Don’t Debate;

Adaptive implementation can help water quality professionals achieve TMDL goals

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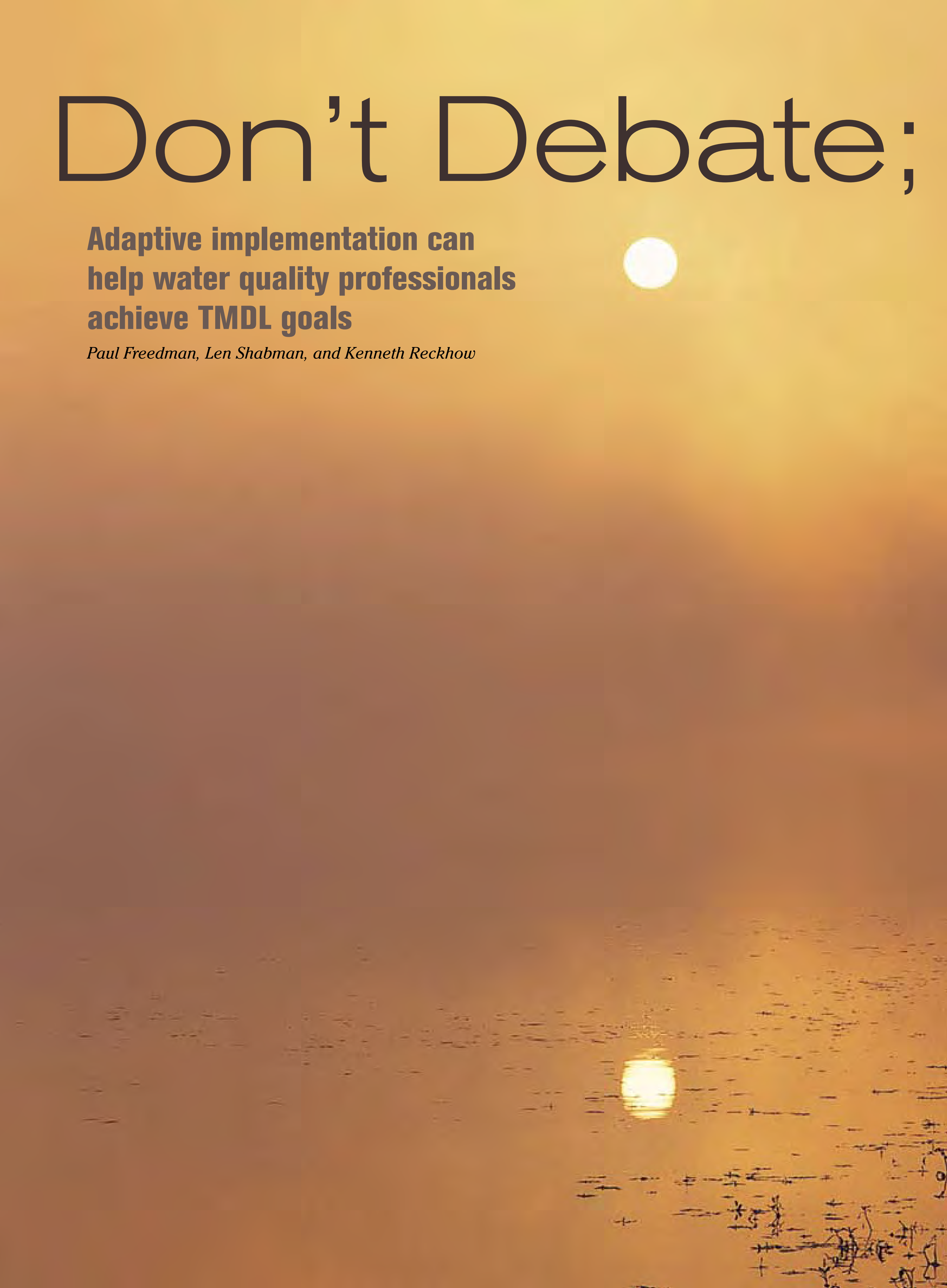


