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Restoring Rivers

The work has begun, but we have yet to determine what works best.

Between 1973 and 1998, U.S. fresh waters and rivers were getting cleaner. But that trend has reversed. If the reverse continues, U.S. rivers will be as dirty in 2016 as they were in the mid-1970s.

Water quality is not the only problem. In parts of the United States, the extraction of surface water and groundwater is so extreme that some major rivers no longer flow to the sea year round, and water shortages in local communities are a reality.

The damage and suffering wrought by Hurricane Katrina demonstrate that the restoration of waterways and wetlands is not a luxury. It is a national imperative. And the imperative does not apply only to hurricane-prone coastal waterways. More than one-third of rivers in the United States are impaired or polluted.

The flood-storage capacity of U.S. rivers is at an all-time low. Water shortages are increasingly common even in eastern states that historically have had plenty of it. Aquatic wildlife is going extinct at a rate much higher than organisms in either terrestrial or marine ecosystems. In June 2004, drinking water in Wisconsin was found to exceed levels of nitrate considered safe. In July 2005, scientists reported that high levels of nutrients and sediments from river tributaries had created a dead zone that blanketed a third of the Chesapeake Bay. In October 2005, homes in Connecticut, New York, and New Jersey were flooded when rivers overflowed their banks after a week of rain. All three of these disasters are linked to the degradation of rivers and streams. And all three of them could have been prevented by ecological restoration.

River restoration means repairing waterways that can no longer perform essential ecological and social functions such as mitigating floods, providing clean drinking water, removing excessive levels of nutrients and sediments before they choke coastal zones, and supporting fisheries and wildlife. Healthy rivers and streams also enhance property

TERRY FALKE, *Bird Refuge in a Dying Sea, Salton Sea, California*, Fujiflex, 40 x 48 inches, 1999.
(Collection of the National Academy of Sciences)

values and are a hub for recreation. Clearly, degraded rivers and streams need to be repaired.

However, just as rivers are in need of restoration, so too are the art and practice of restoration itself. A recent study (in which we participated) published in Science documented a huge number of restoration projects being implemented in every region of the country at great cost and for a variety of reasons. The projects range from land acquisition (at a median cost of more than $800,000), to bank or channel reshaping to restore floodplains (median cost more than $200,000), to keeping livestock out of rivers and streams (median cost $15,000). However, distressingly few of them—just 10% of all restoration project records in the database put together by the National River Restoration Science Synthesis (NRRSS)—included any mention of assessment or evaluation. The study concluded that it is currently impossible to use existing databases to determine whether the desired environmental benefits of river restoration are being achieved. Even when monitoring was reported, it typically was an assessment of project implementation, not ecological outcomes.

The nation can do better. The United States needs regulatory and legislative federal policy reforms in order to improve the effectiveness of river restoration and thus the health of the nation's waterways.

How did the United States reach a point where the majority of our rivers are degraded and ecologically dysfunctional? People have always chosen to live and work near water. Cities and industrial facilities began to grow up along U.S. waterways centuries ago, and for most of U.S. history, dilution was the solution to pollution. U.S. streams and rivers were the dumping grounds for waste, and the hope was that the waste would be carried away.

Settlers also cut down riparian forests and filled in small tributaries and wetlands to make transportation and building easier. There was little understanding of the ecological roles that these forests and tributaries fill. In the first half of the 20th century, massive dams were erected with the goal of supplying power and minimizing floods. They did accomplish those objectives, but damming also led to the loss of water-starved native plants and animals downstream. They could not survive and reproduce without the seasonal changes in flow that the river had always brought them and that their life cycles depend on.

With increasing industrialization and population growth, cities and industries not only continued to dump raw sewage and other wastes into streams and rivers, but also "paved" many U.S. streams—lined them with concrete so they could convey water and pollutants more rapidly. Streams were viewed as pipelines, not the living entities we now know they are. Forgotten was their ability, when healthy, to cleanse water, store sediments, and provide materials essential to healthy coastal fisheries.

