city in 1995, forcing thousands of residents to evacuate.

The Solution
An engineering firm will be hired to design a new channel for the river. The new channel will be 10 feet deep and 100 feet wide. It will be built in a series of sections, starting with a 100-foot section in 2013 and a 200-foot section in 2015.

The Benefits
The new channel will reduce the risk of flooding in Nijmegen. It will also create a new park area and a new residential area. The project will also create 100 new jobs.

The Residents
The residents of Nijmegen are excited about the project. They are looking forward to the new park area and the new residential area. They are also excited about the new jobs that will be created.

ILLUSTRATIONS BY BRIAN CHRISTIE DESIGN

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The Steelth Defense:
Age Flutman in the
Schiedamschenpolder. Steps
and curves disguise a slope
harder to stormy seas.



engineering firm Royal HaskoningDHV, that the surge in Dutch business is closely related to the surge of global disasters. After Katrina, van Leden moved to New Orleans for four years to lead a team that helped the Army Corps strengthen the city's levees. Governments fund most of the water business, but lately, Royal HaskoningDHV has seen strong growth in corporate spending too. In Thailand the 2011 floods crippled factories of multinationals like Honda and Canon, stalling their supply chains. Today, they're devising their own risk-reduction plans. "They could wait for the government," van Leden says, but in many locations they are choosing to move forward independently, and as fast as possible.

While these Dutch companies are competitors, they also collaborate. Arcadis, Royal HaskoningDHV, and a third major Dutch contractor, Boskalis, won business in Louisiana after teaming up with the Dutch government on a post-Katrina plan that offered the Army corps a group of specialists including de Vriendt. They did the same for New York after Sandy last year. All three companies also belong to a research consortium that is testing new

flood-protection solutions in the Netherlands. Meanwhile, five smaller engineering and design firms have banded to form an export-focused group called Dutch Water Design, which now has projects in Belgium, Brazil, and India.

Dutch ambitions go well beyond retrofitting. Architect Koen Olthuis's atelier, Waterstudio.nl, does only water-based projects and has designed several floating houses in the Netherlands. Now, in the Maldives, he—in partnership with the developer Dutch Docklands—is building a resort, complete with an 18-hole golf course, that will float entirely on a Styrofoam-and-concrete foundation. He sees it as an early step into a wholly new market; eventually, he'd like to build floating homes for the poor in the Maldives and Bangladesh. "Building on water gives so much

"IT TOOK US ABOUT 10 CENTURIES TO DEVELOP A LONG-TERM STRATEGY," SAYS ONE DUTCH ENGINEER. "BECAUSE SHORT-TERM MEASURES DID NOT WORK."

A NEW NEW AMSTERDAM?

In 2011, when Hurricane Irene hit New York, it prompted city officials to ask Dutch experts Jeroen Aerts for advice on flood protection. Halfway through Aerts's study, Sandy hit. Its tropical-storm-force winds extended 1,000 miles, steering the storm surge that caused much of the \$27 billion in damage to New Jersey and \$19 billion in destruction to New York. The storm demonstrated how much more preparation was needed—and also why New York placed third behind Tokyo and Miami of major coastal cities in a recent ranking of flood vulnerability.

Mayor Michael Bloomberg's new \$20 billion storm-protection plan offers more than 250 initiatives to reduce risks, including ideas suggested by Aerts. (Not all the Dutchwads were headed—see below.) Aerts deems the Bloomberg plan "good." But asked to name what's most needed for a strong flood-defense system, he doesn't choose seawalls or even money. "Courage," he says.

- **What New York Accepted**
 - Widening and elevating beaches in Queens and Staten Island to create buffers
 - Creating dunes and augmenting them with plantings to prevent erosion
 - Building double storm-surge barriers to protect urban areas
 - Replacing aging infrastructure, such as power and gas grids, subways, sewers
 - Repairing and/or raising water-side buildings
 - Tweaking zoning codes to encourage elevation of equipment such as fuel tanks and elevators
 - Nourishing wetlands and reefs along city shores
- **What New York Rejected**
 - Large-scale barriers like those that protect the Dutch coast. They're under a billion dollars, but they're still the most cost-effective measure. "Why not look at the pros and cons?" he asks.
 - Regional coordination with New Jersey and Connecticut. "This is really strange," he says as we sip coffee in his new kitchen. "We have a lot of coordination, infrastructure and business. Coordination is a must."

