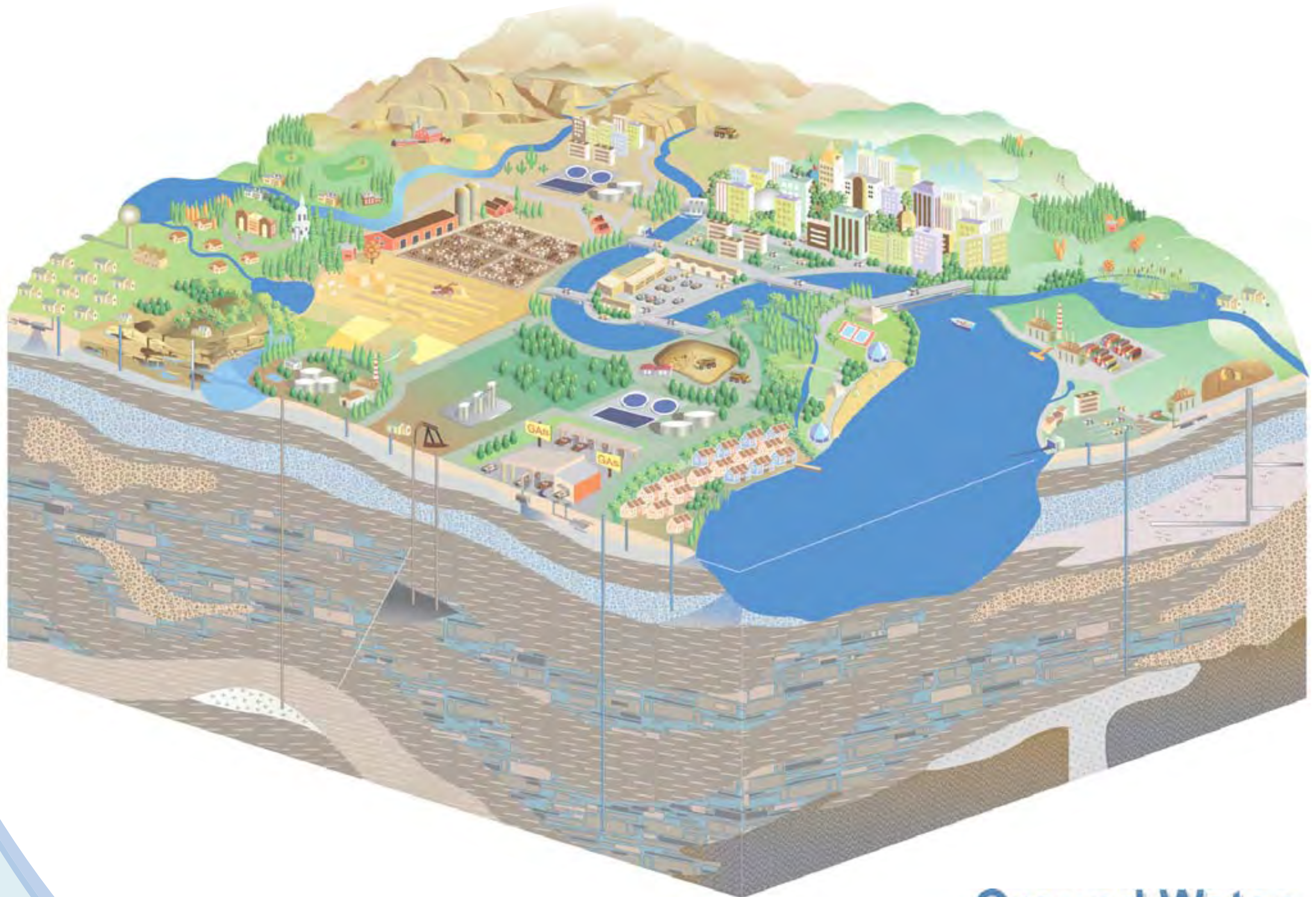
Ground Water Report to the Nation:

A Call to Action



Ground Water Protection Council

To the Reader:

I would like to thank the myriad of state, federal, and local agencies, affiliated associations, universities, and individuals, who have so willingly helped in producing this document. They are too many to list here, but without their help, this document would not have happened. The Ground Water Protection Council Board of Directors and Editorial Board were always positive during this process, and without their review and input, the document would have lacked real-world examples and experiences.

I would like to thank the staff of the Ground Water Protection Council for their lasting enthusiasm for this endeavor and especially Jean McDowell, our in-house report manager, for her dedication and effort from start to finish.

Publication of this report marks the end of one effort and, we hope, initiates a new effort to promote increased awareness that will foster a nationwide commitment to take action to protect ground water.

Mike Paque, CAE
Executive Director
Ground Water Protection Council

Staff Contributors: Dan Yates, Communications Director; Paul Jehn, Technical Director; Ben Grunewald, Associate Director; Mike Nickolaus, UIC Director; Sherri Henderson, Executive Assistant; Jean McDowell, Water Policy Analyst

Foreword

Ground Water Report to the Nation: A Call to Action

Congratulations to the Ground Water Protection Council for developing this call to action to protect one of America's most vital, yet undervalued, natural resources: ground water. We seem to lose sight not only of the resource, but of its importance. Almost half of the nation's citizens obtain their drinking water from ground water wells—from either public water systems or private wells. Ground water is also critical to maintaining surface water quality and healthy wetlands.

We know ground water is contaminated or threatened in communities around the country from varying sources such as underground storage tanks, septic systems, and agricultural activities. Our ground water is also threatened by excessive pumping, which can lead to saltwater intrusion in coastal areas, land subsidence, or increased vulnerability to drought conditions.

Collaboration is key to water quality protection because it offers opportunity to coordinate actions and achieve positive water quality outcomes. In early 2006, I was pleased to make a commitment with GWPC and 11 other national organizations to work together to protect sources of drinking water. The partners in this Source Water Collaborative recognize solutions transcend political and organizational boundaries. To effectively protect drinking water, we must work together and reach people at the local level where decisions that affect drinking water quality are made. Helping communities understand the effect of land use and stewardship decisions on the environment and public health is an important and appropriate role for EPA, and the work of Source Water Collaborative partners, like the "Ground Water Report to the Nation: A Call to Action," will be critical in this effort.

As stewards of our nation's waters, we need to "think like a watershed" and strive for integrated, holistic and sustainable approaches. EPA looks forward to working collaboratively with our local, state and federal partners to protect public health and the water environment, above and below ground, for today and tomorrow.

Benjamin H. Grumbles, Assistant Administrator for Water
U.S. Environmental Protection Agency

Foreword

Ground Water Report to the Nation: A Call to Action

Growing up, I remember many visits to my grandparents' farm in Webster County, Nebraska. Lulling me to sleep and waking me in the morning was the sound of the ground water pump in the yard. Those long summer days planted the seeds for my career as founder and President of The Groundwater Foundation. Somehow I knew, even then, that the ground water pumping from the well was the heart of the farm itself. A Webster County child herself, American author Willa Cather understood this too, writing:

> *"The roots of the tall, branching cottonwood drank deep from hidden waters, deep in the soil. The waters of ancient springs had been found on the virgin prairie…and under the long shaggy ridges she felt the future stirring."*

This hidden and ancient resource creates fierce pride in the hearts of its protectors, and this pride is ably demonstrated by the Ground Water Protection Council's *Ground Water Report to the Nation: A Call to Action.* Like the artesian springs of the Ogallala Aquifer, ground water is about to emerge from the shadows and take its rightful place in the national consciousness.

Ground Water: A Call to Action is our map and bugle call for this journey.

The report, and accompanying poster and summary sheets, propel ground water stewardship forward by underscoring its growing importance as an environmental and economic resource, the threats to its quantity and quality, and the urgency of protecting it.

As our map, the report helps us more fully understand that:

- Ground water and surface water are one resource and their protection depends on the simultaneous protection of both.
- The earth's surface is not a particularly effective filter, and ground water availability and quality contain the indelible footprint of human endeavor.
- All natural resources, including ground water, are connected to each other and to the communities and people they sustain.

As our bugle call, the report provides strategies and tools for:

- Increased program coordination and collaboration on every level.
- Activating watchful citizens through land-use planning, enhanced monitoring, and ground water inclusive policies at the local, state, and federal levels.
- Finding the resources to implement nature- and technology-based best management practices.

I've always believed that protecting ground water brings out the best in human nature, and the *Ground Water Report to the Nation: A Call to Action* reflects this fact. As you read and reflect, you'll find yourself knowing more, caring more, and in your mind's eye, doing more.

Are we up to the challenge? We'd better be. Our environmental and economic future depends on it.

Susan S. Seacrest, President, The Groundwater Foundation

Contents

Ground Water Report to the Nation… A Call to Action

There are numerous ground water issues and human impacts to ground water that could have been selected for this first Ground Water Protection Council *Report to the Nation.* As the Key Messages and Recommended Actions were developed for each selected topic, it was tempting to broaden the discussion to other connected topics. However, to stay focused, it was necessary to limit our scope to ten specific topics, and limit the discussion within each topic as well. The following Sections can be identified according to their respective names and colors on the tabs.

GROUND WATER…A CALL TO ACTION

Why this urgent call to action? We are at a ground water crossroads that necessitates ingenuity and proaction in order to minimize potentially detrimental and costly consequences. Each of us shares responsibility for securing the availability, integrity, and ecological balance of our nation's water resources—for the long haul. It is way past time for us to recognize the significance of ground water to our national welfare—our public health, quality of life, and economic well-being.

GROUND WATER USE AND AVAILABILITY

Why does ground water use and availability matter? Potable fresh water is fast becoming a highly sought-after commodity—it is being called "blue gold." Yet the fact that all the water we have right now is all the water we will ever have is not reflected in our demand for and use of water. As a nation, we can no longer put off the job of answering the essential and definitive questions of supply and demand: Will we have enough water, and what will it cost?

GROUND WATER RESOURCE CHARACTERIZATION AND MONITORING

Why does ground water characterization and monitoring matter? While we have made strides in understanding how ground water/surface water systems work, our ability to characterize how our human activities affect the many natural processes and interactions inherent to specific systems has been constrained. This is primarily due to the lack of long-term sustained support and funding for ground water quality and quantity data collection, analysis, research and development trends, and information dissemination.

GROUND WATER & SOURCE WATER PROTECTION

Why does source water protection matter to ground water? Without diligent attention to managing potential sources of contamination, our drinking water will come at a higher cost over time. This cost includes the increasing need for water treatment, monitoring, remediation, finding alternate water supplies, providing bottled water, consultants, staff time, and litigation. Source water protection is simpler, less expensive, and more reliable over the long term.

GROUND WATER & LAND USE PLANNING AND DEVELOPMENT

Why does land use matter to ground water? Each time the use of a land area changes, it can affect the hydrologic makeup of the landscape. Highways, shopping centers, housing developments, industrial sites, businesses, agricultural operations, golf courses, feedlots, waste disposal sites, airports, ski slopes, and sewer systems (to name a few) have the potential to directly or indirectly impact the quantity or quality of both ground water and surface water.

GROUND WATER & STORMWATER MANAGEMENT

Why does stormwater matter to ground water? In natural, undeveloped areas, a large percentage of relatively uncontaminated precipitation infiltrates the ground, thus recharging the ground water; the remaining runoff flows to nearby water bodies or evaporates. Natural physical, chemical, and biologic processes cleanse the water as it moves through vegetation and soil and into ground water. Development alters natural systems as vegetation and open spaces are replaced with impervious surfaces, such as parking lots, highways, and roofs, that greatly reduce infiltration and thus ground water recharge. Uncontrolled stormwater runoff collects pollutants such as sediments, pathogens, fertilizers/nutrients, and hydrocarbons, which ultimately contaminate and degrade surface and ground water.

GROUND WATER & UNDERGROUND STORAGE TANKS

Why do underground storage tanks (USTs) matter to ground water? Each UST system has the potential to leak, threatening human health and the environment. Leaked product contaminates ground water used for drinking and other uses and, on occasion, enters surface water. Today's improved UST systems are the product of federal and state requirements and programs, improved technologies, and a heightened awareness on the part of tank owners and operators. However, leaks still occur, albeit far less frequently, and we must stay vigilant in order to prevent tank systems from leaking in the first place and to ensure that leaking systems are reported immediately and cleaned up expeditiously.

GROUND WATER & ONSITE WASTEWATER TREATMENT SYSTEMS

Why does onsite wastewater treatment matter to ground water? Nationwide, decentralized wastewater treatment systems (e.g., septic systems) collect, treat, and release about 4 billion gallons of effluent per day from an estimated 26 million homes and businesses. More than half of these systems were installed over 30 years ago, when rules were nonexistent, substandard, or poorly enforced. The percentage of homes and businesses served by these systems varies from state to state, from a high of about 55% in Vermont to a low of about 10% in California.

GROUND WATER & UNDERGROUND INJECTION CONTROL

Why does the underground injection control (UIC) program matter to ground water? The federal UIC Program, designed to prevent contamination of underground sources of drinking water, covers wells used to inject a wide range of fluids, including oilfield brines; industrial, manufacturing, pharmaceutical, and municipal wastes; and water used for solution mining. A "mature" regulatory" program suggests that the major processes are working smoothly, the principal issues are well understood, and significant problems encountered have been solved. While this is the case for Class I, II, III, and IV UIC well types, the Class V category of the UIC program has not kept pace with the rest of the program. Nor is the UIC program well positioned to address new challenges and responsibilities, such as CO_2 geosequestration and management of water-treatment residues.

GROUND WATER & ABANDONED MINES

Why do abandoned mines matter to ground water? Many abandoned coal mines and hardrock mines emit acid mine drainage, because the rock associated with both types of mines often contains metal sulfides, such as pyrite. When the rock or coal deposits are excavated, the sulfides are exposed to water and oxygen, and react to form sulfuric acid. Many surface and underground abandoned mines, and their associated spoil and refuse piles, provide ongoing sources of acid mine drainage and toxic heavy metals that can have long-term devastating impacts on ground water, community water supplies, rivers, streams, and aquatic life.

Ground Water ...A Call to Action

Key Message

Our ground water resources are in serious need of attention. Abundant, high-quality, low-cost ground water resources are fundamental to the long-term growth and vitality of our nation, yet this most important resource is often overlooked, if not neglected. Attention to the protection and management of ground water has consistently lagged behind that given to surface waters, meaning that historic and current water resource laws and policies deal primarily with the protection and management of our more visible lakes, rivers, and wetlands.

These protection disparities and deficiencies can be partly attributed to the hidden nature of ground water. However, there is also a lack of appreciation of the fact that ground water is a key drinking water source nationwide; a critical resource for many sectors of our economy; and an integral part of the water cycle, providing baseflow to the majority of surface waters. Furthermore, many of us are not aware that the quality and quantity of our nation's ground water is now significantly threatened.

To reverse this trend, we must take swift and decisive action to ensure that ground water is meaningfully integrated into federal and state water resource conservation, management, and protection agendas. We must adopt new paradigms in water policy and science that demonstrate the interactive relationships among components of watersheds and ecosystems, and the essential role ground water plays in those systems. We must ensure that these new paradigms are based on solid scientific principles that allow us to better understand the role of ground water in maintaining watersheds so we can make wise water-policy, land-use, and water-use decisions accordingly.

Photo: Pat Tucci, USGS

A karst area of the White River National Forest, Colorado, showing the interface of ground water with surface water.

Toward a New Ground Water Paradigm

> "*Water promises to be in the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations.*"
>
> Maude Barlow, Tony Clarke | *"Who Owns Water?"* | *The Nation*, September 2002

why this urgent call to action?

Water demand, quality, and quantity are matters of national urgency. If we don't act now, we risk degrading and jeopardizing the future health and well-being of our citizens, our economy, and our ecological systems. Water is the essential lifeblood of all living creatures, yet it is already in short supply throughout much of the United States. Fresh water comprises less than one-half of a percent of all the water on earth, and ground water makes up about 97 percent of available fresh water. Ground water is about 60 times as plentiful as fresh water found in lakes and streams (USGS, 2006). In the United States, ground water is the drinking water source for about half the population—about 150 million people. The United States Geological Survey (USGS) estimates that in the year 2000, 84.5 billion gallons of ground water were withdrawn each day (Hutson et al., 2004), up from about 30 billion gallons per day in 1950 (Solley et al., 1998). About 68 percent of this was used for irrigation.

Over the past century, human activities have had a profound affect on ground water quality and quantity. Of greatest significance is the fact that as our population continues to grow, the demand for readily available, good-quality water—ground and surface water—continues to escalate. As demand for fresh water grows, ground water has increasingly become the nexus of many competing interests. It is an essential resource for sustaining the agricultural, commercial, and industrial sectors of our economy—including food production and processing, chemical manufacturing, energy production, mining, livestock operations, and many others. Ground water is fast becoming a prominent factor in other critical processes, such as carbon dioxide geosequestration, brackish water desalination, and emerging waste disposal needs.

Ground water is also essential to a variety of ecological functions, such as maintaining wetlands, contributing to in-stream flow levels, protecting onshore fresh drinking water supplies from saltwater intrusion, and preventing land subsidence, to name a few. Yet increased water demands press many communities and regions to withdraw ground water at rates that overstress the very aquifers that sustain them. In many areas of the United States, more water is withdrawn from aquifers than is replaced, lowering water tables and in-stream baseflow and stripping once-lush riparian areas of associated vegetation and wildlife. Human activities have altered many landscapes, changing the water balance and the physical, chemical, and biological processes that control water quality.

Harmful substances have entered ground water by way of leaks, spills, seepage, disposal, and burial. In the process, ground water has been degraded, placing an added strain on limited water supplies. Traditional land development practices often create and compound impervious surface areas, which prevents ground water recharge and increases flooding potential in nearby rivers and streams.

Ground Water—the Overlooked and Undervalued Resource

Ground water has too often been taken for granted and has suffered from a lack of emphasis on the part of local, state, and national leadership and a lack of funding for protection and research. Ground water protection and management laws and policies are often highly fragmented among multiple state and federal agencies and, as such, do not support a cohesive national approach to sustainable resource management.

At least 16 different federal laws relate directly or indirectly to ground water management. Many focus exclusively on ground water as a source for public drinking water supplies, neglecting its critical importance for other vital purposes, including surface water recharge and a source of drinking water for privately owned wells.

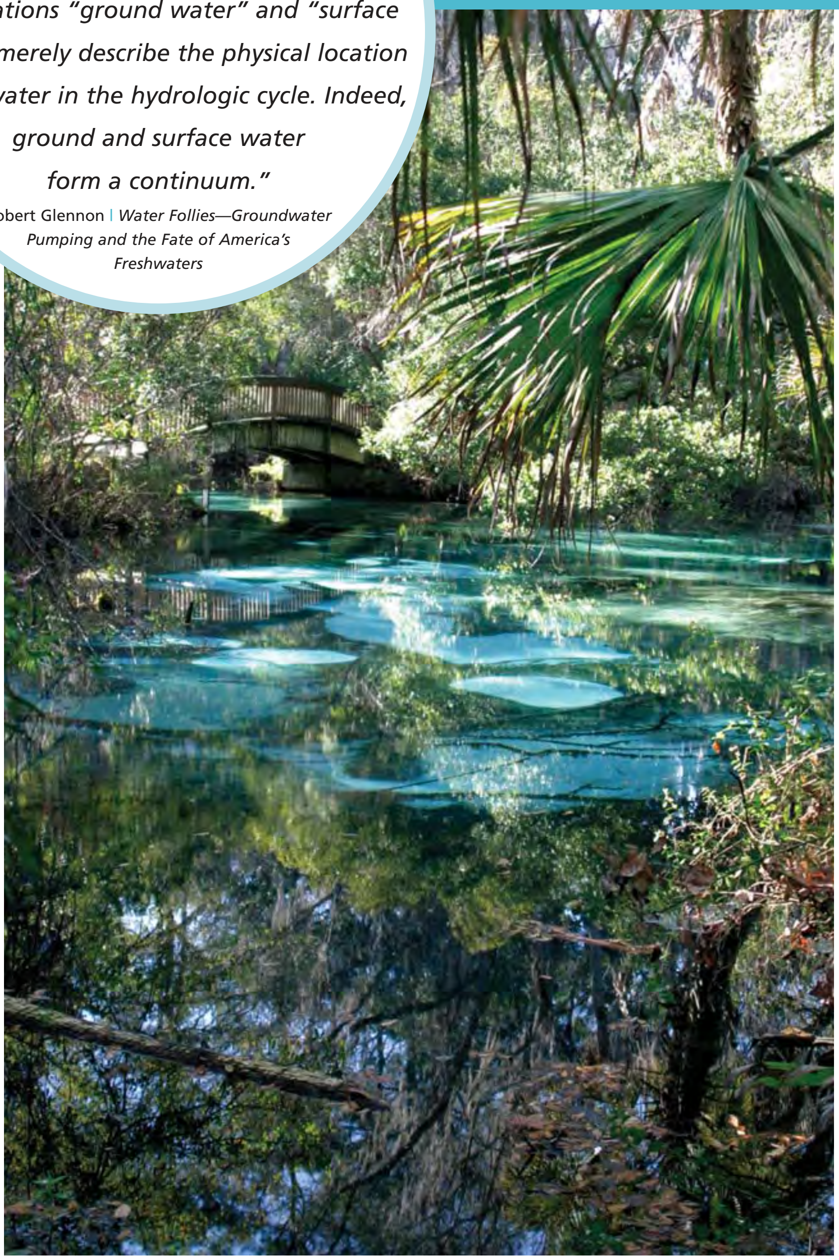
There is currently no national strategy for the comprehensive protection and management of the country's ground water resources. However, the growing competition for water resources demands that we adopt a coherent, comprehensive national ground water protection strategy that clearly articulates ground water protection and management goals and ensures that adequate support is directed toward accomplishing those goals.

If We Don't Take Action Now…

The good news is that our ground water problems are not insurmountable, but it is essential that we act swiftly, intelligently, responsibly, and with an eye to the future. If we don't take action now, it is inevitable that the state of ground water quality in many parts of this country will continue to decline—at a great cost to people and the places they live. When a water supply is no longer available because of overdraft, degradation, or hydrologic relocation, it is usually very difficult and expensive to replace.

"Ground water and surface water are not separate categories of water any more than liquid water and ice are truly separate. The designations "ground water" and "surface water" merely describe the physical location of the water in the hydrologic cycle. Indeed, ground and surface water form a continuum."

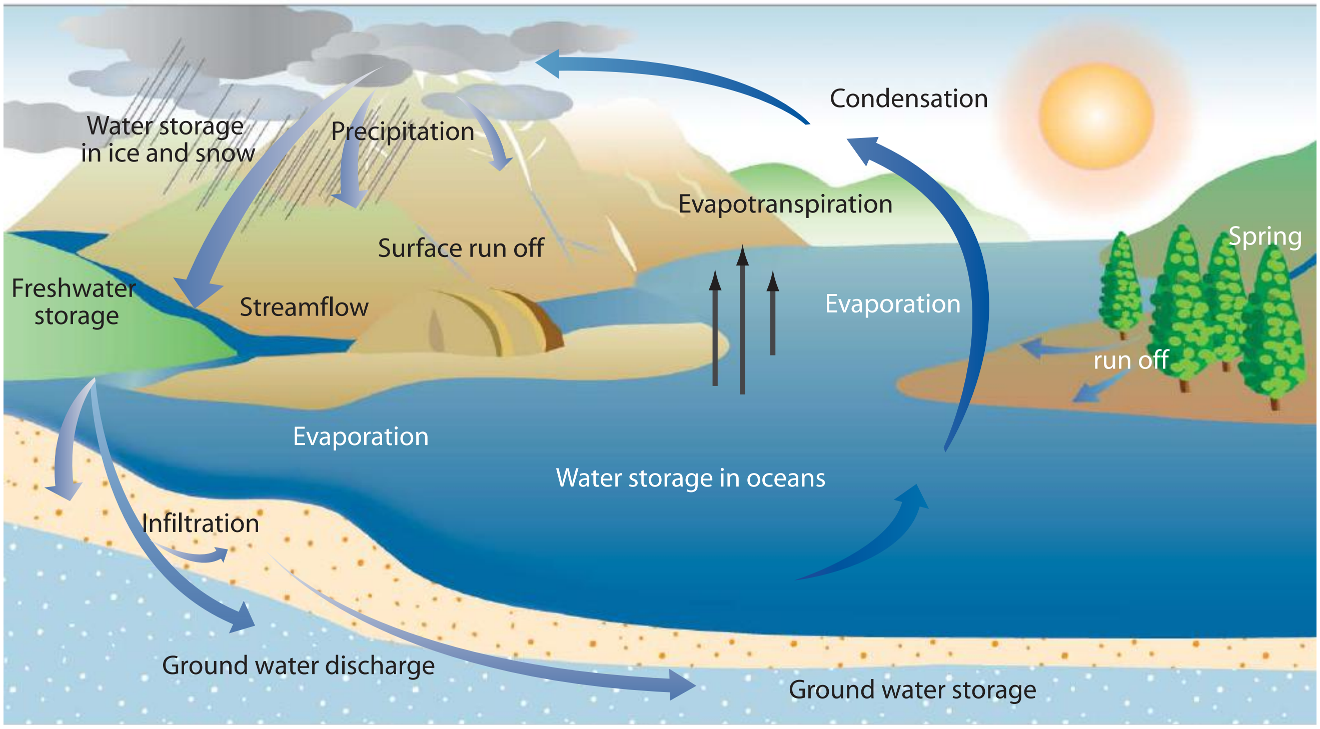
Robert Glennon | *Water Follies—Groundwater Pumping and the Fate of America's Freshwaters*



Fern Hammock Spring, Marion County, Florida. A spring is our window to an aquifer. It is an opening in the earth from which ground water flows to the surface, forming a natural pool of water. Florida's springs are formed because of the porous limestone (or "karst") topography.

Photo: Tom Scott FGS/FDEP

HYDROLOGIC CYCLE



Artwork by Poshen Wang

Figure 1. The movement and continual recycling of water between the atmosphere, the land surface, and underground is called the hydrologic cycle. This movement, driven by the energy of the sun and the force of gravity, supplies the water needed to support life. The hydrologic cycle is basic to our understanding of water. Understanding the hydrologic cycle is key to effective water resources management.

GROUND WATER IN THE NATURAL SYSTEM

Ground water plays a critical role in the hydrologic cycle and thus the maintenance of healthy watersheds and ecosystems. The idea that the water bodies (e.g., lakes, streams, ground water, oceans, wetlands) of this earth are isolated and separate entities is pure myth. In truth, all water is a part of a highly interactive and dynamic hydrologic cycle—the earth's circulatory system—that runs continuously above, upon, and below the earth's surface. (See Figure 1.) This cycle is powered by a series of natural processes that keep water on the move through evaporation, evapotranspiration, condensation, precipitation, infiltration, recharge, and discharge.

Even though it is out of sight, ground water is intrinsic to the hydrologic cycle, serving as a vast subsurface reservoir that is virtually everywhere at varying distances below the surface of the earth. Key to the ground water/surface water relationship is the role that ground water plays as the baseflow for many rivers and streams, allowing them to continue to flow during dry summer months. (See Figure 2.) In fact, based on a national representative sampling of streams, the U.S. Geological Survey has found that the

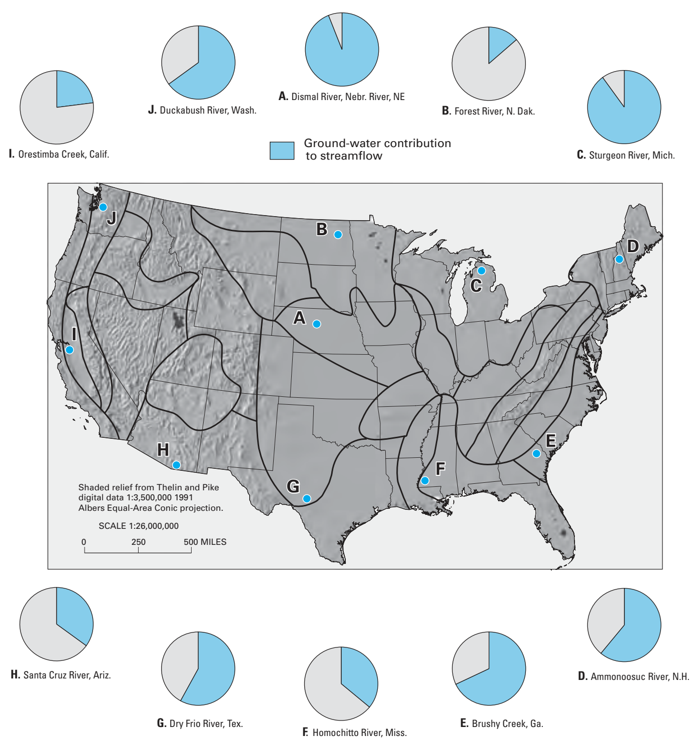
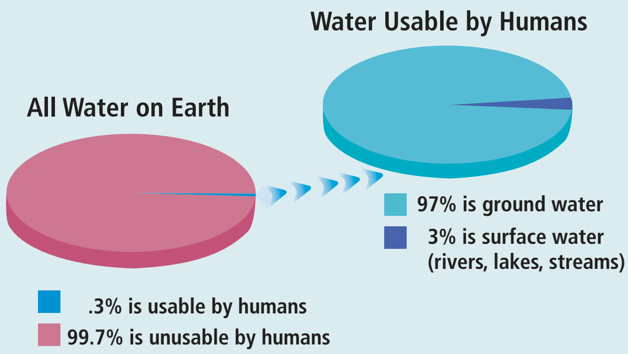


Figure 2. Estimated ground-water contribution to streamflow is shown for specific streams in 10 of the regions. *In the conterminous United States, 24 regions were delineated where the interactions of ground water and surface water are considered to have similar characteristics. Blue portions of the pie charts indicate ground water contribution to streamflow in the various regions.*

Source: http://pubs.usgs.gov/circ/circ1139/htdocs/natural_processes_ of_ground.htm

GROUND WATER– WHY DO WE CARE?

WHY do we care? Because most of the earth's usable fresh water is in the ground.



Over 70 percent of earth's surface is covered with water, but 97 percent is unusable salt water, 2 percent is ice, and less than 1 percent is fresh and available for consumption. That really is "a drop in the bucket"! Of that tiny 1 percent of available fresh water, less than 5 percent is actually found in lakes, streams, and other surface areas. The rest is under our feet! Most of us are unaware of this huge volume of water under every inch of our planet. In some places it is within a few feet, in others, many thousands of feet.

Figure 3. *Source: USGS Water Science for Schools Website: http://ga.water.usgs.gov/edu/earthwherewater.html*

average ground water contribution to stream flow is 52 percent. (Winter et al., 1998)

Overdrafting ground water can and has dried up rivers, streams, lakes, and springs. This, in turn, can have a devastating impact on aquatic ecosystems, not to mention the people who depend on surface water for their water supply. Such changes typically happen gradually and are not necessarily noticed until ground water/surface water supplies are seriously diminished.

The Watershed Framework

The watershed provides a natural and logical framework for understanding and managing water resources, and ground water must be a recognized part of that framework. Any watershed-based water budget without a ground water component is incomplete. Any discussion about the health and integrity of a watershed that does not address ground water is incomplete. Any plans to conserve and protect or restore water resources within a watershed that do not account for ground water are incomplete. To include ground water in this framework we must view the watershed three dimensionally—as a unit with length, width, and depth.

> *"Knowledge carries with it the responsibility to see that it is used well in the world."*
>
> David Orr | *Earth in Mind*

States and communities need to work together across watersheds to develop and implement plans to protect their local water resources. This approach must be based on good science and have broad stakeholder involvement so that everyone understands how the complete hydrologic system functions within the three-dimensional watershed area. (See Figure 4.) This approach allows us to manage our water resources sustainably and gets us out of the bad habit of addressing land-use issues piecemeal.

3-DIMENSIONAL WATERSHED AREA

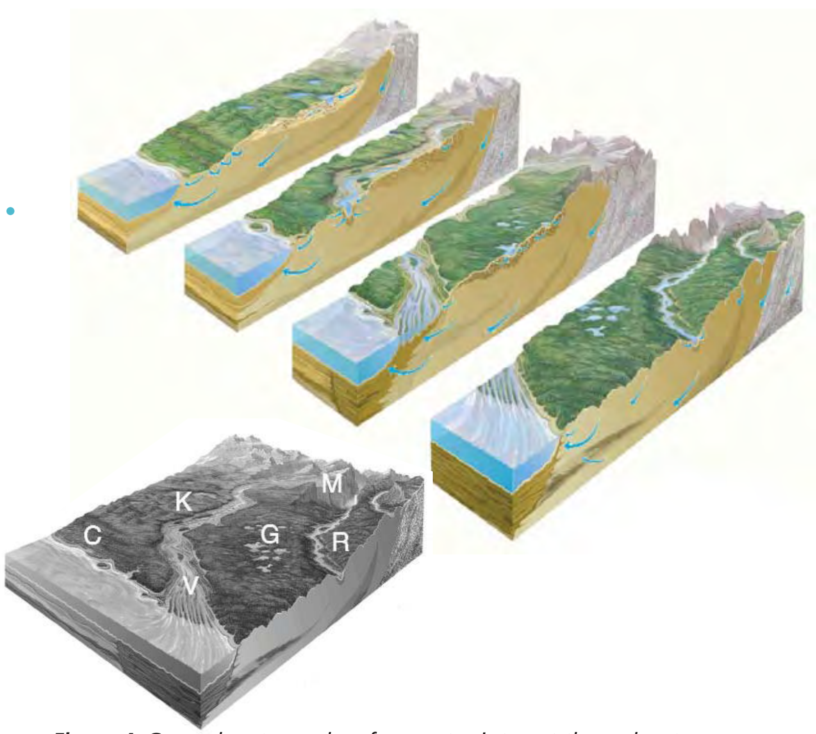


Figure 4. *Ground water and surface water interact throughout all landscapes from the mountains to the oceans, as depicted in this diagram of a conceptual landscape. M, mountainous; K, karst; G, glacial; R, riverine (small); V, riverine (large); C, coastal.*

Source: http://pubs.usgs.gov/circ/circ1139/htdocs/natural_processes_of_ground.htm

HUMAN IMPACTS ON GROUND WATER

While we have been tapping ground water for household, farm, business, and community uses for centuries, we have historically operated under the assumption that ground water would always be there for us. But we are learning that this is not the case. There are better ways to act so that ground water is protected and conserved. While we have become more knowledgeable about the nature of our impacts on ground water quality and quantity and have developed the tools to better evaluate and manage these resources, we need to strengthen our resolve to support the steps needed to reduce human impacts. The following sections provide a brief overview of some of the ways we degrade and deplete our ground water resources.

Overdrawing the Ground Water Account

In many places across the country, water budgets are running at a deficit. The resulting effects depend on several factors, including withdrawal and natural discharge rates, physical properties of the aquifer, and natural and human-induced recharge rates. (USGS, 2003) Ground water depletion is occurring at varying scales, ranging from single wells to enormous aquifer systems underlying several states.

The Ogallala Aquifer in the High Plains, for example, underlies eight states from South Dakota to Texas and has been intensively developed for irrigation since

LOS ANGELES' GROUND WATER IN THE BALANCE

Los Angeles' only local water supply is contained in the vast San Fernando Valley aquifer, a natural storage system capable of holding enough water to supply Los Angeles for five years. The city imports 85 percent of its drinking water from the Sierra Nevada Mountains (where the snowpack has recently been low) and the Colorado River; the San Fernando Valley ground water basin supplies the rest (15 to 30 percent). In dry years, the city can draw as much as 30 percent of its supply from the ground water, saving on the cost of importing water.

The aquifer has never been used to its maximum capacity, partly because it is used as a reserve water supply but also partly because for more than 20 years areas of the aquifer have been undergoing treatment for volatile organic compounds (VOCs), including trichloroethylene (TCE) and perchloroethylene (PCE) contamination from industrial sources, which are less dense than water and float at the surface of the water table. For this reason, ground water must be pumped so that contaminated water is not drawn into the drinking water supply. In fact, time and again the Department of Water and Power (DWP) has had to shut down or restrict wells contaminated with high levels of industrial solvents. There are multiple wellfields where pumping is restricted.

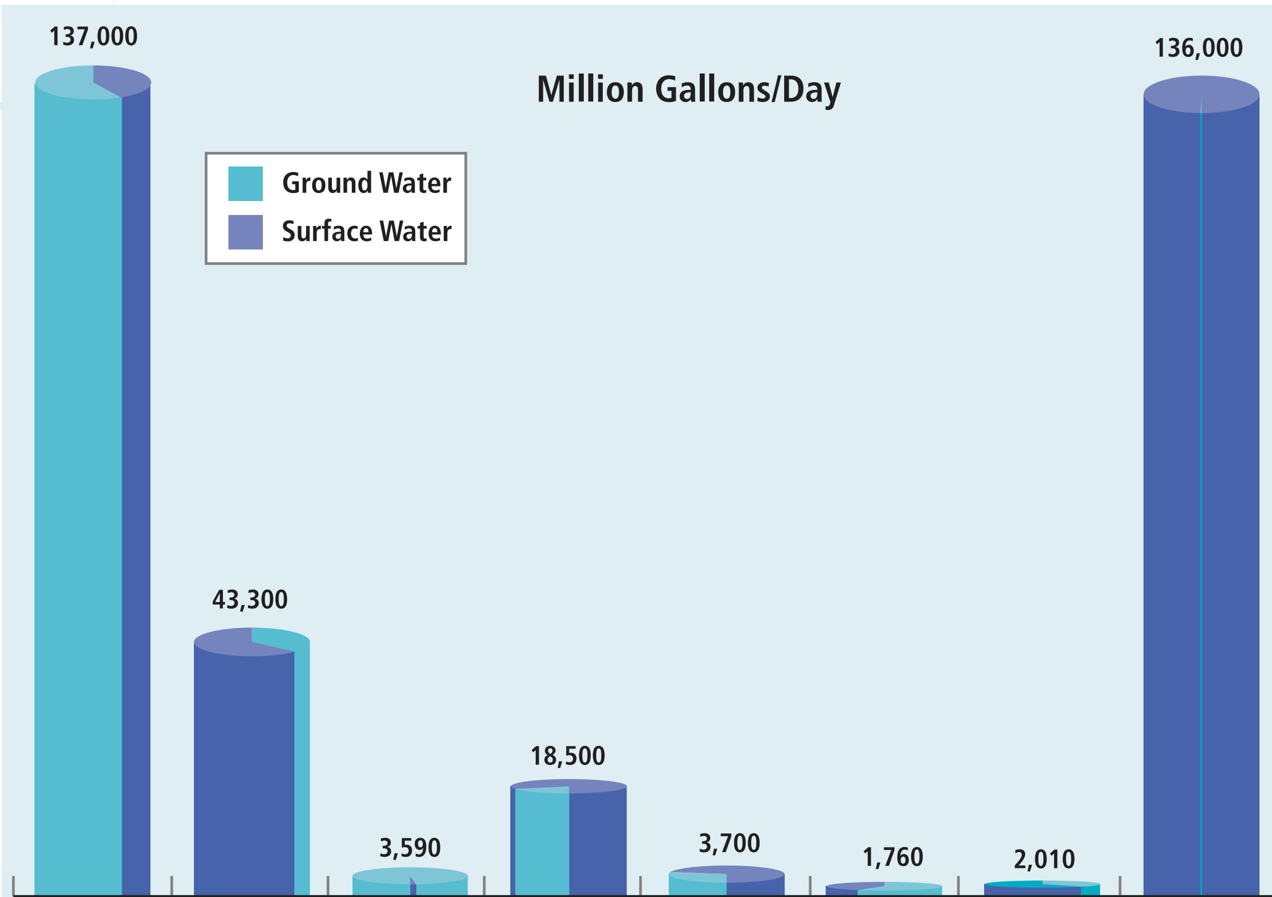
Now, more than four years after being warned that a creeping chromium plume was threatening this water supply, the DWP has had to shut down one well because of chromium contamination and restrict pumping in yet another wellfield because of VOC contamination. DWP officials are concerned that this contamination will spread and jeopardize the local water supply.