The crisis came in the 1960s, when it became known that two-thirds of U.S. waterways were polluted. In 1972, the Clean Water Act (CWA) was passed. Since then, U.S. rivers and streams have become healthier, largely because of controls over point-source pollution. Then in 2004, for the first time since the act was passed, the Environmental Protection Agency (EPA) reported that waterways were once again getting dirtier.

The primary reason why so many rivers and streams are still being degraded today is poor land stewardship. Human activities and alterations of the landscape have diverse and far-reaching effects. As land is cleared to build homes and shopping malls, entire watersheds are affected. Construction and the erosion of farmland introduce massive amounts of sediment into streams. Many streambeds are covered by heavy layers of silt. This silt suffocates fish eggs and invertebrates living on streambeds, destroys aquatic habitat, and even can interfere with the treatment of drinking water. Agriculture and urbanization move excessive amounts of nutrients and toxins from the land to rivers, streams, and coastal waters.

When land is cleared and replaced with hard surfaces such as parking lots and rooftops, stream flows are governed primarily by overland runoff or inputs from stormwater

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systems, not by the interaction of local climate, vegetation, and soil characteristics. Rainwater no longer soaks into the soil before it moves underground toward stream channels, the normal route for water flow in healthy temperate watersheds. Rapid runoff prevents replenishment of the groundwater table and results in "flashy" stream flows. Flashiness means more floods that can damage nearby property as well as flows so low in the summer that entire channels dry up. Stream and river banks begin to scour and slump. Channels widen and deepen. If the riparian vegetation has been removed, which is true for a huge number of streams and most rivers in the United States, erosion worsens. Moreover, the large amount of pavement in urban watersheds retains a lot of heat in the summer, so the flashy flows that follow heavy rains inundate the streams with pulses of warm water, destroying fish and bottom-dwelling organisms.

How has the United States tried to solve these problems? Are the solutions working? It is not as if nothing has been done. The CWA went a long way toward minimizing point-source inputs of pollutants to rivers. Unfortunately, rapid changes in land use and the many effects that urbanization and agriculture have had on rivers and streams are not as easy to remedy as point-source discharges.

Attempts have been made to minimize those effects. For example, the Conservation Reserve Enhancement Program of the Department of Agriculture's Farm Service Agency paid farmers to participate in long-term conservation projects such as planting riparian buffers on their property or keeping land out of agriculture. In recognition that more diffuse sources of pollution of waterways have become increasingly common, the EPA recently adopted stricter standards for control of stormwater runoff. This is Phase II of the National Pollutant Discharge Elimination System, which extends permitting regulations to smaller population centers. These regulations require communities and public entities to develop, implement, and enforce a stormwater program designed to reduce the discharge of pollutants. In addition, many cities and towns enacted their own regulations to slow the clearing of land, to require that only a minimal number of trees be removed during construction, or to mitigate damage to forests and wetlands.

Despite these and many other efforts to minimize the environmental impact of developing the land or extracting natural resources (such as mining), streams and rivers have continued to degrade. The controls have simply not been able to keep up with the rate of development and associated watershed damage. Moreover, many rivers and streams were suffering years before conservation programs were enacted.

River and stream restoration thus grew out of the recognition that active interventions and aggressive programs were needed to improve the health of U.S. waterways. There are many ways to restore rivers, and they vary depending on the underlying problem. The most common goals of river and stream restoration are to improve water quality, manage or replant riparian vegetation, enhance in-stream habitat, provide for fish passage, and stabilize banks. Practices for accomplishing these goals are diverse and overlapping.

For example, bank stabilization can be achieved in a number of ways, including riparian plantings, wire baskets filled with stones, large slabs of concrete, and rope netting. Improving water quality may involve enhancing upstream stormwater treatment and planting vegetation along stream banks. Enhancing habitat and improving fisheries may require adding logs or boulders to streams, constructing ladders for migrating fish that cannot pass dams, or reconnecting a river floodplain to its channel to provide spawning habitat or nursery grounds for young fish.