Against the Tide

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Oosterscheldekering. He also tracked how the barrier disrupted the flow of sand needed to replenish tidal shoals and beaches that naturally help to slow waves and tame storms. He says in professor speak, that the shoals "evolved negatively" because of the Oosterscheldekering. In laymen's terms, they shrank because they didn't get enough sand.

Dutch law compels the government to maintain the coastline at 1990 levels. This is politically sensible and ecologically stupid—a waterfront home may seem permanent, but shorelines shift. This strategy, which keeps the beach a half mile wide in places, requires a costly annual deposit of 1 million cubic meters of sand. Which compelled a group of specialists including de Vriendt and his Delft colleague Marcel Stive to solve an interesting puzzle: Can nature be harnessed to help do this unnatural thing?

Two years ago, the Sand Engine was born. Twenty million cubic meters of sand were rounded to form a half-mile-wide, 1.25-mile-long beach extension. Hydrologists and engineers had calculated that currents would eventually move 60% of the sand northward, 40% south. "Look what happens if you build a castle at the edge of the surf and the tide comes in," says Stive. "You see the wave diffuse around it. The sand is not gone. It just spreads in all directions. If a sand castle disappears in half an hour, the Sand Engine is supposed to last 20 years."

The Sand Engine, which is shaped roughly like a bullet, is a water-engineered beach. It filters a vulnerable coast into the existing shoreline, does mostly what its designers expected. It buffers a steepening coast while delivering recreational and ecological benefits. The lagoon created by the "beach" has become a popular kite-surfing venue as well as an important habitat for juvenile flatfish. Flocks of gulls loiter on the sand. Sea grass has taken root, dredging the white expanse with green. The sand has traveled roughly according to plan. Already local governments in France and England have initiated projects mimicking the Dutch design.

This might be premature: The Sand Engine team also expects surprises. "All models are built with inputs, a system, and outputs. But what if you know how the system works, but don't know the inputs?" says de Vriendt, who is now 66. Usually he has a gentle, grandfatherly mien and thinks for a few beats before speaking. But as we stand on an escarpment carved by the waves since his last visit to the Sand Engine, he seems like a giddy

4-year-old. "Isn't this fantastic?" he tells me. "There's a lot of things always changing. It's very challenging to understand. Models are never more than what we already know."

Six miles north of the Sand Engine sits the district of Scheveningen, which has two distinct stretches of seafloor. The northern section is chockablock with cheap souvenir stands and neon lit bars. On the southern stretch, the sky feels bigger. Construction cranes here are finishing a new, \$100 million promenade that's all bright and clean, bleached wood and powder-blue steel, as if the scene had been run through an Instagram filter called "Dutch."

There was no dike here before—it was one of the 200 least-protected sections—and only the most knowing observer would notice the one there now. The rest of us would see an undulating waterfront park, sloping seaward from the dunes to a one-way street for cars, then to a bike path, then to a pedestrian area and beach. The largest project of architect Age Flutman's career, it is an aerial demonstration of how to integrate traditional beachside amenities with sophisticated protections against future storms. "Making a dike here was quite extreme. You want something 10 or 12 meters high, and 30 meters wide—a big thing," says Flutman as we stroll the promenade. Dressed in a half buttoned check shirt, cargo shorts, and flip-flops, he looks more like a beachgoer than a beachwalk builder. Originally, he explains, the government hired Spanish architect Manuel de Solà-Morales, who was renowned for rejuvenating Barcelona's waterfront. Flutman worked with Solà-Morales and took over after his boss died last year.

Building a multi-layered dike hidden under a beachfront is not easy. Regulators decided that no single object on this dike, which is designed to withstand a storm more than twice the one in 1953, could weigh more than 700 kilograms; anything heavier could puncture the seawall mid-storm. Flutman, lanky and athletic, leans over to a pedestrian bridge linking the dike-top roadway with the pedestrian promenade. "It looks like steel, right? But it's actually built of composites," he says, beckoning me to join him underneath the bridge. Crouching, he points out the small nuts and bolts studing the ends of the beams, explaining that they're calibrated to detach in a major storm surge. "This bridge can support 200 people, but if a future bridge in the world is designed to fall apart into hundreds of pieces," at one point during the planning process, he said, "then a local official asked, 'Can't we plant some palm trees?' In response, Flutman designed 36-foot-tall lampposts crowned with arms

reaching in different directions—stylized palm trees. He smiles. "These palm trees."

