A Torrent of Consequences

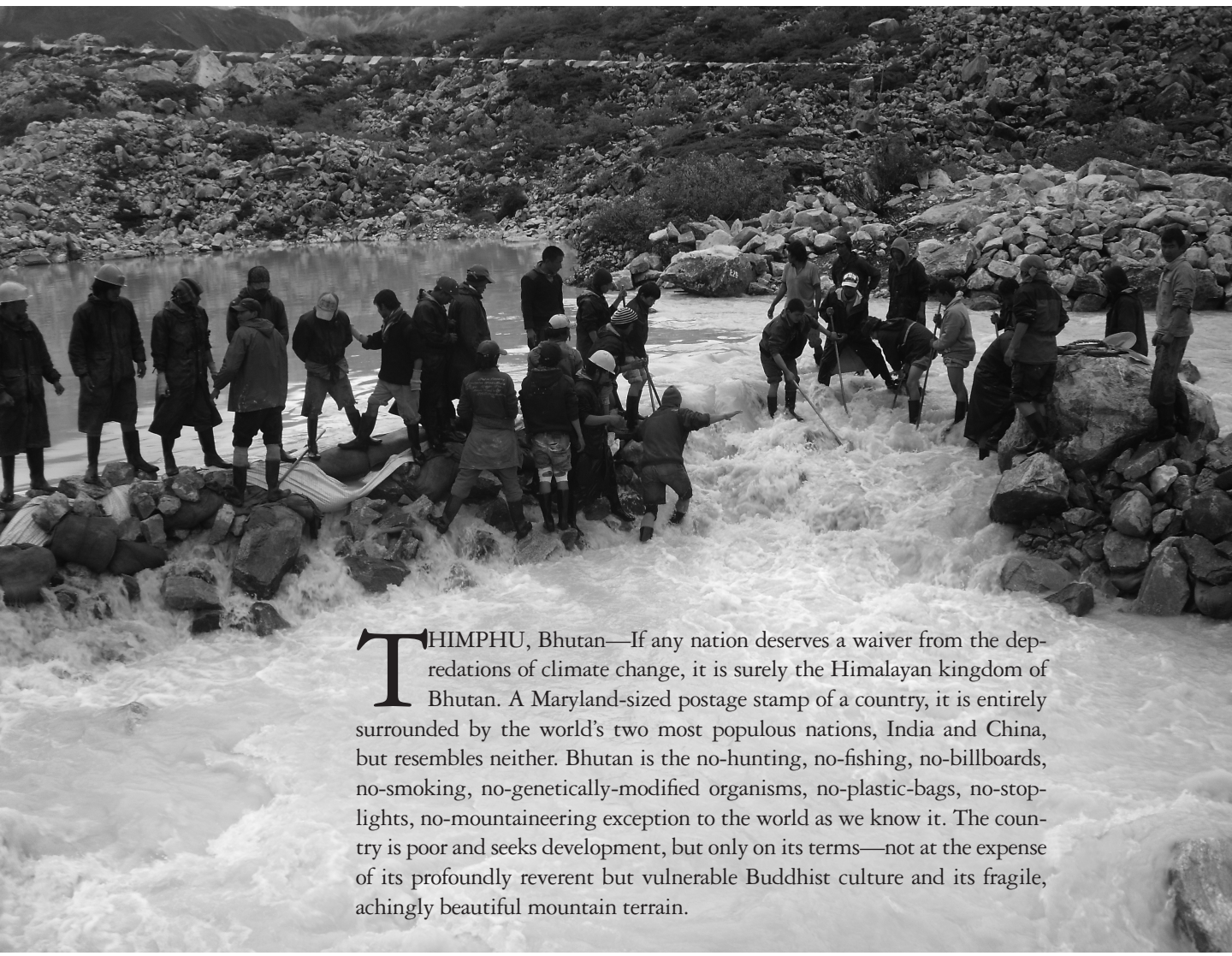
Jacques Leslie

World Policy Journal 2013 30: 59

DOI: 10.1177/0740277513494066

A Torrent of Consequences

JACQUES LESLIE



THIMPHU, Bhutan—If any nation deserves a waiver from the depredations of climate change, it is surely the Himalayan kingdom of Bhutan. A Maryland-sized postage stamp of a country, it is entirely surrounded by the world's two most populous nations, India and China, but resembles neither. Bhutan is the no-hunting, no-fishing, no-billboards, no-smoking, no-genetically-modified organisms, no-plastic-bags, no-stoplights, no-mountaineering exception to the world as we know it. The country is poor and seeks development, but only on its terms—not at the expense of its profoundly reverent but vulnerable Buddhist culture and its fragile, achingly beautiful mountain terrain.

