



A New Great Lake—or Dead Sea?

Turkmenistan intends to create a huge lake in the desert by filling a natural depression with drainage water. Critics say it's a bad idea that could even spark a war

ASHGABAT, TURKMENISTAN—Bone-dry and as forbidding as California's Death Valley, the windswept, 120-kilometer-long Karashor Depression—a natural bowl speckled with the ash-gray, mica-laden sand that gives the Karakum, or "Black Sand," Desert its name—might seem the last place in the world to put a lake. But on a fine day in October 2000, some 450 kilometers south of Karashor, President Saparmurat Niyazov leaned against a spade and breached a few-meters-wide earthen dam. Laborers took over, and soon water was gushing into the initial segment of a canal intended to fill Karashor to its rim. Golden Age Lake, the late president said, would become "the symbol of revival of the Turkmen land," covering 3500 square kilometers—nearly the area of Utah's Great Salt Lake.

With that gesture, Niyazov—known as Turkmenbashi, or "Father of the Turkmen People"—launched one of the most grandiose water projects ever undertaken. According to the plan, two canals that bisect the country will funnel runoff from heavily irrigated cotton fields into Karashor. The \$6 billion project is designed to drain swamps and combat the buildup of salt and other minerals that have degraded three-quarters of Turkmenistan's arable land and eroded renowned archaeological monuments. "The lake will solve

many problems," says Paltamed Esenov, director of the National Institute for Deserts, Flora, and Fauna in Ashgabat. Turkmen officials predict that the project will reclaim 450,000 hectares of water-logged agricultural fields and create a habitat for migratory birds and an inland fishery.

Next month, Turkmen engineers say they will complete the mammoth effort's first phase: excavation of the two "collector" canals, each hundreds of kilometers long. Water apparently has already begun trickling into Karashor. "We are carrying out a unique, pioneering project," says a senior engineer at the Turkmen State Water Research, Production, and Design Institute in Ashgabat, which leads construction of Golden Age Lake. "Everything we are doing is aimed at increasing agricultural productivity," says the engineer, who requested anonymity after agreeing to be interviewed without permission from Turkmenistan's Ministry of Foreign Affairs.

But Golden Age Lake has unleashed a torrent of criticism as well. "There's no sense in this," says Timur Berkeliev, a geochemist who coordinates the Worldwide Fund for Nature's Econet project in Turkmenistan. He and others are skeptical of plans to purify the runoff, laden with pesticides and fertilizers, and contend that the

lake will become an artificial Dead Sea. "Trying to find value in this lake may be like trying to put lipstick on a pig," says Michael Glantz, director of the U.S. National Center for Atmospheric Research's Center for Capacity Building in Boulder, Colorado. "A bad idea, even for the best of intentions, is still a bad idea." Some experts believe that runoff will be insufficient to fill the lake, as the drainage water will evaporate or seep into the desert through unlined feeder canals.

That prospect raises fears that the lake could trigger a water war. Some observers worry that to prevent Golden Age Lake from running dry and to dilute tainted water, Turkmenistan might top it off with fresh water from the Amu Darya, a river on the border with Uzbekistan to the north. Uzbeks rely on the river for irrigation, and their leaders have said they would not tolerate a reduced share of the Amu Darya. "The lake project has incredible geopolitical implications," says Johan Gely, who works on water issues in central Asia for the Swiss Agency for Development and Cooperation. The senior water engineer insists such fears are unfounded: "Every drop of the Amu Darya is valuable, and nobody is planning to use this water for Golden Age Lake," he says.

Some see a window of opportunity to coax Turkmenistan to reconsider. Niyazov died in December 2006, and his successor,

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Making a lake. Two cross-country canals will funnel drainage water from Turkmenistan's heartland into the Karashor Depression.

Gurbanguly Berdimuhamedov, has not yet spoken publicly about the project. Foreign leaders have remained mum as well, perhaps in deference to Turkmenistan's growing clout as owner of the world's fifth largest natural gas reserves. In the meantime, Berdimuhamedov has promoted a gradual opening of the isolated country. "The leadership is now sensitive to world opinion," says Berkeliev. There might be one last chance, he says, to persuade authorities to convene an international scientific review before irreversible steps are taken to fill the lake. "This is the right time to do something," he says.

