FEATURES

POWER PLAY ON THE NILE

Ethiopia stunned neighbors with a colossal dam on the Blue Nile. Could it spread prosperity, not turmoil?

By **Erik Stokstad**

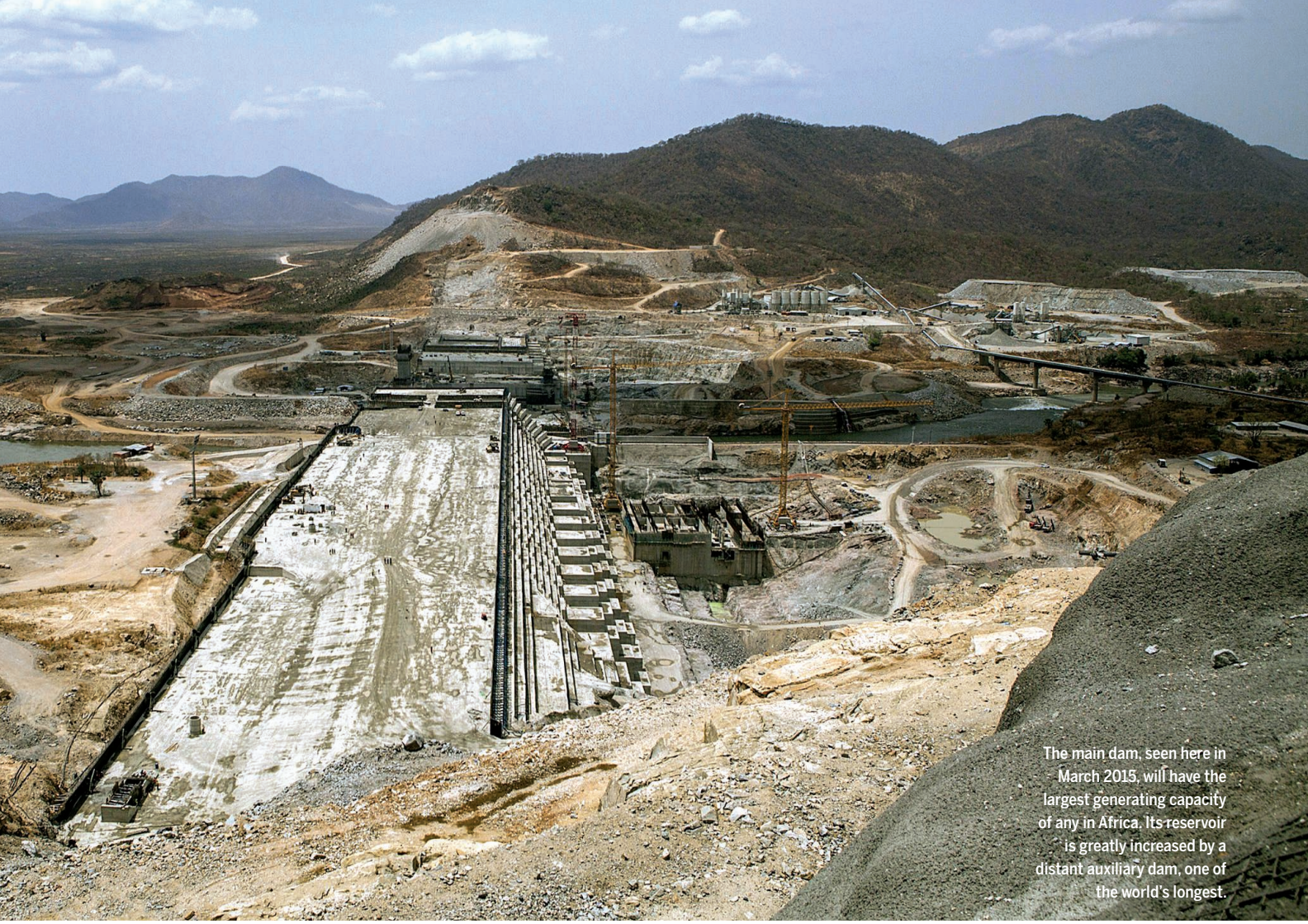
Planned in secrecy, the Grand Ethiopian Renaissance Dam is a massive construction project.