LALIT KUMAR CHHETRI

The nation wears its luxuriantly green, steeply gorged, abundantly canopied, biologically exuberant forests like a crown, with pride and protectiveness. Both are reflected in a nearly 40-year-old law, enshrined five years ago in Bhutan's new constitution, requiring that 60 percent of the nation must be forested in perpetuity—a provision that is largely complied with. More than a quarter of Bhutanese terrain is formally protected. Sangay Wangchuk, the "father of Bhutan's national parks" and the first of 12 Bhutanese graduates of the Yale School of Forestry and Environmental Studies, designed the 10 parks so that all were linked by wildlife corridors. A biological hotspot, Bhutan contains four times as many butterfly species as the United States and a quarter as many plant species as the entire North American continent. As development swallows forests elsewhere in the Himalayas, Bhutan's are becoming refuges for snow leopards, clouded leopards, barking deer, and a menagerie of other wild animals. Bhutan's forests absorb three times as much carbon as its farms, cars, and minuscule industries emit, making it one of the world's only carbon-negative countries. Even its one glaring environmental black spot—its commitment to provide 10,000 megawatts of hydropower to energy-hungry India by 2020, in the form of 10 dams now planned or under construction—is slightly tempered by the fact that all but two of the dams will be reservoir-less run-of-river dams, which inflict less social and environmental damage than storage dams.

Yet for all Bhutan's environmental virtuousness, it is experiencing climate change's consequences in a vivid, catastrophic form. The most serious threats loom downward from the nation's nearly 2,700 glacial lakes,

Jacques Leslie's book, Deep Water: The Epic Struggle Over Dams, Displaced People, and the Environment*, won the J. Anthony Lukas Work-in-Progress Award for its "elegant, beautiful prose." He is a former* Los Angeles Times *correspondent.*

most of which have formed only in the last half-century, including some in the last decade. Warming temperatures and the increase of "black carbon," the heat absorbing particles emitted by cars and power plants, have accelerated glacial melting, creating mountain lakes. The water in these lakes is held in by delicate moraine walls made of the rock and soil debris pushed to the front and side of glaciers during their centuries-long expansion. These fragile dams can collapse as the pressure from water buildup intensifies. Torrents of this kind have been known for centuries, but in recent decades, they've become far more common. They're sufficiently prevalent to have acquired an acronym: GLOF, or Glacial Lake Outburst Flood. As acronyms go, GLOF works nicely, suggesting something clumsy, threatening, indifferent to life. As climate change whittles glaciers around the world, tens of thousands of new glacial lakes are forming beneath them, drastically increasing the likelihood of GLOFs. They now threaten calamities in Peru, Chile, Bolivia, China, Pakistan, Nepal, India, Tajikistan, Kyrgyzstan, and Uzbekistan. In Peru, the world's leading producer of GLOFs, a 1941 flood in the Andes' Cordillera Blanca range killed at least 4,000 people. Since then, the region has experienced 13 more GLOFs, including three lethal ones. The biggest known GLOF, set off by an Icelandic volcanic eruption in 1996, released a cascade so powerful that for several days its flow ranked second among the world's rivers, behind only the Amazon. The torrent was 2,000 feet wide and up to 13 feet high, and deposited 30-foot-tall icebergs on the banks of the river it flooded.

> WHEN THE FLOOD CAME, SENA SAID, SHE AND HER TWO CHILDREN RAN FOR THEIR LIVES.