Back in the USSR

Centuries ago, central Asians learned how to make the most of the region's scarce water with networks of underground canals that conserved water for irrigation and drinking. "The tragic irony is that this region was home to one of the largest and most efficient irrigation systems in history, until the Mongol invasion destroyed much of the network," says Peter Sinnott, director of the Caspian Project at Columbia University.

Josef Stalin managed to outdo the Mongols. During the Cold War, when central Asia was part of the Soviet Union, Stalin's water managers cooked up a notorious fiasco. In the 1950s, they began to divert massive amounts of water from the Syr Darya into a network of canals to irrigate cotton fields in Uzbekistan. The Syr Darya is one of two main sources of water for the landlocked Aral Sea; the river's reduced flow resulted in the Aral's shrinkage to less than a quarter of its original surface area.

Soviet planners were pushing cotton in Turkmenistan as well, and in 1954, work commenced on the Karakum Canal, which would feed water from the Amu Darya—the other big Aral Sea source—into the Turkmen heartland. At 1375 kilometers in length, the Karakum waterway, completed in 1988, is the world's longest irrigation canal. It has been a boon for agriculture—it tripled the arable land in its vicinity—and provides water to the capital, Ashgabat.

But it has a dark side: A sizable fraction of the water that enters the canal (15% to 50%, depending on whom you ask) seeps through its unlined bed into the surrounding soil. The hemorrhaging created a patchwork of ponds and swamps and has exacerbated salinization. As the ground became waterlogged, the water table rose, bringing salts—

primarily sodium sulfate—to the surface by capillary action. With evaporation, the brine crystallizes into mirabilite, a corrosive mineral that ruins oases and poisons fields. "Several kilometers to the left and right of the canal is a death zone," says a Turkmen government scientist who asked to remain anonymous to keep his job. "If you step in the extremely salty water, your shoes are destroyed within a week," adds a Western technician in Ashgabat who has visited the construction site of Golden Age Lake.

The Karakum Canal is not the only villain in the salinization saga. In the mid-1970s, Soviet engineers constructed drainage canals to discharge runoff into the desert. Dumping, coupled with overirrigation of farm fields, has saturated the ground and brought salt to the surface across the watershed. The water table is so high in the Dashoguz region, researchers say, that dozens of saline lakes have formed from water burbling up from the ground. "About 80% of arable land is damaged to different degrees," says Berkeliev. Many Turkmen farmers soak fallow fields in winter, wrongly believing that as fresh water seeps into the soil, it takes salt with it. "But this has the opposite effect," concentrating mirabilite, Berkeliev says: "This is a very complex problem, and the level of study is not adequate."

That hasn't stopped Turkmen authorities from forging ahead with a solution: the resurrection of a 1970s idea to divert Turk-

menistan's irrigation runoff into Karashor, near the border with Uzbekistan. Niyazov dusted off a Soviet rough blueprint for an artificial lake, Glantz and others assert, as a strongman's way of showing dominion over nature. "Only a powerful state can build such a gigantic thing," Niyazov said in 2003. Turkmenistan's leader from the country's independence in 1991 until his death, Niyazov was anointed by parliament as Saparmurat Turkmenbashi the Great and, in 1999, made president for life. Golden Age Lake was not put to public consultation or debate. "It was almost impossible to object before," says Berkeliev. In 2004, after merely asking whether the project included ecological expertise, the country's sole homegrown environmental group, the Katena Ecological Club, was shut down.

One potential beneficiary of the lake project is the region's archaeological treasures. "Water and salt are the main enemies of archaeological sites," says the government scientist, who says that farmland and runoff have begun to encroach on what might be Turkmenistan's most famous site, the Bronze Age ruins of Gonur Depe (*Science*, 3 August 2007, p. 586). Salinization has already taken a heavy toll at one ancient monument, Little Kyz Kala in the medieval city of Merv, which has deteriorated especially rapidly in recent decades. The water table rose, soaking the foundations of the 1400-year-old brick fortress with salt and weakening them (see photos, below).