Because of the need to control the spreading contamination, the city will be able to draw only 10 percent of its supply from local ground water in 2007. This means that the DWP is going to need to import more water—at a cost of more than $7 million to the city's ratepayers. This situation has fueled frustration and a flurry of finger-pointing at government at all levels regarding who should have been remedying this situation much sooner.

This ground water threat comes as the DWP and Los Angeles County are spending hundreds of millions of dollars to increase the amount of water in the aquifer by undertaking projects to capture storm water and infiltrate the ground with it. State water bond money is also being sought for a $78 million project to enlarge Big Tujunga Dam to catch more winter-water runoff that now flows to the ocean.

Primary source:
http://www.presstelegram.com/news/ci_6008394

TOTAL FRESHWATER WATER WITHDRAWALS BY WATER-USE CATEGORY, 2000



	Agricultural Irrigation	Public Water Supply	Private Water Supply	Industrial	Aquaculture	Livestock	Mining	Thermo-electric Power
GW	41.5%	37.0%	98.3%	19.3%	28.6%	57.4%	38.2%	0.3%
SW	58.4%	63.0%	1.6%	80.5%	71.4%	42.4%	61.7%	99.3%

Figures may not sum to 100% because of independent rounding.

Figure 5. *Source: http://pubs.usgs.gov/circ/2004/circ1268/htdocs/text-total.html*

WWII. As a result, water levels in this "bread basket of the nation" have declined more than 100 feet in some areas, and the saturated thickness of the aquifer has been reduced by more than half in others. Water levels are recovering in some areas owing to the implementation of state and local management strategies, improved irrigation efficiency, low crop prices, and agricultural programs (McGuire et al, 2003), but unless the aquifer is replenished at a sustainable rate, the future viability of agriculture in the region is at risk.

Ground water overdraft is not limited to drought-prone areas of the country. Even in "water-rich" areas, such as Florida, overwithdrawal in certain highly populated coastal areas has caused serious water supply problems. Some of the negative effects of ground water depletion include dried-up wells, reduced surface water levels, degraded water quality, and land subsidence.

Saltwater intrusion is another ground water quality concern, particularly in coastal areas where changes in freshwater flows and increases in sea level both occur. As ground water pumping increases to serve water demand along the coast and sufficient recharge does not occur, coastal ground water aquifers are increasingly experiencing seawater encroachment.

THE WATER-ENERGY NEXUS

Energy production requires a reliable, abundant, and predictable source of water. Although some water is discharged for future use, the electricity industry is second only to agriculture as the largest user of water in the United States. Electricity production in the U.S. from fossil fuels and nuclear energy requires 190 billion gallons of water per day, accounting for 39 percent of all freshwater withdrawals in the nation—71 percent of that goes to fossil-fuel electricity generation. Coal, the most abundant fossil fuel, currently accounts for 52 percent of U.S. electricity generation, and each kWh generated from coal requires withdrawal of 25 gallons of water.

In everyday terms, we indirectly use as much water to turn on the lights and run appliances as we do to take showers and water lawns. According to the 2001 National Energy Policy, our growing population and economy will require 393,000 MW of new generating capacity (or 1,300 to 1,900 new power plants—more than one built each week) by the year 2020, putting further strain on the nation's water resources. (Sandia Labs, 2006) While water used for energy production comes primarily from surface water, ground water has become an integral part of the water-energy nexus because of overall competition for water resources.

Primary source: Sandia Labs, 2006

A less predictable phenomenon that is likely to have additional and potentially disruptive effects on the hydrologic cycle and hence water availability and quality is climate change. The amount, timing, and distribution of rain, snowfall, and runoff are changing for several reasons, and are leading to alterations in water availability as well as further intensifying competition for water resources. Changes are also likely in the intensity and duration of both floods and droughts, with related changes in water quality. Drought is an important concern in every region of the United States. Snowpack changes are especially important in the West, Pacific Northwest, and Alaska. While ground water supplies are less susceptible than surface water to short-term climate variability; they are more affected by long-term trends. (National Assessment Synthesis Team, U.S. Global Change Research Program, 2000, 2003)

Ground Water Degradation

In some ways, ground water is the victim of an out-of-sight, out-of-mind phenomenon. Everyday activities, such as pumping gas, flushing the toilet, throwing out unwanted paint and household cleaners, fertilizing the lawn, and building a new housing unit, can have harmful implications for ground water. In some commercial and industrial activities, fuel and hazardous materials are stored underground, and volumes of man-made wastes and industrial by-products are buried in landfills or disposed of underground. Any of these activities has the potential to release contaminants into ground water if not managed properly.

One of the most prevalent threats to ground water is the discharge of household wastes to onsite wastewater treatment (septic) systems. Too often, these wastes, which can contain pathogens, nutrients, metals, and even pharmaceuticals and personal-care products, are flushed down the drain or toilet and, too often, reach ground water. Other ground water threats from human waste sources include improperly treated and disposed of sludge and septage from municipal and industrial wastewater treatment sources and raw sewage escaping from leaking sewer lines on the way to a treatment facility.

Photo: Dave Belyea

A petroleum-contaminated former gas station in Eugene, Oregon. The site was a blight on the face of the community and a dumping ground for tire, garbage, and drums of potentially hazardous wastes. The site has since been transformed into a state-of-the-art biofuels station, and ground water cleanup is still under way.

STRAINED SURFACE WATER/GROUND WATER RELATIONS

The National Water-Quality Assessment Program (NAWQA) of the U.S. Geological Survey is the primary source of long-term, nationwide information on the quality of streams, ground water, and aquatic ecosystems. The following two examples are taken from recent NAWQA findings (http://water.usgs.gov/nawqa/xrel.pdf) that address the importance of surface water/ground water relations.

San Antonio's Edwards Aquifer

NAWQA findings showed that major streams in the San Antonio, Texas, area lose substantial amounts of water to the nearby highly permeable, faulted, and fractured carbonate outcrop of the Edwards aquifer. The streams in large part originate in and flow through what is now mostly undeveloped rangeland; however, these streams also flow through northern San Antonio, which continues to be developed. Some contaminants that are typical of urban runoff are finding their way to the recharge zone and ultimately to the aquifer. For example, chloroform, along with the herbicides atrazine, deethylatrazine, simazine, and prometon, were commonly detected in NAWQA samples from wells in the recharge zone. Findings on water quality in the Edwards aquifer and in the recharging streams point to a critical management issue because the aquifer is the principal water supply for the greater San Antonio region. While the concentrations detected for the 13 pesticides for which drinking water standards or guidelines have been established were substantially lower than their allowable maximums, standards for combinations of pesticides have not been established, and very little is known about these effects on human health.

Photo: Copyright © Larry Fellows, Arizona Geological Survey

Interactions between ground water and surface water aren't always as obvious as the hot spring along Hot Creek, California, pictured here. Greater attention and research on ground water-surface water interactions is critical for effective protection of all water resources.

The Platte River's Alluvial Aquifer

NAWQA findings showed that ground water withdrawals from the Platte River's alluvial aquifer induce infiltration from the river to the aquifer, where public water supply wells provide about 117 million gallons per day to Nebraska's large cities—Omaha, Lincoln, Grand Island, and Kearney. The aquifer provides 70 percent of Nebraska's drinking water and supports such key economic uses as crop irrigation.

Elevated concentrations of atrazine (at times exceeding the USEPA drinking water standard of 3 micrograms per liter) were detected in public supply wells in the Ashland wellfield, the primary source of public supply for the City of Lincoln, which has a population of about 200,000. The atrazine in the Ashland wellfield is found in induced recharge water from the Platte River. These atrazine hits are from spring runoff into the river. This river water is being drawn into the ground water via bank storage and pumping of the city wells (which are right next to the river). The USGS studies improved the City of Lincoln's understanding of the transport of pesticides from the Platte River through channel alluvium and into the ground water at the wellfields near the river. The city now carefully watches spring pumping and atrazine levels, tracking river water and well water much more closely for atrazine spikes. The NAWQA findings are also being used by the city to update its wellfield management plan.

The NAWQA findings also look at the Central Nebraska Platte River Basins where there is heavy agricultural use of fertilizers and herbicides, such as atrazine, alachlor, cyanazine, and metolachlor. In this case, the chemicals are leaching into the ground directly from the farms where they are used, mainly due to very shallow depth to water and very sandy soils. Atrazine is not routinely detected in ground water in other parts of the state.

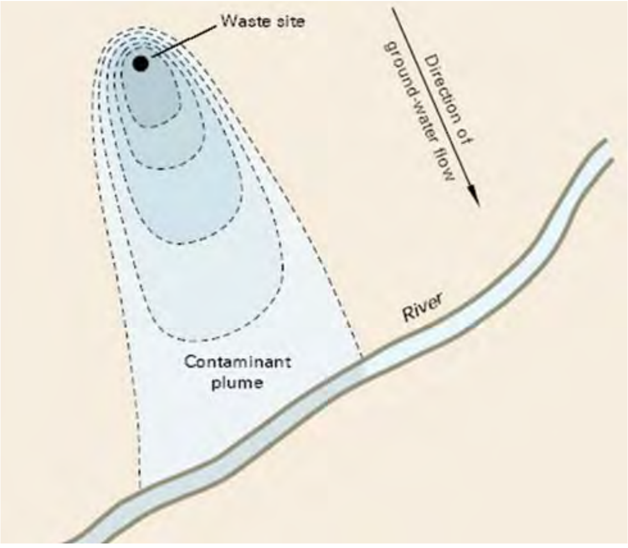


Figure 6. *The transport of contamination from a point source by ground water can cause surface water contamination, as well as extensive ground water contamination.*

Source: http://pubs.usgs.gov/circ/circ1139/pdf/part2.pdf

Contaminant sources—such as leaking underground storage tanks; storm water runoff; fertilizers, herbicides, and pesticides used in agricultural operations; animal wastes from densely packed feedlots and hog- and poultry-raising operations; toxic consumer and industrial products; and hazardous products and wastes spilled or leaked onto highways and parking areas—can all find their way to ground water if we are not careful. (See Figure 6.) Atmospheric transport and deposition (part of the hydrologic cycle) also transport substances, including mercury, pesticides, sulfuric acid from fossil-fuel combustion, and nitric acid, to the land surface and, by infiltration, to ground water.

Rearranging the Landscape

For the most part, our growth and development decisions over the past 100 years have not considered impacts on the hydrologic system. Physical alterations associated with urban and suburban growth, including attendant tree loss, stream channelization and damming, and loss of agriculture land, have had and continue to have significant impacts on both surface and ground water quality and availability. Other land uses such as agriculture, forestry, transportation, and mining contribute additional impacts.

Colorado land being cleared for new housing projects. Each and every time the landscape is modified, we must consider the impact on the hydrologic cycle, including the subsurface ground water environment.

Ground water flows directly into streams, rivers, lakes, and wetlands through stream beds or the bottoms of lakes or wetlands. This is a spring boil in the Bogue Chitto River, Louisiana.

Photo: Arthur Kuehne

Inasmuch as ground and surface waters are connected, our concern for and attention to the fact that contamination of ground water pollutes surface waters should speak loud and clear that these water resources should be given equal footing.

Each year more tracts of undeveloped land are turned into impervious surfaces, such as roads, parking lots, driveways, sidewalks, and rooftops, preventing rain and snowmelt from recharging ground water. Instead, this water rapidly passes over these surfaces, collecting oil, grease, road salt, heavy metals, pathogens, pesticides, and other contaminants. As water is transported in this manner, it causes accelerated erosion and flooding along the water pathway, disarranges river morphology and stability, and contaminates receiving waters and riparian systems.

There are numerous examples of land-development techniques that utilize or mimic the many benefits of natural hydrology while still allowing for development. Local land-use decision makers can adopt and apply land-use practices that consider the location and vulnerability of water resources, ensure long-term water supply availability and protection, and direct development to areas where there is adequate water supply and infrastructure.

DRAWING WISDOM FROM A WELL

Wells are our primary means for drawing water from beneath the land surface. They are also the primary link to our understanding of what is going on in the subsurface. Yet in many respects we remain uninformed. Current ground water monitoring and analysis data are generally insufficient to determine the availability, quality, and overall health of this resource. A June 2004 Government Accountability Office (GAO) report, *Watershed Management: Better Coordination of Data Collection Efforts Needed to Support Key Decisions*, states that "reliable and complete data are needed to assess watersheds…and allocate limited cleanup resources." But the report itself hardly mentions ground water.

As a nation, we simply do not have a clear picture of our ground water resources. In a survey of 28 states, the National Ground Water Association (NGWA) pointed out that increasing federal funding for cooperative ground water quantity and quality data collection and aquifer mapping is a key action the federal government could take to help promote ground water protection. The National Cooperative Geological Mapping Program is an example of one such program.

In its April 6, 2005, testimony before the U.S. Senate Energy and Natural Resources Committee, NGWA member David Wunsch told the Committee that there were glaring data gaps and that there is a need for a national clearinghouse for ground water information and data, including real-time data, to help maximize data-gathering efforts. On behalf of NGWA, Wunsch explained that top priorities for development of long-term ground water sustainability plans include:

- Research on water reuse and conservation.
- Alternative treatment systems.
- Development of brackish ground water supplies.
- Aquifer storage and recovery or artificial recharge.
- Emerging contaminants and development of remediation technologies.
- Development of models and data standards.

In spite of great advances in the fields of hydrogeology, mathematical modeling, and epidemiology, hydrologists still encounter significant data gaps when attempting to quantify interaction between surface and ground water, develop predictive models for ground water flow and contaminant transport, and link ground water contamination to human activities and public health impacts. Ground water reserves are predictable—given good data from adequate monitoring—and they are manageable—given sustained public commitment and investment. There is an urgent need for federal leadership in funding cooperative efforts with state and local governments to address data gaps.

Fragmentation of Ground Water Programs

If ground water characterization and monitoring are so important, why don't we just get out there and do it? Part of the answer can be attributed to program fragmentation. During the 1990s, states and USEPA successfully developed ground water protection program guidelines based on the goals, principles, and guidelines established in a document titled *Protecting the Nation's Ground Water: EPA's Strategy for the 1990s—The Final Report of the EPA Ground-Water Task Force*. However, around 1996, most USEPA regional offices experienced moderate to major reorganizations that resulted in fragmentation or disinvestment in ground water protection staff resources. At the same time, many state programs experienced similar reorganizations.

Since then, state and USEPA ground water protection programs have operated essentially at program-maintenance levels, at best, if not with significantly reduced staff and funding resources. States no longer have a comprehensive ground water protection advocate at the federal level because USEPA's technical ground water expertise was dispersed into other agency programs. Dissolution of the Ground Water Branch at most, if not all, regional USEPA offices has decreased federal emphasis on the importance of ground water, and the states lost a federal coordinating partner.

Water samples being taken from a spring in Clark County on Two Mile Creek, Kentucky. The spring is polluted with crude oil from a break in an oil pipeline. A significant percentage of the ground water in the state moves through karst aquifers. Most karst springs previously used for public water supply have been abandoned because of ground water contamination. Despite that, water from karst aquifers remains vital to the state because karst springs support the baseflow of the streams to which they discharge. In fact, most public systems in karst areas still use water from a karst aquifer when they withdraw from a stream or reservoir.

Source: http://www.uky.edu/KGS/water/general/karst/gwvulnerability.htm

OREGON'S SOUTHERN WILLAMETTE VALLEY GROUND WATER MANAGEMENT AREA

In May 2004, following a public comment period on the final Southern Willamette Valley ground water report and proposal for declaring a Ground Water Management Area, the Oregon Department of Environmental Quality (ORDEQ) issued a declaration that created the Southern Willamette Valley Ground Water Management Area (GWMA). In doing this, the ORDEQ, Department of Agriculture, Water Resource Department, Department of Human Services, and other state agencies were required to focus efforts on the development of an action plan to restore ground water quality.

The GWMA is the result of many years of studies and analyses of the shallow ground water in the lowlands of the Southern Willamette Valley. Studies beginning in the 1990s showed that shallow ground water contains nitrate at levels that are a concern. The Valley is one of Oregon's fastest-growing regions and depends heavily on ground water for both private and public drinking water, irrigation water, and other uses. In fact, ground water provides almost all of the drinking water in the study area. High levels of nitrate contamination in drinking water can pose a health risk. Oregon law requires that ORDEQ declare a ground water management area when there is confirmation of nitrate contamination in the ground water above 7.0 milligrams per liter (mg/L) and the suspected sources of nitrate are not facilities with permits, such as landfills or incinerators.

A citizen's Ground Water Area Management Committee was formed to strategize with the state agencies preparing the action plan. The Committee reviewed and commented on all potential options and approved the final plan prior to its use by the state on November 9, 2006. *The Southern Willamette Ground Water Management Area Action Plan* will now serve to guide activities aimed at reducing nitrate contamination in the area's ground water. To download a copy of the plan, go to: *http://groundwater.oregonstate.edu/willamette/Plan.htm*

Source: http://www.deq.state.or.us/WQ/pubs/factsheets/groundwater/sowillamettegwma.pdf

Consequently, protection efforts, except as they relate to protecting drinking water supplies, have lost ground at a time when the need is great—and growing. Even USEPA's recent Ground Water Rule (November 2006), which will increase protection against microbial pathogens in public water systems that use ground water, addresses a limited range of potential contaminants for a subset of ground water resources. There are too many instances where different entities collect limited-value data, and ground water management proceeds in a fragmented, often ineffective, and sometimes contradictory approach to ground water management.

GROUND WATER POLICY AND REGULATION

With regard to water use and allocation, water rights laws are complicated and often unclear. The evolving trends and practices of water law vary from state to state and often contribute to the wasteful and inefficient use of ground water. In many states, water law still reflects common-law court decisions from the late 19th and early 20th centuries. Ground water and ground water laws are of growing interest due to population growth, changing demographics and land use patterns, potential effects of new waste sources, climate change, and the high cost of getting water where we need it. Furthermore, water law has traditionally overlooked the fact that hydrologic systems do not stop at state boundaries, thus avoiding regional, watershed, or aquifer-based approaches. Thankfully, some states have revised, or are in the process of revising their water law to reflect current knowledge and reality.

With regard to water regulation, there has always been some confusion over which bodies of water are covered by the federal Clean Water Act (CWA), which requires permits for discharge of pollutants or discharges of dredged or fill materials into "navigable waters." The CWA defines "navigable waters" as "waters of the United States, including the territorial seas." However, "waters of the United States" is not specifically defined in the CWA. Nevertheless, court decisions, regulations, and agency policies have

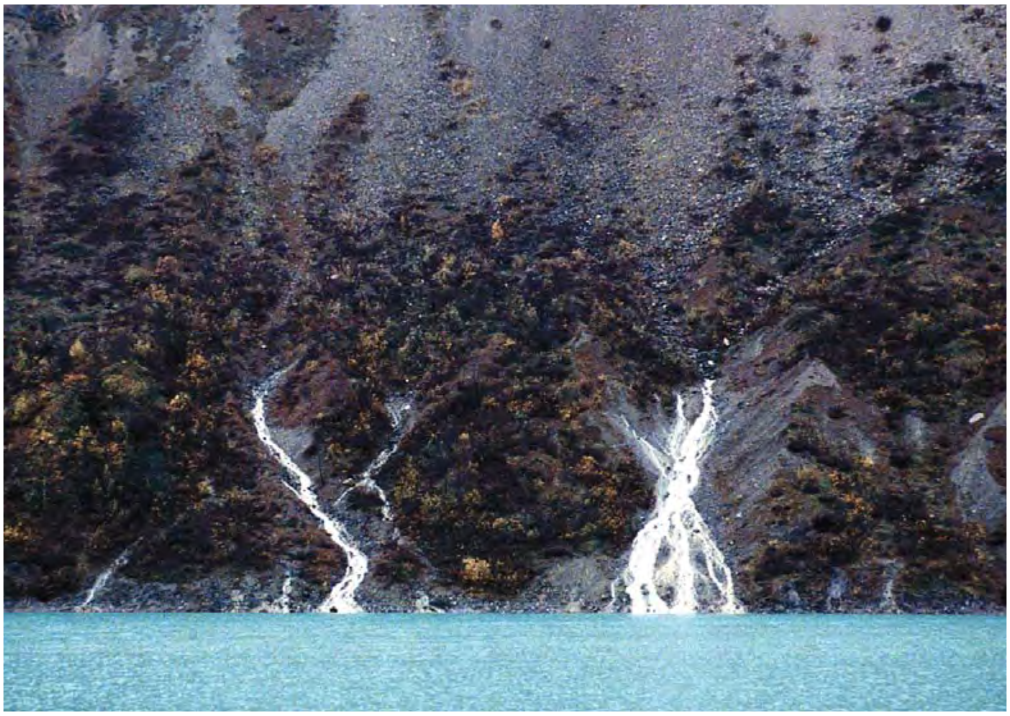


Photo: Copyright © Bruce Molnia, Terra Photographics

These springs are discharging from glacial tills and moraines into a tidal inlet in Alaska.

established that "waters of the United States" applies only to surface waters, including rivers, lakes, estuaries, coastal waters, and some wetlands—and not ground water unless it is in direct communication with surface waters.

Regardless of the confusion over the term "navigable waters," the term "ground water" is included in several sections of the Clean Water Act including Section 102 (Comprehensive Programs for Water Pollution Control), and Section 104 (Research, Investigations, Training, and Information), Section 106 (Grants for Pollution Control Programs), and Section 319 (Nonpoint Source Management Programs).

Section 102 requires development of "comprehensive programs for preventing, reducing, or eliminating the pollution of the navigable waters and ground waters and improving the sanitary condition of surface and underground waters." It further states that "due regard shall be given to...the withdrawal of such waters for public water supply, agricultural, industrial, and other purposes."

Likewise, Section 106 allows for funding to be specifically allocated to support the development and implementation of the comprehensive ground water protection programs required in Section 102. However, guidance to states from USEPA on how to allocate these funds is based on USEPA's strategic plan. Without inclusion of ground water goals and targets in the USEPA strategic plan, beyond its use as a public drinking water supply, USEPA and the states are not encouraged to place a high priority on ground water protection or allocate substantial funding for ground water programs.

A few members of Congress have made several attempts to clarify the definition of "waters of the United States." The most recent attempt is the introduction of the Clean Water Restoration Act (CWRA). This bipartisan bill restores federal protection of waters and wetlands by clarifying Congress's original intent in the 1972 landmark Clean Water Act (CWA), commonly recognized to include inter- and intrastate waters.

The proposed CWRA would define "waters of the United States" to mean "all waters subject to the ebb and flow of the tide, the territorial seas, and all interstate and intrastate waters and their tributaries, including lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, natural ponds, and all impoundments of the foregoing, to the fullest extent that these waters, or activities affecting these waters, are subject to the legislative power of Congress under the Constitution." While still not expressly including ground water, some believe this clarification would strengthen the authority of federal-level ground water programs by emphasizing the interconnections between these surface water resources and ground water.

Inasmuch as ground and surface waters are connected, our concern for and attention to the fact that contamination of ground water pollutes surface waters should speak loud and clear that these water resources should be given equal footing. The Clean Water Act should include provisions that require USEPA and states to provide ground water with all the protection given to surface water.

IF WE KNEW THE REAL VALUE OF GROUND WATER…

If we knew the real value of ground water, would we be more willing to protect it? What, in fact, is the worth of ground water? Is it less than a penny per gallon, the average cost for tap water in the United States? Or is it the price we pay for bottled water, which can cost 240 to over 10,000 times more per gallon than a gallon of average tap water? (Natural Resources Defense Council [NRDC], 2007) (In fact, some bottlers use tap water as their source.) Is it the cost we pay to extract, treat, and deliver water? A Congressional Budget Office report (November 2002) estimates the average annual costs for water treatment systems to be between $11.6 – $20.1 billion annually (2000 – 2019).

Communities with ground water pollution problems become tainted and can suffer losses in property values, businesses, and jobs. Communities that have lost a water supply through contamination quickly learn

COST OF REMEDIATING SOURCE WATER POLLUTION

COMMUNITY	TYPE OF PROBLEM	RESPONSE TO PROBLEM	COSTS
Perryton, TX	Carbon tetrachloride in ground water	Remediation	$250,000
Camden-Rockland, ME	Excess phosphorus in Lake Chickawaukie	Advanced treatment	$6 million
Moses Lake, WA	Trichlorethylene in ground water	Blend water, public education	$1.8 million
Mililani, HI	Pesticides, solvents in ground water	Build and run treatment plant	$2.5 million plus $154,000/yr
Tallahassee, FL	Tetrachloroethylene in ground water	Enhanced treatment	$2.5 million plus $110,000/yr
Pittsfield, ME	Landfill leachate in ground water	Replace supply, remediation	$1.3 million
Rouseville, PA	Petroleum, chlorides in ground water	Replace supply	$300,000+
Atlanta, MI	VOCs in ground water	Replace supply	$500,000 – $600,000
Montgomery County, MD	Solvent, Freon in ground water	Install county water lines, provide free water	$3 million plus $45,000/year for 50 years
Milwaukee, WI	Cryptosporidium in river water	Upgrade water system, immediate water utility, city health department costs	$89 million to upgrade system; millions in immediate costs
Hereford, TX	Fuel oil in ground water	Replace supply	$180,000
Coeur d'Alene, Idaho	Trichloroethylene in ground water	Replace supply	$500,000
Orange County Water District, CA	Nitrates, salts, selenium, VOCs in ground water	Remediation, enhanced treatment, replace supply	$54 million (capital costs only)

Table 1. A sampling of localities of various sizes that have borne high, readily quantifiable costs due to source water pollution. *This table attempts to isolate community costs by excluding state, federal, and private industry funding. Also not included are such costs to individuals as lost wages, hospital and doctor bills, reduced property values, higher water bills, and, in extreme cases, death.*

Source: Steve Ainsworth, Paul Jehn. February 1996. "Source Water Protection: What's in It for You?" Public Management (vol 78, no. 2) by the International City/County Management Association.

the value of ground water. For example, Hyde Park, New York, spent $4.6 million for a system to pipe Hudson River water treated at the Poughkeepsie Water Treatment Facility to about 270 properties in the city's Greenbush area. Local wells in the area were contaminated with pollutants such as MTBE from local gasoline stations and bacteria from septic systems. Residents in the Greenbush Water District were charged about $430 per year to cover construction costs. Ongoing costs for residents will depend on how much water they use. (*Environmental Evaluation & Cost-Benefit News,* 2005/07) (See Table 1 for other examples.)

We are at a ground water crossroads that necessitates ingenuity and proaction in order to minimize potentially detrimental and costly consequences. Each of us shares responsibility for securing the availability, integrity, and ecological balance of our nation's water resources—for the long haul.

There are no market-generated prices for ground water, or even estimates for market prices if water were traded. In fact, ground water is remarkably undervalued, largely because we have no consistent process for determining its total economic value. Typically, more value is placed on the extraction, treatment, and delivery of the ground water "product" than on the total value of the resource itself. How do we determine appropriate ground water protection strategies and establish priorities if we have no valuation basis for making these decisions? A fundamental question is: Where would we be without the ground water we use currently and will need in the future?

According to *Valuing Ground Water—Economic Concepts and Approaches,* a 1997 report published by the National Academy of Sciences, the undervaluation of ground water fosters misallocation of resources in two ways:

- The ground water resource is not efficiently allocated relative to alternative current and future uses/sources.
- Authorities responsible for resource management and protection devote inadequate attention and funding to maintaining ground water quality.

Photo: Copyright © American Geological Institute

This hot spring is located between Echinus geyser and Green Dragon spring in the back basin area of the Norris geyser basin of Yellowstone National Park.

"It is circumstance and proper timing that give an action its character and make it either good or bad."

Agesilaus | King of Sparta (444– 360 BC)

The longer we put off the inevitable task of establishing a consistent and comprehensive means for valuing ground water, the longer we delay the efficient (i.e., sustainable) allocation of ground water.

THE RESPONSIBILITY FOR GROUND WATER IS OURS

We are at a ground water crossroads that necessitates ingenuity and proaction in order to minimize potentially detrimental and costly consequences. Each of us shares responsibility for securing the availability, integrity, and ecological balance of our nation's water resources—for the long haul. It is way past time for us to recognize the significance of ground water to our national welfare—our public health, quality of life, and economic well-being. It is time for federal, state, and local decision makers to take concrete action to ensure that our hydrologic systems are monitored, understood, and managed sustainably for generations to come and that ground water has equal footing in this endeavor.

We must:

- Take swift and decisive action to ensure that ground water is meaningfully integrated into federal and state water resource conservation, management, and protection agendas.
- Adopt new paradigms in science, water policy, and law that demonstrate the interactive relationship among components of watersheds and ecosystems and the vital role that ground water plays in those systems.
- Ensure that these new paradigms are based on solid scientific principles.
- Clarify in federal law the national importance of our ground water resources as well as the financial commitment to effective and comprehensive protection and management of the nation's ground water resources.
- Make a financial commitment to effective and comprehensive protection and management of the nation's ground water resources.

A bottomland hardwood swamp at the confluence of Tubby Creek and the Wolf River (a small alluvial river) in the Holly Springs National Forest near Ashland, Mississippi. The Wolf River rises from ground water at Baker's Pond, north of Ashland, and flows northwest into Tennessee. The river area is home to a large variety of species that are dependent upon good quality water and is fed by the Memphis Sands Aquifer, which is used as a drinking water source for metropolitan Memphis and other Mid-South communities. It is one of many rivers in West Tennessee and Mississippi that prompted the Chickasaw to call the region "the land that leaks." The Wolf's fragile wetlands retain water long enough for it to be absorbed into the ground and serve as natural filters to cleanse polluted waters before they reach the aquifer.

Call to Action

GWPC'S *Call to Action*

In 2006, the Ground Water Protection Council (GWPC) made a decision to move forward with a "Call to Action" to advance the protection of this vital ground water resource. As we will make clear in this report, circumstances surrounding the future of ground water are a cause for concern. The GWPC is committed to promoting these recommendations contained in this report, to monitor and report on their progress, and to serve as a resource for helping targeted audiences achieve the goals of these recommendations. We invite, indeed urge, the media, governmental agencies, academia, industry, and the various public- and private-sector entities targeted in this report, along with the public at large, to join us in making this endeavor a success. The speed with which we adopt a new ground water paradigm will determine the outcome.

It was difficult to prioritize the myriad ground water issues and human impacts that we would address in this first edition of our "Call to Action" for ground water. Even within the topics chosen for this edition, there are many aspects of science, policy, and education that could not be covered in a report of this size or targeted for particular audiences. For this reason, priority topics that were not focused on as sections in this edition will be covered in subsequent editions, and some topics selected for the sections in this edition may be updated over time.

The topics chosen for the first edition are: ● Ground Water Use and Availability, ● Ground Water Characterization and Monitoring , ● Ground Water and Source Water Protection, ● Ground Water and Land Use Planning and Development, ● Ground Water and Stormwater, ● Ground Water and Underground Storage Tanks, ● Ground Water and Onsite Wastewater Treatment Systems, ● Ground Water and Underground Injection Control, and ● Ground Water and Abandoned Mines.

Ground Water *Interactions*

This drawing was developed for this Ground Water Report to the Nation…A Call to Action *to demonstrate how human activities have an impact on ground water.*

Recommended Actions

To Congress:

Take legislative action, including:

- Appropriating the funding necessary to ensure the development and implementation of a national ground water protection strategy.
- Clearly defining ground water's coverage under the Clean Water Act and Safe Drinking Water Act §1429.
- Requiring explicit coordination between Clean Water Act and Safe Drinking Water Act programs.
- Directing that USEPA support state efforts to protect and manage ground water.

To USEPA:

Include more attention to ground water in the national water strategy, giving it scientifically appropriate weight with surface water with respect to programmatic emphasis, funding, research support, and public visibility.

Utilize existing federal laws as the statutory basis and funding authority for protecting and conserving ground water as a component of watersheds and ecosystems, including the reestablishment of an active ground water protection program.

To Governors and State Legislatures:

Support and authorize statewide ground water protection and conservation laws, regulations, and regulatory agencies and programs that recognize ground water as a critical component of state economies, watersheds, and public health protection.

Springs offer a unique opportunity to explore ground water and even encounter many resident plants and animals like the Manatee and, beneath the surface, native species like the secretive Greater Siren and the Loggerhead Musk turtles. Clean, clear water flowing from the aquifer at a constant temperature are essential ingredients that support the variety of life found in and around a spring in Jackson Blue Springs, Florida.

Photo: Tom Scott, FGS/FDEP

Section 1 References: A Call to Action

Alley, William M., Thomas E. Reilly, and O. Lehn Franke. 1999. *Sustainability of Ground-Water Resources.* USGS Circular 1186, U.S. Geological Survey.

Congressional Budget Office. November 2002. Report: *Future Investment in Drinking Water and Wastewater Infrastructure.*

Environmental Valuation & Cost-Benefit News 2005/07. Available at: *http://envirovaluation.org/index.php/2005/07/*

Government Accountability Office (GAO). June 2004. Report: *Watershed Management: Better Coordination of Data Collection Efforts Needed to Support Key Decisions.*

Hutson, S., N. Barber, J. Kenny, K. Linsey, D. Lumia, and M. Maupin. 2004. *Estimated Use of Water in the United States in 2000.* USGS Circular 1268. Available at: *http://pubs.er.usgs.gov/usgspubs/cir/cir1268* (accessed February 19, 2007).

McGuire, V. L., M. R. Johnson, R. L. Schieffer, J. S. Stanton, S. K. Sebree, and I. M. Verstraeten. 2003. *Water in Storage and Approaches to Ground-Water Management, High Plains Aquifer, 2000*. USGS Circular 1243.

National Academy of Sciences, National Research Council Committee on Valuing Ground Water. 1997. *Valuing Ground Water—Economic Concepts and Approaches.* National Academy Press, Washington, D.C.

National Assessment Synthesis Team, U.S. Global Change Research Program. 2000, 2003. Available at *http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm* (accessed February 19, 2007).

NRDC, 2007. *http://www.nrdc.org/water/drinking/bw/chap2.asp*

USEPA Office of the Administrator. July 1991. *Protecting the Nation's Ground Water: EPA's Strategy for the 1990s—The Final Report of the EPA Ground-Water Task Force.* Publication EPA/21Z-1020, NTIS Order Number PB92-224765.

Sandia Labs. 2006. *www.sandia.gov/energy-water/nexus_overview.htm*

Solley, W. B., R. R. Pierce, and H. A. Perlman. 1998. *Estimated Use of Water in the United States in 1995.* USGS Circular 1200.

USGS. 2006. *http://ga.water.usgs.gov/edu/earthwherewater.html*

USGS. 2003. *Ground-Water Depletion Across the Nation,* Fact Sheet 103-03. November 2003. Available at: *http://pubs.usgs.gov/fs/fs-103-03/* (accessed February 19, 2007).

Winter, Thomas C., J. W. Harvey, O. L. Franke, and W. A. Alley. 1998. *Ground Water and Surface Water: A Single Resource.* USGS Circular 1139. Available at: *http://pubs.usgs.gov/circ/circ1139/*

Section 2

Ground Water

Use and Availability

Key Message

Ground water is a renewable, yet finite, resource—and it is usually taken for granted. It is generally pumped from the subsurface in the absence of a sound understanding of how much remains available for sustainable use. Overwithdrawal of ground water supplies can lead to dried-up wells and springs, shrinking wetlands, reduced stream flows and lake levels, saltwater intrusion in coastal areas, and land subsidence. These impacts have serious economic ramifications, which are only worsened when coupled with drought conditions. Unless we employ more effective ways to manage the way we use ground water, current practices of withdrawing ground water at unsustainable rates will ultimately have significant social, economic, and ecological costs.

Our land-use decisions and water-use policies must consider the interrelationship between ground water and surface water supplies and the capacity of individual watersheds to sustain existing, as well as future, water uses. To ensure the long-term availability of water and aquifer yields, we as a nation must use water more efficiently and better tailor our land- and water-use planning to effectively bridge the gap between water law and science.

Left: Ground water pumping in the Arizona desert has caused the land to subside in some basins.
Right: The United States uses more than 83 billion gallons of fresh ground water each day for private and public water supplies, irrigation, livestock, manufacturing, mining, and other purposes. (USGS, 2004)

Getting a Grip on Ground Water Use

"The solution involves charting a new course for the future based on wise policies, then making a commitment to stay the course. It can be done. In the process, there is a role for every individual and for local, state, and federal governments."

Robert Glennon | *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters*

why ground water Use and Availability matter…

Potable fresh water is fast becoming a highly sought-after commodity—it is being called "blue gold." Yet the fact that *all the water we have right now is all the water we will ever have* is not reflected in our demand for and use of water. As a nation, we can no longer put off the job of answering the essential and definitive questions of supply and demand: Will we have enough water, and what will it cost? Global consumption of water is doubling every 20 years, more than twice the rate of our population growth. (Barlow and Clarke, 2002) According to the U.S. Census Bureau, the U.S. population has passed the 301 million mark (2007) and is expected to grow to 404 million by the year 2050. (U.S. Census Bureau, 2004)

Given that the population continues to grow while the volume of fresh water does not, we need to rethink our approach to water use so that we can effectively reconcile hydrologic, legal, economic, and ecosystem realities with population growth. It is essential that we make a concerted move toward long-term water planning and conservation so that we are not using water supplies faster than they can be renewed.