Five years ago, as protesters thronged Cairo's Tahrir Square and the Egyptian government teetered, another revolution with high stakes for the region's future ignited far to the south. On 3 February 2011, Ethiopian Prime Minister Meles Zenawi announced that his country would build a massive dam on the Blue Nile, the main tributary of the Nile, the world's longest river. "We not only have a plan, but we also have the capacity to assert our rights," he said that April at the groundbreaking ceremony.

For Egyptians, who view the Nile as their birthright, Zenawi's declaration was an extreme provocation. Egypt depends on the Nile for drinking water and agriculture, and has long claimed rights to 55 billion m^3 of Nile water per year, much more than any other country. Now, a rival state was taking control of the 60% of Nile water that originates from Ethiopia's Blue Nile. The bold move "shocked everyone," says Paul Block, a civil engineer at the University of Wisconsin, Madison, who has studied water issues in the Nile Basin since 2003.

Five years later, the Grand Ethiopian Re-

PHOTOS: © ZACHARIAS ABUBEKER/AFP/GETTY IMAGES



The main dam, seen here in March 2015, will have the largest generating capacity of any in Africa. Its reservoir is greatly increased by a distant auxiliary dam, one of the world's longest.

naissance Dam (GERD) appears to be a fait accompli. Slated for completion next year, GERD will have the greatest hydroelectric capacity of any dam in Africa. The blueprints call for a main dam 175 meters tall and 1800 meters long. Architects vastly enlarged its reservoir with a secondary "saddle" dam—one of the longest ever built—that spans a low spot. When filled completely, the valley will become Ethiopia's largest lake and hold 74 billion m^3 of water, or nearly the annual average flow into Egypt. Construction is proceeding at a breakneck pace.

Supporters say the dam will be a boon for Ethiopia, one of the least developed countries in the world. At peak capacity it will generate 6000 MW of electricity, and even its regular output of 2000 MW could supply 65% of Ethiopia's demand, although some will be sold to Sudan. The dam will also benefit Sudan, the next country downstream, by regulating torrential summer flows and ensuring water supply during the winter dry season. In addition, GERD will trap silt that would otherwise accumulate in downstream reservoirs, including the enormous Lake Nasser behind Egypt's Aswan High Dam, and could reduce water losses from evaporation. In the long term—if all goes well—it could lead to regional cooperation and economic growth in all three countries. "There is a potential triple win," says Pieter van der Zaag, a water resources expert at Delft University of Technology and the United Nations Educational, Scientific and Cultural Organization–IHE Institute for Water Education in the Netherlands.

But the potential for regional benefits has not lessened Egypt's opposition. An immediate concern is that Egypt could face a water shortfall if GERD's reservoir is filled during years of low rainfall, threatening power generation at Aswan and the livelihoods of Egyptian farmers.

The dam has galvanized scientists in Nile countries, particularly in Egypt and Ethiopia, where outspoken academics have rallied to attack or defend the project. Partisan tempers flared when an expert report, leaked in 2014, raised concerns about evaluations of dam safety, how the reservoir will be filled, and possible downstream impacts. The Ethiopian government, which hired the Italian firm Salini Impregilo to build the dam, has kept a tight lid on details of design and construction.

In a sign of progress, last December Ethiopia, Sudan, and Egypt agreed on an approach to evaluating the dam's potential downsides. Negotiators will then face the challenge of agreeing on how to minimize harm. Meanwhile, "I'm sufficiently optimistic that the dam will bring the countries together," says David Grey, a water policy expert at the University of Oxford in the United Kingdom, and former adviser at the World Bank. "But it's a rough road ahead for the next few years."

ETHIOPIA IS RICHLY ENDOWED with wild rivers that plunge through deep canyons. In the 1950s, the Ethiopian government asked the U.S. Bureau of Reclamation to create a master plan for harnessing that energy for hydropower. The bureau proposed four dams on the Blue Nile, which would together hold 73 billion m^3 of water and generate 5570 MW—nearly two-and-a-half times the output of the Hoover Dam. Over the years, Ethiopian experts and consultants refined the plans. By 2001 they had installed 529 MW of hydropower, but even this small start

raised the ire of Egyptian leaders. Hoping to forestall conflict, the World Bank and others have spent more than $200 million since 1999 on the Nile Basin Initiative to build technical expertise and launch cooperative water projects among the Nile states.

The pace was too slow for Ethiopia. After Egypt in 2008 nixed plans for a joint 2100-MW dam on the Blue Nile, Zenawi upped the ante with GERD. In the past, Ethiopia would have needed foreign aid to undertake such a gargantuan project. But because the country had been gaining economic strength, Ethiopia decided it could fund the dam itself. The estimated $4.7 billion cost is being paid for in part by selling bonds to government workers and other citizens.