Adapt

We've come a long way in four decades. In 1972, the Cuyahoga River caught fire, Lake Erie was declared "dead," and anyone who fell in the Potomac River was presumed to need a hepatitis shot. To cure these ills, the U.S. Congress passed the Clean Water Act (CWA). Its lofty goal was to restore all U.S. waters to swimmable and fishable conditions via a simple strategy: Eliminate the discharge of poorly treated municipal and industrial wastewaters.

Effective wastewater treatment resulted in substantial progress by the 1990s. The Cuyahoga River sported water taxis rather than fire-patrol boats, Lake Erie became a $2 billion tourist mecca, and both striped bass and rowing enthusiasts returned to the Potomac. However, not all waters had become fishable and swimmable. Legal action was taken to enforce CWA Sec. 303(d), a provision requiring that total maximum daily loads (TMDLs) — a "pollution budget" — be developed for all waters that did not meet water quality standards. Suddenly, this once obscure, ignored provision of CWA became the centerpiece of water quality improvement programs.

We have since developed more than 20,000 TMDLs, and yet, roughly 40% of U.S. waters still do not meet water quality standards. Why? Is CWA flawed? Is the TMDL program ineffective? Or are the water quality problems unsolvable?

It may be that our approach is out of date. Imagine trying to repair a 2008 automobile using a 1972 auto-repair manual. The manual would not address many of the car's components (for example, electronic ignition, fuel injection, front-wheel drive, a computer control model, and a hybrid electric–gasoline engine), because these did not exist in 1972.

We are trying to fix today's water quality problems using a 1972 instruction manual (CWA). Our major issues — managing pollutant runoff from farms and urban areas, reversing habitat and flow alterations, controlling invasive species, and limiting the effects of legacy pollutant problems — weren't even conceived of 40 years ago.

Today's goals are much broader than simply minimizing the pollutants discharged from pipes. In fact, we are not always certain which goals we can (or can afford to) achieve, and our current knowledge and models provide only partial guidance. Nevertheless, we continue developing TMDLs that are sometimes unachievable and calling for implementation plans that may be ineffective because we are using an antiquated repair manual to fix today's problems.

A new approach is available: adaptive implementation. Adaptively implementing water quality improvement plans enables water quality professionals to make water progress while still managing the uncertainties and limits of the TMDL approach.

Uncertainty and TMDLs

Conceptually, the TMDL requirement — analyze water quality impairment on a watershed basis and establish load limits for both point sources (waste-load allocations) and nonpoint sources (load allocations) — is attractive. However, uncertainty makes writing this kind of pollution budget problematic.

This uncertainty starts with listing impaired waterbodies (those violating state water quality standards). Most waters are listed for conditions (such as nutrient enrichment, sediment pollution, or fish-consumption advisories) that do not have definitive water quality standards. Furthermore, most states recognize that they lack enough data to assess their waters fully, need to revise their designated uses and criteria, and have assessment tools that are often simplistic.

The uncertainty continues in TMDL development. Nearly all states acknowledge that they lack enough data to quantify nonpoint sources, which contribute to 90% of water quality impairments. Also, surveys indicate that TMDL modeling typically is not site-specific, so its results (waste-load allocations and load allocations) include significant uncertainty. Furthermore, the relevant processes and stressors (such as nonpoint sources, sediment accumulation, and flow alterations) are not well understood, so TMDL assessments are likely to include prediction errors.

The uncertainty even applies to the effectiveness of recommended control measures — particularly nonpoint source best management practices and urban green practices, which are becoming the chief methods for controlling rural and urban nonpoint source pollutants. The typical response to uncertainty is to add a larger margin of safety to an analysis, which reduces the allowable allocated load. This leads to highly stringent effluent limits and increases public spending on pollutant controls. In many cases, it can cause us to dedicate limited resources and regulatory attention to actions that are inefficient or, worse yet, ineffective.