With archaeologist Tim Williams and colleagues at University College London, Sébastien Moriset's team at the International Centre for Earth Construction of the Grenoble School of Architecture in France has helped Turkmen conservators improve drainage and apply sacrificial soil layers at monuments that will bear the brunt of erosion rather than the original walls.

Draining the runoff water from the landscape should, in theory, ameliorate salt-induced erosion of the monuments, says the government scientist. "How it will work in practice," he says, "we don't know."

Salvation or damnation?

To turn a dusty depression into a lake requires a whole lot of moisture. So the first and perhaps most formidable task was to excavate the two cross-country



Going, going ... The 1400-year-old Little Kyz Kala fortress in Merv was in bad shape in 1950 (top); a rising water table accelerated the erosion, greatly diminishing the monument by 2003.



Soaking up new ideas. Turkmen State University students are riveted by the words of a foreign lecturer.

The End of an Intellectual Dark Age?

ASHGABAT, TURKMENISTAN—This autumn, 80 top university graduates in this central Asian nation will take part in a revived system of candidate (the Russian equivalent of a Ph.D.) and doctoral degrees in fields as diverse as art history and zoology. If that sounds modest, consider how many students last year began postgraduate studies in Turkmenistan: zero. This is the country's first crop of postgrads since 1997.

That year, the nation's authoritarian former leader, Saparmurat Niyazov, abolished advanced degrees. Other elements of his stultifying program included halving undergraduate education to 2 years and lopping a year off secondary school. Niyazov also closed the Academy of Sciences in 1997, citing "the lack of any practical scientific results." Perhaps most insidious of all, his underlings enforced rote memorization of a book—the *Rukhnama*, a banal spiritual primer that Niyazov himself penned—as dogma.

Since Niyazov's death in December 2006, his successor, Gurbanguly Berdimuhamedov, has made education reform a top priority. He has upped university education to 5 years—six for aspiring physicians—and reinstated the lost year of secondary school. Science is back in fashion: "Science plays the leading role in the strong state, and therefore we should keep pace with

collector canals. Specialists plotted out routes that would make best use of natural topography. "In some places we had to dig as deep as 50 meters," says the senior water engineer. In other areas they built platforms or added boulders as obstacles to suppress the flow rate. When they encountered giant stone slabs, they invented equipment that could be inserted in cracks between layers to lift the rock out. Blasting was considered too expensive, and "we don't have reliable professionals for that purpose," says the senior water engineer.

The crew dug the northern canal in the Dashoguz region wider and deeper to allow for a larger water flow. For about half its length, the 432-kilometer Dashoguz Collector follows the bed of the ancient Uzboy River. The 720-kilometer Great Turkmen Collector starts in the Lebap region in the east and links up with the Dashoguz Collector 75 kilometers upstream of Karashor. About 45 kilometers from the depression, engineers built a 30-meter-tall, 600-meter-long dam to steer the water; otherwise it would have followed the lower-elevation Uzboy riverbed to the Caspian Sea. The senior water engineer says his engineers have also done some "sculpting" of Karashor's contours.

Water is now moving the length of the Dashoguz Collector and beginning to flow in the Great Turkmen Collector, the senior water engineer says. Satellite images confirm this. "It looks like canals, even unlined, can convey the drainage flow," says Leah Orlovsky, a water researcher at Ben-Gurion University of the Negev in Israel who works in Turkmenistan. On a flight from Tashkent to Tel Aviv last October, Orlovsky noticed that an

area of roughly 20 to 25 square kilometers at the southern end of Karashor was flooded.

Filling the lake should take several decades, says Esenov of the desert research institute. Water must first flow into the capillaries—a 1000-kilometer network of small feeder canals linking at one end to agricultural drainage ditches and at the other to small reservoirs or to the vast collector canals. Pumping stations regulate the flow into the collectors. Eventually, the senior water engineer says, the groundwater table should drop by a couple of meters, allowing for the gradual desalinization and reclamation of farm fields.