Restoration activities such as these are now common in the United States. For example, in Kentucky, the Lexington-Fayette Urban County Government has an annual Reforest the Bluegrass day in which thousands of trees are planted along local streams in order to improve water quality and habitat for aquatic life. In suburban Maryland, restoration of a stream in the Paint Branch watershed involved installation of a bypass pipe that redirected warm stormwater coming from a subdivision. This kept the stream water cool, elim-

inating a thermal barrier to trout, while reducing peak flows during storms. Near Albuquerque, New Mexico, portions of the west bank of the Rio Grande were cleared of the invasive Russian olive plant, and land adjacent to the river was lowered to allow water to flow over the bank during spring snowmelt. This has helped maintain native vegetation and created a functional floodplain.

These examples are among the river restoration success stories. Unfortunately, we also know of many, many failures. In Maryland, an effort to reconfigure a stream channel using bulldozers and artificially created pools resulted in flooding. Fixing the problem involved straightening the stream channel to restore its prior form as well as the large expenditure of money and time. In California, large amounts of gravel are added to rivers every year to provide spawning habitat for salmon, but it is not clear whether this gravel remains in place or that salmon populations are increasing. In the Midwest, sand traps are dug along agricultural fields to prevent silting and eutrophication of adjacent streams, yet large amounts of nutrients still move down the Mississippi to the Gulf.

One of the most pervasive reasons for restoration failure is the implementation of a project at one point along a stream without knowledge of upstream conditions. If serious upstream problems are not addressed, riparian replanting or channel stabilization projects that are implemented downstream are likely to fail.

These failures and the fact that the health of coastal areas such as the Chesapeake Bay continues to decline despite thousands of stream and river restoration projects demonstrate that something is wrong with U.S. restoration policies. The health of U.S. waterways is not improving fast enough despite the fact that the number of projects in the United States is increasing rapidly. The country is now spending well over $1 billion per year on river and stream restoration, and it is not getting its money's worth.

The problem is that there are no policies to support restoration standards, to promote the use of proven methods, or to provide basic data needed for planning and implementing restoration. Although much is known about effective restoration, this information has not been used in most projects or policies. For this reason, many restoration efforts fail: Stream banks collapse, pollutants from upstream reaches that were never considered for restoration overwhelm newly restored sites downstream, channel reconfiguration projects that were overengineered are buried in sediment, and flood waters flow over river banks.

What to do? First, government officials must deal with the fact that most restoration projects are being done piecemeal, with little or no assessment of ecological effectiveness. They do not even know which of the various restoration approaches are most effective. In addition, there is little coordination among restoration plans and projects in most watersheds.

Second, because there are no national standards for measuring success in restoration, there is no system for evaluating how effective projects are. Watershed managers and restoration practitioners have little guidance for choosing among various restoration methods to ensure ecological improvements.

Third, the United States has no national tracking system that gathers basic information on what is done where and when. Thus, there is no way to prioritize projects based on what is being done elsewhere or what is known to work.

The solution to pollution is to reform federal, state, and local policies. Here we address the federal level because of the critical role that federal policies play in funding and permitting restoration projects. Different regulations and laws are needed in four areas.

Federal agencies must be directed to adopt and abide by standards for successful river and stream restoration. Progress in the science and practice of river restoration has been hampered by the lack of agreed-on criteria for judging ecological success. The restoration community—which includes legislators, agencies, practitioners, and citizen groups—should adopt common criteria for defining and assess-

ing ecological success in restoration. Success can also be achieved through the involvement of stakeholders and learning from experience, but it is ecological success that will improve the health of U.S. waterways.