Land-use activities that lead to overuse of water supplies or loss of a water supply due to contamination are key factors in water availability. In the United States, a tremendous amount of growth has occurred in areas with limited, if not inadequate, sources of suitable water. With increasing growth into and development of rural areas, demands on ground water supplies continue to escalate. In addition to increasing demand for ground water, this expanded growth and development reduces the area available for infiltration and aquifer recharge, resulting in further loss of ground water volumes.

Many of our land-use activities create potential sources of ground water contamination (e.g., septage from onsite septic systems; fertilizers, pesticides, and other lawn chemicals from farmland, golf courses, gardens, and lawns; underground storage tank releases from gas stations and heating oil tanks; and stormwater runoff from roads, parking lots, and rooftops). In many parts of the country—even in water-rich areas—we are depleting and diverting our ground water resources, often to supplement diminishing surface water supplies.

Clearly, climate and weather patterns are circumstances over which we have no control but that have a

"The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people."

Pennsylvania State Constitution | Article | Section 27

direct bearing on water availability—less precipitation means less ground water recharge. Drought and long-term climate change pose an added layer of water supply uncertainty (e.g., the potential for long-term drought) and diminished surface water and ground water recharge.

The Agriculture Factor

While agricultural water use issues are are not a featured topic in this report, we cannot discuss water use without addressing the fact that irrigation is one of the largest users of ground water in the United States—137 billion gallons per day in 2000. According to Hutson et al. (2005), "Since 1950, irrigation has accounted for about 65 percent of total water withdrawals, excluding those for thermoelectric power. Historically, more surface water than ground water has been used for irrigation. However, the percentage of total irrigation withdrawals from ground water has continued to increase, from 23 percent in 1950 to 42 percent in 2000. The number of acres irrigated with sprinkler and micro-irrigation systems has continued to increase and now comprises more than one-half the total irrigated acreage."

WATER TRIVIA IS NOT TRIVIAL

The United States uses more than 83 billion gallons of fresh ground water each day for private and public water supplies, irrigation, livestock, manufacturing, mining, and other purposes. (USGS 2004)

We rely on water not just for our own survival, but also for the production of our food and day-to-day goods and services and our economic well-being. The three primary water-use sectors are municipal (e.g., domestic uses in urban and rural areas), industrial (e.g., mining, manufacturing), and agricultural (e.g., irrigation, livestock).

USEPA's *Water Trivia Facts (www.epa.gov/safewater/kids/water_trivia_facts.html)* provide some sobering examples of how much water we use for specific functions. Here are a few examples:

- The average residence uses more than 100,000 gallons per year (indoors and outside), or roughly 275 gallons per day.
- The average automatic dishwasher uses 9 to 12 gallons of water.
- It takes 62,600 gallons of water to produce one ton of steel.
- 300,000,000 gallons of water are used to produce a single day's supply of newsprint.
- 400 gallons of water are used during the raising/production of a single chicken.
- It takes 39,090 gallons of water to manufacture one new car, including new tires.

Photo: Copyright © Bruce Molnia, Terra Photographics

Pivot Point Irrigation on the Oklahoma/Texas border.

CORN ETHANOL AND WATER USE

Ethanol fuel from corn has been presented as a key component in helping lessen U.S. dependence on foreign oil. However, there are concerns about the environmental impacts of increased production of corn and processing the corn into ethanol, not the least of which is increased water use. For ethanol production, water use is twofold: (1) growing corn, which requires both rainfall and irrigation; and (2) converting corn to ethanol inside a plant, which requires four to five gallons of water per gallon of ethanol produced.


Photo: The Bliss Agency

How much water will it take to produce enough ethanol to displace one gallon of regular gasoline? The numbers vary widely depending on the climate in which the corn is grown, the conversion method used, and the efficiency of the ethanol produced. Here are some quick facts:

- It takes about 19 pounds of corn grain to produce one gallon of ethanol.
- In the high plains region it takes about 1,000 gallons of water to grow 19 pounds of corn (1,150-1,300 gallons, including soil moisture, rainfall, and irrigation).
- Once inside the ethanol plant, it takes 4 to 5 gallons of water to convert the grain to ethanol.
- Because ethanol is less fuel-efficient than gasoline, it could take as much as 1.5 gallons of ethanol to displace 1 gallon of gas.

Therefore, it could take as much as 1,500 gallons of water to produce enough ethanol to displace 1 gallon of regular gas, depending on where the corn is grown, the methods of conversion used, and the fuel efficiency of ethanol.

Potential Problems

- Increased corn prices, whether through subsidy or natural market, can cause an increase in corn grown in less suitable climates, creating even greater competition for water resources.
- Competing water needs.
- Rising food and livestock feed prices.

Needs

- More research on corn and water use.
- Factor water use into energy decisions.
- More research into biofuels that need less water to grow and convert into ethanol.

The Ogallala

The Ogallala Aquifer lies under portions of the eight states, including South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas. In 2006, the U.S. consumed roughly 5 billion gallons of biofuels (mostly ethanol, which equates to about 7.5 trillion gallons of water. Increasing ethanol production will increase water use. A large percentage of this water will be pumped from underground aquifers such as the Ogallala, drawing down our already overtaxed water supplies. If we severely draw down aquifers such as the Ogallala in order to produce corn ethanol, is it really a renewable resource?

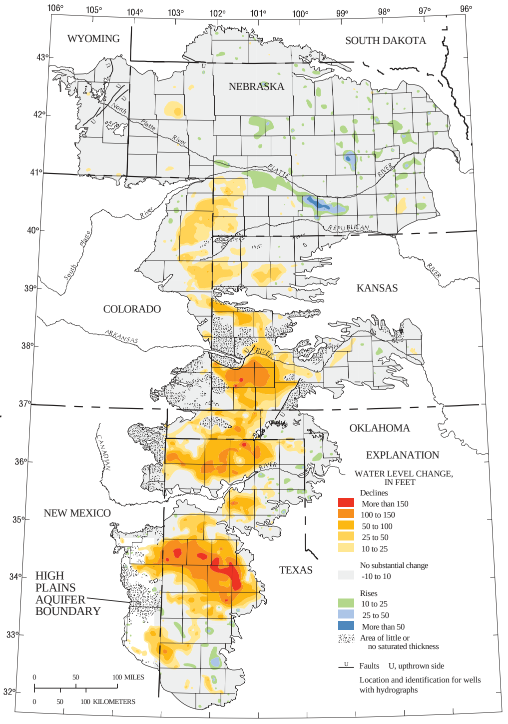


Figure 1. *This map shows water-level changes in the High Plains aquifer from predevelopment to 2003 (based on water levels from 3,792 wells). The changes ranged from between a rise of 86 feet to a decline of 223 feet. Red indicates the largest declines.*

Source http://pubs.usgs.gov/fs/2004/3097/

The Ground Water–Dependent Ecosystems Factor

Ground water plays a vital, but often poorly understood, role in sustaining both surface and subsurface ecosystems. It provides an essential source of water and creates critical habitat conditions for a broad range of species and ecosystems representing a distinct and varied component of the earth's biological diversity. Ground water-dependent ecosystems include wetlands, forests, springs, rivers, lakes, and caves, as well as deep-rooted plant communities, for which access to ground water is critical to maintaining ecosystem viability and biodiversity.

Ground water discharges on land and even at sea as springs and seeps. It provides baseflow to wetlands and rivers, maintaining aquatic ecosystems during dry months. Where the water table is relatively close to the surface, trees tap ground water directly. Hydrogeologists, ecologists, and water managers still have much to learn about how, when, and where ecosystems are dependent on ground water. For example, our understanding of wetland hydrology will be improved if the relationships between ground water and wetlands are more clearly established.

The Nature Conservancy (TNC) has been working to improve this understanding and develop effective approaches for protecting ground water for biodiversity conservation. In its *Pacific Northwest: Groundwater and Biodiversity* fact sheet, TNC describes the ground water-dependent ecosystems it is studying in

THE IMPORTANCE OF SUBTERRANEAN BIODIVERSITY

The caves of the world may be found in many places, such as glaciers and lava fields, but the major cave-bearing landscape is karst, a term for lands where bedrock has been hollowed out over the ages from the slow enlargement of cracks by acidic rainwater. Karst landscapes are found on every continent, and the ground water they contain is critical to the world's water reserves.

Facts about Karsts:

- Karst habitats comprise 20% of the earth's land surface.
- One-quarter of the world gets its fresh water from karst aquifers.
- Scientists estimate 60,000 species of cave-dwelling animals worldwide, with 10% in North America.
- An estimated 90% of subterranean life has not yet been described.
- Animals found only in caves and ground water habitat represent more than half of the imperiled species in the United States, but fewer than 4% have federal protection.
- Caves harbor a rich diversity of freshwater fishes, amphipods, and crayfishes, which are among the world's most endangered animals.
- Cave animals live much longer than their surface counterparts—sometimes 10 times longer.

Source: The Nature Conservancy. SubterraneanConservation. http://www.nature.org/initiatives/programs/caves/ (accessed July 2007).

Photo: Horton H. Hobbs III, Wittenberg University

The Caney Creek Mountain Cave crayfish, or* Cambarus aculabrum*, inhabits only one site in the world. This small, albino, cave-dwelling crayfish has an overall body length reaching about 3.75 inches. Like many other cave creatures, or troglobites, it is specially adapted to its dark surroundings, exhibiting such features as reduced eyes, lack of pigmentation, a reduced metabolic rate, delayed reproduction, and reduced egg production. This crayfish feeds on organic matter carried in by cave streams or left by other animals such as bats. Some say it can live as long as 75 years, but it is extremely sensitive to the quality of the water in which it lives. It is adapted to the clean, filtered water of underground streams and must have dissolved oxygen in the water for respiration. Contamination of water by sewage, animal waste, petroleum products, or any number of chemicals can deplete oxygen concentrations and suffocate the cave crayfish.

Source: http://www.nature.org/initiatives/programs/caves/animals/ Visited July 2007.

the Pacific Northwest, but these observations apply in principle to all such ecosystems:

> *Ground water provides a vital source of water and creates critical habitat conditions for a broad range of species and ecosystems in the Pacific Northwest. Ground water input into rivers creates refuges of cool water that can be critical during hot summer seasons. Some ecosystems, such as fens or springs, receive no other water except ground water. Good water quality, essential to the survival of spring mollusks and other aquatic species, can be provided by ground water.*
>
> *The pressure from humans on ground water is expected to increase as communities are turning more and more to ground water to meet their needs. Human activities have the potential to alter the supply or quality of ground water, which, in turn, can affect how ground water supports biodiversity. Excessive ground water pumping can reduce cool water discharge into streams or lakes and pesticides and fertilizers have the potential to contaminate ground water supplies.*

"If sustainable development is to mean anything, such development must be based on an appropriate understanding of the environment—an environment where knowledge of water resources is basic to virtually all endeavors."

Report on Water Resources Assessment
WMO/UNESCO, 1991

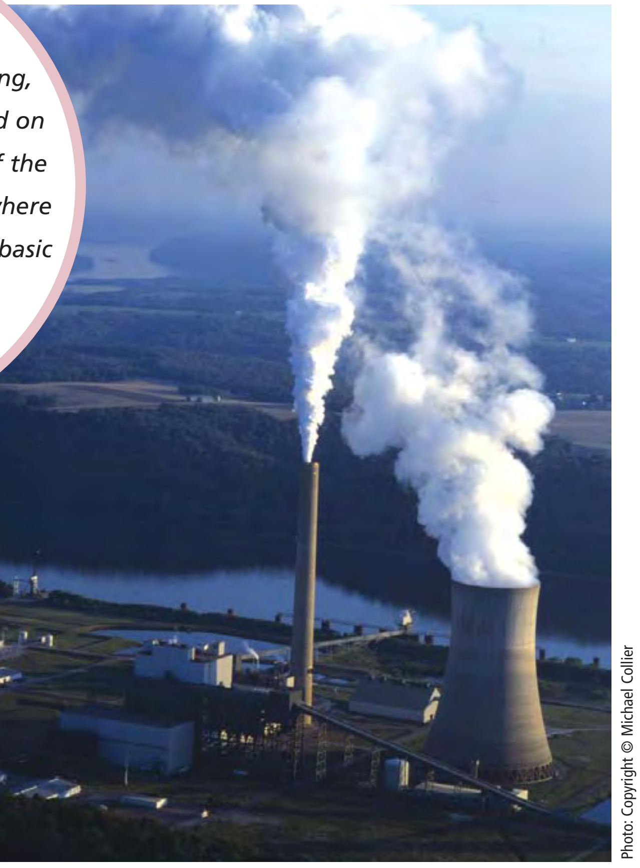


Photo: Copyright © Michael Collier

In Westport, Kentucky, the Ohio River provides the large amount of water required by this coal-fired power plant. While plants such as these typically use surface water, water demand from these operations has an impact on the ground water/surface water environment and total water demand.

The Energy Factor

Another critical factor to consider in the competition for water use is energy production, which requires a reliable, abundant, and predictable supply of water. Electricity production is second only to agriculture as the largest user of water in the United States. The Sandia National Lab, a research arm of the Department of Energy, reports that many newer energy technologies will be more water-intensive.

For example, a biofuels (e.g., ethanol) and hydrogen transportation fuel economy will require significantly more water than one based on fossil fuels, and power-plant siting will face more constraints if the water needed for cooling, advanced scrubbing, and CO_2 removal is not available. Yet, according to Sandia, there is currently no national research program directed specifically at understanding the relationship between energy production and water use.

GROUND WATER WITHDRAWAL AND AVAILABILITY IN THE NATURAL SYSTEM

Ground water and surface water have a uniquely interdependent relationship and are essentially a single resource. In the natural hydrologic cycle, water is constantly on the move. Within the ground water system, water typically moves very slowly and is replenished by recharge from precipitation and to some extent discharge from surface water bodies. In the natural system, water leaves the ground water system through discharge to surface waters and evapotranspiration.

Human activities impact the amount and rate of water movement within a given ground water system. When ground water is withdrawn for human uses, natural flow patterns are altered, affecting the amount of water in the system, leaving the system, and enter-

THE EFFECTS OF GROUND WATER WITHDRAWALS ON SURFACE WATER

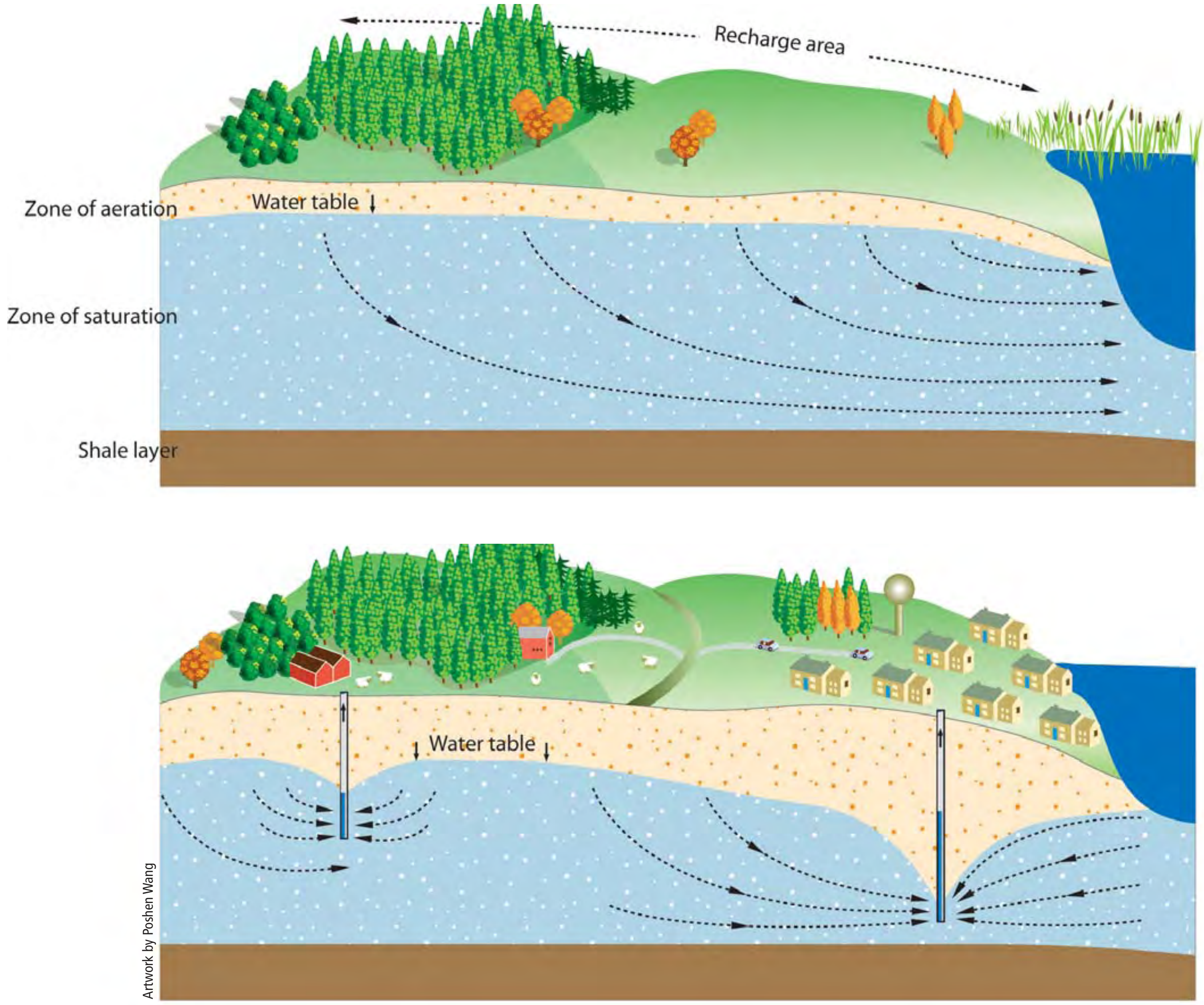


***FIgure 2.** Withdrawing water from shallow aquifers near surface water bodies can diminish the available surface water supply by capturing some of the ground water flow that otherwise would have discharged to surface water or by inducing flow from surface water into the surrounding aquifer system. Furthermore, changes in the direction of flow between the two water bodies can affect transport of contaminants associated with the moving water. Although a stream is used in this example, the results apply to all surface water bodies, including lakes and wetlands.*

ing the system. Withdrawal also affects the rate of ground water movement within the system. Pumping ground water from a well also lowers ground water levels at or near the well and diverts the water from its natural movement to a discharge area (e.g., a stream). (See Figure 2.)

Each system is unique, based on hydrogeology and external factors, such as amount and timing of precipitation, location and size of surface waters in the system, and rate of evapotranspiration. All of this calls for the use of an accounting system called a "water budget." (See Figure 3.)

Like balancing a checkbook, we need to be able to account for the amount of ground water entering, leaving, and being stored in our aquifers so that we have an accurate picture of the volume of water

Key Term

GROUND WATER SUSTAINABILITY

Development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences. (Alley et al., 1999)

HOPE SPRINGS FROM THE ARROYO SECO WATERSHED'S WATER BUDGET

The Tongva people, the settlers who first established villages on the rim of the Arroyo Seco River, called the region *Hahamongna* ("Flowing Waters, Fruitful Valley"). The significance of water has not diminished in the 46.6 square mile Arroyo Seco watershed, located within the larger Los Angeles River watershed and spanning five jurisdictions in southern California, including the Angeles National Forest and the cities of Pasadena, South Pasadena, and Los Angeles. But today, the waters aren't necessarily flowing, nor is the valley so fruitful.

Over the years, water consumption in the region has increased dramatically. Development has altered and stressed the natural water cycle throughout the Arroyo Seco watershed. The most significant change is that there is no longer a balance in the water budget. Furthermore, creeks and rivers throughout the watershed are contaminated with algae, fecal coliform, trash, and runoff from commercial activities, which has resulted in the designation of the upper portion of the watershed as a Superfund site and the closure of nine Pasadena wells. Water users in the Arroyo Seco watershed now depend on a mix of surface water from the river, ground water, and imported supplies for local use.

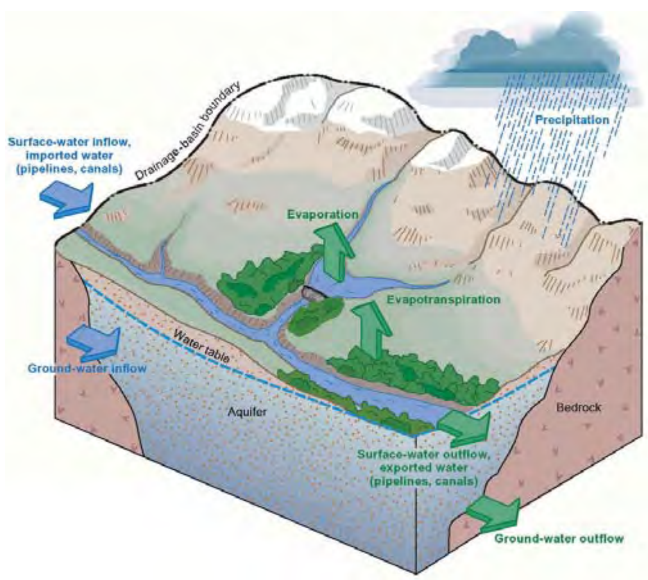


Figure 3. What is a water budget?
Hydrologists use water budgets to account for flow and storage changes in natural systems that contain water. Systems of interest can be features such as rivers, lakes, drainage basins, the land surface, or aquifers. Water budgets for each of these systems use the following formula:

(WATER INFLOW) – (WATER OUTFLOW) =
(CHANGE IN WATER STORAGE)

Source: http://pubs.usgs.gov/circ/circ1223/pdf/C1223.pdf

In December 2003, the Arroyo Seco Foundation produced *A Water Budget for the Arroyo Seco Watershed,* an effort made possible by the Watershed Management Program of the CALFED Bay-Delta Program and created by federal and state agencies to develop and implement a long-term comprehensive plan to restore ecological health and improve water management for beneficial uses of the Bay-Delta System. The program was established in 1998 to work at a watershed level with the communities that use or benefit from the ecosystem.

The water budget has helped set in motion a framework to quantify precipitation, runoff, recharge, evaporation, transpiration, and human uses of water within the watershed so that the public and planners understand the effects of future management options. The information provided in the document can be used to refine, test and assess specific watershed management alternatives. The hope is that the water budget and refined models will provide the context for an informed, prescriptive approach to planning and the development of local codes and ordinances to help "balance the budget."

As the document states: "The Arroyo Seco Watershed Budget is a tool to promote a better understanding of local water use and better management of the water resources of the Arroyo Seco. The approach used here is a relatively simple, straightforward evaluation of all the components of the hydrologic cycle and human interaction with it." It also points out that more detailed and sophisticated techniques are needed to refine this budget.

Source: http://www.arroyoseco.org/AS_Water_Budget.pdf

"From a sustainability perspective, the key point is that pumping decisions today will affect surface-water availability; however, these effects may not be fully realized for many years."

U.S. Geological Survey | Sustainability of Ground-Water Resources

available to meet our needs at a sustainable level now and in the future. Yet, as a nation, we lack the fundamental data necessary to adequately understand our ground water resources and develop a water budget, let alone make informed decisions regarding its use and management. The "Ground Water Resource Characterization and Monitoring" section of this document lists some of the critical data needed to assess and determine ground water availability and to develop a water budget.

HOW OVERPUMPING TAKES A TOLL ON GROUND AND SURFACE WATER

In the relatively short period of time in human history that we have had the technology to access ground water sources, we have had significant impacts on hydrologic systems, and hence water availability. Ground water depletion is primarily caused by unsustainable ground water pumping, or overpumping, and is occurring in many areas of the country. Some of the negative effects of overpumping include:

- **Dried-up wells –** Ground water levels fall when the volume of water extracted exceeds the volume of water available through recharge. As a result, existing wells need to be drilled deeper to find new water supplies, new wells need to be drilled, or an alternative source of water must be located. In many instances this may require that water be purchased, hauled, or stored from an offsite source, or connected to new or existing municipal or water district supply pipelines, if possible.

Photo: Copyright © Larry Fellows, Arizona Geological Survey

These earth fissures in the desert appear to stop at the edge of a cultivated field. The high ground water use for irrigation pulls ground water from the whole of the aquifer, affecting overlying lands.

PRIORITIES FOR GROUND WATER MANAGEMENT

- **Sustainable long-term yields from aquifers.**
- **Effective use of the large volume of water stored in aquifers.**
- **Preservation of ground water quality.**
- **Preservation of the aquatic environment by prudent abstraction of ground water.**
- **Integration of ground water and surface water into a comprehensive water and environmental management system.**

Source: USGS, 1999

"A key challenge for achieving ground water sustainability is to frame the hydrologic implications of various alternative management strategies in such a way that they can be properly evaluated."

U.S. Geological Survey | Sustainability of Ground-Water Resources

- **Reduced flows to rivers, lakes, springs, and wetlands –** With overpumping, the movement of ground water from shallow aquifers to rivers, lakes, springs, and wetland areas is diminished, leading to decreased streamflows, lower water levels in lakes, and shrinking wetlands. At its extreme, overpumping can lead to total loss of flow to surface waters and associated riparian areas, not to mention lost water sources for people, animals, and vegetation.
- **Degraded water quality –** Overdrafting of ground water in coastal areas (or anywhere deep saline ground water exists) can lead to the migration, or "intrusion," of salt water into freshwater aquifers. Once salt water mixes with freshwater, either treating the water or locating and developing an alternative water supply are the only options, however costly.
- **Land subsidence –** Overdrafting of ground water can cause the loss of subsurface support, causing subsidence at the ground surface and resulting in any number of costly structural consequences, including damage to highways, buildings, wells, and pipelines. *(http://ga.water.usgs.gov/edu/gwdepletion. html)*

Photo: USGS

Sinkholes can be classified as geologic hazards, sometimes causing extensive damage to structures and roads and resulting in costly repairs. Sinkholes can also threaten water supplies by draining unfiltered water from streams, lakes and wetlands directly into the aquifers.

CHANGES IN KANSAS RIVERS AND STREAMS: 1961 – 1994

Source: Marios Sophocleous, Kansas Geological Survey

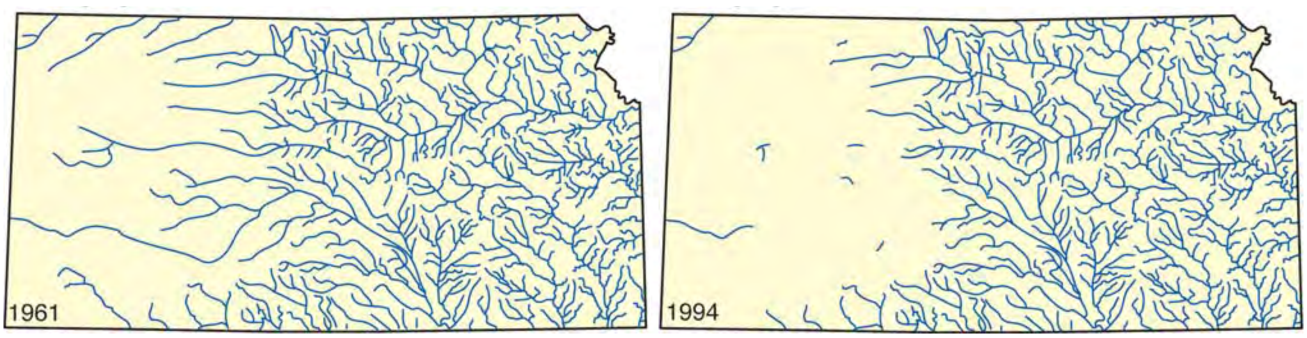


Figure 4. *Kansas rivers and streams changed between 1961 and 1994 due to high ground water pumping rates that caused the loss of perennial streams by 1994 in western Kansas. That area is underlain by the High Plains aquifer, which has been heavily pumped to support irrigation. Over time, the pumping "captured" surface water flows.*

In response to drastically declining water levels in the High Plains aquifer in western Kansas (200 feet or more than 50 percent of the aquifer thickness in some places), local ground water-management districts were authorized by the Kansas Legislature in 1972 to manage the resource. In 1982, the Kansas Legislature passed a law requiring minimum desirable streamflows. Management policies vary in the districts, including planned depletion, zero depletion, and modified sustainable yield. In some locations, new wells are not allowed. Local, state, and regional planning efforts continue to manage collectively the ground water and surface water resources in the High Plains aquifer area.

Minnesota's streams, lakes, and wetlands are vulnerable to this kind of change, and signs of such change are evident in some areas. Looking for ways to minimize the impact of human intervention (i.e., ground water withdrawal), Minnesota uses the Kansas experience as a means for addressing its own similar water issues.

Source: http://files.dnr.state.mn.us/waters/groundwater_section/sustainability/GW-SWinteraction.pdf

FARMERS TAKE A HIT IN THE SOUTH PLATTE RIVER BASIN'S BATTLE FOR WATER

Although agriculture is Colorado's third-largest industry, irrigated farms that rely on ground water stand to be among the first water-shortage victims for several reasons. For one thing, according to Colorado's August 2006 *Statewide Water Supply Initiative Water Demand Forecast,* total water demand in the Colorado basin is expected to increase 95 percent by 2030.

A 2003 Colorado law required that farmers along the South Platte come up with a permanent plan by 2006 to replace the water they'd pumped. The law was prompted by a 2002 drought, when South Platte River users, such as cities, utilities, farmers, and others who relied on surface water supplies, successfully sued the state to limit how much well owners could pump. Without an approved plan, irrigation wells were forced to shut down during periods of low flow (within the South Platte) to ensure that sufficient surface water would be available to provide irrigators holding priority, or "senior," water rights their share first. The constant interplay between the shallow aquifer that supplies the wells and the river was the basis for this relentless tug of war—and unsustainable ground water pumping gradually reduced the flow in the river.

But the replacement plan didn't solve the problem. Since the 2003 law was enacted, nearly one-third of irrigation wells have stopped pumping because farmers lacked the means to replace pumped water. Land once worth more than $2,000 an acre (with water) has plummeted in value. Farmers who hold surface water rights are also struggling and, strapped for cash, many are selling off their rights to urban interests.

The situation became critical in 2006. The April 1 forecast for snowmelt and runoff in the South Platte River Basin of northeastern Colorado gave area residents hope that conditions would be adequate to meet water demands for urban, industrial, and agricultural uses—so the farmers went ahead and planted. Not long afterward, however, it became clear that the billions of gallons of water expected to melt out of the mountain snowpack and run off into the basin had, due to hot winds and drought conditions, vaporized or melted faster than expected and soaked rapidly into the ground.

By early May, more than 200 ground water–dependent farmers came face to face with disaster.

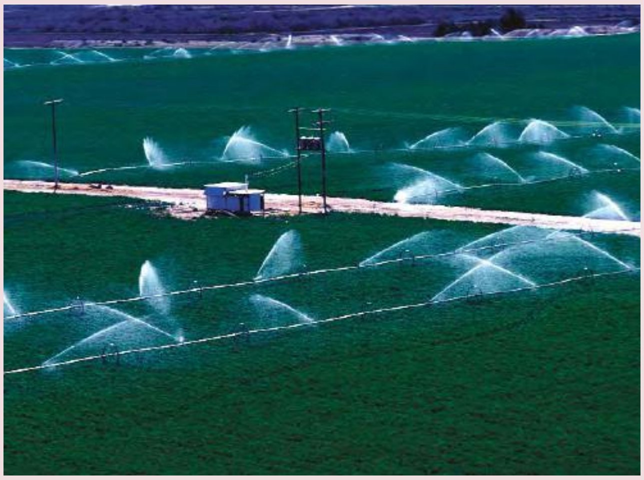


Photo: Copyright © Michael Collier

Irrigation, primarily from ground water, brings lush green crops to an otherwise arid region, but this method forfeits much of the water to evaporation.

Flow levels in streams and rivers took a nosedive, and roughly 440 irrigation wells were ordered shut down, cutting off the lifeline to thousands of acres of such high-dollar crops as sugar beets, onions, sweet corn, broccoli, melons, and sod.

Efforts were made to secure an emergency fix for the water-starved crops, but some of the interests that rely solely on the river's surface-water supplies couldn't agree with the proposal because they felt it would stress the river too much. To provide short-term relief, water was pumped up and over the continental divide.

The Central Colorado Water Conservancy District has been working on a plan to help farmers offset the amount of water used by the deep irrigation wells. The district's strategies include building new reservoirs and purchasing water rights from towns, but the logistics of accomplishing this could take years. The loss of ground water has been extremely costly. As for the farmers whose wells were shut down, the losses are in the millions of dollars—in land, planted crops, livelihoods, and overwhelming debt.

In June 2007, a task force appointed by the governor was given the job of creating a water plan for lawmakers to consider in September 2007. According to Jerd Smith, writing in the *Rocky Mountain News* (June 30, 2007), "Any solutions likely will have to serve farmers and fast-growing cities equally, and may focus on better managing the river's scare supplies, as well as improving reservoir systems on the Eastern Plains.

Overpumping and Drought—the Dangerous Duo

In recent years, drought has hit many parts of the country besides the West. And while many folks in "water-rich" states try to ignore it, some state governments are getting very worried about water supply...and the potential for conflict over access to water. For example, overpumping of ground water to meet rapid population growth has aggravated the saltwater intrusion problem in many cities along the Atlantic coast. In more than a few southeastern states, severe precipitation deficits, low streamflows, and dried out soils have devastated farm productivity and challenged water managers. As in many parts of the water-poor West, the battle for water begins when there is not enough to go around.

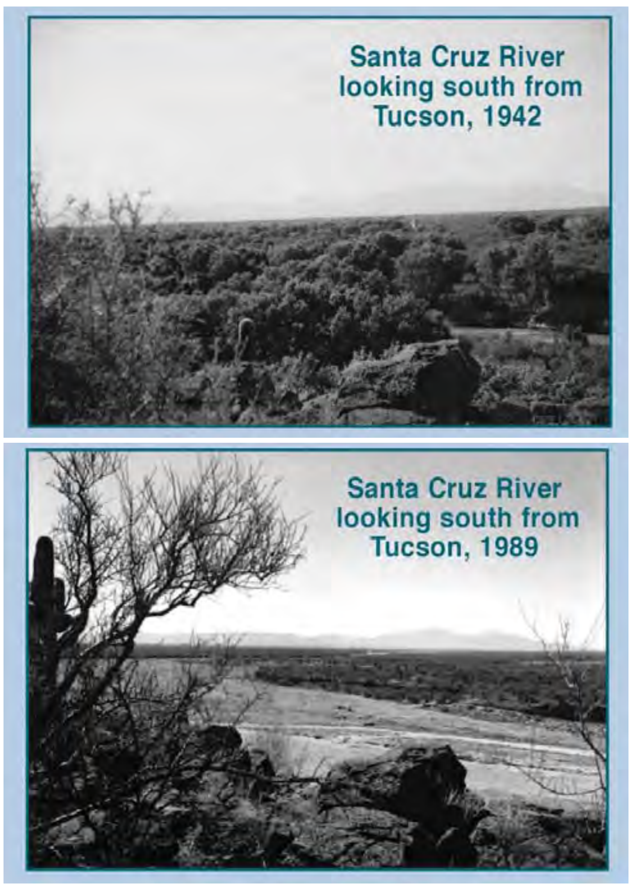


Photo: Robert Webb, USGS

Perennial streams, springs, and wetlands in the Southwestern United States are highly valued as a source of water for humans and for the plant and animal species they support. Development of ground water resources since the late 1800s has resulted in the elimination or alteration of many perennial stream reaches, wetlands, and associated riparian ecosystems. For example, this 1942 photo (top) of a reach of the Santa Cruz River south of Tucson, Arizona, shows stands of mesquite and cottonwood trees along the river. A replicate photograph of the same site in 1989 (bottom) shows that the riparian trees have largely disappeared. Data from nearby wells indicate that the water table has declined more than 100 feet due to pumping, which appears to be the principal reason for the decrease in vegetation.

Source: USGS.

In *Mirage: Florida and the Vanishing Water of the Eastern United States* (2007), author Cynthia Barnett points out that drought coupled with overallocation of water resources and the lack of water conservation practices can add up to water shortages—even in water-rich Eastern states. She says that many of these areas were already overpumping ground water resources to meet demands before drought became an issue. She notes that water managers in a majority of the states believe they will see shortages within a decade, and that is without drought. "But nowhere in the country," she says, "are water shortages more puzzling and prophetic than in notoriously wet Florida." In Florida, ground water is routinely being pumped from aquifers faster than the state's rainfall can refill them.

DETERMINING MINIMUM FLOWS/SUSTAINABLE YIELDS OF AQUIFERS

One of the ways in which a state or other jurisdiction can protect and conserve its water resources is through the establishment of a minimum flows and levels (MFLs) program. Establishing such a program is important in planning for adequate water supplies for future generations while protecting current water resources from significant harm. An MFL program recognizes the concept of a "three-dimensional watershed" where ground water, surface water, soil moisture, and atmospheric deposition are components of a system that must be protected, conserved, and managed as a whole. Therefore, to maintain and sustain the functions and processes of the overall aquatic system, minimum flows and levels must be developed for lakes, streams, rivers, wetlands, springs, and aquifers.

What Are MFLs?

MFLs are minimum water levels and/or flows deemed necessary to prevent significant harm to the water resources or ecology of an area due to water withdrawals for both consumptive and nonconsumptive uses (including the quantities of water necessary to support navigation, recreation, and fish and wildlife

Photo: Alan Cressler, USGS

A ground water pump wellhead, on Colonels Island, near Brunswick, Georgia, in 1999. Before the widespread use of pressure transducers to measure artesian water levels, a tower was necessary to measure the water level at wellhead; the tower was removed in 2000.

habitats). MFLs define how often and for how long high, average, and low water levels and/or flows should occur to prevent significant harm. Three to five MFLs are usually defined for each aquatic system—minimum infrequent high, minimum frequent high, minimum average, minimum frequent low, and minimum infrequent low.

MFLs are established and adopted by a regulatory authority to protect water resources from significant harm resulting from permitted water withdrawals. Some states, such as Florida, require the establishment of MFLs by law and/or by the state's comprehensive water management plan.

Why Are MFLs Important?

MFLs help in determining the ability of aquifers, springs, wetlands, streams, rivers, and their human and aquatic communities to adjust to changes in hydrologic conditions. MFLs allow for an acceptable level of change to occur. If the use of water resources is not adequately managed, it can result in shifts in hydrologic conditions that can, in turn, cause significant economic and ecological harm. MFLs serve as a minimum threshold for hydrologic conditions.