Flutman seems especially pleased by the contours of his promenade. He came to this beach as a boy and recalls it as straight and flat, given the chance to redesign it as an adult (he's 36), he created horizontal and vertical curves to increase visual drama. "See these gentle hills?" Flutman says. "This makes you interested. What's over there? What's beyond that bend?" He discovered that Dutch regulators didn't want a different beach. They rejected the curved proposal, arguing that straighter beaches make stronger barriers. But Flutman asked for evidence. He suggested that rather than rely on conventional wisdom, they do some new modeling. And in the end, he was right. The curve costs less money and is more effective. The straight seawall cannot.

The Dutch love data. Flutman got his curves because of it. And a Dutch sense of caution has compelled everyone working in the field of flood control to collect and analyze immense amounts of data to make a case for a new design. The Netherlands is very conservative. We think we can solve everything with a bit of sand," says Jan-Maarten Verbeke, who heads IT at Nelen & Schuurmans, the water-focused consultancy behind JDI. "But we say with a bit of IT, you can increase safety even more."

The computer system is based on the work of a professor at the Technical University of Delft, Wytte Schuurmans, Nelen & Schuurmans's principal, says JDI is 1,000 times faster—and can be accurate "more or less to the inch"—than any conventional flood models currently in use. In the Nelen & Schuurmans lab, a Spartan collection of desks located in a house in the medieval heart of Utrecht, Verbeke and his colleague Olga Pleumeekers hover over an on-screen projection of the city of Delft. Pleumeekers decides to dump nearly 4 inches of rain on Delft in just one hour. "Just to see." This is not realistic, she tells me. "It's a lot of water."

The zooms in on a neighborhood between a key and an old Dutch Cathedral. Within minutes, the floodwaters reveal the town's topography—though the canal has spilled its banks, some canal-side streets remain dry while roads further inland are awash. Within three hours, water laps at the Cathedral's steps, and as Pleumeekers zooms out for a regional view, a spreading quilt of blue reveals the extent of the storm. Any sane person would want to flee, but not northward—the model shows that the A4, the main artery to Amsterdam, is now underwater too.

The goal here goes beyond disaster planning for the Netherlands; the firm hopes to build a web-based version of JDI that would allow a Manhattan building manager to simulate, say, a hurricane effect on his apartment tower. What JDI most resembles is an aqua-centric version of SimCity—but with realistic data and calculations," says Verbeke. When Pleumeekers switches to a machine holding data for Long Island—less detailed than what it has for the Netherlands, but sufficient to do basic simulations—I can see the potential. "What should we do, she asks? "Make it rain."

I reply. We center a cloud over an area on the edge of New York that was hard-hit by Superstorm Sandy and unleash 2.5 inches of rain. Within two hours, flooding blue ribbons streak across the area, while the water has drained from the higher ground. Even after a day, low-lying coastal areas are still wet.

If you were to choose a person who best represents how Dutch thinking about water management has evolved over the past two decades, it might not be an engineer or architect at all. In fact, it might be Tracy Metz, who was appointed in 2007 to national task force convened to propose ideas for the next 50 years of flood preparedness. Metz was, in her own words, "a representative of the people." She was a journalist, with a typical awareness of the importance of water in the country's past as well as in its policy-making—an awareness reinforced by the 200-to-300-euro-per-person levy that every resident pays for local flood protection. But beyond her own story—born in Los Angeles, she moved to the Netherlands in the 1980s and jokes about growing up in a place with too little water, only to end up in one with too much—she says she was no water expert.