GLOF: BHUTAN STYLE

Bhutan's GLOFs have been less powerful than Iceland's but more lethal. The country

has experienced three major GLOFs in the past 60 years. The last one, in 1994, ushered the kingdom into the new era of climate volatility. A glacial lake that didn't even exist 50 years earlier breached its moraine dam and triggered the most catastrophic flood in Bhutan's recorded history. First, a small glacial lake burst, and its water cascaded into an adjacent glacial lake, causing it, too, to rupture. The resulting cataract took 12 hours to empty, and spilled the equivalent of 7,200 Olympic swimming pools down the Pho River, part of the longest river system in Bhutan. It set loose five million tons of boulders, timber, and mud. What a government official called a "silent tsunami" flowed down the Pho (pronounced Poe) at a stately but omnivorous eight miles per hour. It drowned 22 people, 16 yaks, and an uncounted number of horses and cows. It tossed thousands of fish high onto riverbanks, where those villagers who had eluded the flood's onrush raced to the river's edge to fill baskets with the dead or floundering creatures. The flood shredded five mills and four bridges that provided vital links between villages. It destroyed by erosion and sand and salt inundation 965 acres of scarce pasture and agricultural land, along with six tons of food grains. It uprooted thousands of trees and slung them 60 miles downstream to a bend where they formed a massive logjam. The torrent took seven hours to reach the country's most beloved structure, the handsome 17th century religious and administrative fortress in the former capital of Punakha where Bhutan's king was married in October 2011. The onrushing waters tore away some of the fortress's outer walls, badly damaging it. In a country of only 725,000 people, the flood ranked as a cataclysm.

Nearly two decades later, the GLOF's impact still registers. When I met Sena, 47, and Kinley, her 42-year-old brother-in-law, in their ramshackle house a few miles upstream from the Punakha fortress, they still looked dazed. When the flood came, Sena said, she and her two children ran for their lives. The GLOF destroyed Kinley's house and his acre-sized rice field, covering it with sand, rocks, and uprooted trees. For a couple of weeks afterwards, he and his wife camped on the riverbank, then moved in with Sena. Her house was undamaged, but she and her children lost their paddy fields, seven cows, and all but two of their four or five horses—it was a financial disaster. A slight woman, Sena looked as if she still wasn't eating well. Her blouse was torn, and her skirt was soiled. Both she and Kinley were barefoot.

Before the GLOF, the two families lived on the food they produced. After it, they were forced into Bhutan's sparse cash economy, buying food in shops. For a few months, they had what they now call "a rough time," an understated way of saying they were always hungry. Since then, they have survived by working for small wages in the fields of more fortunate farmers. But Kinley's biggest worry isn't financial. The stuff of his recurring nightmares is another big flood.

RIVETING ATTENTION

The flood's sole benefit, in fact, was that it riveted Bhutanese officials' attention on the likelihood of more GLOFs. The officials realized they lacked even basic information about glacial lakes, such as how many existed and, of those, how many might soon collapse. Too poor to fund its own studies, the government entered into collaborative projects with scientists from India, Austria, and Japan. In at least a dozen projects over the next decade, native and foreign scientists scoured the Bhutanese Himalayas to study the lakes' potential for collapse. The reports

produced by these teams were ominous. A 2001 survey relying on French satellite images and Indian topographical maps conducted by the Kathmandu-based International Center for Integrated Mountain Development (ICIMOD) found that 24 of Bhutan's glacial lakes were potentially menacing. Field observations by other scientists eventually established that most of those 24 posed minimal danger, but they also identified a 25th, Lake Thorthormi, that threatened imminent, catastrophic collapse. The moraine that contained this lake was steadily shrinking as an ice core inside it melted, and the lake's surface area had nearly tripled in the last decade alone, until it covered more than a square mile. If Thorthormi collapsed, as much as three times the volume of water of the 1994 GLOF would cascade down the Pho River basin. Many more people now live there than in 1994, so the potential for casualties is much higher. The 1,200-megawatt Punatsangchhu dam under construction 13 miles downstream from Punakha might be vulnerable, too. If it were damaged, the loss of expected hydropower would register all the way to India, which financed the dam and plans to consume most of its electric output.