How Are MFLs Determined?

MFLs are determined on the basis of hydrographic information for surface waters, aquifer yield, topography, soil, and vegetation data collected within plant and animal communities, as well as other data pertinent to water resources and the best judgment of hydrogeologists and hydrographic engineers familiar with the water bodies and watersheds in question.

How are MFLs Applied?

MFLs apply to decisions affecting consumptive-use permit applications, declarations of water shortages, and assessments of water supply sources. Computer simulation models for surface and ground waters are used to evaluate the effects of existing and/or proposed consumptive uses and the likelihood that they might cause significant harm. In Florida, for example, each of the state's five water management district governing boards are required to develop recovery or prevention strategies in cases where a water body currently does not or will not meet an established MFL. Water uses that cause any MFL to be violated are not permitted.

AN EMERGING WATER STORAGE TECHNIQUE

In the face of concern about the depletion of ground water reserves, aquifer storage and recovery (ASR) has emerged in some states as a water-storage technique. ASR involves injecting water into an aquifer through wells or by surface spreading and infiltration and then pumping it out when needed. The aquifer essentially functions as a water "bank," whereby deposits are made in times of surplus, typically during the rainy season, and withdrawals occur when available water falls short of demand.

While most ASR wells being used today recharge underground sources of drinking water, there is also considerable discussion about expanding ASR for purposes of storing and recovering treated surface water, untreated ground water, or treated wastewater, which would otherwise go unused.

The ASR type of ground water augmentation is up for debate because of concerns about aquifer contamination and human health. Some states see ASR as a welcome water storage solution, while others are concerned that specific characteristics of the aquifer or the water to be injected could contaminate aquifers used for drinking water.

For example, the State of Washington Department of Ecology, recognizes the following benefits:

- Substantial amounts of water can be stored deep underground. This may reduce the need to construct large and expensive surface reservoirs.
- ASR systems are considered to be more environmentally friendly than surface reservoirs. They also offer more protection from tampering.
- ASR may restore and expand the function of an aquifer that has experienced long-term declines in water levels due to heavy pumping necessary to meet growing urban and agricultural water needs. *(http://www.ecy.wa.gov/programs/wr/asr/asr-home.html)*

In contrast, the Wisconsin Department of Natural Resources (WIDNR) has identified the following concerns, based on the results of two ASR pilot projects it conducted (as required by the state legislature):

- An aquifer system has its own natural equilibrium, and the addition of treated water disturbs that equilibrium. Monitoring results from both Wisconsin ASR pilot projects confirmed that geochemical reactions between injected lake water and bedrock aquifer material are occurring and that potential contaminants such as arsenic, manganese, and nickel may be mobilized into the ground water system.

"Innovative approaches that have been undertaken to enhance the sustainability of ground-water resources typically involve some combination of use of aquifers as storage reservoirs, conjunctive use of surface water and ground water, artificial recharge of water through wells or surface spreading, and the use of recycled or reclaimed water."

U.S. Geological Survey | Sustainability of Ground-Water Resources

FLORIDA'S WATER MANAGEMENT DISTRICTS FOCUS ON AN ARRAY OF WATER ISSUES

Why would Florida, a state that gets approximately 55 inches of rain each year, have water problems? As in many places, the problem often has to do with whether water is where it is needed when it is needed. In Florida, rain falls mostly in the northern part of the state, but 78 percent of the population lives in the southern part of the state. Florida has experienced population growth from 1.9 million in 1940 to 15 million today—more than a 600 percent increase in just 50 years.

The other serious water issue facing coastal communities in south Florida is saltwater intrusion—the byproduct of continued development and increased ground water pumping. Brackish ground water has been drawn further inland by pumping of wells, mixing with and tainting the quality and taste of freshwater aquifers it encounters.

The state has established five water management districts to address various water issues through permit programs. The three most common permits deal with how much water is used (consumptive use permits), well construction (well construction permits), and the effects of new development on water resources (environmental resource permits).

Watersheds and other natural, hydrologic, and geographic features determine district boundaries. The districts' responsibilities include, but are not limited to, flood protection, water use, well construction and environmental resource permitting, water conservation, education, land acquisition and management, water resource supply and development, and data collection and analysis.

- Hydraulic control is difficult to maintain. It is difficult to recapture the injected water and predict the speed and extent of water movement.

WIDNR concluded that these pilot tests demonstrate the need for careful environmental monitoring and development of a thorough understanding of the local hydrogeological and geochemical systems that are affected by the use of ASR techniques.

As noted by the National Ground Water Association in its assessment of aquifer storage and recovery, "The principal need with regard to the recharge of drinking water is to develop guidance for ASR legislation and regulations, possibly a model ASR code, so that issues and regulatory experiences in states with operating ASR systems are more readily available to those states that may wish to develop their own ASR regulatory framework."

WE CAN HAVE OUR WATER AND DRINK IT TOO

If we don't assess water availability in a systemwide context, we may well find ourselves in future jeopardy. Problems caused by water scarcity can be expensive, convoluted, and debilitating. In the interest of working toward a water-secure future, we will need to strike a functional balance between the amount of ground water we use, and the amount that we can pump without economic or environmental damage.

Have we learned enough about ground water hydrology and how pumping affects our water systems and our prospects for a healthy environment to stir us to heed this call to action? There are actually many positive signs that states, communities, environmental organizations, businesses, and individuals are on the case.

One sign is that the concept of water conservation is easily understood by most people, particularly people who experience water shortages firsthand (e.g., Western states) and on a routine basis. Most states have water conservation programs, as do many communities throughout the country.

Another sign is the increase in the application of Low Impact Development (LID) practices, which provide ways to maintain and enhance ground-water recharge. But to have our water and drink it too, we will need buy-in from local land-use decision makers, developers, and communities so that this knowledge translates into practical application.

"Because any use of ground water changes the subsurface and surface environment (that is, the water must come from somewhere), the public should determine the tradeoff between ground-water use and changes to the environment and set a threshold for what level of change becomes undesirable."

U.S. Geological Survey | Sustainability of Ground-Water Resources

A prairie rain garden in Maplewood, Minnesota. The town is encouraging residents to plant rain gardens so that rainwater can be routed to the garden, filtered naturally by the plants and soils of the garden, and then allowed to recharge the aquifer locally. A rain garden is a relatively small area of plantings near the drain spout of a building or a paved area that collects stormwater that might otherwise be diverted, eliminating natural recharge potential and often collecting additional pollutants as it travels through urban environments.

Source: http://www.ci.maplewood.mn.us/index.asp?Type=B_BASIC&SEC=%7BF2C03470-D6B5-4572-98F0-F79819643C2A%7D

Recommended Actions

To USEPA:

- **Support state efforts to develop guiding principles that state and local water-planning and water-use entities should take into consideration when conserving the integrity of watersheds and ensuring adequate water supplies.**
- **Require better integration between surface and ground water programs and ensure that the national water strategy addresses both quality and quantity issues, including interaction between surface and ground water.**

To USGS and State Geological Surveys:

- **Continue to conduct research and provide information—at a scale that is useful to states and local entities—about such matters as the safe, or sustainable, yield of aquifers (and methods for determining that yield); water-use data; and delineating boundaries and water budgets of three-dimensional watersheds, including scientifically based and cost-effective methods of quantifying interaction between ground water and surface water.**

To Governors and State Legislatures:

- **Authorize water supply planning at the state level and encourage water supply planning at regional and local levels to conserve the integrity of watersheds and ensure adequate water supplies.**
- **Consider adopting ground water protection and management laws that:**
  - Recognize and manage the impact of ground water withdrawals on surface water.
  - Link development to sustainable availability of water and other water supply infrastructure.
  - Allow for and encourage techniques such as transfer-of-development rights for the purpose of ground water conservation and protection.
  - Ensure coordination among agencies responsible for water quality and water use in order to determine watershed water budgets and base water withdrawal and recharge policies.
  - Regulate the interbasin transfer of water in order to protect ecosystem integrity.
  - Require water conservation practices for all new construction (e.g., agricultural, industrial, residential) by changing plumbing codes so that they require water conservation.

To State Agencies:

- **Ensure coordination among water-quality and water-use agencies/programs and associated surface water and ground water policies/programs. Benefits of this strategy can include:**
  - Integration of ground water resource characterization and monitoring into state water-monitoring strategies.
  - Development and implementation of water-reuse policies.
  - Development of tools and policies to match water sources of various quality with the most suitable use (e.g., domestic, agricultural, industrial).

To Local Governments:

- **Conduct water resources planning for long-term resource sustainability, focusing on 5- to 50-year water availability projections and plans. Incorporate this information into local comprehensive and infrastructure plans, zoning, and other local ordinances, as well as incentive programs, including:**
  - Ordinances that tie development to sustainable water availability.
  - Ordinances and best management practices (BMPs) that provide for sustainable ground water recharge and improved stormwater management practices.
  - Transfer-of-development rights and development of property tax incentive programs to encourage land owners and developers to maintain recharge areas as open spaces, helping to achieve ground water protection and conservation goals.
  - Ordinances and plumbing codes designed to conserve water through improved efficiency, water reuse, water rationing, and gray water-use requirements.

Section 2 References: Ground Water Use and Availability

Alley, W. M., T. E. Reilly, O. L. Franke. 1999. *Sustainability of Ground-Water Resources,* USGS Circular 1186, U.S. Geological Survey.

Barlow, M., T. Clarke. 2002. *Blue Gold: The Fight to Stop the Corporate Theft of the World's Water.* New York: The New Press.

Barnett, Cynthia. 2007. M*irage: Florida and the Vanishing Water of the Eastern United States.* Ann Arbor: University of Michigan Press.

Glennon, Robert. 2002. *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters.* Washington, DC: Island Press.

Hutson, S., N. Barber, J. Kenny, K. Linsey, D. Lumia, and M. Maupin. 2004. E*stimated Use of Water in the United States in 2000.* USGS Circular 1268 (released March 2004, revised April 2004, May 2004, February 2005). Available at: *http://pubs.er.usgs.gov/usgspubs/cir/cir1268*) (accessed February 19, 2007).

Jones, L. E, D. C. Prowell, M. L. Maslia. *Hydrogeology and Water Quality (1978) of the Floridan Aquifer System at U.S. Geological Survey Test Well 26, on Colonels Island, Near Brunswick, Georgia.* USGS Water-Resources Investigations Report 02-4020, 44 pages. Available at: h*ttp://ga.water.usgs.gov/publications/abstracts/wrir02-4020.html*

McGuire, V. L. 2004. *Water-Level Changes in the High Plains Aquifer, Predevelopment to 2003*. USGS Fact Sheet 2004–3097. Available at: *http://pubs.usgs.gov/fs/2004/3097/*

NGWA Issue Assessment: Aquifer Storage and Recovery. *http://www.ngwa.org/public/releases/iaaquifer.aspx* (accessed July 2007).

Sandia Labs. Available at: *www.sandia.gov/energy-water/nexus_overview.htm* (accessed July 2007).

The Nature Conservancy. Fact sheet: *Pacific Northwest: Groundwater and Biodiversity. http://www.nature.org/wherewe work/northamerica/states/oregon/files/groundwater_fact_sheet.pdf* (accessed July 2007).

U.S. Census Bureau. 2007. *www.census.gov/main/www/popclock.html*

U.S. Census Bureau. 2004. "U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin." *http://www.census.gov/ipc/www/usinterimproj/*.

USGS. 2002. *Report to Congress: Concepts for National Assessment of Water Availability and Use.* Circular 1223. Available at: *http://pubs.usgs.gov/circ/circ1223/pdf/C1223.pdf*

USGS. 1998. *Ground Water and Surface Water: A Single Resource.* U.S. Geological Survey Circular 1139.

Photo: Alex Marentes

A water well in the middle of the desert south of Socorro, New Mexico.

Section 3

Ground Water
Resource Characterization and Monitoring

Key Message

As a nation, efforts to monitor and characterize ground water resources with regard to quantity and quality have been sporadic and, while successful in some local jurisdictions and watersheds, largely inadequate. We need to collect more reliable, consistent, and comprehensive data that will sufficiently characterize ground water quality and quantity in order to support critical water resource use, protection, and management decisions. This should be done through a coordinated (federal, state, and local) national data collection and monitoring program that gives decision makers the ability to identify such critical information as:

- Baseline ambient ground water quality.
- Where and how ground water quality is being degraded.
- Location of ground water recharge areas.
- Patterns of ground water withdrawal and recharge within identified watersheds (to sustainably allocate resources and maintain healthy ecosystems).
- Ground water contribution to stream baseflows and areas of ground water/surface water interaction.
- Relationship and significance of ground water quantity and quality to the maintenance of healthy rivers, lakes, streams, wildlife habitats, and fisheries within given hydrogeologic settings.

Left: Snake Plain Aquifer discharging ground water to the Snake River in the Thousand Springs area near Twin Falls, Idaho. Right: Eutrophication in the Snake River in the Thousand Springs area.

Photo: Tom Litke, Idaho DEQ

Do We Have Enough Water?

"The primary challenge related to hydrologic forecasting is in forecasting coming variations in water availability (and water quality), not just amounts of water expected based on 'average conditions.' To make advances in forecasting, more comprehensive assessments of the amounts of water stored in the atmosphere, surface, and subsurface, as well as the exchange between these, are needed."

Science and Technology to Support Fresh Water Availability in the United States | Report of the National Science and Technology Council Committee on Environment and Natural Resources | November 2004

why ground water Resource Characterization and Monitoring matter…

While we have made strides in understanding how ground water/surface water systems work, our ability to characterize how our human activities affect the many natural processes and interactions inherent to specific systems has been constrained. This is primarily due to the lack of long-term sustained support and funding for ground water quality and quantity data collection, analysis, research and development trends, and information dissemination.

At a time when water scarcity is a concern in so many areas of the country, when water allocation and withdrawal practices are creating conflict and upsetting natural systems, and when contamination threats to ground water from human activities are pervasive, we cannot afford to come up short in our ability to ensure an adequate water supply for our nation's future. Without the benefit of reliable and comprehensive data on the quantity and availability of ground water resources, it is difficult to support pivotal and increasingly contentious decisions regarding the allocation of ground water resources among states, regions, communities, and a variety of competing uses.

According to a July 2003 report by the United States General Accounting Office (GAO)—"National water availability and use has not been comprehensively assessed in 25 years, but current trends indicate that demands on the nation's supplies are growing." The National Ground Water Association (NGWA) has stated: "We lack fundamental data necessary to understand adequately the nation's ground water resources and make informed decisions regarding its use and management." (NGWA, 2004) And according to a June 2004 GAO report, ground water level data are not being collected by any federal agencies on a national scale; although the U.S. Geological Survey (USGS) and National Park Service are collecting data on a regional basis.

GROUND WATER LEVELS 1991 – 2001
MONROE COUNTY, MICHIGAN

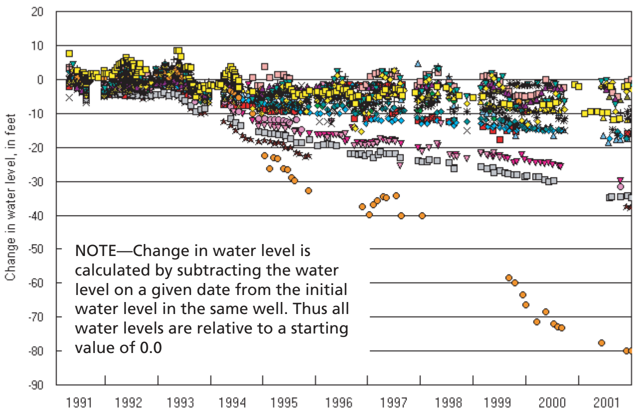


Figure 1: *This chart shows the change in ground water level in USGS observation wells in Monroe County, Michigan, from 1991 to 2001 (Nicholas and others, 2001). During this time period, ground water levels declined 10 feet or more in 17 of the 33 USGS observation wells in the County.*

Source http://mi.water.usgs.gov/splan6/sp11000/monroe.php

The need to expand research and monitoring efforts and develop a comprehensive, consistent, and reliable database from which to better understand and characterize existing conditions, identify existing and potential problems, establish priorities, and develop viable water policies and strategies is at the very least compelling. Current programs of acquiring and managing water-monitoring data are inadequate to meet our water quantity and quality challenges.

The potential for severe economic consequences has not been exaggerated. Policy makers at all levels of government will be faced with crucial decisions regarding growth and development alternatives and tradeoffs. These decisions must be based on high-quality data. Because our water resources are integrated, decisions in one area can have negative repercussions in other areas. With adequate and reliable monitoring programs and data, such negative consequences can be managed and minimized.

In this report, the Ground Water Protection Council is adding its voice to a growing chorus of distinguished entities (e.g., NGWA, GAO, the National Science and Technology Council's Committee on Environment and Natural Resources) that have carefully assessed our ability to secure sustainable freshwater resources and have decried the overall lack of fundamental ground water data and a system for managing such data.

Photo: Copyright © Larry Fellows, Arizona Geological Survey

This karst spring in Val Verde County, Texas, issues from the Edwards Aquifer at the edge of the Edwards Plateau.

CHARACTERIZING AND MONITORING THE GROUND WATER SYSTEM

As stated by the NGWA (2004), "Obtaining accurate data on water use and the sustainable yield of aquifers, knowing past and current land-use and pumping rates as well as identifying human and ecosystem water needs are integral to managing and protecting the nation's ground water resources." In this regard, we have a lot of catching up to do in understanding the status and relationships of our ground water and ground water/surface water systems. For example, one of the most fundamental realities concerning surface water and ground water is that they are, in many cases, hydraulically connected—what happens to one affects the other. Yet this crucial fact has been all too often ignored in water management considerations and policies.

Since ground water is out of sight and less accessible than surface water, it is more difficult and expensive to monitor with respect to quality, quantity, and movement in specific aquifers. It is relatively simple to take a water sample from a stream in order to monitor surface water, but it takes drilling and well sampling to monitor ground water. In layered aquifers, sampling is even more expensive and complicated because it is necessary to determine which layer(s) should be monitored, which may entail coring the formation ahead of time. (Winter et al. 1998)

Ground water management should be aquifer-based and an integral part of watershed management. Aquifers are the natural units of management for ground water within the watershed context. For example, we can only get a complete picture of the impacts, or potential impacts, of contamination sources by monitoring the whole watershed, including ground water. When determining the Total Maximum Daily Load (TMDL) for a stream segment, it is critical to monitor the ground water contributing to the stream. It is incorrect to think that ground water/surface water resource protection and development decisions can be made in the absence of a comprehensive resource assessment.

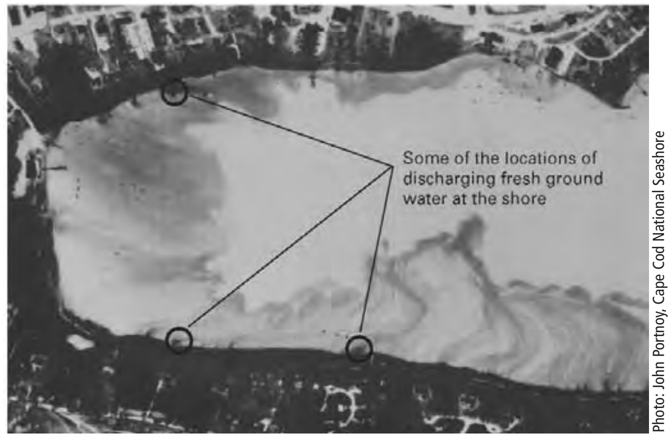


Figure 2. *Aerial thermal infrared scan of Town Cove, Nauset Marsh on Cape Cod, Massachusetts. Discharging fresh ground water is visible as dark (relatively cold) streams flowing outward from shore over light-colored (warm) but higher density estuarine water. Data were collected at low tide at 9:00 p.m. eastern daylight time on August 7, 1994.*

Source: USGS Circular 1262

OUR INCOMPLETE RESOURCE ASSESSMENT

Currently, our understanding of ground water availability and quality is like a jigsaw puzzle with a substantial assortment of missing pieces—the insufficient data. This shortage of critical ground water information was recognized by the Subcommittee on Water Availability and Quality, part of the National Science and Technology Council's (NSTC's) Committee on the Environment and Natural Resources, in its November 2004 report *Science and Technology to Support Fresh Water Availability in the United States.*

The NSTC is a cabinet-level council, and it is the principal means for the President to coordinate science and technology policies across the federal government. An important objective of the NSTC is the establishment of clear national goals for federal science and technology investments. The 2004 report focuses on science issues and policy related to needed improvements in technology and research that will advance the goal of ensuring a safe and sustainable supply of water in the United States for human and ecological needs.

The report does a good job of defining the problem, providing recommendations for action, and identifying the types of information that needs to be collected from monitoring efforts in order to answer important questions. It also does a good job of acknowledging the importance of ground water and specifically states the need for "renewed synthesis and collection of ground water resources data on the regional and national scale through process-based regional assessments of the nation's ground water resources." This is perhaps the strongest statement of need and urgency for monitoring that has come from the federal level in quite some time.

USEPA and State Monitoring Programs

Section 106(e)(1) of the Clean Water Act (CWA) requires USEPA to determine that a state is monitoring the quality of navigable waters, compiling and analyzing data on water quality, and including this information in the state's Section 305(b) report prior to the award of Section 106 grant funds. However, states are not required to report on ground water quality and conditions.

In March 2003, USEPA took the step of publishing the guidance *Elements of a State Water Monitoring and Assessment Program,* which states were expected to follow in developing strategies and plans to monitor their water resources. The guidance "...recommends the basic elements of a state water-monitoring program and serves as a tool to help EPA and the state determine whether a monitoring program meets the prerequisites of CWA Section 106(e)(1)" (from cover memo).

The first of ten required "elements" of the guidance says that state monitoring strategies are to address all state waters, including ground water. According to the results of a GWPC-NGWA 2006 Survey of State Ground water Programs, 30 states have included some ground water monitoring component in their monitoring program strategies, but the amount of USEPA support or emphasis placed on the ground water components of the strategies varies among regions.

There are several reasons why ground water monitoring is often either left out or minimized in many state strategies:

- Those at USEPA responsible for coordinating with states to develop strategies are largely in the agency's surface water monitoring programs (i.e., National Pollutant Discharge Elimination System [NPDES] and Total Maximum Daily Loads [TMDLs], so coordination with states focuses primarily on state surface water programs, and not state ground water programs. Clearly, the lack of a viable ground water program within USEPA creates a void for communicating the ground water portion of the strategy guidance to state ground water monitoring programs.
- Federal funding to support state surface water and ground water programs comes from the same "pool" of grant monies—CWA Section 106. Without clear instruction from USEPA that the state monitoring strategy must address ground water as well as surface water, it is not in the best interest of state surface water (monitoring) programs to include a ground water monitoring component that would effectively divert resources away from and diminish their own efforts. And, only the monitoring described in these strategies is eligible for CWA Section 106 funding.

If a state monitoring strategy does not include a ground water monitoring goal, there is little basis for USEPA to press states to meet that goal or to assist them in meeting that goal by providing supplemental funding. Without such funding, many states do not have the resources to develop and implement a statewide, ambient ground water monitoring program. Given that the monitoring described in the strategy is to be completed within 10 years, many states have yet to begin any systematic ground water monitoring whatsoever. That being said, some states do have long-standing, strong ground water monitoring strategies and programs. Others have recently made progress.

USES OF RECHARGE POTENTIAL MAPS

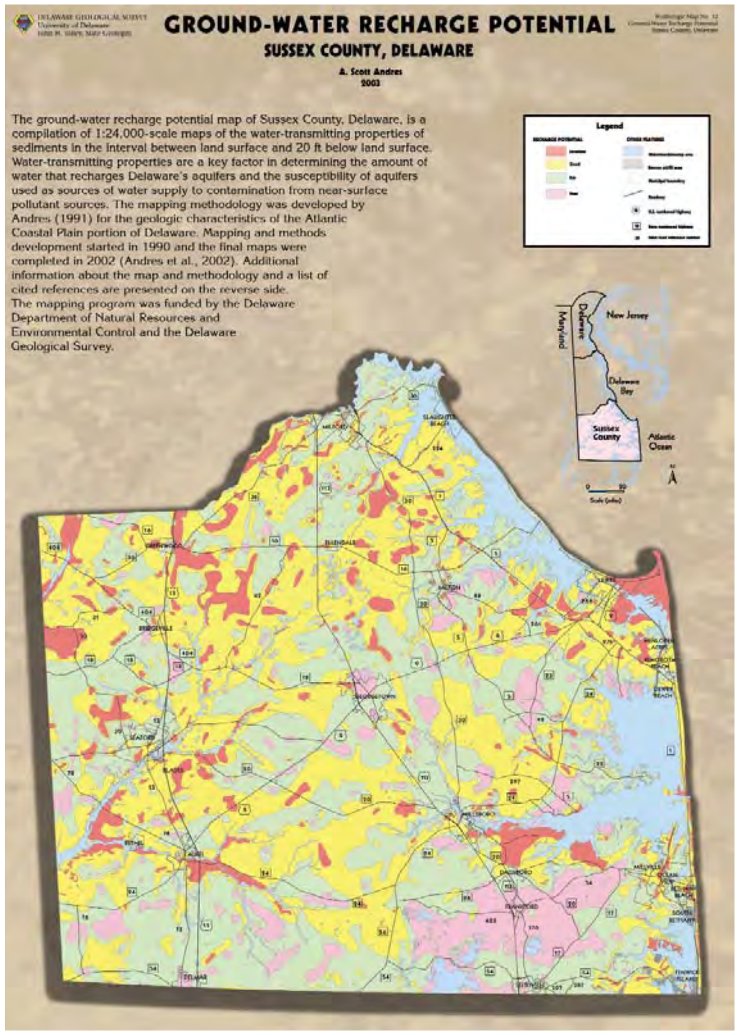


Figure 3. *The ground water recharge potential map of Sussex County, Delaware, is a compilation of 1:24,000-scale maps of the water-transmitting properties of sediments in the interval between land surface and 20 feet below land surface. Water-transmitting properties are a key factor in determining the amount of water that recharges Delaware's aquifers and the susceptibility of aquifers used as sources of water supply to contamination from near-surface pollutant sources. The red in this map indicates excellent recharge potential, yellow =good, green = fair, and pink = poor.*

Source: http://www.udel.edu/dgs/Publications/pubsonline/hydromap12.pdf

TMDL STUDY IDENTIFIES GROUND WATER'S CONTRIBUTION TO PHOSPHORUS LOADING IN WASHINGTON STATE'S MOSES LAKE

Moses Lake has historically exhibited eutrophic or hypereutrophic conditions, and is listed as a federal Clean Water Act 303(d) "impaired waterbody." Phosphorus has been identified as the limiting nutrient for the lake. Based on characteristic uses of the lake, an in-lake total phosphorus concentration target of 0.050 mg/L has been proposed to manage water quality concerns. In order to develop an allocation strategy for phosphorus loading to the lake, a TMDL study was conducted by the Washington State Department of Ecology.

To better characterize the concentration and potential source of nutrients in ground water directly discharging to the lake, 12 lake-bed monitoring stations were installed. The majority of stations (75%) exhibited ground water organophosphorus (OP) concentrations above the 0.050 mg/L surface water target criteria. Concentrations of OP in ground water generally increased from north to south, paralleling increases in concentrations of parameters that indicate anthropogenic (human-caused) impact to water quality.

A statistically significant relationship was established between OP concentration and the relative percentage of urban development upgradient of each station. These findings suggest that urban releases of wastewater to the aquifer are the primary source of phosphorus entering the lake via ground water discharge. Loading calculations predict an annual OP mass flux to the lake from approximately 400 to 40,000 kgop per year via ground water discharge, with a value from 10,000 to 20,000 kgop per year considered the best estimate of field conditions.

Source: http://www.ecy.wa.gov/pubs/0303005.pd

PERSPECTIVE MODEL OF THE BASE OF THE SANTA FE GROUP AQUIFER SYSTEM

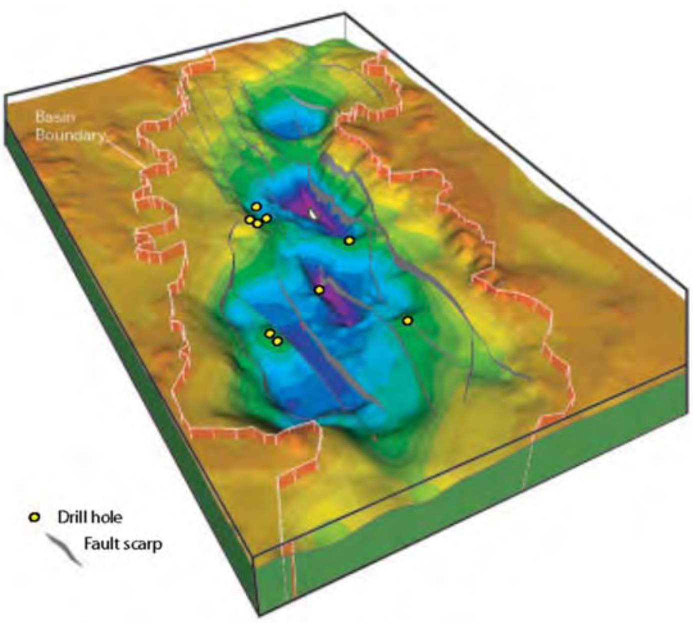


Figure 4. *Perspective view of the southern part of a model of the Middle Rio Grande Basin showing the base of the Santa Fe Group aquifer system. The model was derived from gravity data and constrained by information for the deep drill holes shown as yellow circles. (Courtesy of V.J.S. Grauch, USGS.)*

Source: http://pubs.usgs.gov/circ/2002/circ1222/pdf/chap3.pdf

For example, in Vermont, lawmakers recently (2006) gave a crucial jumpstart to a long-ignored law when they appropriated more than $300,000 to get a mapping program started. Although the Agency of Natural Resources has had the statutory authority to map the state's ground water since 1985, this is the first time money has been earmarked specifically for the purpose of mapping, which is an essential first step. As demand for ground water continues to grow (two-thirds of the state's population relies on ground water for its drinking water), the state's lawmakers are recognizing the importance of ground water and taking needed action toward passing comprehensive ground water protection legislation. As a start, the House passed a requirement that most large users of ground water report how much water they are using.

Recently, USEPA, along with the USGS and the Ground Water Protection Council (GWPC), has taken a very positive step to encourage ground water monitoring on a national scale. In January 2007, a national Subcommittee on Ground Water was formed by the Advisory Committee on Water Information (ACWI). Members include representation from USGS, American Society of Civil Engineers, NGWA, GWPC, Water Environment Federation, USEPA, Association of State Geologists, Interstate Conference on Water Policy, and the National Water Quality Monitoring Council.

The goal of the new subcommittee is to develop a national framework and network design for ground water monitoring, with particular emphasis on changes in the availability of potable water. Integrated monitoring design and consistent data reporting will improve information needed to make timely and economically efficient and effective ground water management decisions.

In 2006, the NGWA and the GWPC developed a detailed set of questions regarding ground water quality and quantity protection programs from a comprehensive list of ground water agencies. The results of this survey will help assess existing ground water quality and quantity data availability issues.

In late 2006 the American Water Works Association Research Foundation announced that it will survey utilities and user groups in an attempt to assess their interest in having accessible ground water quality and quantity data. The results of this study could be a catalyst for increased national interest and funding for a centralized ground water data center.

And What About TMDLs?

Short-changing attention to ground water monitoring has an impact on Total Maximum Daily Load (TMDL) development. Section 303(d) of the Clean Water Act requires states to identify waters that are impaired by pollution and to establish a TMDL of selected pollutants to ensure that water quality standards can be attained. TMDLs are intended to quantify all pollution sources, including point discharges from municipalities and industry and nonpoint sources.

A TMDL is a calculation of the maximum amount of a pollutant that a body of water can receive and still meet its designated use as determined by water quality standards. On that basis, a specified amount of pollutant becomes acceptable for discharge into the water body. In other words, a TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. If pollutant loads coming from ground water into surface water are not included in this calculation, then those pollutants are not being factored into the protection of a given water body.

Photo: Dan Hippe

Gary Holloway welds glass ampules for age dating ground water from a spring discharge from the Upper Floridan aquifer to a spring pond located in the Dougherty Plain of southwest Georgia.

Ground water can be a major contributor to streams and rivers, and contaminated aquifers that discharge to streams can thereby serve as nonpoint sources of contaminants to surface water. Quantifying the contribution is, therefore, a critical step in developing water quality standards and criteria, issuing permits, and meeting Clean Water Act goals for swimmable, fishable, and drinkable waters. Yet ground water inputs are typically not included in estimates of contaminant loads in streams. The TMDL process should include ground water so that all pollution sources will be considered and the process will be effective in protecting and restoring streams.

Likewise, surface water can be a major contributor to ground water, serving as a major nonpoint source of contamination to aquifers, particularly where high-capacity public water supply wells are located near streams and rivers. While ground water is generally thought to be safe for consumption without water treatment, ground water from wells located near streams can share the same contaminants as the surface water recharging the well. Water managers should consider such connections when developing source water and wellhead-protection strategies. (NAWQA, 2007)

WHAT DO WE NEED TO KNOW ABOUT GROUND WATER?

Hydrogeologic mapping and ground water monitoring networks (including ambient, impacted-area, and targeted monitoring) are needed to ensure the availability of quality data at the appropriate scale to make sound ground water planning, management, and development decisions. Information is necessary to determine:

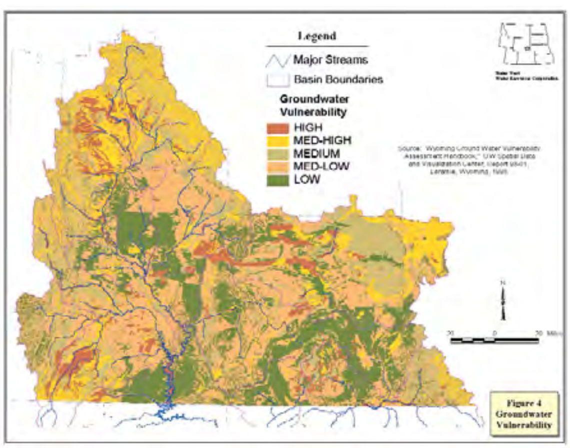
- Where ground water resources are located (both current and future sources of drinking water as well as ground water that may be more suitable for other uses).
- Where ground water/surface water interaction is occurring.
- How much ground water is sustainably available for human uses (i.e., the ability of the ground water resource to support current and additional population growth and development).
- How much ground water is needed to sustain healthy ecosystems.
- Location of ground water recharge areas.
- Background quality of ground water (i.e., ambient ground water monitoring).
- Appropriate uses of ground water of varying quality.
- Design and effectiveness of ground water management and protection programs.
- Short- and long-term changes in ground water recharge, storage, flow direction, and quality, as impacted by land use, land-use changes, climatic variability, and water use.
- Potential opportunities to artificially recharge the ground water supply in order to renew the resource and provide cost-effective water storage water for future use.

What Constitutes Sufficient Characterization and Monitoring?

Sufficient characterization and monitoring refers to the development of a comprehensive, consistent, and defensible database from which to better understand and characterize existing conditions, identify existing and potential problems, establish priorities, and develop viable water policies and strategies. It includes identifying the appropriate period of monitoring, the number of wells or stations per watershed, and the group of parameters monitored in order to represent adequate indicators of pollution.

An October 1993 USEPA document, *Ground Water Resource Assessment,* written during a time when ground water received a good deal more attention within the agency than it does today, contains valuable information that is as valid today as it was when the document was published. The document lists ten components that are necessary to characterize the physical and chemical properties of the ground water resource:

GROUND WATER VULNERABILITY AND CONTAMINANT SENSITIVITY MAPS



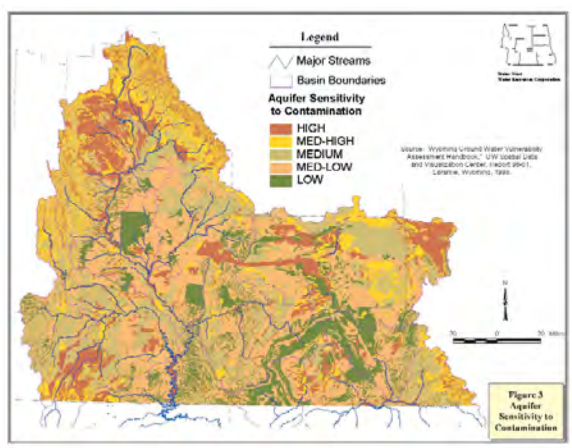


Figure 5. *The Wyoming Department of Environmental Quality, in conjunction with the Wyoming Department of Agriculture and USEPA, contracted with the University of Wyoming to develop statewide vulnerability maps to assess the tendency or likelihood for contaminants to reach a specified position in the ground water system after being introduced at a location above the uppermost aquifer. Ground water vulnerability maps were developed to determine the potential impact of anthropogenic influences on the ground water quality. The left map shows ground water vulnerability; the right map shows sensitivity to contamination.*

Source: http://waterplan.state.wy.us/plan/green/techmemos/swquality.html

MONITORING, MAPPING, AND RECHARGE AREAS: NEW JERSEY'S EXEMPLARY GROUND WATER CHARACTERIZATION PROGRAM

The State of New Jersey has put in place three essential ground water characterization and monitoring elements that serve as excellent examples of what can and should be taking place at state and national levels: an ambient ground water quality monitoring network, a subsurface mapping program, and ground water recharge mapping and ranking.

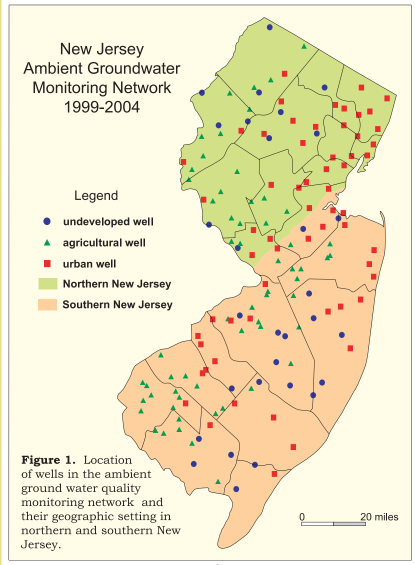


Figure 6. *Location of wells in the Ambient ground water quality monitoring network and their geographic setting in northern and southern New Jersey.*

The Ambient Ground Water Quality Monitoring Network

The Ambient Ground Water Quality Monitoring Network (AGWQMN) is a NJDEP/USGS cooperative project. The original (pre-1999) network mainly focused on determining ground water quality as a function of geology throughout the state using public, private, irrigation, observation, and other types of existing wells. The goals of a recently completed redesigned network are to determine the status and trends of shallow ground water quality as a function of land-use-related nonpoint-source pollution in New Jersey. Most of the shallow wells used were installed by the New Jersey Geological Survey (NJGS) or its contractors to meet the goals of the redesigned network.