The site is a 17-hour drive northwest of Addis Ababa, Ethiopia's capital, and just 12 kilometers from the border with Sudan, where the Blue Nile flows through an arid valley dotted with scrubby trees. Before construction could begin, Salini Impregilo had to build 120 km of access roads and camps for some 9000 workers, who are working round-the-clock. One of its subcontractors claims to have set a world record for daily cement production: 23,200 m^3, enough to fill nearly 10 Olympic swimming pools. "In all my travels I've never seen anything like it," says Harry Verhoeven, a political scientist at Georgetown University School of Foreign Service in Qatar in Doha, who studies water issues. "You feel that this is a national project and that it has to work."

> ***"In all my travels I've never seen anything like it."***
>
> **Harry Verhoeven**, Georgetown University School of Foreign Service in Qatar

Sparks flew in early 2014 after a confidential report on the dam's design and possible impacts was leaked to the nonprofit advocacy group International Rivers. The study had been completed in 2013 by an expert panel consisting of two representatives each from Ethiopia, Sudan, and Egypt and four outside experts. They urged Ethiopia to better analyze the dam's impact on water supplies in Sudan and Egypt and geotechnical risks such as dam failure. The experts also recommended further studies of its effects on water quality and other issues. To International Rivers, the dam-planning process seemed "chaotic and incomplete," with "precious little oversight." In its official response to the report, the Ethiopian government accepted the report's recommendations but maintained that it showed the "GERD project was being undertaken in line with international design criteria and standards."

Compared with other megadams, GERD will be less disruptive to ecosystems, experts agree. The biological diversity of the reservoir site and the Blue Nile downstream is fairly low, says limnologist Henri Dumont of Ghent University in Belgium, who has studied the areas.

The dam's impact on local communities is cloudier. The Ethiopian government has said that just 3000 people are being relocated from the reservoir site. River geographer Jennifer Veilleux, a postdoc at Florida International University in Miami, visited and studied the GERD site in 2013 and estimated the number to be relocated at 20,000, primarily the ethnic minority Gumuz people. "This could completely eliminate these communities and their culture forever." Still, other experts say overall social harm will be negligible.

Most of the rancor focuses on the plans for filling the reservoir—and the reduced downstream flow that will mean. Impoundment is expected to take place over 5 to 7 years. At first, 10% of the river's base flow will be retained in the reservoir each year, then the fraction will increase. A study by Block and colleagues, published in 2014 in the *Journal of Water Resources Planning and Management*, found that a 10% reduction would mean 5% less water reaching Lake Nasser, assuming the White Nile and other tributaries flow normally. This could result in less hydropower from Aswan High Dam and possibly less water released for irrigation.

A lot hinges on the climate. If the reservoir is filled during normal or wetter-than-average years, Egyptian farmers might feel no impact. A stretch of dry years, on the other hand, would mean greater hardships downstream or a longer timetable for impoundment. "We understand that it is a very sensitive issue downstream," says Yilma Seleshi, a water resources expert at Addis Ababa University. But he says Ethiopia can't afford to wait to generate hydropower, and he hopes downstream countries will accommodate that in the negotiations. "If they don't agree, we will continue to fill it using our own share of water." (Ethiopia and five other Nile states reject a 1959 treaty between Egypt and Sudan, and have signed their own accord.)

Once the reservoir is full, the benefits begin to flow. By trapping all the sand and 80% of the silt in the Blue Nile, GERD will preserve the storage capacity of dams in Sudan and Egypt, prolonging their lifetimes. Agriculture in Ethiopia may benefit indirectly, as the government will have a financial incentive to fight soil erosion; this will reduce the amount of silt that settles in GERD's reservoir and keep the dam's turbines spinning as long as possible.

Other wins come from taming the Blue Nile. For more than half the typical year, the river discharges just 300 m^3 per second. The flow usually rises in July and peaks in September, reaching nearly 4000 m^3 per second. GERD will even out the flow, allowing Sudanese dams to operate in dry months and generate an extra 1000 gigawatt hours or so of electricity per year, a 20% increase. "Now, Sudan is thinking about upgrading the turbines to tap the potential," says Yasir Mohamed, the director of the Sudan government's Hydraulics Research Centre in Wad Medani. Preventing extreme floods will also be a relief for Sudan, where a deluge in 2013 destroyed about 27,000 houses.