Over time, she became one. She learned that the dream of Holland as watertight fortress—canals are moats, straighter rivers are safer rivers, higher walls are better walls—is compelling but flawed. She discovered that the materials deployed in the Deltaworks, the country's coastal bulwark, were sophisticated, but the methodology was essentially "the way they've done it from the Middle Ages." Last year, she wrote *Sweet & Salt: Water and the Dutch*, the seminal book on Dutch water management. One of the book's lessons is how Metz's own education coincided with a shift

in the official Dutch mind-set: They now accept that the Netherlands may be landlocked, but she seems willing to part with it. "We used to defend against the water as our enemy," Metz says. "You could say that there's a new attitude: Water as our friend."

This attitude has become as crucial to the Dutch as their technical sophistication—if not more so. And once again, floods helped bring about the change. In 1993 and 1995, as Delta works finally neared completion, floods hit the Dutch from behind. The Rhine, Meuse, and Waal rivers swelled with Alpine snowmelt, forcing 250,000 people from their homes. The decision was made to strengthen river defenses, but this time in a different way. For centuries, the Dutch had tried to channel rivers and streams into ever narrower courses and canals. But gradually they came to realize that river systems were akin to greyhounds, that they try to confine them to small spaces, but they will always need room to run.

Hence, Room for the River, an initiative with 24 interconnected projects, including most ambitiously the digging of a new 2.5-mile channel in the city of Delft. Metz will alleviate the pressure at a particularly tricky bend in the river and create an island from what was a peninsula. In some places, dikes will be bolstered and raised. In others, they'll be lowered. The Dutch had tried to channel rivers and streams into ever narrower courses and canals. But gradually they came to realize that river systems were akin to greyhounds, that they try to confine them to small spaces, but they will always need room to run.

The largest dike to be lowered will be the Noordwaard, an area in the southwestern Netherlands. For the past century this area has been a polder—a wetland turned into fertile fields. Within the next two years, a 1.5-mile stretch of 25-foot-tall dikes will be lowered by 10 feet, creating new low-lying homes that will be threatened by the new swamps. "There were 75 families living in the Noordwaard. Forty will stay. It has been difficult. It has been painful."

The government has done little to buy into the idea of a new Netherlands. It has been a long time since the Dutch government has bought into the idea of a new Netherlands. It has been a long time since the Dutch government has bought into the idea of a new Netherlands.

ence, refusing to pay above market for condemned properties, and neither has it deployed eminent domain. Vic Gremmer, a social worker who moved to the Noordwaard "to stay in nature," says his payoff and the building subsidies offered by the authorities didn't cover the costs of his new land and construction of his new house, down the road and up a small but significant rise from the old one. "We lived there for 21 years," he says as we sip coffee in his new kitchen. He gazes out at his new patio and the new reed-edged canal beyond that. "We've got this new house, and these beautiful sights. But the old house, we were used to it—the keys go here, that goes there. Our children were born there."

Perhaps the most innovative element of Room for the River is how officials built relationships with those whom the program will displace. Room for the River has project managers whose main job is to talk with residents. One whom I met was formerly a political lobbyist at EU headquarters in Brussels. He calls his current work "lobbying at the kitchen table." The long-term work in the Noordwaard—pile-perch, heavy on humulites; officials repeatedly struck various compromises to help residents' support—or at least acquiescence. And slowly, through these conversations—15 years and counting—the officials helped Gremmer and most of his neighbors to understand the science behind the project as well as the necessity.

An effort to de-populate—and more broadly, Room for the River—"is not only about engineering and design and technical innovation. It's also about collaboration, a regional approach, and a mind-set," says Henk Otten, a former director-general at the Dutch Ministry of Infrastructure and the Environment, who has been expert in Washington, D.C., to serve as special adviser to Shaun Donovan, secretary of housing and urban development. "You can't build a levee with a mind-set—you need money, you need ideas, and you need innovation. At the same time, you will never build those things if the mind-set isn't right."

Gremmer says he's been much to talk about his new home. It sits 13 feet above sea level, so it's unquestionably safe. He's an avid birdwatcher, and a variety of species have been arriving in greater numbers. And if he's hungry for fish, he just slides open the big glass doors to his patio and casts his line. The canal out back teems with eel, carp, and his favorite, sea bream—pile-perch, "Eelkik," he says. "Put it in a pan with a little bit of lemon, salt, pepper, butter. Delicious."

"Are you happy here?" I ask. He sighs a little before replying: "We're not there yet."

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