This network consists of 150 wells screened at the water table that are sampled 30 per year, on a five-year cycle. The first cycle was completed and the second started in 2004. The NJGS manages the network design, well installation, well maintenance, and data interpretation and reporting. The NJDEP Bureau of Fresh Water and Biological Monitoring and USGS collect the well water samples, and the USGS laboratory in Denver, Colorado, analyzes them. Chemical and physical parameters analyzed at each well include: field parameters such as pH, specific conductance, dissolved oxygen, water temperature and alkalinity, major ions, trace elements (metals), gross-alpha particle activity (radionuclides), volatile organic compounds, nutrients, and pesticides.

Source: http://www.state.nj.us/dep/njgs/geodata/dgs05-2.htm

Subsurface Mapping

The NJGS geophysicists assist the NJGS mapping section by providing remotely sensed subsurface information. This greatly increases the value of geologic maps by providing three-dimensional information (cross-sections). This is especially important where buried valley aquifers only occupy a narrow part of a river valley, but supply ground water to an entire region. NJGS also provides support to USGS to help establish the subsurface geologic framework.

Ground Water Recharge (GWR)

GWR refers to the water that infiltrates the ground and reaches the water table regardless of the underlying geology. It supports aquifer recharge, stream baseflow, and wetlands. New Jersey estimates recharge by using the methodology outlined in NJGS Report GSR-32, *A Method of Evaluating Ground-Water-Recharge Areas in New Jersey,* by E. G. Charles and others (1993). Application of this method using the Arc/Info geographic information system (GIS) produced 19 county and 20 watershed management area ground water recharge GIS coverages. The county recharge coverages were created by overlaying three coverages: (1) soils, (2) land use and land cover, and (3) municipalities. These three coverages provided the following attributes: soil series names, land-use and land-cover (LULC) categories, and climate factors, respectively. These data were then used to calculate ground water recharge values. The recharge factor and constant are determined by the cross tabulation of LULC and soil series. The climate factor is determined using zonal statistics and is a ratio of precipitation over potential evapotranspiration.

http://www.state.nj.us/dep/njgs/geodata/dgs02-3/mercer.htm - associated graphic

- **Regional hydrologic setting:** Factors that control the regional occurrence, movement, and availability of ground water.
- **Aquifer and aquifer-system occurrence:** Real distribution and three-dimensional position of aquifers in the geologic setting.
- **Water table levels:** The upper surface of the saturated portion of an aquifer.
- **Hydraulic properties:** Soil, rock, sediment, and other geologic materials that govern the movement of water into, through, and out of an aquifer.
- **Confinement and interaction among aquifers:** Ease with which leakage among aquifers occurs—greater confinement, less interaction.
- **Ground water recharge and discharge characterization:** Where and at what rate ground water is recharged by precipitation and discharged to a water body or land surface.
- **Ground water and surface water interaction:** Where and at what rate water moves between ground water and surface water, including stream baseflow. Baseflow is a critical parameter that is typically not adequately established. It is important in relation to quantifying ground water contribution to surface waters, especially in relation to modeling TMDL.
- **Ground water budget:** An accounting of all natural and anthropomorphic removals from and additions to the ground water system.
- **Chemical and physical characteristics of ground water and overlying and underlying materials:** Characteristics that impact water quality and affect the fate and transport of contaminants.
- **Ambient ground water quality:** The quality of ground water at a baseline time selected by the decision-making agency (ambient quality refers to the natural quality of ground water or may be the quality as affected by widespread historical contamination).

The last point is especially prescient. Ambient monitoring has been and still is being ignored by most states and federal agencies, which focus instead on regulatory compliance and enforcement of standards that have been developed largely on the basis of impacts of contaminants on humans. This information has little value for evaluating the benefits of environmental regulation to the health of ecosystems. For the latter we must design ambient monitoring networks that combine chemical, microbiological, hydrogeological, and biological parameters. These networks must be designed to be free from the direct influence of point-source pollution in order to reflect how the entire system is reacting to all the regulatory measures and BMPs on which millions of dollars are being spent.

THE NAWQA MODEL FOR GROUND WATER MONITORING

The USGS implemented the National Water Quality Assessment (NAWQA) Program in 1991 to develop long-term consistent and comparable information on streams, rivers, ground water, and aquatic systems in support of national, regional, state, and local information needs and decisions related to water quality management and policy. The program is directed at answering the following questions:

- What is the condition of our nation's streams, rivers, and ground water?
- How are these conditions changing over time?

USGS Chief Hydrologist, Bob Hirsch, experiences karst terrain firsthand while kayaking on Cedar Creek, located about 20 miles south of Winchester, Virginia. Cedar Creek is a tributary of the North Fork of the Shenandoah River. In 2005 there were two streamgages on Cedar Creek,

WHAT IS A PRINCIPAL AQUIFER?

A principal aquifer is defined as a regionally extensive aquifer or aquifer system that has the potential to be used as a source of potable water. An aquifer is a geologic formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. Aquifers are often combined into aquifer systems.

Source:http://water.usgs.gov/nawqa/studies/praq/images/USAaquiferMAP11_17.pdf

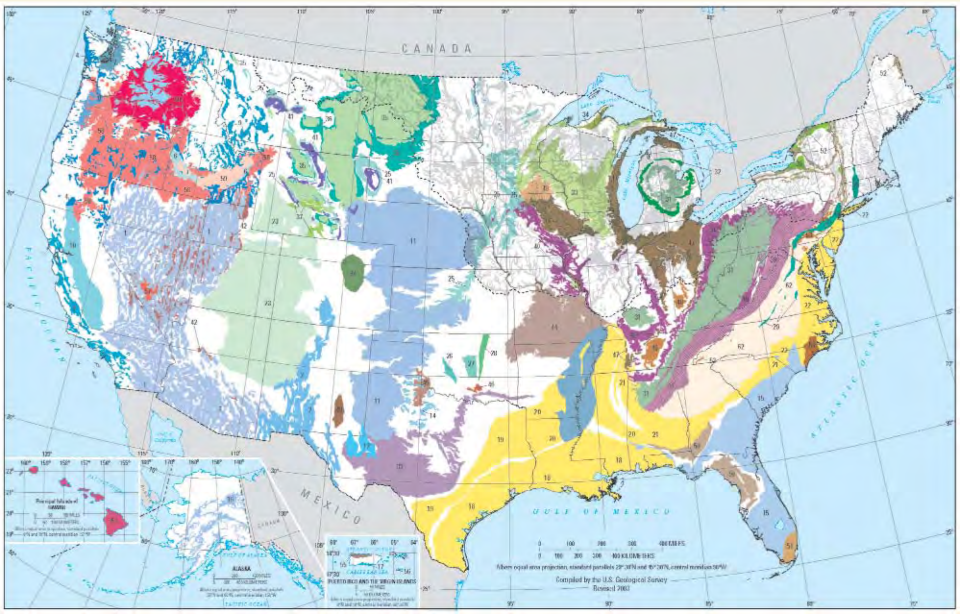


Figure 7.

- How do natural features and human activities affect these conditions, and where are those effects most pronounced?

Through NAWQA, USGS scientists collect and interpret data about surface and ground water chemistry, hydrology, land use, stream habitat, and aquatic life in parts or all of nearly all 50 states using a nationally consistent study design and uniform methods of sampling analysis. Their work is a major and positive step in the direction of what should be happening nationwide at a far more expansive level of aquifer coverage.

From 1991–2001, NAWQA conducted interdisciplinary assessments and established a baseline understanding of water quality conditions in 51 of the nation's river basins and aquifers, referred to as "study units." Descriptions of water quality conditions in streams and ground water were developed in more than a thousand reports. Nontechnical "summary reports," written primarily for those interested or involved in resource management, conservation, regulation, and policy making, were completed for each of the 51 study units. Nontechnical national summary reports on pesticides, nutrients, and volatile organic compounds (VOCs) were also completed, comparing water quality conditions to national standards and guidelines related to drinking water, protection of aquatic life, and nutrient enrichment. (*http://water.usgs.gov/nawqa/)*

A major focus of the NAWQA Program in its second decade (2002–2013) is on regional- and national-scale assessments of ground water status and trends in principal aquifers. The USGS Office of Ground Water has identified 62 principal aquifers in the United States, about one-third of which are the focus of water quality assessments at the principal aquifer scale by NAWQA. (See Figure 7.) The principal aquifer assessments consider the physical setting of the aquifer, in addition to its susceptibility and vulnerability to contamination.

A brand new USGS publication *The National Water-Quality Assessment Program—Informing Water-Resource Management and Protection Decisions* (2007) documents its many projects and provides numerous examples of how the data their efforts has generated has been used by states to initiate and support critical ground water protection programs and activities.

MOVING TO A WATERSHED PARADIGM

Characterizing and monitoring ground water must be carried out within the natural boundaries of the three-dimensional watershed (i.e., including both surface water and ground water). The notion of watershed monitoring has been much discussed; however, little attention has been given to scoping out details of what is needed. It is difficult for some groups to agree on how to define a watershed; and when they do agree, they may still not know how to delineate the actual boundaries. To this end, USGS has developed a series of hydrologic unit codes (HUCs) to aid in ground water assessments.

Much more research is needed, however, in order to better understand how we can move to a true watershed paradigm that includes both surface water and ground water dimensions. The following are examples of the type of work that is needed:

- Develop a scientifically acceptable definition of a watershed.
- Develop methods of delineating watershed boundaries.
- Develop remote-sensing techniques to locate areas of ground water/surface water interaction within identified boundaries.
- Develop methods for quantifying ground water contribution as baseflow to surface waters.
- Develop methods for calculating a water budget for a given watershed.
- Develop geophysical methods for locating and describing the morphology of conduits and channels through which interaction between surface and ground water is likely.
- Apply water-aging and tracing (e.g., dye, isotope, bacteriophage) techniques to help in quantifying ground water or surface water sources within a watershed.
- Conduct basic research to develop numerical models to use in multiporosity aquifers that are interacting with surface waters.

GETTING ORGANIZED

A plan for organizing available ground water resource information, determining data gaps, and assigning responsibilities for moving forward with a coordinated program sounds logical, but it is not happening. As the GAO points out in its June 2004 report *Watershed Management: Better Coordination of Data Collection Efforts Needed to Support Key Decisions*: “The coordination of water quality data is falling short of its potential.” The problem is even more acute with regard to the status of ground water data collection and coordination.

The GAO report identifies the following four key factors that impede effective water quality—and we would add to these water quantity, data collection, and coordination:

- Significantly different purposes for which groups collect data.
- Inconsistencies in data-collection protocols.
- Lack of awareness on the part of data collectors as to which entities collect what types of data.
- Low priority given to data coordination.

It is incumbent upon us to complement and reinforce the NGWA position (2004) pertaining to action the federal government should take to organize long-term ground water quality and quantity monitoring efforts, including:

- Synthesizing, in coordination with state and local governments, existing data and identifying data gaps.
- Developing guidelines that set out a consistent methodology for data collection to enable data sharing.
- Developing guidance for establishing ground water monitoring networks in differing hydrogeological settings.
- Establishing milestones to measure progress in reaching data-collection goals and committing to provide adequate funding to reach those milestones.
- Promoting the use of more robust data sets to better inform and reduce the uncertainty of incorporating federal requirements into state and local ground water decision making, such as decisions regarding the application of the Endangered Species Act.
- Developing statistical analysis guidelines for identifying long-term trends for each basin, aquifer, or watershed (choosing which depends on how extensive and well planned the monitoring network is).
- Establishing a national clearinghouse to store or link collected data.

Recommended Actions

In addition to the recommended actions listed here, the Ground Water Protection Council supports the recommendations (and was part of the working group that developed the recommendations) contained in the National Ground Water Association's (NGWA) "Ground Water Level and Quality Monitoring Position Paper" (April 2006).

To Congress:

- **Support the efforts by, and provide the necessary funding to, federal and state geologic surveys and water resource agencies to further hydrogeologic mapping and ground water monitoring networks (e.g., ambient, impacted-area, targeted) needed to understand, manage, and protect the nation's ground water resources.**

To USEPA:

- **Ensure that ground water is clearly identified as an integral part of EPA's strategic plan, national monitoring strategy, and other federal agency resource management plans. Specific changes should include:**
  - Giving states flexibility in their use of the Clean Water Act §106 and §319 funding for ground water protection.
  - Guidance to states to include ground water as part of state monitoring strategies and monitoring reports, such as Clean Water Act §305(b) reports.

To USGS:

- **Ensure the availability of quality data at scales amenable to watershed-based decision making associated with water planning and allocation, management, and development, especially in watersheds that may cross state boundaries and jurisdictions.**
- **Continue to actively support, including financially, the Advisory Committee on Water Information's Subcommittee on Ground Water.**

To Governors and State Legislatures:

- **Provide funds to establish, operate, and maintain ground water quality and quantity monitoring networks that include ambient, targeted, and impacted areas.**

Policy makers at all levels of government will be faced with crucial decisions regarding growth and development alternatives and tradeoffs. These decisions must be based on high-quality data.

Photo: JECO Photo

NEW TECHNOLOGIES FOR TRACKING GROUND WATER FLOW AND NUTRIENT TRANSPORT TO DELAWARE AND MARYLAND COASTAL BAYS

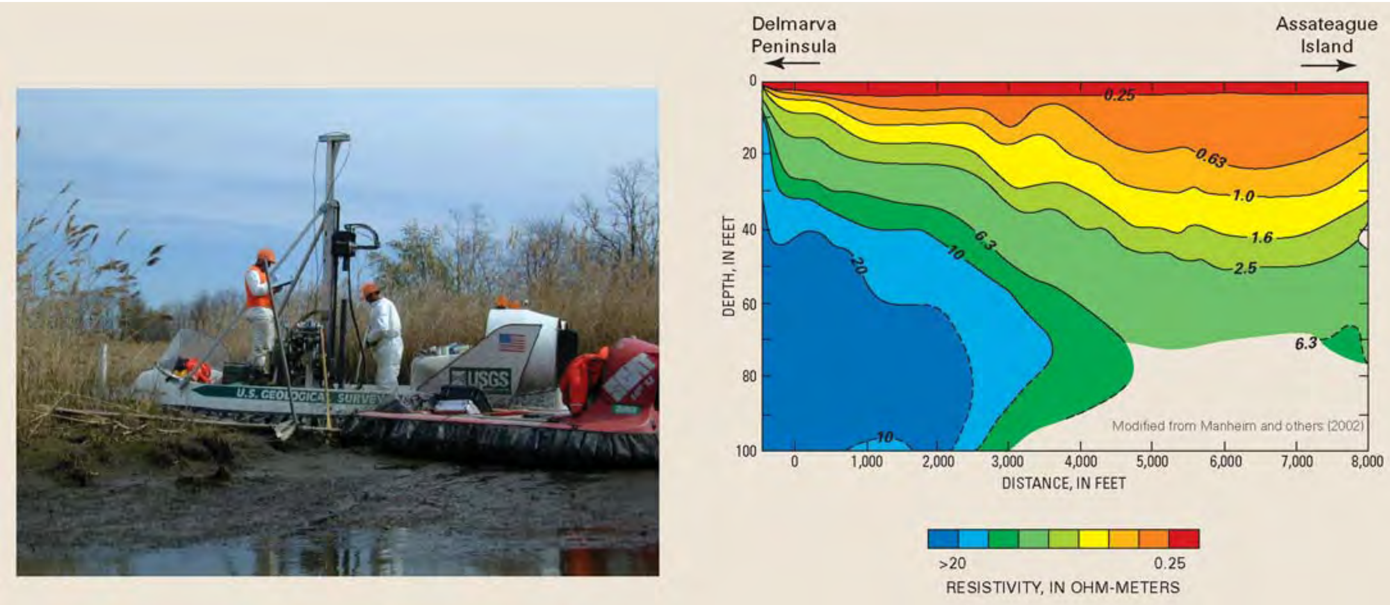


Figure 8. *Innovative drilling and geophysical techniques have been used to map the sediments that make up the surficial aquifer and to determine the water chemistry and age of ground water beneath the bays. For example, in the photograph on the left, researchers are sampling sediment coring and ground water quality from the USGS Hoverprobe in a tidal wetland of Maryland. Drilling is done by hydraulic vibracore equipment in the center of the hoverprobe craft. The map on the right depicts a representative resistivity profile across Chincoteague Bay, Maryland. The blue zones are interpreted to be fresh ground water flowing from the upland area west of the bay and mixing with saltwater beneath the bay (shown by the yellow to red zones).*

Source: http://pubs.usgs.gov/circ/2003/circ1262/

Section 3 References: Ground Water Resource Characterization and Monitoring

Barlow, P. M. 2003. *Ground Water in Fresh Water-Salt Water Environments of the Atlantic Coast.* USGS Circular 1262. Available at: *http://pubs.usgs.gov/circ/2003/circ1262/*

General Accounting Office. 2003. *Freshwater Supply: States View of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages.* GAO-03-514. 2003.

General Accounting Office. 2004. *Watershed Management: Better Coordination of Data Collection Efforts Needed to Support Key Decisions)* GAO-04-382, June 2004. Available at: *http://www.gao.gov/new.items/d04382.pdf.*

National Ground Water Association (NGWA). 2004. *Ground Water Sustainability: A Call to Action.* Available at at: *http://www.ngwa.org/PROGRAMS/government/issues/possustain.aspx* (accessed July 2007).

National Science and Technology Council Committee on Environment and Natural Resources. November 2004. Report: *Science and Technology to Support Fresh Water Availability in the United States.* Available at: *http://climate.gsfc.nasa.gov/viewStory.php?id=47*

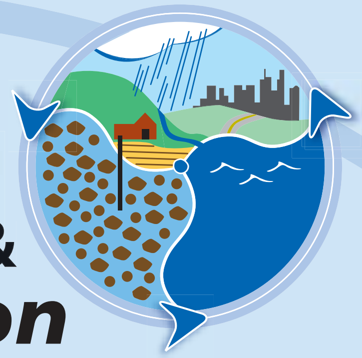
Nicholas, J. R., S. P. Blumer, and R. M. McGowan. 2001. *Comparison of Hydrologic Data from Monroe County, Michigan,* 1991 – 2001. U.S. Geological Survey Open-File Report 01-498. Available at: *http://mi.water.usgs.gov/pubs/OF/OF01-498/pdf/OF01-498.pdf*

U.S. Geological Survey. 2007. *The National Water-Quality Assessment Program — Informing Water-Resource Management and Protection Decisions;* written communication, Pixie A. Hamilton, May 2007; *http://water.usgs.gov/nawqa/xrel.pdf*

U.S. Geological Survey. August 1997. *Conceptual Frameworks for GW Quality Monitoring, Ground Water Focus Group,* ITFM, USGS/EPA. *http://water.usgs.gov/wicp/gwfocus.pdf.*

Winter, Thomas C., J. W. Harvey, O. L. Franke, W. M. Alley. 1998. *Natural Processes of Ground-Water and Surface-Water Interaction.* USGS Circular 1139, *http://pubs.usgs.gov/circ/circ1139/*

Ground Water & Source Water Protection



Key Message

Access to clean, safe drinking water is the essential ingredient to a healthy and viable community. Severe human health, ecological, and economic consequences follow from losses of current and future drinking water sources—losses that can be prevented. The potential for contamination of drinking water, coupled with the high cost of treating water and locating and developing alternate water sources, makes it imperative that federal, state, and local entities adopt and implement effective strategies for long-term protection of drinking water sources.

Congress and USEPA have taken the first step in developing such strategies by requiring assessments of all public water systems—termed Source Water Assessment and Protection. To be most effective, assessments and strategies must be based on an understanding of the factors that affect water quality and quantity, including how surface water interacts with ground water, how water quality factors into water availability, and how the management of potential water contamination involves everyone.

Our Source Water Protection Imperative

"When we honor water, we honor ourselves and the rest of life."

Veer Bhadra Mishra

why Source Water Protection matters to ground water…

All drinking water sources, both public and private, are vulnerable to contamination from an array of human activities such as septic system discharges, waste-site releases, underground storage system leaks, nonpoint-source pollution, and agricultural chemicals. Without diligent attention to managing these potential sources of contamination, our drinking water will come at a higher cost over time. This cost includes the increasing need for water treatment, monitoring, remediation, finding alternate water supplies, providing bottled water, consultants, staff time, and litigation. Source water protection is simpler, less expensive, and more reliable over the long term.

Drinking water wells are rarely as visibly contaminated as the water from this well, which is being pumped to waste, at a former wood treating facility in Minnesota. Routine monitoring is necessary to determine water quality; however, even with monitoring, it is often difficult to pinpoint an actual cause of contamination and many pollutants are not even looked for or assessed.

Prevention Costs a Whole Lot Less

If an aquifer that supplies drinking water to a community becomes contaminated, the cost of restoring clean drinking water to that community skyrockets far beyond what it costs to treat water. Research is needed to quantify the costs and benefits of source water protection so that cost/benefit analysis tools can be developed to help communities and stakeholders quantitatively assess the potential merit of source water protection. Some rough estimates were collected from USEPA Region 10. (See Table 1.)

Burlington, North Carolina, is a good example of how a community can save money by going the source water protection route. When the herbicide atrazine was found in the water supply, Burlington worked to eliminate the pollutant rather than pay to treat an ongoing contamination problem. Using water quality monitoring and guidance from the Water Resources Research Institute (WRRI), the city was able to trace the atrazine to agricultural operations in parts of the water supply watershed. With the help of Cooperative Extension Service agents, farmers came to understand that

Key Term

SOURCE WATER

Untreated water from rivers, streams, lakes, or aquifers that is used to supply public drinking water.

DELINEATED SOURCE WATER PROTECTION AREA

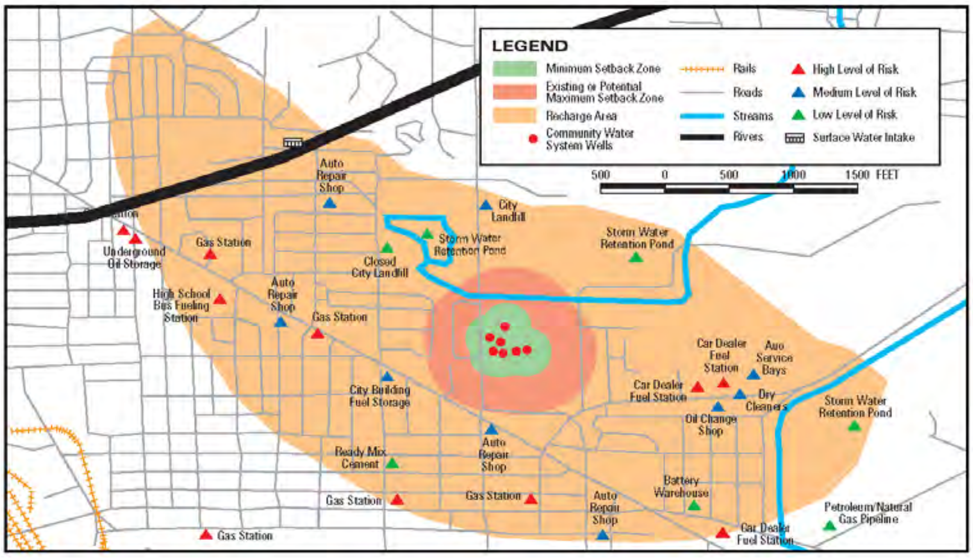


Figure 1. This sample map shows the delineation of a Source Water Protection Area and includes locations of known and potential sources of contamination to drinking water sources in that area.

Source: Consider the Source: A Pocket Guide to Protecting Your Drinking Water, USEPA.

the water treatment plant did not remove atrazine and, with subsidies from the city, they transitioned to other pesticides and practices.

This approach resulted in a total cost to Burlington of $30,000 (for lab analyses and subsidies to farmers). Contrast that one-time expense with an estimated cost of $108,000 per year to treat contaminated ground water with activated carbon. By implementing source protection, Burlington not only has clean drinking water again, it has eliminated the source of the problem. (North Carolina Division of Water Quality, 2002)

The Big Push for Local Source Water Protection

While public water system operators have primary responsibility for delivering safe drinking water, they do not control the many potentially harmful land-use activities and decisions that take place beyond their operational jurisdiction—often the source areas of the water they collect from water intakes or wells. This responsibility lies primarily with community decision makers, such as planning and zoning boards, municipal administrators, health departments, public works departments, and the general public. Protection of private ground water sources is typically left to the well owner and the health department.

In many instances, public and private drinking water source water areas extend beyond a community's or a private well owner's jurisdiction—out of their immediate control. To adequately protect source water, the identification of potential sources of contamination, elimination of threats, and application of best management practices to address these threats must occur

COMMUNITY	CONTAMINATION COST	BASIC SOURCE WATER PROTECTION COST	RATIO OF CONTAMINATION TO SOURCE WATER PROTECTION
Gilbert	$547,323	$2,744	200:1
Norway	$545,904	$101,014	5:1
Tumwater	$570,813	$22,073	26:1
Gettyburg	$4,015,351	$22,579	178:1
Dartmouth	$1,176,646	$99,052	12:1
Middletown	$491,823	$22,761	22:1

***Table 1.** Examples of relative costs of source water contamination versus prevention measures in selected USEPA Region 10 communities.*
Source: Eric Winiecki, USEPA Region 10.

Photo: Brian Hicks

Photo: Donald Childs Jr.

Top: Sacramento River water intake sign.
Bottom: Sacramento river and intake facility.

throughout the geographic area influencing the aquifer or surface water source.

Our challenge is to ensure that both public and private sectors take ground water resource protection into account in development plans, ordinances, public works practices, construction practices, and other land-use decisions. Indeed, all citizens share responsibility for source water protection.

The 1996 Safe Drinking Water Act (SDWA) Amendments took a bold and essential step forward in protecting sources of drinking water by requiring every state to take a serious look at potential contamination threats to public drinking water supply sources, including ground water sources. These new requirements set the stage for providing citizens with a better understanding of potential threats to drinking water. The underlying principle in source water protection is that prevention is the most effective and efficient method to assure long-term safe water.

This program has gotten off to a promising start; however, it must be nurtured. The states' ability and willingness to sustain these efforts is uncertain, since the SWDA placed no requirements on communities to follow up on the state programs and implement the steps needed to protect source water, nor did it provide funding to carry out the implementation.

DRINKING WATER SOURCES AND HUMAN ACTIVITY

Any human activity that alone or cumulatively degrades the quality of source water is a threat to source water. Many types of land uses have the potential to contaminate ground water—spills from tanks, trucks, and railcars, leaks from buried containers,

LAND AREA CONTRIBUTING TO GROUND WATER RECHARGE

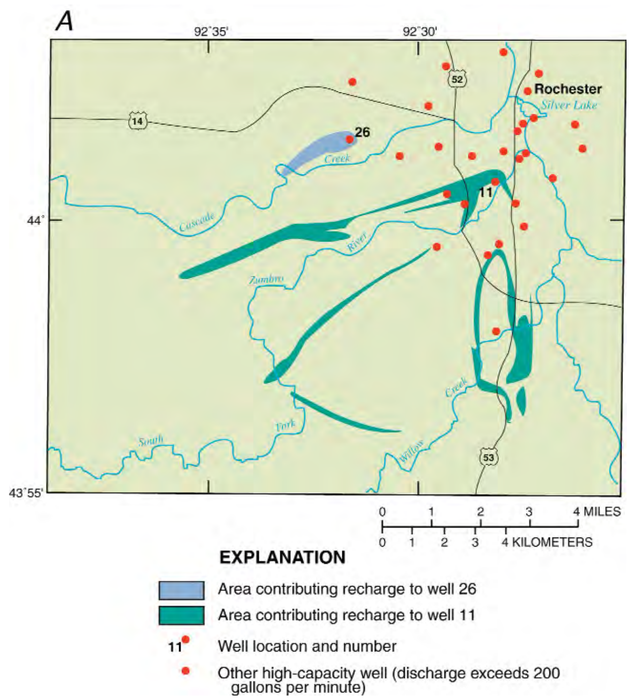


Figure 2. *Most human-derived contaminants enter ground water after passing through unsaturated soil. A second important point of contaminant entry is at the beds and banks of streams, reservoirs, lakes, and wetlands. One approach to protecting public ground water supplies is to estimate the area contributing recharge to public supply wells and then to implement ground water protection practices within that area. This map shows the recharge area for the wells for the City of Rochester, Minnesota.*

Source: USGS, http://water.usgs.gov/ogw/pubs/Circ1174/circ1174.pdf failed septic systems, burial or injection of wastes underground, use of fertilizers, pesticides, and herbicides, road salting, and polluted urban and agricultural runoff. While catastrophic contaminant spills or releases can wipe out a water resource, ground water degradation, in particular, can also result from a plethora of small releases of harmful substances, such as gasoline from a nearby service station or perchlorethylene from a dry cleaner.

Ground water degradation can be acute, the result of a sudden event, or it can be the gradual and insidious erosion of water quality. Contaminants can cumulatively impact the resource and degrade it over time. According to USEPA, nonpoint-source (NPS) pollution (when water runoff moves over or into the ground, picking up pollutants and carrying them into surface water and ground water) is the leading cause of water quality degradation.

Photo: Paul Jehn

Nationally, states rank agriculture as the second most prevalent and threatening potential source of contamination for both ground and surface water sources of drinking water. Pathogens that can be carried in animal waste include E. coli, salmonella, cryptosporidium, and giardia. Source water from waste generated from upstream concentrated animal feeding operations require additional treatment and may require additional technology to achieve required results. There are many efforts at all levels of government to prevent contaminants from animal feedlots from entering source waters.

Pathogens and the Ground Water Rule

Viral and bacterial pathogens are present in human and animal feces, which can, in turn, contaminate drinking water. Fecal contamination can reach ground water sources, including drinking water wells, from failed septic systems, leaking sewer lines, and by infiltrating soil and fractured bedrock. The Centers for Disease Control and Prevention reports that, between 1991 and 2000, ground water systems were associated with 68 outbreaks that caused 10,926 illnesses.

To provide for increased protection against microbial pathogens in public water systems that use ground water sources, USEPA issued its Ground Water Rule in November 2006. There are several components to this rule that apply to all community and noncommunity water systems. They include determining the sensitivity of the groundwater system; performing additional monitoring for total coliform-positive samples; correcting significant deficiencies identified in the system's sanitary survey; and taking corrective actions after certain triggers are exceeded. Systems must begin to comply with the new requirements by Dec. 1, 2009. For more information on the Ground Water Rule see: *http://www.epa.gov/safewater/disinfection/gwr/index.html*

Source Water and Ubiquitous Pesticides

Our world is filled with potential threats to ground and surface water, but one such threat is remarkably widespread—the array of pesticides (including herbicides) used on agricultural fields, lawns, gardens, golf courses, along highways, and even around the home. As a society, we are somewhat lax about our use of pesticides, not necessarily considering the potential health risks associated with exposure. Adding to this is the fact that many contaminants and their breakdown products do not have drinking water standards or guidelines. A 2007 USGS report, *Pesticides in the Nation's Streams and Ground Water,* 1992–2001, says, for example, that only about half the pesticides and volatile organic compounds (VOCs) measured by the USGS National Water Quality Assessment (NAWQA) Program have current USEPA standards.

EPA's Office of Pesticides relies on USGS for high-quality, nationally consistent monitoring data for pesticide registration and for its assessments of pesticide exposure. The federal Food Quality Protection Act (FQPA) requires USEPA to factor potential exposures to pesticides through drinking water into already complex procedures used to set pesticide "tolerance levels" in foods. NAWQA data helps guide USEPA's decisions on the commonly detected herbicides aldicarb, alachlor, and acetochlor, and the insecticides chlorpyrifos, diazinon, and carbofuran.

State source water assessments (see page 4•7) have shown that both agricultural and residential land uses are in the top five most prevalent and most threatening potential sources of ground water contamination. According to USGS, we need to better understand the correlations of pesticide occurrence with the amounts and characteristics of pesticides used so that we can anticipate and prioritize the pesticides most likely to affect water quality in different land-use settings.

The entire hydrologic system and its complexities must be considered in evaluating the potential for pesticide contamination of source water. Protection efforts must be made at the local level, and they are very challenging. Many times the solution is educating people in all sectors on the proper use of pesticides, which boils down to finding ways to minimize use or find less threatening alternatives.

Photo:USGS

The most intensive pesticide applications are in agricultural and urban areas, including substantial use for residential lawn and garden pest control. Reducing the use of pesticides is the most effective way to reduce their concentrations in the hydrologic system.

Looking at the Entire Hydrologic System and Its Complexities

Ground water protection and drinking water protection overlap to a considerable extent. Protection of any drinking water source must be carried out in the context of the land area that influences the water supply, whether it is the area upstream of a surface water intake or a wellhead protection area. For ground water supplies, an understanding of ground water hydrology within a delineated watershed or aquifer system provides the basis for evaluating the vulnerability and sustainability of that source water and the means for determining how it can be protected and preserved.

Regardless of its intended use (drinking or other purposes), all water is a segment of a watershed's or aquifer system's water budget, which must be maintained at a healthy level to be viable. Watershed viability requires that we apply exact hydrologic science and facts before we transfer water across basins. Where we locate new development, the degree to which we draw down existing water resources, and how well we provide for future and/or alternative water sources are all functions of the watershed or aquifer budget, and therefore source water protection.

OVERVIEW OF PESTICIDE OCCURRENCE

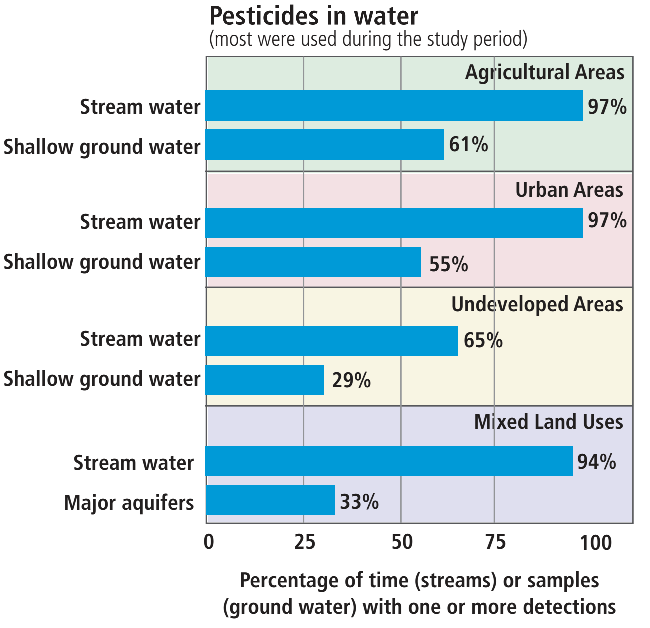


Figure 3. *In this NAWQA study,* Pesticides in the Nation's Streams and Ground Water, 1992 – 2000, *one or more pesticides were detected in water more than 90 percent of the time during the year in streams draining watersheds with agricultural, urban, and mixed land uses. In addition, some organochlorine pesticides that have not been used in the United States for many years were detected along with their degradates and byproducts in most samples of whole fish or bed sediment from streams sampled. Pesticides were less common in ground water, but were detected in more than 50 percent of wells sampled to assess shallow ground water in agricultural and urban areas.*

Source: USGS http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291.pdf

SOURCE WATER ASSESSMENT PLANS

Although many states, water systems, and localities have had watershed and wellhead protection programs since the 1980s, the 1996 SDWA Amendments broadened the focus of these programs by requiring all states to develop a Source Water Assessment Plan (SWAP). The state SWAPs include the following required assessment activities:

- Delineate the source water protection area for all public water supply sources (wellhead protection area for ground water sources; watershed area for surface water sources)—160,000 nationwide.
- Conduct an inventory of potential sources of contamination in each delineated area.
- Determine the susceptibility of each water supply to those contamination sources. (The information from these three steps is compiled into a report called a source water assessment.)
- Release the results of the assessments to water systems and to the public.

The ultimate goals of this program are to prevent contamination of public drinking water sources, avoid the costs of dealing with contamination, and protect public health by motivating water suppliers and concerned citizens to develop and implement local Source Water Protection programs (SWP programs). Source water protection, by its very nature, requires the effective integration of key federal, state, and local functions. The success of the program depends on the ability of communities to adopt protective measures and strategies and develop partnerships with water suppliers, businesses, states, and the local citizenry.

MOST PREVALENT POTENTIAL CONTAMINATION SOURCES

GROUND WATER (46 states reporting)	SURFACE WATER (46 states reporting)
1. Commercial/Industrial	1. Commercial/Industrial
2. Agriculture	2. Agriculture
3. Wastewater	3. Wastewater
4. Residential	4. Transportation
5. Contamination sites	5. Residential

Table 2. *National Source Water Assessment Summary data showing top five most prevalent potential contamination sources.*

MOST THREATENING POTENTIAL CONTAMINATION SOURCES

GROUND WATER (46 states reporting)	SURFACE WATER (46 states reporting)
1. Commercial/Industrial	1. Commercial/Industrial
2. Agriculture	2. Agriculture
3. Residential	3. Wastewater
4. Contamination sites	4. Transportation
5. Wastewater	5. Residential

Table 3. *National Source Water Assessment Summary data showing top five most threatening potential contamination sources.*

REGIONAL SUMMARY DATA

SOURCE WATER ASSESSMENTS COMPLETE			
	% CWS	% all NC	% all PWS
National Total	**99%**	**98%**	**99%**

SOURCE WATER PROTECTION STRATEGIES (NATIONAL TOTALS)		
	CWS	Pop
Protection Strategy in Place	**43%**	**50%**
Protection Strategy Substantially Implemented	**24%**	**34%**

2005 data used for states that did not report in 2006 (SD, WY, and CA). Total percentages based on systems/population in SDWIS (Q4 2005).

Table 4. *A 2006 summary of USEPA regional data showing percent of completed source water assessments for community water supplies (CWS), noncommunity water supplies (NC), and public water supplies; percent of strategies in place; and strategies substantially implemented for CWS and total population.*

Source: US EPA

Photo: Alan Cressler

Tennessee is blessed with an abundance of high-quality ground water. The vulnerability, quantity, and quality of the state's ground water sources are inextricably linked to the geology, particularly karst terrain (limestone characterized by caves, sinkholes, and springs) and in unconfined sand aquifers. This vulnerability is particularly true for contamination from volatile organics (e.g., chlorinated solvents, gasoline components), which are highly mobile and widely used. In Tennessee, approximately 1.5 million people rely on public water systems that use ground water as a drinking water source.