Larger farms in Sudan should prosper. Regulated flow will increase the number of months they can pump or divert water from the Blue Nile into irrigation canals. This will be good for the Gezira Scheme, one of the largest irrigation projects in the world, which distributes water stored behind the Roseires Dam to 880,000 hectares of farmland. But steady, lower flows could hurt subsistence farmers who tend small fields in Nile floodplains and depend on the annual flooding to renew their soil, Mohamed says.

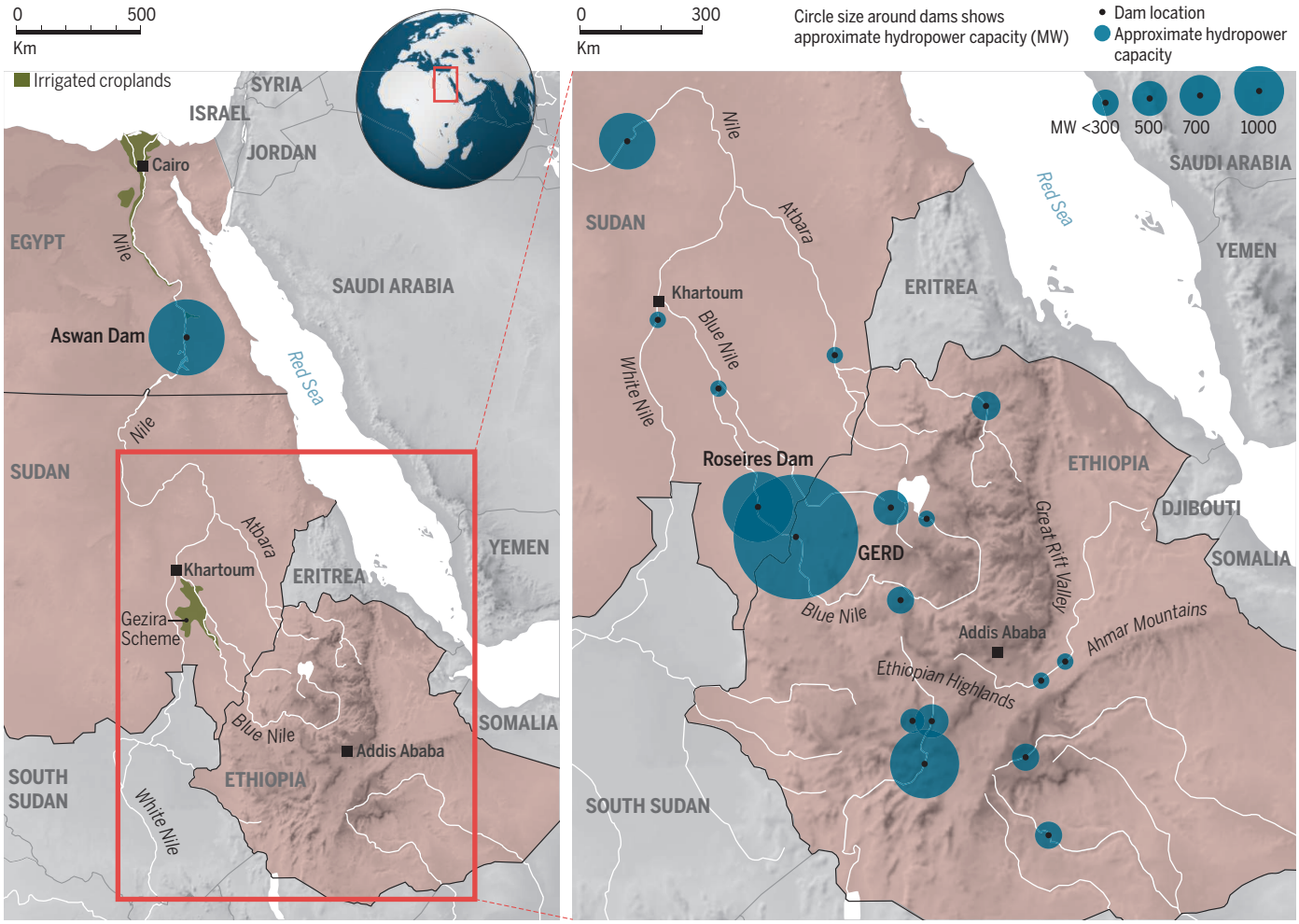
Egypt has less to gain than Sudan, because the Aswan High Dam already provides flood control and irrigation. The biggest fear is that if an epic drought sets in, Ethiopia will hoard water and the level of Lake Nasser will drop. This worst case scenario "will result in abandoning huge areas of agricultural lands and scattering millions of families," the Group of Nile Basin, a dozen academics at Cairo University, asserted in a public statement in 2013. Even a smaller reduction in flow could affect the Nile's ability to flush salts from the soil or keep Mediterranean Sea water from intruding aquifers.