If the uncertainties are significant, those paying for the controls may call for more certainty before they must act. The result can be TMDLs that are stalled indefinitely due to debates over the related science. As a result, many inexpensive, clearly warranted control actions are delayed.

We need a better way. When uncertainties are present, we need to design restoration strategies that avoid both stalemates and potentially costly errors. Adaptive implementation is such an approach.

A New Approach

Adaptive implementation is "learning while doing." In this approach, a state develops an initial TMDL assessment while acknowledging and identifying decision-critical uncertainties. However, uncertainty is not an excuse for inaction; in fact, the only way to reduce uncertainty is to act and learn from experience. So, the project team writes an implementation plan that both reduces pollutant discharges and establishes a process for learning.

The team then implements certain control actions and monitors the waterbody to reduce decision-critical uncertainties. Team members then use what they learn to update water quality planning models, revise TMDLs, and revise the implementation plan (if necessary). This enables the team to implement new control actions with more confidence that they will result in cost-effective water quality improvements. Team members continue using this process until they achieve water quality standards.

The adaptive implementation approach ensures both continual progress and the persistence to achieve the goal (the water quality standard). It can be used to implement

- TMDLs when there is no question about the goal;
- TMDLs when the applicability of the original water quality standards is questionable; and
- watershed management when the impairment is caused by stressors (such as habitat disturbance, hydrologic modification, or geomorphic alteration) not addressed by TMDL regulations.

Adaptive implementation is not the same as a standard TMDL implementation (multiple phases over time). In standard implementation, the pollutant-reduction plan is established when the TMDL is completed and never intentionally revisited. The governing principle is "stay the course" as initially composed. The only question in a standard TMDL implementation plan — "when?" — implies that implementation success depends solely on the availability of financial resources to implement control measures. Standard implementation is effective when the project team is confident about the causes, remedies, and waterbody condition, or when the costs of errors are low.

Adaptive implementation is best when the uncertainty is substantial and the costs of errors are high. Besides asking "when?", the implementation questions include "where?" (Where should we focus attention?); "what?" (What practices should be tried first?); and "how?" (Who is responsible for each task?). If the applicability of existing water quality standards is uncertain, the questions also include "why?" (Why are we seeking this goal?) and "how much?" (How much implementation is effective and financially feasible?).

The Process

Both adaptive and standard implementations use the water quality management process (see figure, right):