Are the Assessments Improving Source Water Protection?

Most states have completed their source water assessments for public water systems and have made the assessments available to the public. Each assessment provides a concise summary of available information regarding the source(s) (e.g., well, lake, river) supplying a public water system. These documents are normally produced by state source water protection staff and are intended to provide basic information to public water suppliers and the general public regarding: (1) where their drinking water comes from, and (2) the degree to which it may be impacted by potential sources of contamination. (See Tables 2 and 3.)

States are at various stages of developing and implementing their source water protection strategies. Though states are not mandated to implement source protection, they are expected to develop their own Source Water Protection programs and strategic plans. States are using their assessment reports in different ways. Drinking water agencies are using them to help improve their programs by prioritizing overall protection efforts, upgrading contaminant inventories, and targeting education and outreach efforts. Some state agencies are also looking seriously at coordinating source water protection with other overlapping programs, such as underground storage tanks and onsite sewage disposal.

States have provided the completed assessment reports to their public water system owners and appropriate municipal officials. However, use of the assessments has been limited at the local level (USEPA, 2005). This is not surprising, in that many local governments lack the technical and human resources to facilitate developing and implementing source protection strategies—some may also lack sufficient motivation.

Typically, communities and public water suppliers need encouragement and assistance from state agencies and/or non-government organizations, such as state chapters of the National Rural Water Association, Trust for Public Land, and Cooperative Extension Service, and involvement from agricultural, industrial, and development sectors within the community. They need help in understanding how to use the assessments as tools for developing a source protection strategy and interpreting the results. In this type of collaboration among various sectors of the community, it is critical to maintain a focus on source water protection planning as well as the implementation of identified protection measures.

The Importance of Keeping Track

Source Water Protection programs have started off well. However, the initial assessments are just a springboard for putting effective long-term protection measures in place. Next steps will require adequate federal support to the states and in turn adequate

KING & QUEEN COUNTY, VIRGINIA, WATER QUALITY: SOURCE DRINKING WATER SUPPLY

Figure 4. *Forests and pure water go hand in hand. Forests filter precipitation as it infiltrates ground water. Forests also diminish the impact of powerful storms by intercepting rainfall and filtering stormwater.*

Source: Virginia Department of Forestry http://www.dof.virginia.gov/R2/kaq-wq-source-water.shtml

NEW HAMPSHIRE MOVES FORWARD ON MUNICIPAL SOURCE WATER PROTECTION ACTIVITIES

New Hampshire's Drinking Water Source Protection Program emphasizes local implementation of source water protection in addition to state-level activities. Prompted by USEPA's annual request for water system–specific information on source water protection, the N.H. Department of Environmental Services (NHDES) had developed a fairly complete picture of protection measures implemented by water suppliers. Missing, however, was information on the extent to which municipal ground water protection ordinances helped protect public water supply sources.

Beginning with a survey of municipalities and a review of local ordinances in cooperation with the state's Office of Energy and Planning and with the assistance of the Ground Water Protection Council (with USEPA funding), NHDES compiled a geographic database of local ground water protection ordinances that will serve as a planning resource for local communities. The project revealed, for example, that 12 percent of community water system ground water sources are protected using local land-use restrictions in at least 50 percent of their wellhead protection areas.

The data set is also being used by NHDES to target activities it will undertake to help fill in the gaps in local protection and to provide guidance to municipalities on improving their ground water protection-related ordinances. NHDES is also working to extend the data set to include the protection of surface water sources through local shoreland protection ordinances.

Photo: NH DES

A private well in New Hampshire.

state support to communities and utilities (USEPA, 2005). In order to maintain federal funding, tracking and reporting progress is particularly important.

This track record is a means of informing Congress about where funding, such as Drinking Water State Revolving Funds (DWSRFs) set-asides for drinking water protection, is necessary. States also need to know what is occurring at the local level and, thus, need a means for gathering, tracking, interpreting, and reporting on local source water protection efforts. Measuring and characterizing state and local SWPs can provide the data and information states need to inform decision makers about where to target or refine source water protection activities.

GAPS AND OBSTACLES

While Congress mandated that the states develop a state Source Water Assessment Plan (SWAP) and complete their source water assessments, the state Source Water Assessment and Protection programs are not mandated. Congress and EPA anticipated that states and locales would voluntarily take the assessments and develop source protection programs that would address local issues and many are trying to do this. But given the serious lack of financial and human resources, when it comes to tasks states are required to do by federal mandate versus others that are not mandated but that also need to be done (voluntarily), state environmental and health agencies find themselves pushed into a corner, making choices based on mandates and funding.

Federal and state programs can lose sight of the need for long-term water-supply protection as they balance resources between regulatory requirements and long-term goals. There has also been a lack of effective coordination among state SWPs and other federal programs, such as USEPA's clean water program, U.S. Department of Agriculture, Bureau of Land Management, U.S. Forest Service, and their affiliated state counterparts.

Water suppliers and municipalities are expected to make use of their source water assessments voluntarily, but in most cases this cannot happen without education, financial and technical assistance, and a local champion. Utilities that supply drinking water are often not able to focus on source water protection for several reasons:

- The land encompassed in source water areas is not under their ownership or jurisdiction.
- They must meet daily challenges of delivering water.
- They are busy maintaining the infrastructure, treatment, and monitoring.
- They are concerned with complying with regulatory requirements.
- They must position themselves to accommodate growth.

There are several significant gaps associated with the current federal source water requirements that underscore why protecting all ground water regardless of use is critical. First, while the assessments provide an initial snapshot of threats, there is no requirement for the routine reassessment of potential contaminant sources, and new development typically brings new threats to source water. Second, the program addresses only current sources of public water, not potential future sources. If we strive to protect only current drinking water sources, we not only put future sources at risk, we also allow for the potential that unprotected sources will influence the quality of current sources.

Furthermore, the Source Water Protection program addresses only public drinking water covered by the federal Safe Drinking Water Act, not private water wells. More than 42 million people in the United States obtain water from private wells (Solley et al., 1998), which may or may not draw from the same ground water as public supplies. In some cases, private wells have a greater vulnerability to contamination, especially if they are inadequately constructed or if their water quality is not routinely checked. States and private organizations have, however, taken steps to provide homeowners with information on how to protect their water wells.

Congress and USEPA need to set attainable goals, provide technical guidance and information management assistance, and make a financial commitment to ensure successful development of state Source Water Protection programs. According to a 2005 USEPA Inspector General's report, "There is no consistent and secure source of funding for source water protection activities." The report says that states rely heavily on DWSRF set-asides and annual appropriations, which several other competing regulatory programs also rely on, for source water protection program administration and implementation. There are also some limited funding options available through other state and federal programs. Without a sustained commitment to source water protection at both the federal and state levels, the significant health and economic benefits of source water protection will remain limited.

SOME SUCCESSFUL STRATEGIES

The clear intent of the SWAP Program was to analyze existing and potential threats to the quality of public drinking water. To accomplish this, states made a tremendous investment in time and money. Nationwide, approximately 160,000 water systems were assessed. Now that this effort is complete, a new question has emerged: What is the best way to build upon SWAP results and achieve tangible progress in source water protection?

Despite various obstacles, there are numerous examples of states that have found opportunities for achieving more widespread implementation of source water protection. Statewide approaches that partner, integrate, and leverage federal, state, and local programs can effectively drive source water protection goals and have a positive outcome for many related pubic health program goals.

Sharing information among programs can greatly improve effectiveness. Many state drinking water programs have posted source protection areas on their websites or shared data by other means to encourage other agencies and municipalities to take these areas into consideration with regard to making land-use and permitting decisions and setting cleanup priorities.

The USEPA Office of Ground Water and Drinking Water (OGWDW) has been advocating for more effective integration of existing federal programs with source water protection objectives. This has taken the form of encouraging both federal and state agencies to seek opportunities such as those described above for cross-program integration.

Photo: Zachary Jean Paradis - http://www.flickr.com/photos/zacharyparadis/499059710/

A drinking water intake and "crib" in Lake Michigan. A water crib collects water from close to the bottom of a lake to supply a pumping station onshore. At this facility, water is collected and then transported via pipes 200 feet below the lake's surface to pumping stations at purification plants at the shores of the lake; from there the water continues on its journey to the Chicago area.

Photo: K.M. Neitzert, USGS

A well house for a municipal well in Tripp County, South Dakota.

Much success has been made in improving coordination between OGWDW and USEPA's Office of Underground Storage Tanks, specifically with promoting and enabling inspection, enforcement, and cleanup prioritization in source water areas. This successful initiative could be duplicated with other programs as well. Opportunities for such program/agency integration include Clean Water Act programs (e.g., NPDES, TMDL, other watershed initiatives, standards, water quality criteria, monitoring, stormwater, onsite wastewater treatment), Resource Conservation and Recovery Act programs (e.g., small- and large-quantity generators, solid waste, household hazardous waste), pesticides and other agricultural programs, forestry, transportation, and CERCLA (Superfund) programs.

Louisiana – The Louisiana Source Water Assessment Program illustrates how state programs can work together to each other's advantage using source water as a prioritization tool. For example, the Louisiana Department of Environmental Quality's (LADEQ's) Source Water Program is notified by the Louisiana Department of Health and Hospitals (DHH) when new wells come on line or when wells go out of service so that LADEQ can update its SWAP database and conduct a Source Water Assessment for the new wells. This keeps Source Water Assessments current and available for use by DHH when it conducts sanitary surveys.

The Louisiana Department of Natural Resources (LADNR) lets the Source Water Program know when high-volume wells are applying for a permit so they can evaluate whether a drinking water supply will be adversely impacted. LADNR is involved with aquifer quantity issues while the LADEQ Program focuses on aquifer quality issues. Both assist local Source Water Protection Committees and give public presentations on water quantity issues throughout the state. In addition, the Natural Resource Conservation Service (NRCS) has access to all of the Source Water Protection Areas in the state and can use this information to induce farmers to take farm land out of production in these areas as part of the Conservation Reserve Program.

THE LAKE CHAMPLAIN BASIN ATLAS

Phosphorus Loads

Initial (1995) and Target Phosphorus Loads by Lake Segment Showing Adjacent Watersheds in Metric Tons/Year (mt/yr)

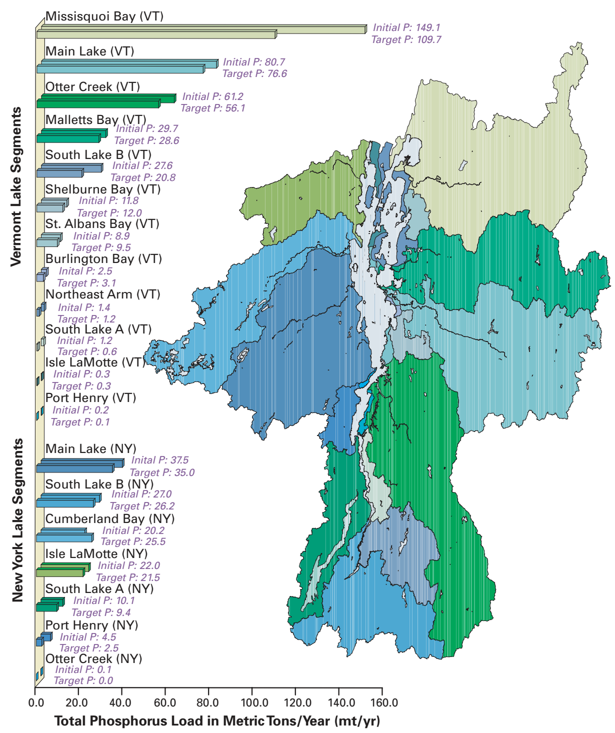


Figure 5. *Lake Champlain is a reservoir for about 188,000 people, or 32% of the basin population. Almost all (about 98%) of these people obtain their water from 100 public water supplies monitored and regulated by three jurisdictions—Vermont has 73 systems, New York has 26, and Quebec, Canada, has one. Phosphorus, found in lawn fertilizers, manure, and human and other animal waste, causes algal blooms and excessive aquatic plant growth in the lake. These plants and the water quality problems that occur when they decompose can harm fish and other organisms and affect public water supplies. The three jurisdictions have agreed to reduce phosphorus loads to each of Lake Champlain's segments. This Phosphorus Loads Map shows the area draining to each of the lake segments and both the initial (1995) and target phosphorus loads for each.*
Source: http://www.lcbp.org/ATLAS/HTML/is_pload.htm

LADEQ is most proud of its direct efforts to work with local communities. Department representatives work with local communities to form teams of local citizens, water suppliers, and government officials and to provide technical assistance in developing community-based Source Water Protection programs.

Oregon – The Oregon Drinking Water Protection Program has had success communicating directly with county planners, other state agencies, and public water providers. The Oregon Drinking Water Program (ORDWP) staff/management team meets regularly to discuss feedback and concerns from its partners. The drinking water assessment GIS data was sent to each county's board of commissioners, land-use planners, health departments, and GIS departments for incorporation into land-use planning and special-area designations at the local and county levels.

Counties and cities are now able to directly overlay the identified drinking water source areas onto other planning information available to them. The program is now working to integrate the drinking water protection work with the existing watershed approach used for other Clean Water Act implementation both at the Oregon Department of Environmental Quality (ORDEQ) and other state agencies such as the Oregon Department of Transportation, Oregon Department of Agriculture, and Oregon Department of Forestry.

Early in the state's source water protection implementation efforts, it became clear that a method was needed to prioritize water systems based on their susceptibility to contamination and the specific risks they faced. This prioritization was undertaken statewide to create a risk ranking (Tiers 1 – 4) of surface water and ground water systems. The state is focusing technical assistance toward high-risk systems first.

To assist the individual ground water supply systems with their protection efforts, the Oregon Department of Human Services (ORDHS) and the ORDEQ developed an Implementation Matrix, which presents information on relative risk in a format that water systems can use to identify and prioritize their own efforts. Prior to meeting with a community, the state calculates a "relative benefit" score for each identified potential contaminant source (PCS) based on the susceptibility of the drinking water source to a specific PCS and the location of that PCS within the source water protection area. This score reflects the relative benefit to the community of reducing the risk from this PCS.

The Drinking Water Protection Program then links the activity-appropriate best management practices (BMPs) to each PCS. This information is then taken to the community where, under the community's direction, the relative benefit is compared to the ease (time or cost) of implementing the appropriate BMP. The individual PCSs are then transferred to the implementation matrix. Presented in this manner, the cost-benefit of protection strategies can be easily understood, providing city councils or other local government officials with a mechanism for prioritizing drinking water protection strategies.

North Carolina – North Carolina has recently embraced a strategy to build upon its source water assessments and achieve tangible results for source water protection. The state Source Water Assessment and Protection (SWAP) program is attempting to insert SWAP priorities into the agendas of other agencies and programs. The initial response has been positive. For example, the Natural Resources Conservation Service has adopted drinking water protection as a statewide priority within its Environmental Quality Incentives Program. The North Carolina Division of Soil and Water Conservation has supported SWAP priorities within

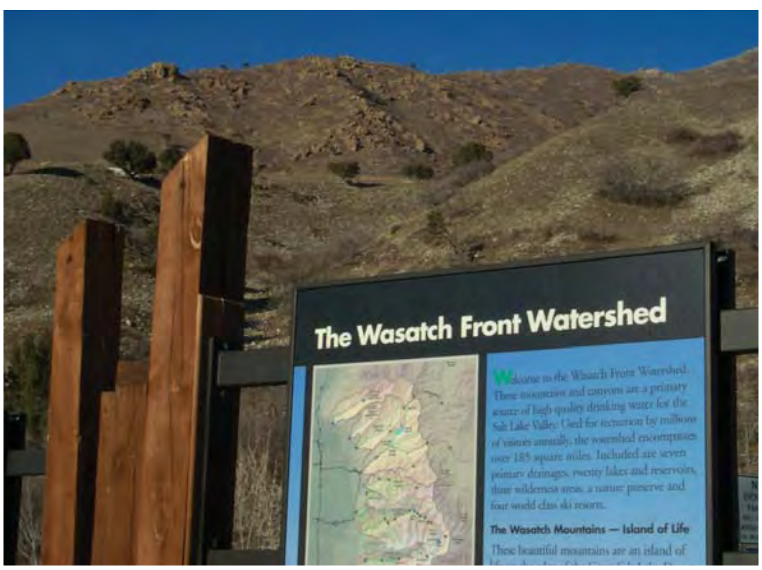


Photo: Robin Davis

The Wasatch Front Watershed delineated on a roadside marker in Salt Lake City, Utah.

its Agriculture Cost Share and Urban Cost Share programs. These three programs alone allocate more than $20 million annually for projects related to environmental protection and conservation.

In addition, the SWAP program has entered into discussions with the North Carolina Clean Water Management Trust Fund and other land conservancies that are eager to consider SWAP priorities to evaluate potential projects. North Carolina believes that results from these partnerships can have a significant impact on drinking water protection throughout the state.

There are multiple benefits associated with establishing SWAP priorities within other programs. Building active partnerships with other agencies raises awareness of the SWAP program and its objectives. Moreover, source water protection activities are promoted and financed using the resources of cooperating agencies. Finally, arrangements with participating agencies provide ready incentives and solutions to stakeholders developing local Source Water Protection plans.

SOURCE WATER PROTECTION AT THE LOCAL LEVEL

While other stakeholders have a role, state drinking water programs have a variety of ways to motivate and assist local source water protection implementation. An important feature of an effective strategy for motivating local actions is the availability of easy-to-use tools that target local capabilities and interests. Other motivational possibilities include:

- Phase II/V chemical monitoring waivers.
- Grants funded with DWSRF set-asides (funding available for state programs is expanded significantly with DWSRF set-asides).
- Requirements for communities to develop source water protection plans.
- Outreach, training, and partnerships with entities such as regional planning groups and National Rural Water Association chapters.
- Initiatives by other organizations.
- Model land-use ordinances for local governments.

GROUNDWATER GUARDIANS—SOURCE WATER PROTECTION MOVERS AND SHAKERS IN THEIR COMMUNITIES

Groundwater Guardian, a program of The Groundwater Foundation, encourages communities to begin ground water and source water awareness and protection activities at the local level, supports the communities in their efforts, then recognizes their achievements. This program began in 1994 with eight test-year communities and is now working with communities in more than 32 states.

Communities begin the process by forming a Groundwater Guardian team consisting of citizens, business and/or agricultural representatives, educators, and local government officials. These teams then develop Result-Oriented Activities (ROAs) to address the community's ground water protection concerns and keep the goals active for implementation. ROAs fall into many categories including education and awareness, pollution prevention, public policy, conservation, and best management practices. Communities represent diverse settings, including rural areas, large incorporated cities, Tribal Lands, and watersheds in the United States and Canada.

Photo: The Groundwater Foundation and Rock River Coalition Groundwater Guardian Team

Wisconsin Rock River Coalition Ground Guardians at work.

The Groundwater Foundation provides information and materials helpful to the communities as they implement their ROAs, such as the Groundwater Guardian Assistance Kit, *The Aquifer*, and "hot topic" materials, such as the *Drinking Water Source Assessment and Protection Workshop Guide. (http://www.groundwater.org/gg/gg.html)*

- Sharing information, especially GIS data.
- Meetings with stakeholders.
- Continuing education units (CEUs) for drinking water utility operators who attend training sessions on source water protection.

USEPA's Office of Ground Water and Drinking Water (OGWDW) has produced a compendium of products in CD format called *Safe Drinking Water Tools for Public Water Systems.* The CD and companion website provide a one-stop portal for many of OGWDW's products and tools already in print. *(http://www.epa.gov/safewater/pws/tools/index.html)*

Photo: Mary Ann Massie, Virginia Department of Environmental Quality

Sixth graders model backpacks they received at the 2006 Natural Resources/Ground Water Festival held at the Russell County Fairgrounds in Castlewood, Virginia. A group of 212 students participated in 14 learning stations covering topics as varied as topographic maps, onsite sewage disposal systems, soils, the water cycle, caves, and mining. Citizen-involved education events provide much needed support for ground water protection efforts at the community level.

FINANCING SOURCE WATER PROTECTION

States and communities have an assortment of source water protection funding options. Chief among these options has been DWSRF set-asides for state programs, which significantly expanded funding available for source water protection. But there are also a number of funding opportunities outside of state set-asides. There are several websites that states, communities, and public water systems can explore to learn more about source water funding options. Among these are:

- EPA Catalog of Federal Funding Sources for Watershed Protection *(http://cfpub.epa.gov/fedfund/)*
- Environmental Finance Center *(www.efc.umd.edu/)*
- EPA Clean Water State Revolving Fund *(http://www.epa.gov/owm/cwfinance/cwsrf/)*
- Directory of Watershed Resources *(http://sspa.boisestate.edu/efc/)*

THE SOURCE WATER COLLABORATIVE

Sourcewater COLLABORATIVE

In 2006, USEPA and 14 national organizations, including the Ground Water Protection Council, committed to work in partnership to protect present and future drinking water sources. They formed the Source Water Collaborative, which is focusing efforts on improving our understanding and management of the land-water connection at the local level in order to protect water resources. The Collaborative provides a powerful national network of affiliates, and the member organizations offer diverse expertise and resources that can then be filtered down to the state and local levels.

For example, the Delaware Source Water Protection program has retained its original Source Water Citizen and Technical Advisory Committee (CTAC), which was formed to advise the state's Source Water Protection program on the delineation process. In 2001, the Delaware General Assembly passed the Source Water Protection Law expanding the CTAC's authority and requiring local communities with 2,000 or more citizens to develop SWP ordinances and adopt the SWP areas in their Comprehensive Land Use Plans by December 2007.

The CTAC, which provides broad-based input to the state Source Water Protection program, has provided advice during development of the Source Water Assessments and development and distribution of state protection guidance to local governments, and on research projects. The committee maintains a regular meeting schedule. Members reflect state-level

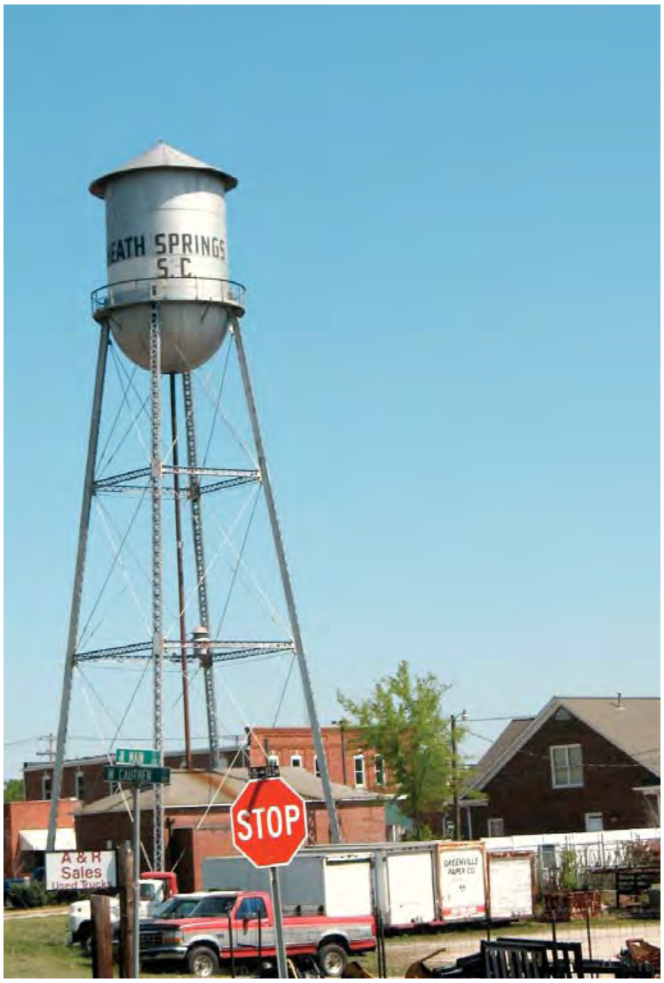


Photo: Doug Short

This water tower in Heath Springs, South Carolina, is located in rural Lancaster County. More than 50 percent of the state's residents rely on ground water as their source of drinking water. Most of this water is still at or near its natural excellent quality and is suitable for drinking with no treatment, which is an enormous economic and public-health benefit. The South Carolina Department of Health and Environmental Control's source water protection website provides a collection of tools and outreach materials to assist local source water protection efforts. See http://www.scdhec.gov/environment/water/srcewtr.htm

representatives from many of the organizations represented on the national Source Water Collaborative, including health, agriculture, and other programs that manage potential contaminant sources; representative local governments (cities and counties); the Delaware Rural Water Association; environmental groups; water utilities; USGS; academic institutions; land-use experts; community development, and the agricultural sector.

The Source Water Collaborative has established a website, *www.ProtectDrinkingWater.org,* to facilitate networking and resource sharing. Through the website and other modes, the group will identify opportunities and tools that local decision makers and practitioners can use to incorporate water resource protection into their community planning and land-use practices.

Other activities under development include a summary of research needs on costs and benefits (including monetary benefits) of source water protection; a financing guide; and a framework of best practices for local decision-makers for drinking water protection.

Source Water Collaborative members include:

- American Planning Association
- American Water Works Association
- Association of Metropolitan Water Agencies
- Association of State Drinking Water Administrators
- Association of State and Interstate Water Pollution Control Administrators
- Clean Water Fund
- Environmental Finance Center Network
- Groundwater Foundation
- Ground Water Protection Council
- National Association of Counties
- National Ground Water Association
- National Rural Water Association
- North American Lake Management Society
- River Network
- Trust for Public Land
- U.S. Department of Agriculture
- U.S. Environmental Protection Agency
- U.S. Geological Survey

"There shall be no man or woman dare to wash any unclean linen, wash clothes, nor rinse or make clean any kettle, pot, or pan or any suchlike vessel within twenty feet of the old well or new pump. Nor shall anyone aforesaid, within less than a quarter of a mile of the fort, dare to do the necessities of nature, cinse [sic] by these unmanly, slothful, and loathsome immodesties, the whole fort may be choked and poisoned."

by order of Governor Gage of the Jamestown Colony in 1610.

Recommended Actions

To USEPA:

- Incorporate source water protection considerations into other programs at the federal level (e.g., hazardous waste, underground injection control [UIC], Clean Water Act) and allow for flexibility so that state programs can do the same.
- Sustain a federal-level Source Water Protection program.
- Provide additional financial support and incentives for state and local Source Water Protection programs.
- Integrate ground water value into Source Water Protection programs.

To State Agencies:

- Establish and sustain a statewide Source Water Protection program that coordinates the activities of all agencies responsible for natural resources and environmental protection programs so that they proactively address potential source water impacts. This includes periodically evaluating the effectiveness of current source water protection efforts. (See *Elements of an Effective State Source Water Protection Program,* a joint Ground Water Protection Council (GWPC) and Association of State Drinking Water Administrators (ASDWA) document, October 2006.)

To Local Governments:

- Create, or participate in creating, a municipal watershed or regional-level comprehensive Source Water Protection Plan that includes:
  - Strategies for managing threats and protecting resources.
  - A combination of voluntary and regulatory strategies.
  - A long-term vision, short-term strategies, and measurable goals.
  - A strategy for how to fund the activities in the plan.
- Coordinate land-use planning with source water protection plans, incorporate source water protection as an element of the local comprehensive plan, and integrate source water areas into land-use planning and zoning regulations.

Our challenge is to ensure that both public and private sectors take ground water resource protection into account in development plans, ordinances, public works practices, construction practices, and other land-use decisions. Indeed, all citizens share responsibility for source water protection.

Section 4 References: Ground Water Use and Source Water Protection

Franke, O.L., T.E. Reilly, D.W. Pollock, J.W. LaBaugh. 1998. *Estimating Areas Contributing Recharge to Wells: Lessons from Previous Studies.* USGS Circular 1174. Available at: *http://water.usgs.gov/ogw/pubs/Circ1174/circ1174.pdf*

North Carolina Division of Water Quality. Spring 2002. "Source Water Protection and Cost Savings in Burlington, North Carolina." *Streamlines*, Vol. 6, No. 2. Available at: *http://h2o.enr.state.nc.us/wswp/SL/v6i2.pdf*

McGuire, V. L., M. R. Johnson, R. L. Schieffer, J. S. Stanton, S. K. Sebree, and I. M. Verstraeten. 2003. *Water in Storage and Approaches to Ground-Water Management, High Plains Aquifer, 2000*. USGS Circular 1243.

USEPA, March 28, 2005. *Inspector General's Report: Source Water Assessment and Protection Programs Show Initial Promise, but Obstacles Remain.* EPA Report No. 2005-P-00013.

USGS [U.S. Geological Survey], May 2007, T*he National Water-Quality Assessment Program — Informing Water-Resource Management and Protection Decisions;* written communication, Pixie A. Hamilton, May 2007; *http://water.usgs.gov/nawqa/xrel.pdf*

USGS. 2007. T*he Quality of Our Nation's Waters: Pesticides in the Nation's Streams and Ground Water,* 1992–2001. Available at: *http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291.pdf*

Solley, W. B., R. R., Pierce, and H. A. Perlman, *Estimated Use of Water in the United States in 1995.* USGS Circular 1200 (1998).

Suggested Reading:

How to Update and Enhance Your Local Source Water Protection Assessments. September 2006. EPA816-K-06-004.

Water Today...Water Tomorrow? Protecting Drinking Water Sources in Your Community: Tools for Municipal Officials. 2004. New England Interstate Water Pollution Control Commission. *http://www.neiwpcc.org/sourcewateroutreach/index.asp*


Photo: Joshua McDill

A recreational area of Barton Springs, Austin, Texas. The Barton Springs aquifer is an important ground water resource for municipal, industrial, domestic, recreational, and ecological needs. Approximately 50,000 people depend on water from the aquifer as their sole source of drinking water. Various spring outlets are the only known habitats of the endangered Barton Springs salamander. However, the amount of ground water available to meet current and future needs is limited, owing to the combined effects of drought and substantial pumping. A 2004 report by the Barton Springs/Edwards Aquifer Conservation District evaluated the potential impacts on ground water availability in the Barton Springs segment of the aquifer during a recurrence of drought-of-record (1950s) conditions and various rates of pumping. Results indicate that water levels and spring flow would be significantly impacted—wells going dry, water levels dropping below pump levels, intermittent yields. In addition, there is the potential for saline water to flow from the saline-water zone into the freshwater aquifer, which would affect water supply wells and endangered species. *Source: http://www.bseacd.org/graphics/SYM_Final_Report.pdf*

Ground Water & Land Use Planning and Development

Ensuring enough quality water to support various land uses and economic development can be the driving force toward increased ground water protection efforts at the local level. As uses change from rural to urban or agricultural to suburban lifestyles, we must pay careful attention to how we modify the natural environment. Land-use decisions that fail to consider the long-term quality, availability, and susceptibility of ground water resources create conditions that contribute to loss of ground water recharge, overuse of water resources, and human health and ecological impacts resulting from ground water contamination. On the other hand, land-use practices that protect and conserve water resources and maintain or even increase aquifer recharge are key to maintaining long-term water availability and economic vitality.

Key Message

Land-use planning and development decisions must routinely take into account such factors as the location, quality, yield, vulnerability, and recharge potential of aquifers and the projected availability of water for the long term. To be truly effective, this information must be incorporated into local comprehensive plans and policies. Fortunately, there is a growing body of land-use tools that provide effective ways to protect ground water and the environment as a whole, and to maintain and improve our quality of life. But it is essential that local decision makers have access to these tools and that they apply them to land-use planning, zoning, and land-acquisition decisions. When they do this, they can effectively protect and sustain their local ground water resources.

A ground water spring emerges from a group of trees at the base of Fredrick's Hill in Middleton, Wisconsin, and flows south through a marsh to Lake Mendota. The marsh is being surrounded on all sides by housing developments. There is concern that paved surfaces and increased ground water pumping will threaten both the spring and the wetland.

Changing the Land-Use Paradigm

"The health of our waters is the principal measure of how we live on the land."

Luna Leopold | Former Chief Hydrologist, USGS

why Land Use matters to ground water…

The long-term viability of any community is dependent on the availability and quality of its water. Many communities throughout the United States are grappling with the challenge of meeting increasing water demands associated with population growth, economic development, and changing trends in water use. Many recognize that the manner in which they develop their local landscape has an immediate and dramatic impact on the quality and quantity of their water resources and that they need to utilize smart growth approaches to development.

Each time the use of a land area changes, it can affect the hydrologic makeup of the landscape. Highways, shopping centers, housing developments, industrial sites, businesses, agricultural operations, golf courses, feedlots, waste disposal sites, airports, ski slopes, and sewer systems (to name a few) have the potential to directly or indirectly impact the quantity or quality of both ground water and surface water.

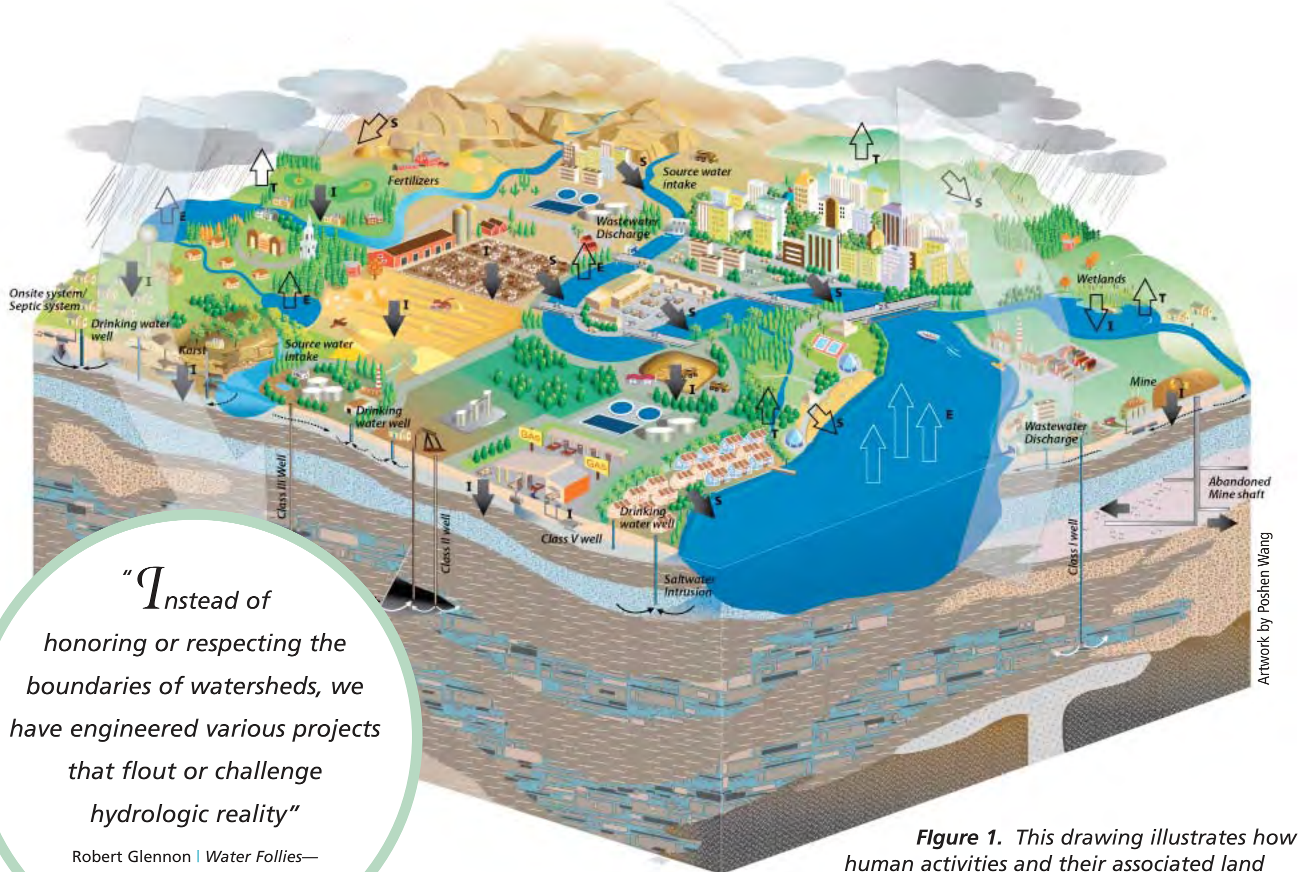
Photo: © 2006 Craig L. Patterson

The subdivision shown here near Belton, Missouri, typifies development patterns throughout the country. Many communities are beginning to realize that it is smart to incorporate ground water protection measures into their local planning and development decisions in order to protect the very resources that sustain them.

These impacts are also cumulative. The more we modify the hydrologic cycle—runoff, evapotranspiration, infiltration—the more we risk reducing or losing water resources over time. The good news is that we can prevent and even repair many of these problems if we act quickly to institute science-based land-use management measures. Often, this is most doable at the local level, where governing bodies have sufficient authority to control land-use activities and conditions that threaten their ground water, particularly if it is an existing or potential drinking water source.

But doing the right thing by source water at the local level can be challenging. In some cases, communities do not have jurisdiction over the recharge areas that influence the supplies of ground water they use. Also, in too many instances there is insufficient guidance,

GROUND WATER INTERACTIONS



"Instead of honoring or respecting the boundaries of watersheds, we have engineered various projects that flout or challenge hydrologic reality"

Robert Glennon | *Water Follies—Groundwater Pumping and the Fate of America's Freshwaters*

Figure 1. *This drawing illustrates how human activities and their associated land development can impact ground water.*

technical and scientific information, and assistance filtering down from the federal, state, and regional levels to the local level to enable the "people in the trenches" to make environmentally sound land-use decisions. Even if this information were available, many communities do not have the level of staff expertise needed to interpret ground water data needed to implement land-use tools for ground water protection.

Our challenge is to ensure that local decision makers have access to appropriate and instructive information that they can actually use. This can be accomplished through partnerships with state planning and environmental agencies and other entities, such as water suppliers, regional planning agencies, local watershed associations, land trusts, and programs such as the National Nonpoint Education for Municipal Officials (NEMO) Network, and the Cooperative State Research, Education, and Extension Service (CSREES).

LAND USE AND THE NATURAL SYSTEM

Many land-development practices reconfigure landscapes and reroute both hydrologic systems and related habitats. For example, when we create new impervious surfaces, such as highways, parking lots, and buildings, and redirect the runoff to surface water, we prevent rain or snow from seeping into the soil and replenishing the underlying ground water. The resulting increased stream flow can cause property damage, stream bank and soil erosion, and water pollution from nonpoint sources as pollutants are swept into both surface and ground water by this runoff from land surfaces.