Five basic standards have been recommended by an eminent team of U.S. scientists and engineers and endorsed by an international group of river scientists as well as by restoration practitioners. The standards are:

- The design of a river restoration project should be based on a specific guiding image of a more dynamic, healthy river.
- The river's ecological condition must show measurable improvement.
- The river system must be more self-sustaining and resilient to external perturbations, so that only minimal followup maintenance is needed.
- During the construction phase, no lasting harm should be inflicted on the ecosystem.
- Both pre- and post-assessments must be completed and data made publicly available.

Simple metrics are already available that can be applied to each standard, so implementing the standards would not be difficult. If federal agencies involved in funding river restoration adopted these standards, it would go a long way toward ensuring that projects meet their stated ecological goals.

Congress should ensure that restoration projects are credible by requiring recipients of federal funds to adhere to the standards for ecologically successful restoration projects. Several notable authorization bills that govern river restoration at the federal level are the Water Resources Development Act (WRDA), the farm bill, and the transportation bill. These bills can be used to establish requirements for monitoring outcomes and tracking agency performance. Authorization bills can thereby direct money increasingly toward effective strategies. Appropriations bills can also require agencies to adopt standards. These bills often include language that directs an agency to take specific action. Requiring an agency to adopt particular standards for implementing ecological restoration projects could also be included in an agency's annual appropriations.

Regardless of the mechanism, requiring standards that ensure better tracking and evaluation of restoration project outcomes will enhance not only individual projects but also others that follow. Accountability is essential.

Federal standards and guidelines that have implications for river restoration should be amended to incorporate the five proposed basic standards. This should include the revision of restoration manuals and design criteria. Formal policies, guidance documents, and manuals include not only those dealing with the design and implementation of projects, but also those offering general guidance or addressing restoration planning or oversight. Although amending of statutes or regulations may be ideal and in some cases required to inject basic standards for ecological restoration, amending present practices and procedures also will be helpful. Because a number of agencies provide funding for river restoration, often with agency-specific areas of emphasis, it may be preferable to assign responsibility for the development of standards and guidelines to individual agencies. However, all should comply with the five goals listed above, and mechanisms must be developed to ensure interagency coordination and common reporting.

For example, the U.S. Army Corps of Engineers undertakes a wide array of activities that affect rivers and streams, including river restoration. Like most agencies, the Corps is supposed to adhere to statutes and the interpreting regulations that govern these activities to protect and restore environmental quality, among other public interests. The Corps, like other agencies, is further governed by standards and guidelines. These are outlined in a series of engineer manuals that provide general guidance on how to undertake various activities, including, for example, how to construct flood-control projects, how to stabilize riverbanks, and how to manage water releases from dams. Because of the significant increase in the amount and frequency of the Corps' involvement in river restoration projects, the agency should publish a new engineer manual that outlines acceptable practices and specifications for river restoration. Those should include some codification of the five basic standards for ecological success described above or something similar. Other agencies—for example, the Department of Agriculture and the Natural Resources Conservation Service—use similar guidance documents. They also should undertake similar revisions.

In addition, new restoration funding programs should be formed and some of the existing ones reformed. There is a critical need for federally funded programs that focus on specific regions and serve as model programs in balancing both human and ecosystem needs to maximize the restoration of services that healthy rivers provide.

To incorporate key elements of sound science into river restoration, projects must include goal- or hypothesis-driven restoration projects that place a high priority on monitoring, develop restoration designs that minimize environmental impacts, and demonstrate ecological improvement. These key elements should be incorporated into the internal policies and guidelines of the new or reformed restoration pro-

grams and be met before grants or contracts to fund restoration are awarded. This will require programmatic tools to assist groups in effective project implementation and compliance with environmental, monitoring, and reporting regulations. Existing programs that attempt to do what we have outlined include the CALFED Bay-Delta Ecosystem Restoration Program and the Chesapeake Bay Program.