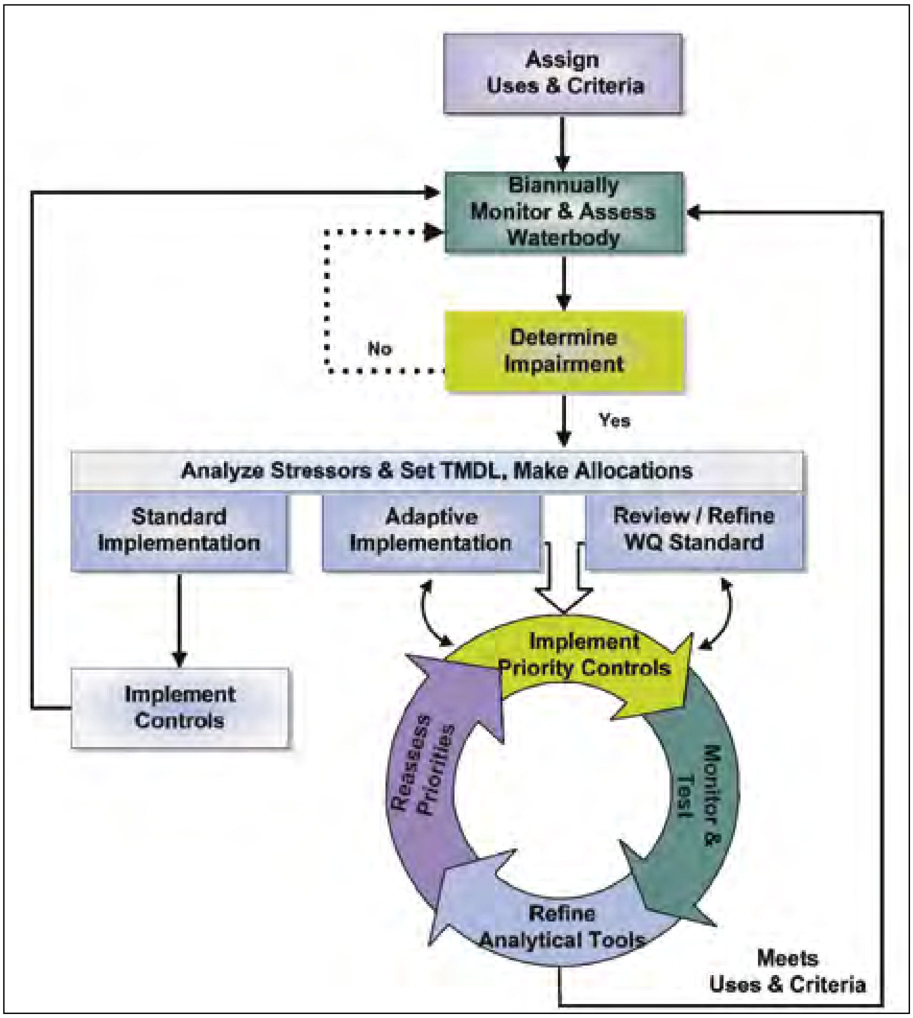
1. Assign water quality standards (both designated uses and associated water quality criteria) to a waterbody.
2. Assess compliance to the water quality standards.
3. Determine the need for a TMDL.
4. Develop the TMDL and a control strategy for reducing pollutant loads and meeting standards.
5. Implement the controls to restore the uses by meeting water quality standards (criteria).

Most people presume that the first step precedes the TMDL. In standard implementation, it would not be revisited, but in the adaptive process, the team uses this step to consider the assigned standard's applicability and achievability. The standard is reviewed and may be refined as the adaptive implementation process proceeds. (It only would be refined if new data indicate that another criterion is scientifically justified for the site or that a site-specific use is appropriate.) Of course, any revisions must conform to the CWA regulatory process and related state water quality standards programs.

The second and third steps are basically the same in both adaptive and standard implementations. Regulations require a biennial water quality assessment, which typically is used to produce the list of impaired waters needing TMDLs. Although uncertainty may be involved, this assessment generally is the basis of the TMDL process and, more importantly, of determinations as to whether the waterbody has been restored. Data collected during the biennial assessment might be applied to the adaptive implementation process.

The standard and adaptive approaches differ dramatically in the fourth and fifth steps. In standard implementation, the TMDL is developed, the pollutant controls are stipulated when the

The Adaptive Implementation Process



TMDL is approved, and implementation proceeds without revision or refinement of the original plan. In the adaptive process, the project team continually reassesses the TMDL, its endpoints, its allocations, and the implementation strategy.

In the adaptive process, the project team develops an initial TMDL and identifies priority controls. The team then implements the controls to reduce pollutant loads and to learn. As monitoring data are collected, the team refines the analytical tools and assessments and reassesses the proposed TMDL control plan. Team members then identify and implement a new set of priority controls. The process continues in this adaptive fashion until standards are met.

In the adaptive process, more monitoring and other forms of learning will be required to reduce critical uncertainties and improve model predictions over time. If the new data and analysis indicate the need to refine standards, the adaptive process will proceed with a revised goal.