Outside experts say that if GERD is operated in coordination with the Aswan High Dam, the direct impacts on Egypt's water supply will be minimal. "They're not going to lose, that's for sure," says Amaury Tilmant, a civil engineer at Laval University in Quebec, Canada, who has modeled Nile water supply. In fact, there could be net gains. Ideally, less water would be stored in hot, low-lying Lake Nasser, which loses roughly 10 billion m^3 each year from evaporation, and more would be stored behind GERD, which is higher and cooler. Ethiopia would release regular supplies, and Egypt would benefit from the increase in storage capacity, providing extra insurance during droughts. But Mohamed Allam of Cairo University, a former water minister, remains wary of Ethiopia's intentions and thinks GERD was deliberately oversized. "They will continue to build dams in order to control every water drop for political reasons."

The greater strategic concern, Tilmant and observers say, ought to be Sudan. Once

Ancient rivals vie for upper hand in the Nile Basin

Long North Africa's hegemon, Egypt in 1970 harnessed the Nile with the Aswan High Dam (see left) to expand irrigation and generate 2100 MW of hydropower, then half the country's electricity. But others are now reaping benefits from the river. Sudan is poised to expand its irrigation, and since 2009 it has tripled its hydropower to 3000 MW (see right). The true powerhouse is Ethiopia with its high-elevation tributaries: It has built six major dams over the past 15 years that can generate 3500 MW, a sevenfold boost. The Grand Ethiopian Renaissance Dam (GERD) will give the country potential for nearly 10,000 MW in all—and control over much of the Nile's flow, sparking fear and anger in Egypt.



GERD has smoothed out the Blue Nile's flow, Sudanese farmers are likely to take more water to intensify production and expand croplands. Egypt, where population is growing explosively, can ill afford to lose any water. "Already we have some deficit in our water resources," says Alaa Yassin, professor of hydraulics at Alexandria University and adviser to the Ministry of Water Resources and Irrigation in Cairo.

Of all the possible hazards, the most terrifying is posed by GERD's saddle dam. It will stretch for 5 km between two hills to the south of the main dam and increase reservoir capacity fourfold. If it were to fail, a catastrophic flood would be unleashed, threatening millions of people. The 2013 expert review said it lacked adequate documentation to verify that the saddle dam's design is robust. Panelists worried that the structure, which is made of crushed rock, might slide under the weight of the water. And because the saddle dam is built on weathered rock, rather than solid bedrock, water might seep underneath and weaken the structure.

An expert group convened by Massachusetts Institute of Technology (MIT) in Cambridge in 2014 reiterated those concerns. "This is going to be one of the biggest saddle dams in the world," says Dale Whittington, a water resources expert at the University of North Carolina, Chapel Hill, and a member of the group. "It should be looked at very carefully." In a response to the MIT report, Ethiopian scientists noted that Salini Impregilo will use concrete to seal both the saddle dam and fractures in underlying rock. "It's solid," Seleshi says. The Egyptian view: "I can't say I'm confident," Yassin says.

AT THE DISPUTE'S NADIR in June 2013, Egyptian politicians were caught live on TV floating the option of sabotaging the dam. But in March 2015, heads of the foreign ministries and water agencies of the three countries pledged to agree on the reservoir's filling and subsequent operations. Egypt and Sudan praised Ethiopia for continued work to guarantee dam safety. "My view is that they're not far away from a deal," Grey says.

After years of acrimony, no one expects a deal that ensures full cooperation and maximal benefits. "We need to be realistic about what's possible," says Kaveh Madani, an environmental policy analyst at Imperial College London. But over the next 3 decades, the region's population will double, adding nearly 200 million people who will need food and electricity. If trust can be created and GERD proves to be a smarter approach to tapping the Nile, that would be a revolution in its own right. ■

GRAPHIC: P. HUEY/*SCIENCE*