Somehow the water in Lake Thorthormi had to be released gradually, before all its contents spilled uncontrollably down the Pho. But given Bhutan's poverty and steep terrain, moving equipment and laborers to the lake was a huge logistical challenge. Peru's government has decades of experience in reducing the threat of GLOFs by lowering the water level of glacial lakes, but those lakes were invariably close to roads and within reach of machinery. Thorthormi, on the other hand, is exceptionally remote. The nearest road is more than a week's hike away, over one of the toughest trekking trails in the world, and the trail can be traversed only for a few months of the year. Helicopters were out of the question. Landings would have been possible only on cloudless days, which are rare. Workers who abruptly climb 7,000 feet of elevation in a chopper ride from Thimphu, Bhutan's capital, to 14,500-feet-high Thorthormi wouldn't have time to acclimatize and risk altitude sickness. Besides, Bhutan didn't own any helicopters, and the Indian Army, which did, would have charged thousands of dollars per trip. But it wasn't just helicopters. Heavy equipment of any kind made no sense. Diesel engines won't start in the high altitude, and track-mounted machines slip on boulder-strewn terrain. Maintenance would be unreliable, among other reasons because overland delivery of parts would take weeks. Most worrisome of all, heavy equipment could emit vibrations that would destabilize Thorthormi's precarious moraine walls. That consideration also ruled out dynamite. Siphoning water from the lake, too, was rejected. In 1995, a Dutch team succeeded in installing pumps and pipes at a menacing glacial lake in Nepal, and for a few years, it siphoned water. But the amount of water that left the lake was a small fraction of the meltwater entering it. Plagued with ice blockages and broken parts, the system stopped working entirely within a few years, and parts were distributed to villagers for use in sewage systems.

FACE-TO-FACE WITH CLIMATE CHANGE'S MENACE, BHUTAN HAD TO NEUTRALIZE THE LAKE OR SUFFER CERTAIN DISASTER.

Only one approach struck officials as workable. Indeed it held special appeal, because it was consistent with Bhutan's do-no-harm, leave-no-footprint, community-oriented values. Out of the crisis, they decided to create a public works project that would employ up to 360 manual laborers for three months each summer. The $10 a day that workers would receive, three to five times what they could expect to earn as day laborers at lower altitudes, would eventually be spent in the workers' home villages throughout the country. The wages might even spawn food stalls and other small businesses, helping to stem the gradual depopulation of the countryside. In return, the laborers would toil in harsh conditions. They would ascend a muddy, slippery, leech-infested trail over three high-altitude passes while steady monsoon rains kept them cold and wet. After setting up a campsite an 80-minute hike from Thorthormi, they'd march daily to the lake, stand in icy water sometimes up to their knees, and tug huge boulders with ropes. They'd hear the glacier writhe and buckle. They'd see boulders and ice chunks tumble from it, and they'd hope that none was big enough to generate an engulfing wave. Using tools no more sophisticated than pick-axes, crowbars, shovels, and hammers, they'd carve a water channel from the lip of the lake with their hands to relieve the pressure on the natural dam.

To virtually all the workers, the high Himalayas were unknown, and many were frightened. "When I went the first time," says Lalit Kumar Chhetri, the project surveyor, "I wondered if I would come back."

CERTAIN DISASTER?

Face-to-face with climate change's menace, Bhutan had to neutralize the lake or suffer certain disaster. Thanks largely to its superlative environmental record, Bhutan became the first nation in the world to receive a grant from the United Nations' Least Developed Countries Fund, set up to help poor countries cope with climate change. Together with funding from the UN Development Program, the World Wildlife Fund, and the government of Austria, Bhutan collected $7 million to mount the project in 2009, but it took four and a half years to meet the agencies' requirements, by which time the lake's danger had grown significantly.

> LAKE THORTHORMI WAS STILL MOSTLY ICE, AND NOBODY HAD EVER EXCAVATED AN ICE-FILLED GLACIAL LAKE BEFORE.

Karma Toeb, the project's management team leader, had spent only one summer in the Himalayas when in 1998 he met Yutaka Ageta, head of a three-year joint Bhutan-Japan glacier hazard assessment project. A recent recipient of an honors bachelor's degree in geology from Jadavpur University in Calcutta, Karma had never studied glaciology. Ageta, on the other hand, was an archetypal glaciologist, whose interests in glaciers and mountaineering meshed. "Untrodden peaks and areas," he wrote in an email, "have drawn me to the Himalayas." In 1973, five years into his glaciology career, he performed the first ascent of Kangchenjunga West, a 27,900-foot ridge of the world's third tallest mountain, and lost all his toes to frostbite in the process. The only other man to reach the summit with him disappeared during the descent. Though the climb ended Ageta's mountaineering career, it deepened his fascination with what