Appropriate Uses

Adaptive implementation should not replace the standard TMDL implementation in all — or even most — situations. In fact, because it can be more resource-intensive, adaptive implementation is appropriate only in certain situations. Generally, a project team should choose the approach that will achieve water quality standards most cost-effectively.

Adaptive implementation should be considered when the TMDL plan contains enough uncertainty that strictly adhering to the original implementation plan could either waste resources or not be sufficient to meet water quality goals.

It also should be considered if the stakeholders' debate over uncertainty indicates that no action may be taken. Because this approach emphasizes incremental controls, continuing study, and implementation flexibility, it may break through deadlocks and disputes over the "perfect" long-term action plan.

In addition, adaptive implementation should be considered if there is significant uncertainty about the cost and effectiveness of controls. This is likely if the dominant problem is nonpoint source pollution, or if point source controls are expensive and their effectiveness is uncertain.

It also is beneficial in complex TMDL situations, where scientific understanding of the processes, loads, and outcome is highly uncertain. Such situations include large estuaries and places with significant sediment or atmospheric pollution sources, where the timing and extent of reductions is uncertain.

Finally, adaptive implementation is useful when the TMDLs needed to restore beneficial uses are not well defined.

That said, adaptive implementation is not appropriate if the project team lacks regulator and stakeholder support for the approach, enough resources for the entire process, and a commitment to continue until water quality standards are achieved.

Other Applications

The adaptive approach has applications in other water quality programs besides TMDLs. For example, adaptive implementation can be part of a watershed management effort — one with a broader, nonregulatory perspective. If a waterbody's physical, chemical, or biological characteristics have been altered via human activities, an adaptive approach could help a watershed management team cost-effectively restore habitat, improve hydrology, improve channel hydraulics, or implement geomorphic modifications.

Adaptive approaches also could be useful in combined-sewer overflow management. Under the National Pollutant Discharge Elimination System, utilities must develop long-term control plans for combined-sewer overflows, which degrade water quality. Such plans can cost hundreds of millions, even billions, of dollars and take decades to implement. However, success often is uncertain because of numerous other pollutant sources, such as nonpoint and septic seepage, and because experimental watershed and green solutions are not yet proven. An example of this application is Sanitation District No. 1 in northern Kentucky, which is using an adaptive watershed management strategy as part of a consent decree to meet its regulatory requirements and, ultimately, its water quality goals. The project team expects the adaptive approach to help ensure that progress is both cost-effective and meets regulatory objectives.

Adaptive implementation also could be useful at contaminated sediment sites, such as rivers and harbors whose sediments contain PCBs or other bioaccumulative chemicals. Dredging such sediments often can cost billions, and its benefits are both uncertain and can take decades to be fully realized. Other controls, such as natural attenuation, sediment armoring, or channel modifications, may be effective but are not yet widely demonstrated. So, many large sites, including the Hudson and Housatonic rivers, are using adaptive implementation plans. These plans involve source control, selective dredging of hot spots, and a subsequent re-evaluation before more comprehensive remediation is undertaken.

A Worthy Approach

The documented benefits of adaptive implementation are not widespread, because the approach is relatively new. However, there are numerous examples in which adaptive implementation (or elements of this approach) has been used effectively. For example, in North Carolina's Neuse Estuary, the project team conducted annual post-implementation assessments of reductions in estuarine chlorophyll *a* (the water quality criterion) in response to progressive nitrogen load reductions. These assessments, which began in 1992, confirmed that North Carolina had achieved compliance by the late 1990s.

More than 40,000 TMDLs are still required, with only about half of U.S. waters assessed to date. The sheer scope of this program and the inherent uncertainties involved challenge our ability to find cost-effective solutions. To avoid successes that exist only on paper, water quality professionals should consider using the adaptive implementation approach whenever practical. It can help us use our resources more efficiently and ensure that we will eventually achieve our water quality goals.

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For a list of further reading on this topic, see "Features" in the August 2008 issue at www.wef.org/magazine.