Intense development can also increase both surface and ground water use, which also modifies the hydrologic cycle. For example, overdraft of ground water leads to reduced stream flow in the surrounding area and can occasionally cause permanent damage to the aquifer owing to land subsidence.

Photo: Aaron Gustafson - http://www.flickr.com/photos/aarongustafson/268094569/in/set-72157594322645277/

Bristol, California.

LOCAL GOVERNMENT—WHERE THE RUBBER MEETS THE ROAD

Stewardship of our nation's ground water resources is the responsibility of all levels of government—but particularly local government. Though federal and state agencies have important roles to play in ground water protection, responsibility for land-use planning and regulations is primarily local. Therefore it is essential that those with the authority to make land-use decisions have access to the kind of information and assistance they need to plan responsibly, make informed decisions, and employ effective ground-water protection strategies.

The day-to-day decisions that affect ground water are typically made by dedicated but sometimes untrained volunteers (e.g., planning commissions and zoning boards, conservation commissions, health boards, wetlands commissions) and in a venue where there is often a high turnover rate. At a time when the importance of ground water is not universally recognized, these otherwise well-intentioned local decision makers may not know how important it is to consider the potential impacts of a proposed land-use activity on ground water. Furthermore, they may lack the proper data to support resource-protective decisions that may be economically or politically unpopular.

Local governments face an abundance of water resource management issues—drought, flooding, development pressure, stormwater and nonpoint-source pollution, cross-boundary water disputes, and limitations on water withdrawal and discharge, including total maximum daily loads (TMDLs). For this reason alone, community leaders need an arsenal of effective and innovative land-use development approaches as they struggle to balance economic growth with natural resource protection and preservation of community character. Natural resource-based planning within a comprehensive, three-dimensional watershed framework is one of the best approaches to achieving that balance.

Recognizing that the economic health and well-being of their communities depend on the sustainability of their water resources, some local officials are, in fact, looking to new approaches to development. By implementing laws and regulations already on the books, they are seizing on their ability to select from a growing collection of methods and technologies that have been developed to accommodate growth without destroying the very resources that sustain their communities. By adopting water policies that promote water-efficient growth, they are effectively taking giant leaps forward in reaching their water goals. In many respects, communities hold the ultimate power to determine the fate of water resources throughout the United States.

Meshing Ground Water Protection with the Planning Process

It is an axiom in planning that *everything is related to everything else.* Thus local governments must think comprehensively and in a long-range framework. This is not something most people do naturally. It's hard to talk about saving land 25 years before it is threatened. It's difficult to think about protecting drinking water if it appears to be just fine. Why make the effort when there are so many other pressing matters? Comprehensive planning provides the community with a road map for getting to its long-term vision for itself. In the absence of such planning, a community can find itself perpetually reacting to undesirable development proposals and ultimately paying a high price to undo the cumulative effects of earlier decisions.

By thinking ahead and comprehensively, those interested in protecting ground water, working closely with urban planners, city managers, and others, can effectively plan for long-term protection. There are several points in the planning process where ground water protection issues and initiatives can be incorporated. These points include:

Visioning—A point in the planning process where local leaders visualize the goals as well as the effects of future actions. Planners, city managers, developers, and utility engineers need to be sure that ground water protection is “on the table” when they conduct long-range visioning processes for their communities, Visioning helps communities account for relationships between issues, avoiding piecemeal and reactionary approaches.

Comprehensive Planning—The framework that informs decisions about where and how development occurs and future public investments, and provides a selection of recommended management tools. Plans should contain meaningful and effective ground water protection goals, strategies, and metrics.

Management Tools—Ordinances, regulations, and incentives that are based on adopted plans.

Site Design and Development Review—A professional and technical review opportunity to provide ground water protection and site-development expertise to the decision-making process so that water resources are not compromised and onsite mitigation measures are encouraged.

Public Investment in Infrastructure—A five-year capital improvements program (CIP). CIPs can include raised and planted medians, neighborhood parks, hazardous-site clearance, expanded and diversified transit, improved walking and biking facilities, urban forestry planning, roof gardens, rain gardens, greenways, upgraded sewer and water facilities, and additional landscaping for streets and sidewalks. These public investments may have a major impact on ground water, either positive or negative.

Land Conservation Actions—Ways to acquire open lands, forested land, or agricultural land either through municipal actions or through private land trusts.

Photo: Stateline.Net - http://www.flickr.com/photos/oldonliner/4259390713/

Planners and facilitators explain planning concepts to citizen participants at the City of Beloit, Wisconsin's, Comprehensive Plan Open House Workshop. Such visioning sessions allow citizens to provide input in identifying priorities for healthy, livable communities early in the planning process.

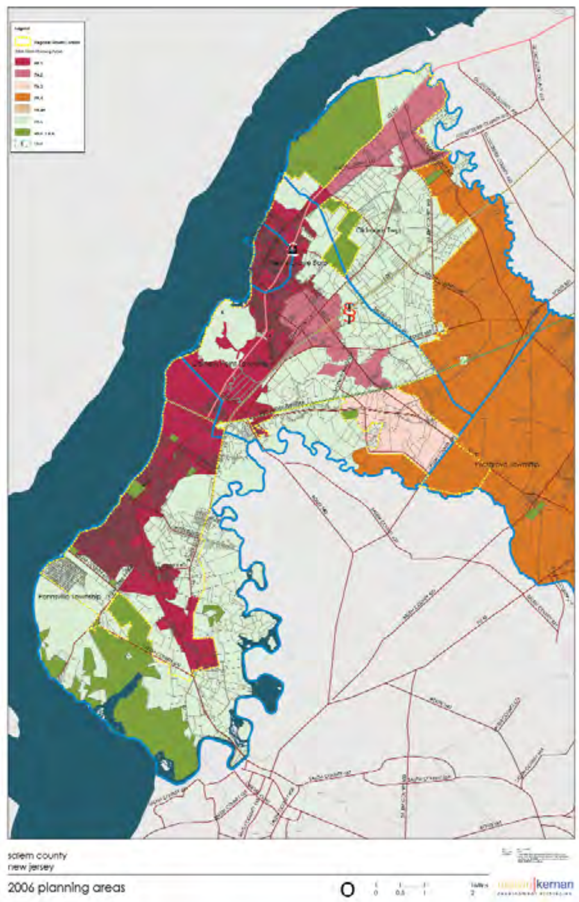


Figure 2. *Salem County, New Jersey's, natural features include six rivers, more than 34,000 acres of unique meadow and marshland, tidal and freshwater wetlands, 40 lakes and ponds, bay beaches, dunes, expansive woodlands, a critical underground aquifer, numerous streams, and important headwaters. County leadership is committed to preserving this rural character and is dedicated to pursuing balanced growth. In this State Plan Policy Map 2006, the growth corridor is shown by the yellow outline. Solid-colored areas indicate the various planning areas.*

Source: http://www.salemcountynj.gov/departments/publicinformationoffice/

LOCAL TOOLS FOR PROTECTING GROUND WATER

Using comprehensive long-term planning that incorporates water resource protection and infrastructure needs and availability, communities can: (1) encourage development in areas with adequate infrastructure and steer it away from sensitive natural areas such as ground water recharge areas; (2) integrate water budgeting into land-use planning; (3) ensure that developers put forward designs that reduce water demand per unit of development; and (4) implement land-management practices that preserve ground water recharge areas and help minimize the risk of ground water contamination.

Photo: Paul Locke

City of Melrose, Massachusetts, Towner's Pond conservation land.

The following are examples of land-use planning tools local governments can use to protect ground water quality and quantity.

Comprehensive Plan—A community's official long-term vision for growth and development. Water resource protection goals should be clearly established in the plan. The most effective comprehensive plans integrate smart growth and water budget policies into their overall goals and objectives.

Designated Growth Area or Urban Service Boundary—A designation used to steer development toward areas with adequate infrastructure and away from sensitive natural areas.

Zoning Ordinance—The primary means by which communities control the type of development allowed in a particular area. The designation of permitted uses allows a community to, among other things, control incompatible uses, the size of open space, and population density; promote public health and welfare; and protect water resources. Zoning can help control ground water resource degradation within wellhead protection or ground water recharge areas.

Overlay Protection Zone—A zone designated by a community (e.g., wellhead protection zone) that can be used as a basis for restricting the locations and/or controlling the design, operation, and management of high-risk land uses. This tool is similar to zoning regulations in its goal of defining the resource (e.g., watershed, recharge area) where development and high-risk land uses would threaten water quality.

Transfer of Development Rights—A plan prepared by a government entity designating land parcels from which development rights can be transferred to other areas. This allows for a variety of land uses (e.g., a gas station) while assuring that these uses are outside sensitive areas.

Special Permit—A type of permit that can be required to regulate certain uses and structures that may potentially degrade water and land quality.

Development-Impact Fee—A fee allocated and charged on new development for a pro rata share of infrastructure and governmental services. This can include financial consideration of additional water costs.

Tax Benefit to Landowners—A compensation (e.g., transfer of development rights, reduced property taxes) for preserving key watershed, ground water recharge, and other natural areas.

Growth Control/Timing—A tool that can be used to guide a community's growth, ideally in concert with its ability to support growth. The availability of ground water is an important consideration.

LOCAL TOOLS FOR PROTECTING GROUND WATER (continued from page 6)

Underground Storage Tank (UST) Regulations—These measures are often adopted to enhance local water resource protection. They include prohibiting new residential USTs, removing existing residential USTs, and prohibiting new UST installations in ground water and surface water management areas.

Well Construction/Closure Standards—Standards for new well construction and for identification and closure of abandoned wells to prevent ground water from being contaminated. Well bores are a direct conduit to ground water.

Non-Zoning Ordinances and Codes—Many communities have the ability to adopt ordinances or codes that are designed to protect water resources. For example, ordinances can be written to tie development to sustainable water availability; promote water conservation by allowing for water rationing or conservation rates; or allow or require water reuse and gray-water use that is protective of ground water. Plumbing codes can be modified to allow water reuse or protect against potential ground water impairment.

Subdivision and Site-Plan Review Regulations—An authority that allows communities to set design and engineering standards and construction practices that must be met for subdivision and site-plan approval—powerful tools for controlling stormwater runoff and soil sedimentation and erosion.

Low Impact Development (LID) Techniques—The use of various site-design practices to conserve and protect natural resource systems and reduce infrastructure costs. This is a highly effective and creative approach to controlling nonpoint source pollution and preserving ground water recharge while also considering ground water quality.

New Approaches to Stormwater Management—Stormwater best management practices (BMPs), stormwater utilities, and stormwater management plans that are designed to conserve and protect both surface water and ground water and promote natural ground water recharge. (These approaches go hand in hand with LID techniques.) Ordinances that discourage the creation of additional impervious surfaces, encourage narrower street widths and natural stormwater management systems (e.g., grassy swales), and allow home clustering and other environmentally sensitive design techniques can help increase ground water recharge and at the same time manage its quality before it recharges aquifers.

Multiyear Capital Improvements Program (CIP)—A long-term planning technique that can be used as a ground water protection tool. Resource-protective components might include neighborhood parks, raised and planted street medians, expanded and diversified transit, improved walking and biking facilities, urban forestry planning, roof gardens, greenways, and upgraded sewer and water facilities.

Critical Ground Water Areas for Land Conservation—Acquiring land or conservation easements of open lands, forested land, or agricultural land either through municipal actions or private land trusts. Ways to secure land for conservation include purchasing land or development rights, targeting subdivision open space areas identified in a town open space or comprehensive plan, and using conservation easements, tax benefits, partnerships with land trusts, or transfer of development rights.

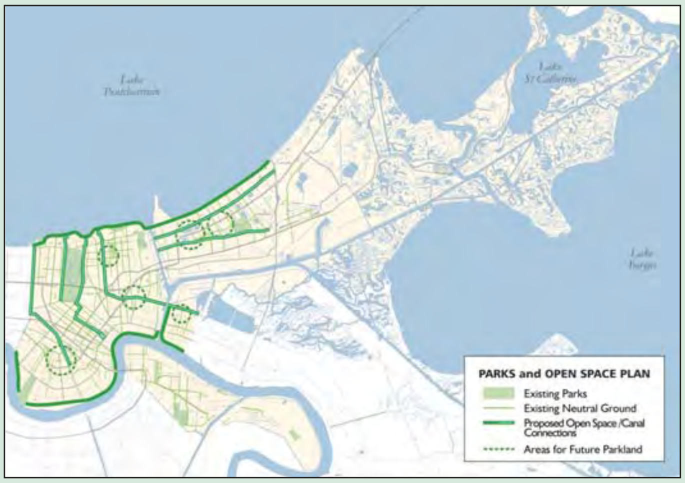


Photo: Bring New Orleans Back Commission
http://www.bringneworleansback.org/

Critical ground water areas can be identified and prioritized when planning for city parks and open space. This is the Parks and Open Space Plan for New Orleans, Louisiana.

THE BEAUTY OF "BROWNFIELDS"

A brownfield is generally defined as an abandoned or underused industrial or commercial property where redevelopment is complicated by actual or perceived environmental contamination. Brownfields vary in size, location, age, and past use, and can range from a small, abandoned corner gas station to a large, multi-acre former manufacturing plant that has been closed for years. These properties typically have lower levels of contamination that can be successfully addressed using standard environmental cleanup practices, but they are often stigmatized based on their past use. Cleaning up and reinvesting in these properties can take development pressure off of undeveloped, open land, and both improve and protect the environment.

USEPA's *Ground Water Use and Value Determination Guidance* (*http://www.epa.gov/region1/brownfields/guidance/grndwter.htm*) combines the goals of two major regional initiatives: the Superfund Beneficial Reuse Initiative and the Comprehensive Ground Water Protection Strategy. As part of the Superfund Beneficial Reuse Initiative, this guidance is intended to result in more informed and focused decision making, and more common sense, cost-effective ground water cleanups that will facilitate the beneficial reuse of contaminated properties.

Growing Recognition of the Value of Brownfields

Redeveloped, brownfields can:

- Be catalysts for community revitalization.
- Restore urban property to productive use, thus increasing property values.
- Increase job opportunities and local tax revenues.
- Improve public health and the environment.
- Utilize existing public infrastructure.
- Eliminate neighborhood blight, thus improving a community's image and long-term sustainability.

Whereas in the past developers avoided these contamination hotspots, in recent years they have been more willing to work with state and local entities to find mitigation solutions in order to revitalize these properties. For example, whether developers receive state assistance or strike deals with other private parties to attend to contamination, they must address liability concerns. Getting financing is often difficult without some assurance that a property will not be haunted later by environmental liability. Many state environmental agencies now agree to write "comfort letters" to help establish whether environmental conditions at the site might be a barrier to redevelopment or transfer and ease liability concerns.

Photo: Mike Burns - http://www.flickr.com/photos/eklektikos/222507252/

Redevelopment area of Dubuque, Iowa.

Photo: Todd Ehlers - http://www.flickr.com/photos/eklektikos/222507252/

Eagle Point Park, Dubuque, Iowa.

The revitalization of this brownfield area (left) can help direct growth in already developed areas, allowing critical undeveloped areas to stay preserved as open space and protecting valuable ground water recharge areas such as Eagle Point Park in Dubuque, Iowa, pictured on the right.

GROW SMART WITH GROUND WATER IN MIND

"Smart growth" is emerging as a key approach to protecting ground water from development. It is an approach that serves the economy, the community, and the environment as an alternative to sprawl. It takes the terms of the development debate away from the traditional question of growth versus no growth to how and where new development is best accommodated while preserving ground water and other natural resources.

Photo: Village Habitat Design, LLC

An organic garden that is part of a preserved open space designed into the East Lake Commons in Decatur, Georgia.

Smart growth is about what people want their communities to be like—places to gather, vibrant streetscapes, transportation choices, residential choices. Ground water protection is just one benefit of following smart growth principles. These development practices support environmental goals by preserving open spaces and parkland and protecting critical habitat; improving transportation choices, including walking and bicycling; promoting brownfields redevelopment; and reducing impervious surfaces in order to improve water quality and help ensure adequate water supplies.

Smart growth is also about finding new ways to develop resourcefully and cost-effectively. Studies show that compact growth can help communities reduce water demand and save on water delivery costs. For example, encouraging compact development in areas where infrastructure already exists can ease both the demand for, and the cost of, water. Smaller lots mean less per capita demand. If development takes place in areas that are already served by existing services, then replacing and repairing that service system accomplishes two goals: it serves new customers and maintains service standards for established customers.

Smart Growth Principles for Protecting Community Water Resources

- Establish community goals for water resources in the three-dimensional watershed.
- Direct development where most appropriate for comprehensive watershed health.
- Minimize adverse impacts of development on watershed health, including ground water.
- Promote opportunities for restoration (e.g., brownfields redevelopment).
- Assess and prevent unintended consequences of federal, state, and local decisions affecting three-dimensional watershed health.
- Plan for safe, adequate, and affordable water supplies as an integral part of growth.
- Consider the cumulative impacts of growth-management decisions on the three-dimensional watershed.
- Monitor and evaluate the success of initiatives.

Adapted from USEPA. Protecting Water Resources with Smart Growth, May 2004.

Today, successful brownfields projects are cropping up all over the United States. For example:

- **Jackson, Mississippi,** is revitalizing its downtown and preserving its heritage by cleaning up and redeveloping sites in the city's historic district—the oldest post-emancipation African-American residential and commercial area intact today. The project strategy will include selecting and assessing 100 sites, identifying redevelopment barriers, developing a comprehensive redevelopment plan for the sites, ensuring community involvement, and coordinating cleanup activities.
- HarborPark in **Kenosha, Wisconsin,** is a 69-acre redevelopment on the lakefront site of a former AMC-Jeep factory. The site is bounded

by downtown Kenosha, Lake Michigan, and the Southport Marina, which blends park and open space development with a new public museum, new residential housing, and a planned commercial district. With extensive community input, HarborPark provides year-round lakefront enjoyment including a public gathering space, public transportation via a trolley system, and pedestrian and biking paths.

- **Dubuque, Iowa,** underwent a transformation with the redevelopment of its port and waterfront area. Situated on the banks of the Mississippi River, Dubuque's once vibrant industrial and manufacturing port area fell into decline and disrepair. The city's efforts to redevelop the waterfront have turned the area into America's River Campus, complete with entertainment and recreational venues such as the Grand Harbor Resort and Waterpark, a riverfront casino, plaza, amphitheater, as well as open space and natural recreational areas. The city is using a federal brownfields cleanup grant to address a petroleum plume—resulting from former use as an aboveground petroleum storage tank yard—that is contaminating a five-acre area between the hotel and the riverfront casino. Petroleum hydrocarbons exist in the soil and ground water, and in order to return this property to productive use, cleanup was deemed necessary.

WHAT DO LOCAL GOVERNMENTS NEED TO KNOW ABOUT GROUND WATER?

Local land-use decision makers need access to a range of water resource information so they have the tools to make land-use decisions that are based on a plan, and so they can effectively use other land-use tools, such as subdivision and zoning ordinances.

Technical information is necessary to determine:

- Where ground water resources are located (both current and future sources of drinking water and ground water resources that may be more suitable for other uses).
- Where ground water/surface water interaction is occurring.

GROUND WATER RECHARGE IN SUSSEX COUNTY, NEW JERSEY

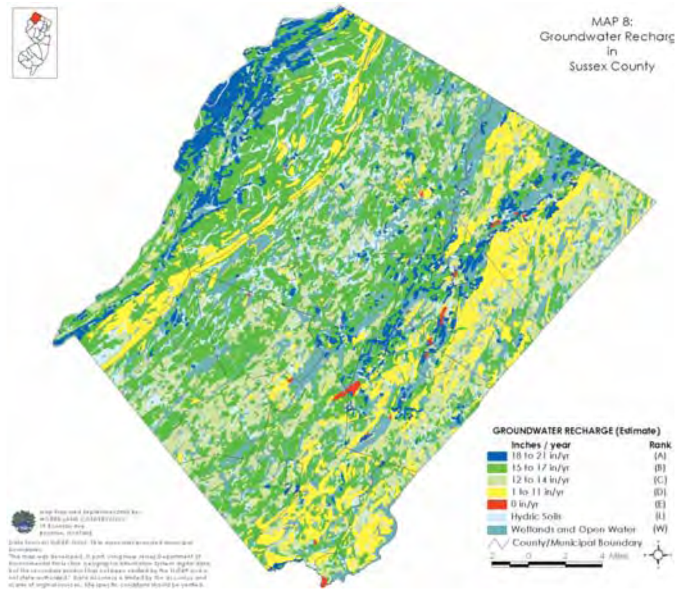


Figure 3. *Highest ranking estimated ground water recharge is shown in blue and green (18 – 21 inches per year and 15 – 17 inches per year, respectively) with areas of lowest estimated recharge of 0 inches per year shown in red. Local governments need mapping information, such as recharge areas and aquifer vulnerability, as well as land use information that indicates potential sources of contamination in order to plan effectively with ground water resources in mind.*

Source: Morris Land Conservancy 2003. http://www.morrislandconservancy.org/JPG/Groundwater%20Recharge%20in%20Sussex%20County.jpg

- How much ground water is sustainably available for human uses.
- How much ground water is needed to sustain healthy ecosystems.
- The location of ground water recharge areas.
- The quality of ground water and the most appropriate uses for the varying quality of ground water.

Tools such as Geographic Information System (GIS) overlay maps and remote-sensing technologies are particularly valuable for developing or revising comprehensive plans. Ground water characterization, monitoring information, data collection, and data analysis within delineated watershed boundaries are also key to an efficient and effective ground water management program.

PROTECTING GROUND WATER RECHARGE AREAS IN NEW CASTLE COUNTY, DELAWARE

Since the late 1980s New Castle County has enacted measures to protect both ground water recharge areas and wellhead protection areas. Key components of this program include detailed and updated maps that are readily available to the public and to developers; limits on impervious cover within protected areas; prohibitions on storage of hazardous substances; options for flexibility, including developing clean ground water recharge basins; and the use of a technical advisory committee to advise the county on specific cases. The advisory committee meets monthly to advise the county on proposed developments within the critical areas to assure that the ground water resources are maintained at predevelopment quality and quantity.

TEMPLATES FOR LOCAL GROUND WATER PROTECTION

There many examples of material that has been developed to assist local governments in protecting their water resources. Here are four excellent examples:

Georgia's *Water Resources Toolkit for Local Governments*

Georgia's *Water Resources Toolkit for Local Governments* website brings together a wide variety of useful information to help address the issues facing local governments. It is a basic educational tool for local officials and employees new to water resource management and, because of its comprehensive nature, is also a valuable resource for elected officials and water resource staff already familiar with water management concerns.

The website pulls together a wealth of resources to help local government officials address water management issues and relies heavily on the resources found on the Internet. This site will provide users access to the most current regulatory, educational, and decision support information available. It also provides users with a brief introduction to the issues as well as links to additional information. It would be impossible to provide sufficient printed information to adequately cover all the topics that are presented in the site.

To visit the website, go to: *http://www.georgiaplanning.com/watertoolkit/main.asp?PageID=3*

LGEAN's Long-Term Hydrologic Impact Assessment (L-THIA) Model

The Local Government Environmental Assistance Network (LGEAN), located at Purdue University, has developed a "Long-Term Hydrologic Impact Assessment" (L-THIA) model to assist local officials in considering the impact that land-use changes will have on a community's water quality. The model was developed as an accessible online tool that can be used to generate community awareness of potential long-term problems and to support planning aimed at minimizing disturbance of critical areas. The L-THIA model is packaged in the following ways, based on level of detail:

- **Basic L-THIA—**Users need only to input their location, soil type, and the type of land-use change taking place.
- **Impervious L-THIA—**Allows users to input the percentage of impervious cover of different land uses.
- **GIS L-THIA—**Enables users to download an ArcView GIS version of L-THIA for PCs.
- **Detailed Input L-THIA—**Enables users to input detailed and customized land uses.
- **Advanced Input L-THIA—**Enables users to input detailed and customized land uses and customized pollutant coefficients

To visit the website, go to:
http://www.ecn.purdue.edu/runoff/lthianew/

Community Planning & Zoning for Groundwater Protection in Michigan— A Guidebook for Local Officials.

This excellent guidebook was written by Lillian F. Dean and Mark A. Wyckoff for the Office of Water Resources, Michigan Department of Natural Resources. It was printed by the Michigan Society of Planning Officials (MSPO) with funding assistance from the W.K. Kellogg Foundation under the Groundwater Education in Michigan (GEM) program. The GEM project provides assistance and resources to organizations, schools, colleges, and elected officials around the state to stress the importance of ground water protection. MSPO uses the guidebook as a valuable reference in its courses for planning and zoning officials.

Access the guidebook at: *http://www.vbco.org/planningeduc0029.asp#INLINK002*

The Land Information Access Association's Community Information Systems

Land Information Access Association (LIAA), a nonprofit organization in Traverse City, Michigan, provides citizens and public officials access to information about the cultural and natural resources of their communities and provides tools necessary for informed land-use planning. LIAA's program

ILLINOIS STATEWIDE POTENTIAL FOR AQUIFER RECHARGE

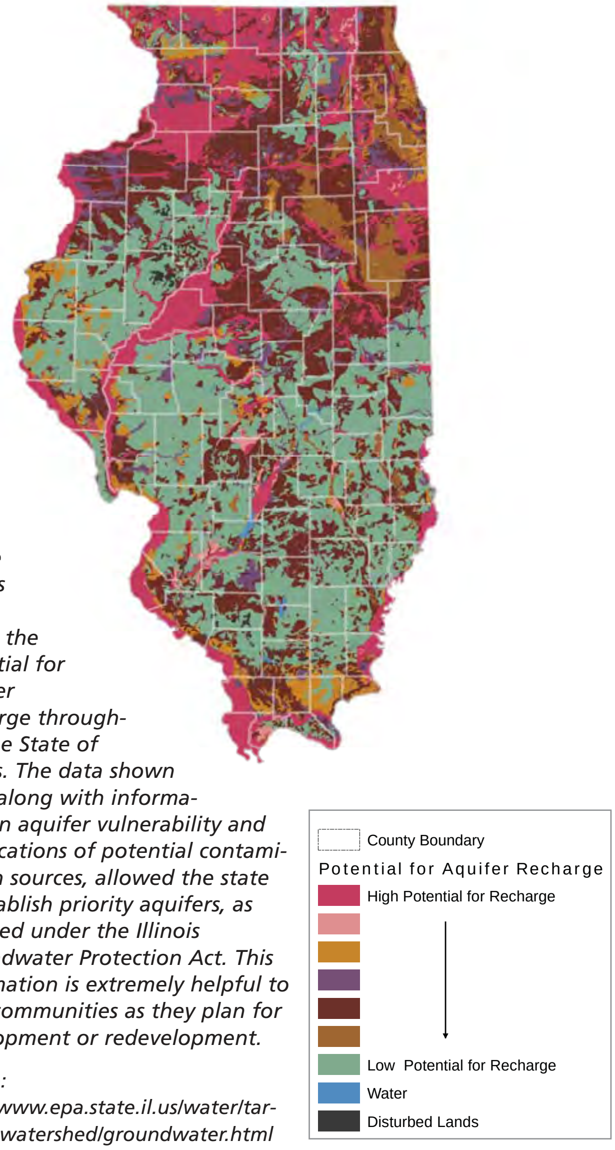


Figure 4. *This map shows the Potential for Aquifer Recharge throughout the State of Illinois. The data shown here, along with information on aquifer vulnerability and the locations of potential contamination sources, allowed the state to establish priority aquifers, as required under the Illinois Groundwater Protection Act. This information is extremely helpful to local communities as they plan for development or redevelopment.*

Source: http://www.epa.state.il.us/water/targeted-watershed/groundwater.html

Memphis, Tennessee, audience listens to their mayor's vision for the city at a Greening Greater Memphis Summit in February 2007. Groups and citizens signed a manifesto signifying their support and commitment for creating a region that is competitive, healthy, safe, and environmentally wise through the creation of more parks, greenlines, greenways, and outdoor recreation.

Photo: Gary Bridgman - http://www.flickr.com/photos/wolfriver/41221805З/in/photostream/

Photo: Bill Vedra

Ohio sprawl.

"Building a Sense of Place" involves the development of Community Information Systems (CIS). CIS has enabled communities throughout Michigan to set up a number of innovative information resources, including touch-screen information kiosks and multimedia presentations on CD-ROM. CIS can deliver zoning ordinances, photographs of sites, information about local history, and links to local and regional agencies. Citizens can view community information contained in various databases of local, county, and state agencies. LIAA also works to make Geographic Information Systems (GIS) data available for a range of citizen needs.

For more information, go to:
http://www.smartcommunities.ncat.org/toolkit/TCDDM/LIAA.htm

THE STATE ROLE IN LAND USE

Most state agencies recognize the pivotal role local governments play in managing water resources, and some states are more enabled than others to drive or assist in local planning decisions that further ground water protection. In its 2001 report *Environmental Protection: Federal Incentives Could Help Promote Land Use That Protects Air and Water Quality,* the U.S. General Accounting Office (GAO) reported that most states and localities do not comprehensively assess the impacts of existing land use or future development on water quality and systematically factor such analysis into water quality protection and improvement plans. The relatively few jurisdictions that have the necessary resources and support from local decision makers and the public are more likely to do this.

Clearly, the more support local governments can get from state and regional agencies and research institutions the better. The GAO report specifically points to the lack of funding, technical staff, and public and official support as important impediments to a greater assessment of the impact of land use on water quality. It says that analyzing the impacts of existing and future land uses on water quality is technically difficult and resource-intensive, and that neighboring jurisdictions often do not have, or will not share, funds and staff. The report also notes that "many local development codes, zoning laws, and building ordinances, as well as much state-planning legislation, are outdated, are not based on a consideration of the need for environmental protection, and do not allow for more innovative land-use practices that protect water quality."

The report adds that while some jurisdictions with sufficient resources and public and official support have begun to employ land-use management practices and development strategies that limit adverse effects on water quality, many local land-use decision makers do not understand the relationship between their decisions and water quality, or they feel pressure to focus on economic development rather than environmental concerns.

Public agencies and research institutions that collect and analyze water-related data and other information can and should leverage their efforts by routinely making relevant material available to municipal land-use decision makers. Local governments also need the wherewithal to use this information. Geographic Information Systems (GIS) and other tools help local land-use decision makers recognize the spatial link between land use and water resources and visualize the impacts of alternative land-use planning scenarios.

The states are key to supporting and bolstering local land-use decisions. Through statutes, planning enabling legislation, policies, model ordinances, and guidelines, states have varying means to:

- Address specific ground water management goals.
- Require state review of certain types of development proposals in order to:
  - encourage development practices that limit threats to ground water.
  - evaluate water usage/demand as well as water quality impacts.
  - educate planning and zoning boards on sensitive source water protection areas.
- Require local authorities to control potential contamination sources by:
  - establishing mechanisms such as construction standards, operation and maintenance standards, performance standards, and siting criteria.
  - providing educational and technical assistance and financial and other economic incentives for encouraging ground water protection.

States can enact statutes that enable (or require) local governments to make use of innovative land-use controls to meet certain ground water and other water resources objectives. It is important that state legislatures provide these specific powers statutorily so that communities have the legal backing if they elect to move ahead with their own ordinances. A number of states are moving toward enacting statutes that call for adoption of "smart growth" principles that promote a more rational use of existing developed land and buildings in order to preserve natural, scenic, and historic resources.

COORDINATION OF STATE GROUND WATER PROTECTION PROGRAMS WITH OTHER PROGRAMS

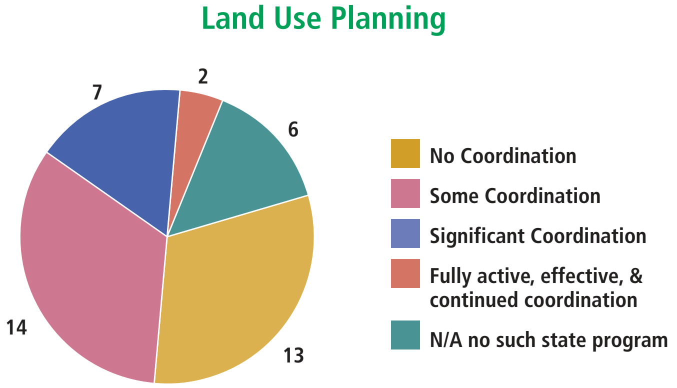


Figure 5. *Only 2 of 42 state ground water programs reported having fully active, effective, and continued coordination with their own state-level land-use planning program, while 13 states reported no coordination at all between the ground water protection and land-use planning programs at the state level.*

Source: GWPC-NGWA Survey of State Ground Water Programs, 2006.

States originally passed enabling legislation that gave local governments various types of permission to plan, but they did not require it. This generally

Photo: Ian T. Farragher

Ground water is one of North Dakota's most valuable resources. It is considered essential for maintaining sensitive aquatic ecosystems (e.g., rivers, lakes, wetlands), industry, agriculture, small communities, and private homes. As communities continue to grow, they will need to give serious consideration to how new development will impact local ground water resources and adopt strategies and tools to protect ground water in order to sustain long-term economic and environmental viability.

followed the model State Planning Enabling Act developed in the 1920s. Since then, many states have chosen to require one or more categories of local government to develop local comprehensive plans. Most states list elements that should or must be in a plan. The level of specificity and detail varies widely. *(http://www.ibhs.org/publications/downloads/20070327_095149_22013.pdf)*

How Can States Set the Stage for Water Resource Protection?

There are many examples of state-level planning requirements and guidance that advance the cause of water resources protection. Here are some examples from Florida, Arizona, and Colorado.

Florida: Preservation 2000 Program

In Florida the purchase of natural, environmentally sensitive areas by both state and local governments has been the most successful land-use measure taken in protecting the state's vulnerable areas. Concerned that at the 1990 rate of development, some three million acres of wetlands and forests would be converted to other uses by the year 2020, dooming much of the state's freshwater aquifer recharge areas, unique ecological diversity, open space, and recreational lands, as well as many of the state's 548 species of endangered and threatened animals and plants, Florida lawmakers determined that the single most effective way to accomplish large-scale gains in the state's environmental well-being would be to substantially increase the level of funding for the state's land-acquisition programs. Thus Preservation 2000 (P2000), the most ambitious land-acquisition program in the United States, was created, establishing a mechanism for supplemental funding of existing land acquisition programs.

So far, P2000 has preserved more than 1.75 million acres of conservation land throughout the state. The program has been successful in saving many of Florida's unique and fragile environmental habitats and spawning local community conservation efforts. More than 20 local governments have matched state funds to purchase environmentally sensitive lands to fulfill their conservation needs. (Source: *http://www. dep.state.fl.us/lands/acquisition/P2000/BACKGRND.htm)*

Another Florida program more directly related to ground water is the "Spring Initiative Program," which allocates money to conduct hydrogeological research and to help in writing protective statutes and regulation to protect spring sheds in Florida, including submarine springs.

Arizona: Groundwater Management Act

Rather than rely on water markets, a public trust doctrine, or some combination of the two, several jurisdictions around the country have crafted policies that specifically require a link between water availability and development. Perhaps the most sweeping such policy is Arizona's Groundwater Management Act (GMA), adopted by the legislature in 1980 in response to a growing concern over pumping and using ground water at a rate faster than it can naturally replenish itself. Ground water is the source for about half of the total annual demand for water in the state. Like most western states, agriculture accounts for about 70 percent of water use in Arizona, although this percentage is slowly decreasing as

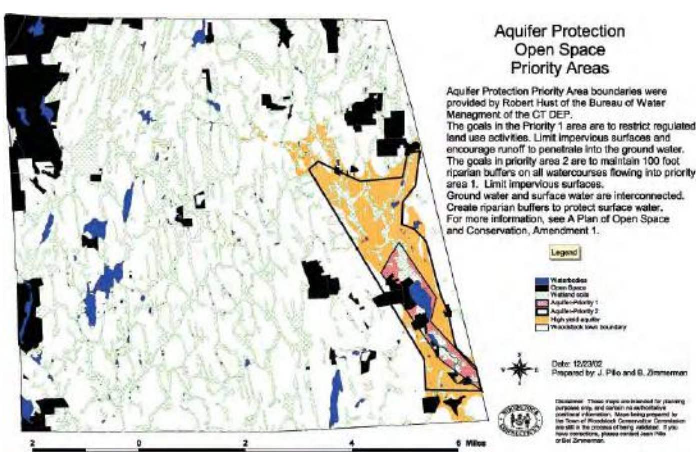


Figure 6. *The Connecticut Aquifer Protection Program recognizes that the most effective way to prevent contamination of the state's most prolific drinking water resources is to control land uses in areas that contribute recharge to the stratified-drift aquifers. In this map, Aquifer Protection Priority Area boundaries were provided to the local community by the Connecticut Department of Environmental Protection. Goals in the Priority 1 area (in pink) are to restrict regulated land-use activities, limit impervious surfaces, and encourage runoff penetration into the ground water. Goals in the Priority 2 area (thick black outline) are to maintain 100-foot riparian buffers on all watercourses flowing into the Priority 1 area and limit impervious surfaces, recognizing the interconnection of ground water and surface water.*

Source: http://www.woodstockconservation. org/images/mapsgif/priority_aquifer.gif

CASE EXAMPLE

THE USDA FOREST SERVICE'S BUDDING GROUND WATER PROGRAM

USDA Forest Service (USFS) lands comprise 193 million acres of forests and grasslands in 42 states and Puerto Rico and encompass the source water areas for many important rivers and local and regional aquifer systems. USFS lands are the largest source of municipal water supply in the United States, serving over 66 million people in 3,400 communities in 33 states. These lands are the largest single source of water in the continental United States—over 14 percent of available supply. At the same time, grazing and logging activities on USFS lands can have a significant effect on the distribution and availability of water. These lands also contain more than 38,000 abandoned or inactive mines and several hundred nonmining Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) cleanup sites.

LAND USE IN GROUND WATER PWS AREAS IN THE STATE OF MAINE

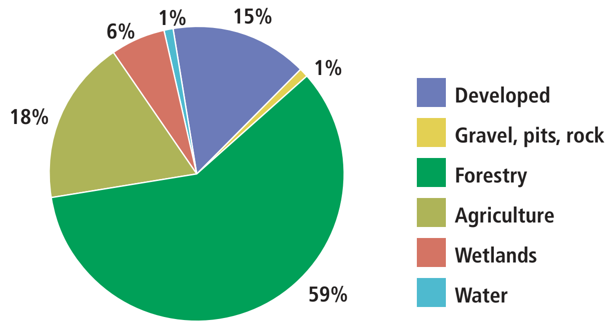


Figure 7. *In Maine, land use in ground water source protection areas, based on an analysis of 1990 imagery, is about 15% developed, and almost 20% agriculture.*

Source: http://www.maine.gov/dhhs/eng/water/forms/Sections/Resolve029finalrpt.htm

The USFS Ground Water Program

The USFS has been experiencing increasing water development pressures on its lands and has recognized the need to take a more comprehensive view of its water resources and agency responsibilities, as well as build its in-house technical capacity. Thus, overcoming a 100-year orientation toward surface water, the agency initiated a ground water program in 2005. The program is organized around management of ground water–dependent resources and is conceptualized as a cooperative resource management effort with states, providing project-level technical assistance where needed.