he calls the "attractive spectacle" of glaciers. Before he retired in 2007, he paid 14 visits to the Himalayas as a researcher. In 1998, when he was 55, he and Karma Toeb walked from one end of the Bhutanese Himalayas to the other, covering 300 miles at a pace of at least 10 miles a day, ascending a dozen passes of at least 13,000 feet—it was the most difficult glaciology expedition of Ageta's career. Karma didn't seem to mind. Along the way he discovered that studying glaciers guarantees "an adventurous life" and that he loved adventure. He became Ageta's student at Nagoya University, and got a master's degree in glaciology there in 2001. When I met Karma in November 2011, a couple of weeks after he returned to Bhutan's capital following his third summer as leader of the Thorthormi project, he often displayed a puckish smile, as if he knew a gratifying secret he couldn't divulge. His face was a smooth oval, distinguished by his puffy cheeks, an indication that he'd started to regain the pounds he'd lost during the expedition. He laughed easily and chewed betel constantly. He liked to have a good time.

He would need all his humor to contend with the project's challenges, beginning with the ascent to the lake. "If you plan to trek this route," *Lonely Planet's Guide to Bhutan* says of the Snowman Trail that workers climbed to the project campsite, "double-check your emergency evacuation insurance." Bhutan tourist agencies report that fewer than half the trekkers who start the Snowman trail complete it. There are often many days of arduous hiking from the nearest road when they realize they can go no farther, and a helicopter evacuation costs $25,000. Of course, *Lonely Planet* directs its advice at affluent foreigners—adventure trekkers willing to pay $6,000 or more for the privilege of a 25-day ordeal, leavened by Bhutanese guides who cook for them and manage the yaks and horses that carry their gear. The Thorthormi Mitigation Project was considerably harder. It sent up to 300 laborers along the Snowman's most difficult portion, over one 17,000-foot and two 16,000-foot passes. The laborers carried their own food and clothing, and no tents and cooked meals awaited them at their overnight stops along the way. Though the *Lonely Planet* guide advises against a summer trek because "this is a miserable place to be during the monsoon," the laborers hiked precisely then, the only time when Lake Thorthormi was reachable.

MOSTLY ICE

On top of this, Lake Thorthormi was still mostly ice, and nobody had ever excavated an ice-filled glacial lake before. The lake is the third in a row of five glacial lakes nestled beneath the southern face of the 24,000-foot Table Mountain in the Eastern High Himalayas. The lake bristles with sharp-edged ice formations and pile after pile of pulverized rock, a testament to centuries of glacial grinding that left it a cauldron of rubble. Yet looming above it was the nearly horizontal snow-covered crest of Table Mountain, a long ridge of exquisite white that seemed to sanctify everything beneath it. The ice surface of the lake was, in the parlance of glaciologists, "hummocky"—it rolled like a meadow, with height variations up to 20 feet, and it was cobwebbed with crevices. Beneath the glacial snout that extended over part of the lake was an unknown amount of water. The bigger the lake grew, the greater the chances that the excavation of the moraine could free the snout from its tenuous mooring to the rest of the glacier. A break could set in motion the collapse of the moraine, the drowning of hundreds of workers,

KARMA TOEB

and a catastrophic GLOF. Or perhaps an ice core lurked within the moraine near the point of excavation—the work might remove enough debris from above the ice core to cause it to slip from its mooring and escape the moraine, another way of inducing a GLOF. Karma Toeb's team, which included an engineer and a surveyor, had to implement its cut into the lake's rim with extreme care to keep this from happening.

Bhutanese don't engage in the sort of organized treks that adventure tourists favor, but they're superb hikers. In a country without flat terrain, they're used to walking from village to village, clambering up and down daunting ridges of thousands of vertical feet while wearing wildly unsuitable footwear. Even so, the laborers were unprepared for the Snowman. Namgay Dorji, a 29-year-old laborer who spent the summer of 2011 in the project, told me that he could walk any distance at a "low" altitude—say, up to 12,000 feet—but on the Snowman trail, he could barely catch his breath. The laborers carried packs of 20 or 30 pounds. They walked six to eight hours a day on slick, steep, stony trails that at times narrowed to the width of their shoulders and overlooked sheer drops. Near the high passes, it snowed. Everywhere else, it rained—every day. Since the transit camps lacked firewood, the workers' clothes stayed wet all the way to the Thorthormi camp. On top of that, the altitude consumed their energy and body weight. Though most were compact to begin with, over the course of the hike virtually everyone lost 10 or 15 pounds, which they didn't regain until after descending from

the camp two months later. As they neared Ganglakarchung, the desolate 17,000-foot pass with an astounding view of jagged peaks 6,000 feet higher, many got headaches, the first indicator of altitude sickness. They arrived at the Thorthormi campsite already depleted, and consoled themselves with one thought—they'd survived the hardest part of the summer.