A coordinated tracking system for restoration projects must be implemented. If the restoration of aquatic ecosystems is to be effective, restorers must be able to learn from past efforts. At present there is no coordinated tracking of river restoration projects. Existing federal databases are highly fragmented, often relying on ad hoc or volunteer data entry. They are inadequate for evaluating even the most basic trends in river restoration. Bernhardt et al. found that these national databases cataloged less than 8% of the projects in the NRRSS database. They could not be used to evaluate regional differences in restoration goals, expenditures, and assessment.

Agencies at all levels of government that share jurisdiction over rivers and streams are engaging in restoration projects of various kinds. Legislators who authorize projects and appropriate funds are also taking greater notice of the opportunities presented by river restoration projects that can drive funding toward their districts and constituents. Thus, there is an urgent need for a centralized tracking system that catalogs every stream and river restoration project implemented in the United States. This should include at least the following information for every project: Geographic Information Systems coordinates; spatial extent, intent, and goals; a catalog of project actions; implementation year; contact information; cost; and monitoring results.

Restoration monitoring presents its own suite of challenges. Implementation monitoring—determining whether a project was built as designed, is in compliance with permit requirements, and was implemented using practices that had been vetted by effectiveness-monitoring research programs—is not carried out routinely. This monitoring should be required of all projects and included in the centralized database. This ensures compliance with permits and with stated intents and requires that monitoring be part of project planning and designed in light of project goals.

Effectiveness monitoring involves an in-depth research evaluation of ecological and physical performance to determine whether a particular type of restoration or method of implementation provides the desired environmental benefits. Because effectiveness monitoring is time-consuming and expensive, it is unrealistic to make this a routine expectation. However, it is necessary when comparing the effectiveness of different restoration approaches, when evaluating unproven restoration practices, or when the ecological risks of a project are considered high.

The national tracking of restoration projects, including implementation and effectiveness-monitoring information, will ensure that projects are chosen wisely and that money is spent carefully. The EPA is a good candidate because of its role in overseeing compliance with the CWA and involvement in ecological monitoring. The U.S. Geological Survey is also a good candidate because of its involvement in water science and stream-flow monitoring. Regardless of which agency houses the national database tracking stream restoration, it is essential that individual agencies and other reporting entities maintain compatible databases with an internal structure that allows easy merges and "drop-down" boxes to ensure reporting in standardized categories.

Undertake a national study to evaluate the effectiveness of restoration projects. Because restoration effectiveness has not received adequate attention, it is not always clear which restoration methods are most appropriate or most likely to lead to ecological improvements. Agency practitioners often rely on best professional judgment that their projects are meeting intended ecological goals, rather than undertaking scientific measurement and evaluation. Only a small fraction of projects are currently being monitored to determine their relative success, so little is known about the environmental benefits. Something must be done to ensure that projects are doing what they set out to do and that money is well spent.

Although monitoring of project effectiveness in meeting ecological goals is always desirable, not every project requires sophisticated and costly effectiveness monitoring. In fact, many people worry that such an expectation would diminish the number of restoration projects on the ground by siphoning off available resources.

One way to balance the need for evaluation and accountability with limited resources is to conduct detailed monitoring of a sample of projects. The information gained would provide an efficient means of understanding project effectiveness and help restorers learn from the experience of others. Such a program could involve detailed monitoring of a sample of all projects within each of the major categories of river and stream restoration, perhaps beginning with the most interventionist restoration practices (such as channel reconfiguration) or the most costly forms of restoration (such as floodplain reconnection).

In 2002, Congress included language in a Department of the Interior appropriations bill that directs the National Research Council (NRC) to examine federal and nonfederal

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water resources programs and provide recommendations for a national research program that would maximize the efficiency and effectiveness of existing programs. The NRC has completed several reports that evaluate water research programs and is considering a study on river restoration. We recommend that such a study panel be funded immediately and directed to recommend the design, scope, and costs of a new research program. The program should explicitly evaluate which restoration methods are most effective at achieving the desired goals and delineate which project types require only modest compliance monitoring and which need detailed monitoring.