Although Golden Age Lake could save some iconic monuments, lesser known archaeological sites were damaged during construction. "They just bulldozed some small monuments and sites that hadn't been excavated yet," says the government scientist. The project's design called for an archaeology rescue program, he says, but it had no funds. Living heritage is being lost as well. The collectors have raised the water table along their length, spoiling drinking water wells in some desert settlements. "Villages with ancient roots are being moved," says the independent scientist. "It's a degradation of the cultural landscape."

Future plans call for widening and deepening both collectors, says the senior water engineer. But there are no plans to line them. He referred questions about their dimensions and anticipated flow rates to institute colleagues, who were not available for interviews. One told *Science* privately that the lake's depth should reach 130 meters and its anticipated volume is 135 to 145 cubic kilometers.

"Data from Turkmenistan are hard to come

by ... and not so reliable," says Glantz. But even rough approximations suggest that the project is doomed, says Berkeliev. The quality of the lake will depend on what goes into it, and Turkmen authorities in the past have predicted a water inflow of 10.5 cubic kilometers a year. About two-thirds will come from Dashoguz, including cross-border runoff from the Khorezm region of Uzbekistan; the Great Turkmen Collector will supply the other third of the water. However, Uzbekistan plans to build a drainage canal from Khorezm to the Aral Sea, so the amount feeding Golden Age Lake would eventually taper off, says Kai Wegerich, a central Asia water expert at Wageningen University in the Netherlands. "If the Uzbek drainage canal is built, it might not make sense anymore to construct the lake," he says.

Khorezm canal or no, Berkeliev says his calculations are damning. Based on the high evaporation rate in Karakum, he asserts, "there will never be a water body there." Others say Golden Age Lake may well come into being but is fated to become an environmental nightmare: a salty broth of organic pesticides and fertilizers.

Not so, says Vyacheslav Zharkov. He and his colleagues at the desert research institute in Ashgabat are devising filter media that absorb heavy metals and organic contaminants from runoff. These can be installed at treatment plants at points where water enters the collector canals—if the Turkmen government finds money to build such treatment plants. "After treating water with our sorbents, it is suitable for agriculture and for drinking," Zharkov says. He claims that salt will be drawn out as water moves along the

its latest achievements,” Berdimuhamedov said recently, according to the state press. But recovery will not be easy. “After so many years of the forced degradation of the education system, it’s really hard to revive it,” says one Turkmen government scientist. “The serious scientists didn’t wait for changes within the country—they left.”

Turkmenistan is not the first modern nation to willfully erode its intellectual capacity: Afghanistan under the Taliban, for instance, suffered severely. But Turkmenistan’s descent took place largely out of sight, as Niyazov isolated the country and placed sharp limits on international cooperation. In this twilight, in 2001, the *Rukhnama* appeared. The book is a mix of folksy guidance about how to lead a good life and a history of the Turkmen people that mangles the chronology of real events and fabricates others. “It did great damage for historians,” says the government scientist. Workplaces formed *Rukhnama* study circles, and TV programs showed children reciting passages while professing their love for Niyazov. *Rukhnama* knowledge was necessary to pass exams, including the driver’s test.

The *Rukhnama* is still for sale in Ashgabat, and in some primary and secondary schools “it remains a strong part of the curriculum,” says Leon Yacher, a geographer at Southern Connecticut State University in New Haven, who lectured in Turkmenistan last month. When he visited a school in Turkmenbashi, a

city on the Caspian coast, “every student had a copy of the book on their desk, and they were expected to read from it every day.” But to the relief of scholars, the *Rukhnama* is being phased out in universities and government offices.

Turkmen academics are trying to pick up the pieces. “A change of the curriculum is needed badly,” Yacher says. One problem is that there are few solid Turkmen textbooks, and no recent textbooks in Russian or in English, says the government scientist. That matches the general decrepitude of the faculty. Even in a field that was in favor under Niyazov—archaeology—the department was eliminated at Turkmen State University in 1999 and, says the government scientist, “the youngest archaeologist we have is a 60-year-old guy. When the last generation of archaeologists is gone, only foreigners will work here.”