The laborers' first job was to build their campsite. Their foremost need was wood, as vital to the project as water. Without it, they had no cooking fuel and no poles to hold up tents. The camp was just below the tree line, but the nearest usable trees were two miles down the mountain, a three-hour hike away. To minimize environmental damage, wood-gatherers were shown which trees were protected, but the project's environmental impact was still substantial—in a single season, it used 330 tons of wood.

The project's goal was to lower Lake Thorthormi by 16 feet, thereby safely releasing as much water as flowed down the Pho in the 1994 GLOF. Even so, the threat of an even bigger GLOF would remain. All this epic labor would merely reduce the potential flood's maximum volume by a third. Some work teams broke boulders. Some attached ropes to the boulders and dragged them away. Some carried buckets filled with rocks, dirt, and mud. The workers placed boulders along the rebuilt channel's walls, reinforcing them against erosion, and put excavated soil in more than 1,500 jute gunny sacks.

Moving the boulders was a formidable undertaking. The workers wrapped inch-thick steel cables around the boulders, then attached ropes made of coconut husks to the cables. To move the biggest boulders, all 300-plus workers tugged on the ropes at once, finding their rhythm in a chant: "Pull, friends, pull," they sang. Where mass tugging didn't work, the workers got creative. They prepared paths of small rocks or logs beneath unmovable boulders and found that they could sometimes roll the boulders down them. If that didn't work, they resorted to "silent explosives." Wielding a 70-pound portable drill called a *pionjar*, the closest thing to high technology the project deployed, workers drilled as many as 200 narrow holes into a single large boulder. Then they filled the holes with a slowly expanding powder that over a couple of days left the boulder riddled with cracks. Finally, they carried the shards to nearby dumping sites chosen to minimize the project's environmental impact.

Minor injuries happened often at the lake. The workers' hands and feet reddened, peeled, and blistered. The nearly incessant rain made them shiver, while sunlight burned and blistered their faces. Their lips developed cracks and sores. The campsite had its own dangers, too. The preferred intoxicant was Black Mountain Whiskey, a product of Bhutan. Its greatest benefit was its seeming warming effect. The one wool blanket the project provided couldn't keep the laborers warm, particularly after the weather turned frigid in September. Almost every night, workers got drunk. When during a darts match a dart caromed off a stone into a laborer's head, an Indian Air Force helicopter evacuated him for a $14,000 fee. He left with another worker who'd gotten tuberculosis, for another $14,000. By one measure, the evacuees were fortunate. Two workers lost all their toes to frostbite after taking an unauthorized route down the mountain at the end of the first summer, and in the second summer, three workers died of altitude sickness, two of them during the ascent to the camp. The project promptly tightened its medical procedures, which proved prudent. The next summer, a team doctor newly trained

in high-altitude emergency medicine saved still another worker who came close to dying from altitude sickness during the ascent.

AN UNLIKELY MODEL

The deaths and arduous work conditions scared off so many workers that only 110 signed up for the last summer of the project, and officials had to commandeer 123 soldiers from the Royal Bhutan Army to form a sufficient work force. With the soldiers' help, the project met its five-meter goal, yet for all the sweat and drama involved in the accomplishment, it may not be a model for GLOF mitigation. Instead, it is likely to stand as a kind of heroic experiment, pointing toward some proposed GLOF solutions and away from others. The Thorthormi project was launched out of a sense of emergency, with no time for detailed research to determine the best way to disable the lake's threat. Yet it's far from certain that the target of lowering the lake's water level by 16 feet was optimum, particularly since even after a third of the lake's water was released, it could still disgorge twice as much water was released in the 1994 GLOF. In addition, scientists point to another menacing glacial lake, Imja Tsho in Nepal, where a GLOF could harm, either physically or financially, as many as 100,000 people downstream. UN Development Project officials have proposed lowering the water level at the lake by 10 feet, but computer modeling of potential flooding carried out by University of Texas Austin researchers Daene C. McKinney and Marcelo A. Somos-Valenzuela suggests that Imja must be lowered by at least 65 feet to reduce the impact of the expected flood.