Because the data are currently insufficient to enable an NRC study committee to reach firm conclusions through synthesis of existing data and expert analysis, the panelists should be directed to identify needed further research. Furthermore, the panel should identify the appropriate agency to oversee this research program in order to ensure that peer review of all research is conducted and that restoration effectiveness data are collected by an entity that is independent from those conducting or funding restoration. It is standard practice to conduct double-blind studies when human health is concerned. It is no less important when the future of clean water and freshwater resources is at risk.

Use existing funding for river restoration more efficiently and supplement funding. Although there are many areas in which Congress and federal agencies could make improvements in the policy and practice of river restoration, it is first necessary to ensure that existing funding is wisely allocated so that projects are successful. That means developing a mechanism to authorize and fund restoration projects in a much more coordinated fashion than the balkanized system that supports them today. There are more than 40 federal programs that fund stream and river restoration projects. Although large-scale high-profile projects such as those in the Everglades receive a great deal of attention, most projects in the United States are small in spatial extent. The cumulative costs and benefits of the many small restoration projects can be very high, which argues for better coordination.

We suggest that a Water Resources Restoration Act (WRRA) could serve as a mechanism to authorize and fund river restoration projects. Like WRDA, WRRA would support projects of various shapes and sizes, all for the purpose of making federal investments in natural capital and infrastructure. Money would still flow through individual agencies, but prioritization and coordination would be achieved through an administrative body with representation from all agencies that fund river restoration activities. That body would ensure that restoration funds are spent efficiently as well as address unmet needs. These projects would yield enormous benefits in the form of ecosystem services, including flood control, protection of infrastructure, and maintenance of water quality. They also would have benefits similar to those of more traditional infrastructure projects. They create jobs in member districts, but if they are carefully chosen and designed, they can also save taxpayer money. By including interagency tracking mechanisms and building in compliance monitoring requirements to each project, Congress can ensure the necessary feedback and accountability to make these projects wise investments. Instead of funds being allocated independently by 40-plus federal programs, WRRA would ensure that project prioritization occurs on watershed scales and is based on criteria that are consistent across the nation.

In addition to the need for better coordination and thus more efficient use of existing funding, current funding falls short of what is needed. The magnitude of the problems and the demands that citizens are making for healthier waters require additional funds for cleaning U.S. rivers and streams. Aging sewer and stormwater infrastructure combined with increased development of the land make it imperative that a combined approach involving better coordination and an increase in funding be a priority. Additional funding will not only make possible more recovery of damaged river ecosystems, but will enable inter- or intraagency mechanisms for tracking projects and allow more pre- and post-project monitoring of their effectiveness. New funding will not be

easy to come by in the current budget climate and with increased competition for investments in water quality. Many federal programs that involve river restoration are being cut, not increased. The growing need for upgrading stormwater and sewer infrastructure goes hand in hand with river restoration; one cannot replace the other. Only together will they accomplish the goals of improved water quality, more productive fisheries, and the restoration of other services that rivers provide.

River restoration is a necessity, not a luxury. U.S. citizens depend on the services that healthy streams and rivers provide. People from all walks of life are demanding cleaner, restored waterways. Replacing the services that healthy streams provide with human-made alternatives is extremely expensive, so river restoration is akin to investments such as highways, municipal works, or electric transmission. Congress already commits billions of taxpayer dollars in public infrastructure through the transportation bill or WRDA. It should make similar investments in natural capital.

Much can be accomplished by allocating scarce resources and prioritizing efforts based on sound policies that ensure that the most effective methods are applied and that agreed-on standards are adhered to. Changes in agency policies and practices require overcoming bureaucratic inertia and confronting competing constituencies. Instituting tracking systems and comprehensive studies of project effectiveness requires cooperation among multiple agencies, scientists, environmental groups, and affected industries. But with congressional oversight and wise appropriation of scarce dollars, U.S. rivers and streams can once again flow clear and clean.

Recommended reading

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