Among signs of progress, construction has begun on a \$35 million building for Turkmen State’s physics and mathematics faculty, and a new campus is in the works for Turkmen State Medical Institute. The country is looking beyond its borders as well, with plans this fall to dispatch 1500 students to overseas universities, including Columbia University. “If [students] are off-the-charts good, we should do what we can to overcome any obstacles and get them here,” says Peter Lu, a physicist at Harvard University, who lectured in Turkmenistan in 2005. Foreign institutions can play a critical role in the intellectual revival, starting with the next generation. —R.S.

canals. “We have asked how the salt will be removed. They say the water will clean itself. Nobody is able to explain to me how this works,” says the Western technician. Berkeliev too says he is mystified.

Looming shortage

The overarching question is whether Turkmenistan might tap the Amu Darya to improve the new lake. Under the Soviet-era water-sharing agreement, Turkmenistan and Uzbekistan each can use up to 22 cubic kilometers of water flowing out of Afghanistan and along their shared border—despite a huge difference in population size. (Turkmenistan has 5 million people; Uzbekistan has 28 million.) “The Uzbeks will not tolerate any ‘vanity diversions’ to the new lake,” says Glantz. In a tense situation, “new diversions will lead to a real war.”

Even if water isn’t diverted to the lake, Afghanistan’s plans to rev up irrigation are likely to curtail the Amu Darya’s flow. Currently, it uses only a few cubic kilometers each year. “They are planning a massive expansion of irrigation,” says Wegerich. Several major projects launched in the last 2 years aim to irrigate more than 1 million hectares, with completion dates staggered over the next 5 to 15 years. Adds Glantz, “The Uzbeks think it is decades away. Wrong.” A complicating factor is the retreat of glaciers in the Pamir Mountains—the source of much of central Asia’s fresh water. “Eventually, there will be no Amu Darya, no Syr Darya,” Mamadsho Ilolov, president of Tajikistan’s Academy of Sciences, told *Science*. Golden Age Lake, he says, “will be very dangerous for neighboring countries.”

The best solution to Turkmenistan’s water problems, Berkeliev and others argue, is conservation. Currently, Turkmenistan uses 5000 cubic meters of water per capita per year. That’s twice the rate of Uzbekistan and more than 10 times that of Israel. “We are the champions of water waste,” says Berkeliev. It’s high time, he and others say, that the country revises its Soviet-era agricultural system and switches to water-saving technologies, like drip or subsoil irrigation, and converts a significant portion of farmland to less water-intensive crops like wheat, corn, grapes, and olives.

Turkmenistan must also solve another problem arising from its poorly maintained infrastructure: water hoarding. Public supplies are sporadic, and when the spigot is on, Turkmen farmers funnel off as much as they can. Upgrading the irrigation system would be a much better investment than the lake,



Soaking up contaminants. Vyacheslav Zharkov says his sorbents can render the waters of Golden Age Lake suitable for drinking.

says Aral Sea expert Philip Micklin, a geographer at Western Michigan University in Kalamazoo. In his view, Golden Age Lake is “a big waste of money.” When the plan was being put together in the late 1990s, it had a conservation component—“but that disappeared,” says the independent scientist. “If they spent half the budget of the lake on water conservation,” he says, “they would not have had to build the lake.”

The senior water engineer says he is not bothered by the criticism and that it will not derail the lake project. “We faced the same opposition when we built the Karakum Canal,” he says. “Any such great project will have negative effects. But these are outweighed by the benefits.”

Berkeliev says it’s refreshing to be able to have this debate; it could never have happened under Niyazov. “But to change the minds of decision-makers, we need strong support from the outside,” he says. “We must have an international review of this project while there’s still time,” adds geographer Igor Zonn of the Engineering Research Center on Water Management, Land Reclamation, and Environment in Moscow. That might be possible, as Turkmenistan continues a cautious opening up to the world. “We are trying to increase international cooperation on environmental issues,” Ogulsona Karyeva of the Ministry of Nature Protection told a Fulbright conference in Ashgabat last month.

“We would be very happy to work with foreign scientists,” says Esenov. “It’s a complex problem.” That’s something everyone can agree on.

—RICHARD STONE