> IF GOVERNMENTS DO NOT TAKE SOME VITAL STEPS, THEY'LL HAVE ONLY ONE ALTERNATIVE, AND IT'S NOT PRETTY.

It's even questionable whether the Bhutanese project's overriding objective—keeping the flood away from people—will often be practical. The cost of the Thorthormi lake-lowering effort, more than $2.5 million, is almost certainly prohibitive in most cases, particularly if threatening glacial lakes continue to proliferate as the impact of climate change deepens. This will come as a major disappointment to many villagers threatened by GLOFs. Those living downstream from Imja, for instance, have told officials they want the problem eliminated so they can go to sleep without worrying that their homes and fields will be washed away during the night. Because an Imja GLOF would devastate lucrative tourism in the Mt. Everest region, perhaps harming the entire country's economy, they may get their wish. But if they do, Imja won't be typical. If any systems are put in place to deal with most potential GLOFs, it's far more likely that they'll be designed to keep people away from the flood, by warning villagers of approaching GLOFs in time to move to safe terrain. Indeed, that is the objective of the Thorthormi project's less expensive components—a satellite-based early warning system ($1.25 million) that has been functioning since 2011 and a community outreach program ($374,000) that identifies GLOF-threatened areas and links residents by cell phone trees so that they can be alerted to move to higher ground when the Thorthormi moraine gives way. The two systems overlap, because an earthquake that triggers a GLOF could also impair cell phone communications, and in any case, not all communities enjoy cell phone coverage. The early warning system,

the first of its kind in South Asia, consists of six automatic water-level monitors stationed at four of Table Mountain's glacial lakes and at two points downstream, plus 17 sirens installed in at-risk villages. But the early warning system is delicate, and requires constant monitoring of equipment and frequent on-site surveillance of the lakes.

PROACTIVELY DEFUSING

What seems essential is a proactive approach to deactivating GLOFs. If potentially dangerous glacial lakes are identified early in their development, a decade or two before they fill with water and become imminent threats, drainage systems can be installed that keep the lakes from filling. By the time they become Thorthormi-sized, they're loaded weapons, and the difficulty of disarming them multiplies. Yet even this cost-effective approach would require increased funding to poor countries such as Nepal and Bhutan through mechanisms like the UN's Least Developed Countries Fund. Installing drainage systems may cost $1 million to $2 million per lake, and frequent, physically demanding on-site glacier inspections would still be necessary. ICIMOD's early failure to identify Lake Thorthormi as threatening while citing many other lakes that turned out to be harmless shows that satellite reconnaissance alone can't do the job.

Peru's experience in dealing with GLOFs is instructive. After the 1941 GLOF that obliterated a third of the Andean town of Huaraz, the Peruvian government conducted glacier surveys to identify potentially dangerous lakes. Over the next four decades, they devised an array of different techniques to defuse 35 potentially menacing lakes. Their approach is still paying off. Over the last four years, three Andean lakes experienced avalanches that might have been devastating if safety systems had not been installed decades earlier, but instead produced no ill effects.

Even so, it's uncertain whether enough money will be available to treat the Peruvian response to GLOFs as a model. Alton Byers, director of science and exploration at the Elkins, West Virginia-based Mountain Institute and a key organizer in the effort to dismantle GLOFs' threat, says, "There's no way in the world there's going to be enough money to do what the Peruvians were able to do back in the 50s and 60s and 70s." In fact, even Peru has grown sluggish in dealing with GLOFs. Lake Palcacocha, whose rupture caused the 1941 GLOF, now holds nearly 50 percent more water than it did in 1941, and it threatens to burst again. A second Palcacocha GLOF would almost certainly be even more destructive. Huaraz's population has swollen from 40,000 to 140,000, but the government has so far acted ineffectually, if earnestly, to dismantle the new threat.

Yet if governments do not take some vital steps, they'll have only one alternative, and it's not pretty. They can invest in measures to defuse incipient GLOF and install warning systems for imperiled villagers. Otherwise, they'll be driven to the most draconian form of keeping people away—forcefully moving them out of expected GLOFs' paths. That would require compensation of villagers and preparation of suitable resettlement areas, if they even exist, and the villagers might still resist. Having so far failed miserably to ward off climate change by curbing greenhouse gas emissions, the world's carbon emitters would effectively punish the likely victims. They'd destroy the villages in order to save them. ●