While recognizing its ground water responsibilities, the agency has limited staffing, no specific ground water funding, and limited knowledge of the existing ground water resource base. Nevertheless, the USFS is working to strengthen its program by:

- Establishing a clear internal policy.
- Educating USFS decision makers.
- Developing cooperative inventory and monitoring efforts for USFS ground water resources.
- Educating the public on the importance of ground water resources on public lands.
- Instituting constructive dialogue between the USFS and states on cooperative ground water resource management and national ground water issues.

The USFS Technical Guide to Managing Ground Water Resources is now available at:

http://www.fs.fed.us/biology/resources/pubs/watershed/groundwater/ground_water_technical_guide_fs-881_march2007.pdf

municipal demand increases and the agricultural economy declines.

The GMA created four "active management areas" (AMAs) around the state's most populous areas. The primary intent of the GMA is to sustain a long-term balance between the amount of ground water withdrawn in each management area and the amount of natural and artificial recharge. This is accomplished through a combination of mandatory water conservation requirements and incentives to augment existing supplies. To help achieve the goal of "safe yield," the GMA prevents new subdivisions from being approved in AMAs unless developers can prove that renewable water supplies are available for 100 years. Water managers in the state say the program is responsible for much of the substantial progress that has been made in fast-growing municipalities to move away from ground water overdraft toward renewable water supplies, including water from the Colorado River and reuse of effluent. (Source: *http://www.lincolninst.edu/pubs/PubDetail.aspx?pubid=794)*

Colorado: Extraterritorial and Cooperative Powers for Municipalities

Colorado has placed the majority of has placed the majority of land-use responsibility and control at the local (county and municipal) level of government. For example, county and municipal planning commissions are required to prepare and adopt a comprehensive plan for the physical development of their jurisdictions. They also have broad authority to plan for and regulate the use of land, with no prescribed restrictions, conditions, or procedures.

In addition to the more typical statutes regarding the use of land within respective jurisdictions, the state has other statutes that give one jurisdiction certain powers over land-use activities in a different jurisdiction. Specifically, a municipality may construct waterworks outside its boundaries and protect the waterworks and water supply from pollution (up to five miles above the point from which the water is taken). Also, a municipality may establish, manage, and protect its park lands, recreation facilities, and conservation easements (including the water in those parks) located beyond city limits. (Source: *http://www.cde.state.co.us/artemis/loc6/LOC62L222006INTERNET.pdf)*

THE FEDERAL ROLE

USEPA has been active in helping states and communities realize the economic, community, and environmental benefits of "smart growth" by providing communities with information, model programs, and analytical tools; working to remove federal barriers that could hinder smarter community growth; and creating new resources and incentives for states and communities pursuing smart growth. *(http://www.epa.gov/dced/)*

Besides USEPA, other federal agencies that have authorities and activities that can impact ground water include the Bureau of Land Management, U.S. Department of Agriculture (e.g., Forest Service), U.S. Department of the Interior (e.g., National Park Service), U.S. Bureau of Mines, and the U.S. Department of Transportation. Many of these agencies have been directed by Congress to manage lands, in part, for water, watersheds, and streamflows.

PARTNERS FOR LAND-USE DECISION MAKERS

Both states and local governments can and should promote and participate in partnerships among such entities as federal programs, planning regions, academic institutions, developers, nonprofit organizations, land trusts, businesses, construction companies, and others so that all parties work together to achieve comprehensive and effective approaches to maintaining sustainable water quality and quantity. Some examples and their websites are listed below.

NEMO

The National Nonpoint Education for Municipal Officials (NEMO) Network is a confederation of 29 educational programs in 28 states dedicated to protecting natural resources through better land use and land-use planning. *(http://nemo.uconn.edu)*.

Cooperative State Research, Education, Extension Services

The Cooperative State Research, Education, and Extension Service (CSREES) is an agency within the U.S. Department of Agriculture. Natural Resources and Environment is a CSREES broad emphasis area. CSREES conducts its programs primarily in partnership with land-grant university scientists and cooperative extension faculty. *(http://www.csrees.usda.gov)*

The National Rural Water Association

The NRWA is a nonprofit federation of State Rural Water Associations. Its mission is to provide support services to its state associations, which have more than 24,550 water and wastewater systems as members. *(http://www.nrwa.org/au.htm)*

The Groundwater Foundation

This effective nonprofit organization initiated the Groundwater Guardian program and is dedicated to educating and motivating people to care for and about ground water. *(http://www.groundwater.org)*

The National Association of Counties (NACo)

The NACo effort "Using GIS Tools to Link Land-Use Decisions to Water Resources Protection" is supported by USEPA and is designed to help county officials learn more about tools that model how different decisions influence the various systems in their community. Often dubbed "decision-support systems," these geographic information system (GIS)–based tools work by bringing together data and models to create real-life scenarios depicting the benefits and consequences of various decision options. *(http://www.naco.org/Template.cfm?Section=New_Technical_Assistance&template=/ContentManagement/ContentDisplay.cfm&ContentID=21158)*

Photo: Robert Whitlock

Walking around Olympia, Washington, photographer Robert Whitlock noted: "Seeing this sign conjured up a few questions for me. For example: Why is there a ground water protection area? Is the destruction of ground water, one of our most valuable resources for life (along with air), an acceptable part of the current social and economic systems? What about the cost to future generations? How will recent development around the South Sound affect ground water? Currently, what is (are) the biggest threat(s) to ground waters?"

Land Conservation Partnerships

There are numerous partnership opportunities available to municipalities for protection of their ground water resources through public outreach, implementation support, and access to funding sources. Key among these are state, regional, and local nongovernmental organizations such as land trusts and watershed associations. Many of these organizations are tuned in to a larger support network of organizations with shared land and water protection goals. The following are examples of national land conservation organizations.

- **The Trust for Public Land (TPL)—**The TPL is a national, nonprofit, land conservation organization that conserves land for people to enjoy as parks, community gardens, historic sites, rural lands, and other natural places, ensuring livable communities for generations to come. TPL has played a major role in educating the public on source water protection. (*http://www.tpl.org)*
- **The Nature Conservancy (TNC)—**TNC works to preserve the plants, animals, and natural communities that represent the diversity of life on earth by protecting the lands and waters they need to survive. As one of the nation's preeminent land conservation organizations, TNC operates with the knowledge that unless we protect the natural areas that replenish water supplies, we won't have the water we need for future generations. *(www.nature.org)*

Recommended Actions

To Congress:

- Support and provide funding to the USGS and state geologic surveys and water resource agencies to support increased ground water resource characterization. The availability of this kind of information will enable local and state governments to direct development in ways that are compatible with the quality, availability, and sustainability of water resources.
- Include ground water protection targets and continue to provide funding for federal conservation and revitalization programs (e.g., Environmental Quality Incentives Program, Conservation Reserve Program, Land and Water Conservation Fund, Army Corps of Engineers water resources funds, Urban Parks Restoration and Recovery program, EPA Brownfields grant program, EPA watershed grant programs, NOAA Coastal and Estuarine Land Preservation programs).

To Federal Land Management Agencies (e.g., BLM, Forest Service, USDA):

- Direct program efforts toward managing lands in a manner that is protective of ground water and specifically focus conservation and protection programs on preserving land within critical ground water recharge and source water protection areas.

Photo: Plum Creek www.plumcreektx.com

To USGS:

- Support and conduct mapping of ground water resources for use by local governments.
- Support and conduct research to provide a scientific basis for understanding how specific land-use practices and land-use changes affect ground water, emphasizing local community needs.

To USEPA:

- Enhance EPA Smart Growth/low-impact development outreach and assistance activities and materials to support ground water protection to the same extent as surface water protection, including the following:
  - Support research to provide a scientific basis for understanding how specific land-use practices and land-use changes affect ground water.
  - Encourage state water-quality programs and local governments to utilize available land-use tools to protect ground water.

To Governors and State Legislatures:

- Enact legislation to develop state criteria for local governments to incorporate ground water and source water protection elements into zoning regulations and comprehensive planning processes.

To Local Governments:

- Ensure that land-use policies and plans recognize and incorporate the protection of ground water resources as integral to sustaining the long-term social, economic, and environmental health of our communities.

Section 5 References: Land Use Planning and Development

American Planning Association. *Growing Smart Legislative Guidebook: Model Statutes for Planning and the Management of Change,* 2002 edition (Stuart Meck, FAICP, ed.).

American Planning Association Smart Growth website: *http://www.planning.org/growingsmart/states.htm.*

Nolon, John R. 2002. "Considering the Trend Toward Local Environmental Law." Pace University and *Environmental Law Review.*

USEPA. January 2006. *Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies,* EPA 230-R-06-001. Available at: *http://www.epa.gov/smartgrowth.*

USEPA. May 2004. *Protecting Water Resources with Smart Growth.* EPA 231-R-04-002, Available at: *www.epa.gov/pied page/pdf/waterresources_with_sg.pdf*

USEPA Smart Growth Website: *http://www.epa.gov/smartgrowth/index.htm.*

USGAO. October 2001. *Environmental Protection: Federal Incentives Could Help Promote Land Use That Protects Air and Water Quality.* GAO-02-12.

USGS, 1999. *The Quality of Our Nation's Waters—Nutrients and Pesticides:* U.S. Geological Survey Circular 1225.

Suggested Reading

County Water Quality—Issue Brief: Using GIS Tools to Link Land Use Decisions to Water Resource Protection. June 2007. National Association of Counties. *http://www.naco.org/Template.cfm?Section=New_Technical_Assistance&template=/ContentManagement/ContentDisplay.cfm&ContentID=23928* .

Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies. USEPA, January 2006, EPA 230-R-06-001.

Land Conservation: A Permanent Solution for Drinking Water Protection. The Trust for Public Land.

Smart Growth for Clean Water: Helping Communities Address the Water Quality Impacts on Sprawl—National Association of Local Government Environmental Professionals, Trust for Public Land, and Environmental Research Group.

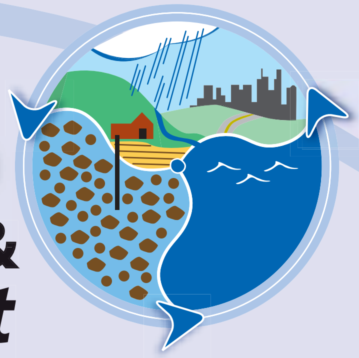
Parking Spaces/Community Places: Finding the Balance Through Smart Growth Solutions. USEPA, January 2006, EPA 231-K-06-001.

Protecting Water Resources with Smart Growth. USEPA, May 2004, EPA 231-R-04-002.

Photo: Payton Chung - http://www.flickr.com/photos/paytonc/79973436/

Suburban Honolulu stretches into the buildable surfaces of mountains and valleys northeast of the city.

Ground Water & Stormwater Management



Key Message

Contaminated stormwater is a major source of ground water and surface water degradation. Furthermore, land-development practices often create impervious surfaces that increase stormwater runoff and inhibit ground water recharge. A combination of approaches is needed to improve runoff quality and maximize quality recharge to ground water. These approaches include preventing the contamination of stormwater, minimizing impervious surfaces, segregating clean and contaminated stormwater, and applying best management practices (BMPs) that promote natural aquifer recharge and treat stormwater sufficiently before it is discharged to ground water.

Top: Construction of buildings, streets, and parking lots prevents rainfall from recharging soil and ground water. It also increases the rate of runoff and contributes to water pollution. This is an aerial view of San Francisco, California.

Left: An unknown number of stormwater drainage wells (UIC Class V) such as this can be found throughout the country, discharging stormwater directly into ground water.

Photo Credits. Top: Copyright © Bruce Molnia, Terra
Left: Oregon DEQ

Keeping on the Sunny Side of Stormwater Runoff

"Local governments nationwide are beginning to utilize Low Impact Development (LID) along with other storm water management approaches to deal with water quality problems associated with urban development and redevelopment. Many have revised their ordinances and building codes and incorporated these concepts into holistic growth-development plans. However, it is critical that they acknowledge and address the potential for transferring a problem from surface water to ground water. The key to protecting both surface and ground water is to make sure that we select best management practices that proactively address the generation and treatment of potential storm water contaminants before they enter the hydrologic cycle."

Mary Ambrose, P.G. | Water Policy Specialist | Texas Commission on Environmental Quality

why Stormwater matters to ground water…

While stormwater runoff is the natural result of a precipitation event, stormwater in urbanized watersheds greatly influences ground and surface water quality and quantity—not to mention the health of aquatic ecosystems. Whether it is rainwater or snowmelt, water has to go somewhere. In natural, undeveloped areas, a large percentage of relatively uncontaminated precipitation infiltrates the ground, thus recharging ground water; the remaining runoff flows to nearby water bodies or evaporates.

Development alters natural systems as vegetation and open spaces are replaced with new areas of impervious surfaces, such as roads, parking lots, roofs, and turf, which greatly reduce infiltration and thus ground water recharge. A much larger percentage of precipitation becomes surface runoff, which moves across land areas at accelerated speeds, creating additional

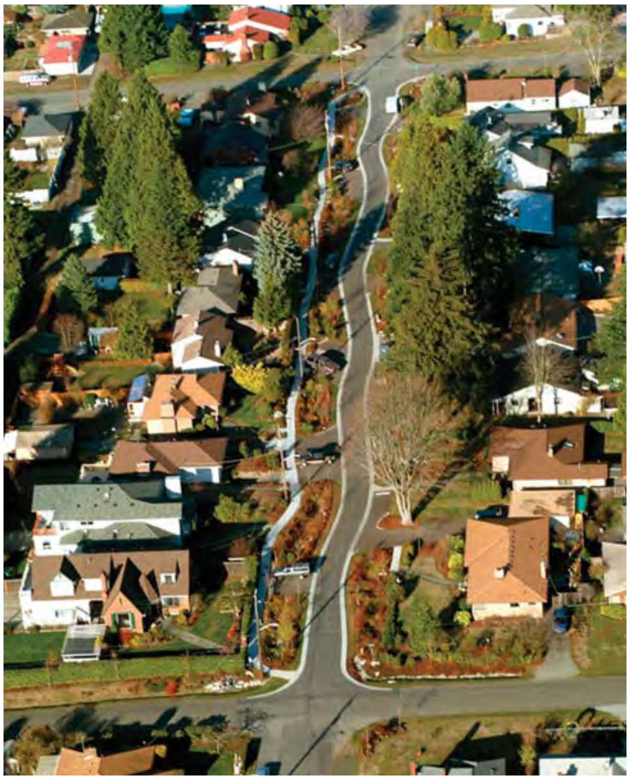


Photo: Stormwater magazine www.StormH2o.com

A redevelopment project in Seattle, Washington, includes a natural drainage system and a site-design strategy to treat and promote onsite stormwater infiltration. Such proactive approaches save communities and property owners money while reducing overall environmental impact.

problems of soil erosion, flooding, and natural habitat destruction. Uncontrolled runoff also collects pollutants such as sediments, pathogens, fertilizers/ nutrients, hydrocarbons, and metals, which ultimately contaminate and degrade surface and ground water.


Photo: Michael Kedzierski

A stormy day in Salt Lake City, Utah.

Historically, stormwater hasn't received the same level of attention as other pollution sources, but it is now clear that this neglect can have serious consequences. So, taking their cue from nature, communities, planners, engineers, architects, and businesses have begun to identify practical ways to restore natural hydrology and prevent the contamination of our water resources.

Photo: Paul Jehn

Many innovative, effective, and earth-friendly stormwater management approaches are in practice already—and more are hitting the streets each day. Federal and state policies, guidance materials, and outreach efforts are turning this corner. USEPA and some states have embraced Low Impact Development (LID), which emphasizes reducing impervious areas, disconnecting impervious areas from one another, and treating stormwater so that it can infiltrate the ground near the source. The real challenge will be to make these approaches standard practice at the local level and to ensure that they are designed and maintained properly so that ground water is not degraded.

STORMWATER IN THE NATURAL ENVIRONMENT

In the natural environmental, the fate of stormwater is influenced by the timing of precipitation and/or melting, and by topography, geology, and land cover. Under natural hydrologic conditions, a large percentage of rainwater infiltrates soil or bedrock and replenishes ground water. Natural physical, chemical, and biological processes cleanse the water as it moves through vegetation and soil. Water that does not infiltrate the soil is taken up by plants (evapotranspiration), runs off into surface waters, or evaporates. Ground water, in turn, discharges to surface waters, such as rivers, streams, lakes, and wetlands. Stormwater is an integral part of the hydrologic cycle and the interplay between surface water and ground water. During periods of dry weather, ground water sustains stream baseflow and helps maintain freshwater wetlands and aquatic habitats.

STORMWATER IN THE URBAN ENVIRONMENT

In urbanized environments, the natural water cycle is drastically altered owing to a reduction in permeable

POTENTIAL STORMWATER IMPACTS TO GROUND WATER QUALITY AND QUANTITY

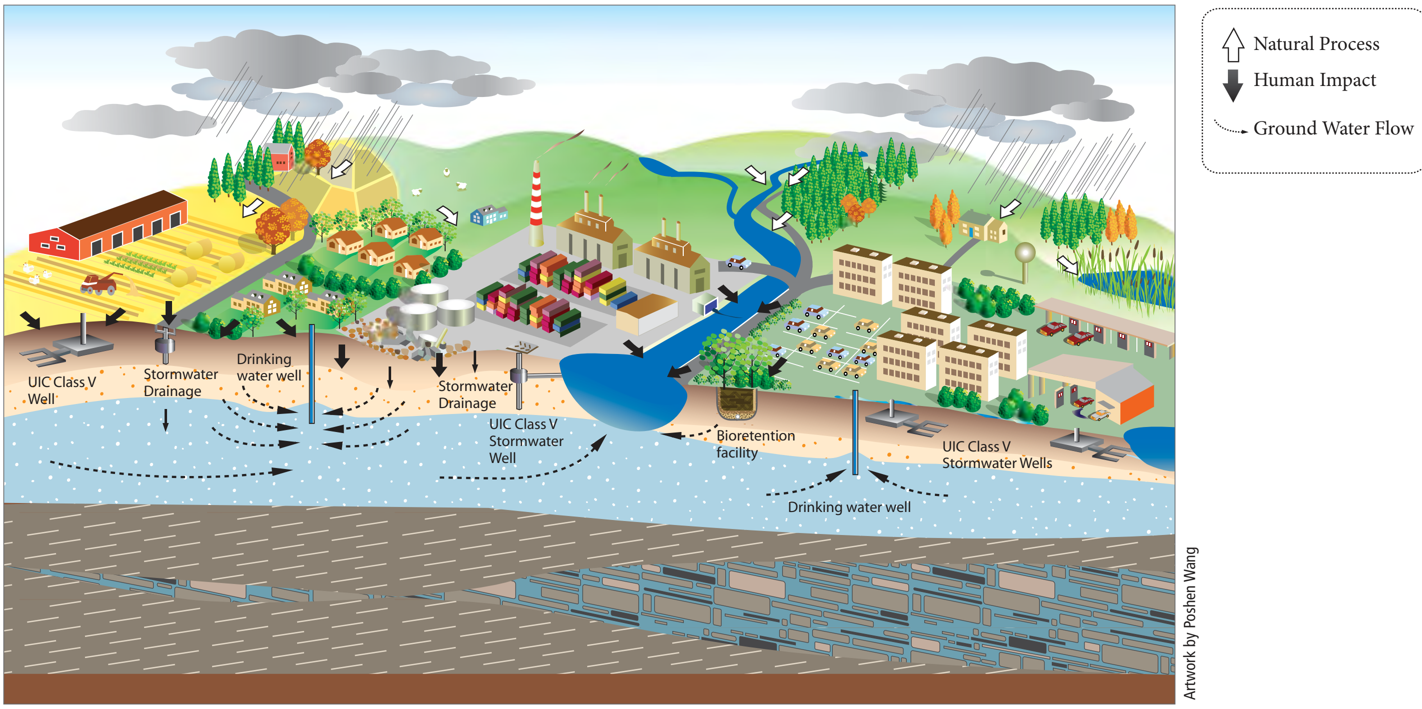


FIgure 1. This diagram shows the many of the potential impacts on ground water from various land use types (e.g., agriculture, suburban, urban, industrial, commercial, protected areas) and the variety of paths contaminated stormwater can take to ground water (e.g., UIC Class V stormwater injection or drainage wells, bioretention facilities, land-surface runoff into rivers and streams, and land-surface infiltration into shallow aquifers). The interconnection between surface water and ground water is also shown as stormwater contaminants move between the two regimes. Showing the location of drinking water sources further demonstrates how stormwater contaminants can influence the water we drink.

areas, such as fields and woodlands, and an increase in impervious surfaces, such as roads, rooftops, sidewalks, parking lots, concrete structures of all sorts, and compacted soils stripped of vegetation. The amount of stormwater runoff and concentrations of contaminants in stormwater runoff tend to increase with population density.

With increased impervious surfaces, less rain soaks into the ground, and less vegetation is available to soak up, store, and evaporate water. Impervious surfaces reduce ground water recharge, which leads to reduced stream baseflows. Impervious surfaces cause an increase in runoff volume and speed, which increases the frequency of high stream flow and associated flooding and erosion. Impervious surfaces also retain heat, which increases runoff temperatures and, in turn, surface water temperatures.

In the developed environment, stormwater also plays an active role in transporting contaminants. As stormwater flows over the land surface, it picks up materials such as debris, chemicals, oil and grease, dirt, road salt, sediment, fertilizers, bacteria, and animal wastes—which then enter water courses or infiltrate to ground water. The longer pollutants remain in the environment, shifting through different phases of the hydrologic cycle and building up in ponds and wetlands and, in some cases, basins designed to control stormwater, the greater the possibility that they will infiltrate and accumulate in ground water over time. Besides increasing pollutant loads in surface and ground water, contaminated stormwater can have adverse effects on people, plants, animals, fish, and the aquatic ecosystem as a whole.

STRATEGIES FOR REDUCING STORMWATER IMPACTS

Traditional stormwater management techniques use devices such as gutters, drains, and pipes to collect runoff from impervious surfaces and convey it to various discharge points, often by way of detention basins or other treatment structures. As a result, large

MICHIGAN GROUND WATER STEWARDSHIP PROGRAM SPREADING THE WORD ON ECO-FRIENDLY LAWN CARE

Half of Michigan's residents rely on ground water for their drinking water. That's why the Michigan Ground Water Stewardship Program (MGSP), within the Michigan Department of Agriculture's Environmental Stewardship Division, has been created as a cooperative effort designed to reduce the risks of ground water contamination associated with the use of pesticides and nitrogen fertilizers. The program is funded through fees that are assessed on sales of pesticides and nitrogen fertilizers. More than $3 million annually is distributed through a competitive grants process to local stewardship teams that set local ground water protection priorities based on local needs.

The MGSP, which is voluntary, locally driven, and designed to address the concerns of individuals, offers community outreach and education throughout the state to address a number of ground water-related issues, including environmentally friendly lawn care. With the goal of educating everyone, not just farmers, MGSP seeks to enlighten residents that what they do on their property can have an impact far beyond it.

Lawn care practices are a major source of stormwater runoff and ground and surface water pollution. Residents learn that fertilizers and pesticides applied on their on land can move off site and eventually get into the waters that make up their watershed. Rather than just putting an ordinance in place, MGSP helps homeowners evaluate their lawn management in light of its impact on water resources. They learn about relatively simple things they can do to help the environment—starting with their own lawns and yards. MGSP's tips include:

- Use native plants to create "rain gardens" near storm drains in their yards and natural buffer strips along shorelines and drainage ditches to filter out pollutants before they reach the watershed.
- Before purchasing fertilizer, have a soil test done to determine soil needs.
- Maintain septic systems properly and locate compost piles far from waterways,
- Cut grass high, at about 3 to 4 inches. (Studies performed at Michigan State University's Hancock Turfgrass Research Center show that with a higher cut, lawn quality is improved and nutrients and other contaminants are kept on the property, rather than running off. A higher cut also reduces weed competition, improves drought tolerance and promotes beneficial insects.)
- Mulch fallen leaves into the lawn and return clippings to the turf to recycle the nutrients.

For more information, go to:
http://www.kbs.msu.edu/mgsp/

volumes of untreated or minimally treated stormwater rapidly discharge into ground and surface waters.

There are better ways to manage stormwater that aim to replicate the predevelopment hydrology of a site. These approaches also seek to mimic nature's processes for treating stormwater. In this scenario, stormwater management becomes an integral part of site and building design, rather than an afterthought.

This new stormwater management paradigm can be found under the umbrella of Low Impact Development (LID), pioneered in Prince George's County, Maryland. LID is a hydrology-based approach to land development that is designed to reduce impacts on watersheds and other aquatic resources through the

A rain garden in the Marcy Holmes Neighborhood of Minneapolis, Minnesota. Rain gardens are designed to slow down, capture, and absorb water using elements similar to those in nature—plants, rocks, shallow swales and depressions—that hold water temporarily rather than let it quickly drain or run off. Rain gardens reduce drainage and flooding problems, keep pollutants out of the nearby streams, rivers, and lakes, and bring beauty and wildlife to the landscape.

Photo: Dawn Easterday

use of a variety of best management practices (BMPs). It is based on the premise that natural systems can accomplish a great deal if they are not overwhelmed with large volumes of stormwater or inordinate pollutant loadings.

A key aspect of LID is reducing the amount of impervious surface on development sites, thus reducing the amount of runoff that must be managed. This approach relies on thoughtful site design, decentralized stormwater management, native vegetation, landscaping, and small-scale hydrologic controls designed to minimize, capture, treat, and infiltrate stormwater.

LID stormwater BMPs can involve one or a combination of strategies. For example:

- Reducing impervious surfaces to decrease surface runoff and promote stormwater infiltration into the ground. This often involves protecting and encouraging trees and open space, minimizing pavement, and using permeable surfaces (e.g., permeable pavement, turf block, gravel).
- Disconnecting impervious areas by directing runoff elsewhere (e.g., directing residential downspouts to landscaped areas or rain barrels, and eliminating roadside curbs, where appropriate, to allow water to run off over the shoulder).
- Intercepting stormwater by capturing rainwater before it comes into contact with an impervious surface (e.g., trees, ecoroofs, roof gardens).
- Detaining and infiltrating stormwater in small vegetated areas, allowing it to soak into the ground or move more slowly into the storm system (e.g., planter boxes, infiltration basins, swales, soakage trenches, drywells, rain gardens).

LID seeks to design the developed environment so that it remains a functioning part of the hydrologic system. It provides technological tools to plan and develop most types of urban sites to maintain or restore a watershed's hydrologic and ecological functions. It is an important means for maintaining stream baseflows, minimizing loss of recharge to aquifers, maintaining stream and wetland buffers, addressing flood concerns, and reducing stormwater pollutant loads from developed areas.

Photo: http://commons.wikimedia.org/wiki/Image:North-Bend-Uplands-Runoff-pond-3942.jpg

A system of stormwater infiltration ponds in the Uplands neighborhood of North Bend, Washington.

It is important to note, however, that while many LID techniques effectively manage stormwater, they are not always applied from the perspective of potential impacts to the three-dimensional watershed, which includes ground water. Without considering ground water, even LID techniques can allow polluted stormwater to impact ground water.

RECHARGE WITH CARE

While the LID approach has both strong environmental benefits and great possibilities to enhance the developed landscape, it can pose a threat to ground water if we are not careful. As discussed earlier, stormwater, particularly from urban areas, contains high concentrations of contaminants that may not be adequately removed or attenuated when stormwater is infiltrated into the ground. As techniques that capture, treat, and infiltrate stormwater onsite continue to be developed, improved, and widely used, federal and state regulators and local communities must keep in mind these potential impacts by considering aquifer sensitivity, the quality of stormwater, and the potential impact of stormwater on ground water.

Infiltration drainage systems typically allow stormwater from impervious surfaces to be temporarily stored and then released into ground water over a period of time. However, a New Jersey study found that "infiltration of storm water through detention and retention basins may increase the risk of ground water contamination, especially in areas where the soil is sandy and the water table shallow, and contaminants may not have a chance to degrade or adsorb onto soil particles before reaching the saturated zone" (Fischer et al., 2003).

An 18-month study monitoring swales and detention pond systems receiving stormwater runoff from interstate highway, residential, and commercial land-use areas in Florida found that most stormwater can likely be infiltrated with minimal impacts (Harper, 1988). The study indicated that removal processes in soils are likely to reduce most infiltrated pollutants; however, some pollutants are more likely to cause problems than others, and these must be more carefully considered in infiltration projects. The author cautions that critical pollutant source areas should be avoided and that pretreatment before infiltration to remove particulate forms of the pollutants should be considered.


Photo: Dawn Easterday

This development project in Minnesota uses several methods of managing stormwater to mitigate negative impacts to water quality. The grassy swale area provides filtration before stormwater recharges the underlying aquifer.

Concerns associated with stormwater infiltration involve the design life of the systems and the potential to contaminate ground water if they are not applied appropriately and monitored and maintained so they function as intended. Earlier generations of infiltration BMPs (e.g., infiltration trenches, retention ponds) tended to clog with silt, largely because they were not properly sited, designed, installed, or maintained. Once clogged, such systems do not work and may even degrade surface water quality by allowing resuspended sediment to run off into receiving waters. (NHDES, 2001)

A big issue is that while there is more and more interest in using infiltration BMPs, we have relatively little information on the transport of pollutants around and through infiltration systems. What is the risk to ground water resources from recharging polluted stormwater? There are situations where infiltration is simply not suitable because the potential to contaminate ground water is too great (e.g., stormwater from industrial sites, petroleum storage facilities).

Rain in Fisherville, Kentucky, and a strip mall in Lexington, Kentucky. Ground water quality in Kentucky is generally good; water quality is directly related to land use, geology, ground water sensitivity, and well construction. Nonpoint-source impacts on ground water quality from anthropogenic sources occur primarily from nutrients and pesticides associated with agricultural activities. In addition, urban sprawl and stormwater runoff impact karst aquifers and improper stormwater injection in karst areas also impacts local karst ground water quality.

A study by Robert Pitt and colleagues (1994) found that some pollutants in stormwater may have an impact on ground water in certain circumstances. These pollutants include nutrients (e.g., nitrates), pesticides (e.g., lindane and chlordane), other organics (e.g., 1,3-dichlorobenzene, pyrene, fluoranthene, VOCs), pathogens, heavy metals (e.g., nickel and zinc), salts (e.g., chloride, road salts). (See Table 1.)

Pollutant threats vary with land uses and human activities. For example, as detailed in the study, pesticides tend to be found in urban runoff from residen-

POTENTIAL OF STORMWATER POLLUTANTS TO CONTAMINATE GROUND WATER

					Contamination Potential		
Pollutants	*Compounds*	*Mobility (sandy/low organic soils)*	*Abundance in Stormwater*	*Fraction Filterable*	*Surface Infiltration and No Pretreatment*	*Surface Infiltration with Sedimentation*	*Subsurface Injection with Minimal Treatment*
Nutrients	nitrates	mobile	low/moderate	high	low/moderate	low/moderate	low/moderate
Pesticides	2,4-D	mobile	low	likely low	low	low	low
	γ-BHC (lindane)	intermediate	moderate	likely low	moderate	low	moderate
	malathion	mobile	low	likely low	low	low	low
	atrazine	mobile	low	likely low	low	low	low
	Chlordane	intermediate	moderate	very low	moderate	low	moderate
	diazinon	mobile	low	likely low	low	low	low
Other Organics	VOCs	mobile	low	very high	low	low	low
	1,3-dicloro-benzene	low	high	high	low	low	high
	anthracene	intermediate	low	moderate	low	low	low
	benzo(a) anthracene	intermediate	moderate	very low	moderate	low	moderate
	bis(2-ethylhexyl) phthalate	intermediate	moderate	likely low	moderate	low	moderate
	butyl benzyl phthalate	low	low/moderate	moderate	low	low	low/moderate
	fluoranthene	intermediate	high	high	moderate	moderate	high
	fluorene	intermediate	low	likely low	low	low	low
	naphthalene	low/inter.	low	moderate	low	low	low
	pentachlorophenol	intermediate	moderate	likely low	moderate	low	moderate
	phenanthrene	intermediate	moderate	very low	moderate	low	moderate
	pyrene	intermediate	high	high	moderate	moderate	high
Pathogens	enteroviruses	mobile	likely present	high	high	high	high
	Shigella	low/ inter.	likely present	moderate	low/moderate	low/moderate	high
	Pseudomonas aeruginosa	low/ inter.	very high	moderate	low/moderate	low/moderate	high
	protozoa	low/ inter.	likely present	moderate	low/moderate	low/moderate	high
Heavy Metals	nickel	low	high	low	low	low	high
	cadmium	low	low	moderate	low	low	low
	chromium	inter/very low	moderate	very low	low/moderate	low	moderate
	lead	very low	moderate	very low	low	low	moderate
	zinc	low/very low	high	high	low	low	high
Salts	chloride	mobile	seasonally high	high	high	high	high

Table 1. *A summary of the pollutants found in stormwater that may cause ground water contamination problems for various reasons. Source: Robert Pitt et al., 1994.*

tial areas, especially in dry weather flows associated with landscaping irrigation runoff. Volatile organics are mostly found in industrial areas. Zinc is often found in roof runoff and areas where galvanized metal comes into contact with rainwater. Road salts are at their greatest concentrations in snowmelt and early spring runoff in northern areas.

The Pitt study emphasizes that control of these compounds requires various approaches, including source-area controls, end-of-pipe controls, and pollution prevention. However, "with a reasonable degree of site-specific design considerations to compensate for soil characteristics, infiltration may be very effective in controlling both urban runoff quality and quantity problems." In keeping with the LID approach to stormwater management, the study encourages use of the natural filtering and sorption capacity of soils to remove pollutants, but cautions that the potential for some types of urban runoff to contaminate ground water through infiltration requires some restrictions, including adequate pretreatment or diversion of polluted waters away from infiltration devices.

Stormwater infiltration is of greater concern now because federal stormwater requirements under the National Pollutant Discharge Elimination System (NPDES) encourage infiltration of stormwater as a means of avoiding an NPDES permit for a discharge to surface water, and because more states are recognizing the potential for reducing hydrologic impacts of urbanization by recharging a prescribed amount of stormwater.

LEMON GROVE, CALIFORNIA'S, STANDARD URBAN STORMWATER MITIGATION PLAN (SUSMP) INCLUDES RESTRICTIONS ON INFILTRATION

The City of Lemon Grove, California, has adopted a local ordinance that includes the guidance contained in USEPA's *Potential Ground Water Contamination from Intentional and Non-Intentional Stormwater Infiltration* (EPA/600/R-94/051). Step 10 of the ordinance addresses restrictions on the use of infiltration BMPs. This provision states that three factors significantly influence the potential for urban runoff to contaminate ground water: pollutant mobility, pollutant abundance in urban runoff, and the soluble fraction of the pollutant. The risk of ground water contamination may be reduced by pretreating urban runoff. At a minimum, stormwater infiltration BMPs must meet the following conditions:

- Urban runoff from commercial developments must undergo pretreatment to remove both physical and chemical contaminants prior to infiltration.
- All dry weather flows must be diverted from infiltration devices.
- Pollution prevention and source control BMPs must be implemented at a level appropriate to protect ground water quality at sites.
- The vertical distance from the base of any infiltration structural treatment BMP to the seasonal high ground water mark must be at least 10 feet.
- The soil through which infiltration occurs must have physical and chemical characteristics that are adequate for proper infiltration durations and treatment of urban runoff for the protection of ground water beneficial uses.
- Structural infiltration treatment BMPs may not be used for areas where there is industrial or light industrial activity and other areas where there is a high threat to water quality land uses and activities.
- The horizontal distance between the base of any infiltration structural BMP and any water supply wells must be 100 feet.

Where infiltration BMPs are authorized, their performance must be evaluated for impacts on ground water quality. In those instances where the City has determined that implementation of proposed infiltration BMPs has the potential to impact ground water quality in another jurisdiction, the City may require that a notification be placed upon those proposing such use in addition to the required protection measures.

Source: www.ci.lemon-grove.a.us/documentview.asp?DID=97

THE UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

DEDICATED TO PROTECTING WATER RESOURCES THROUGH EFFECTIVE STORMWATER MANAGEMENT

The UNH Stormwater Center, funded by the National Oceanic and Atmospheric Administration (NOAA) through a grant from the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), studies stormwater-related water quality and quantity issues. The center's mission is to:

- Test stormwater control measures.
- Disseminate test results and evaluations.
- Demonstrate innovative stormwater management technologies.

One unique feature is its field research facility used to evaluate and verify the performance of stormwater management devices and technologies.

This facility serves as a site for both testing stormwater treatment processes and performing technology demonstrations. The testing results and technology demonstrations serve a vital role for municipalities, town engineers, and others charged with developing and implementing stormwater management plans. The purpose of the stormwater management plans is to reduce nonpoint-source pollution, the nation's single largest water quality problem.

The research facility houses three categories of stormwater treatment processes: conventional structural devices, low-impact development designs, and manufactured devices. In addition to its main field facility, center researchers are planning two other field projects: a porous pavement parking lot (already built and being tested) and a street-vacuuming study. Both of these projects represent measures to treat and/or minimize stormwater at the source, rather than after it is collected.

The center's research program has three main objectives: (1) to provide rigorous independent evaluations of stormwater treatment technologies, (2) to aid municipalities and others charged with developing and implementing stormwater management plans in compliance with Phase II of the Clean Water Act, and (3) to address concerns that have surfaced as the result of research.

Visit the UNH Stormwater website at: *www.unh.edu/ erg/cstev/*

An assortment of stormwater treatment technologies.

Photos: University of New Hampshire Stormwater Center

FEDERAL STORMWATER REGULATION

In 1987, Congress amended the Clean Water Act to create, in two phases, a comprehensive national program for addressing stormwater discharges. Phase I extended the National Pollutant Discharge Elimination System (NPDES) to require permits for stormwater discharge from a large number of priority sources, including medium and large municipal separate storm sewer systems (MS4s) that serve urbanized areas and several categories of industrial activity, including construction activity.

The Stormwater Phase II Final Rule (December 1999) expands the Phase I program by requiring operators of smaller systems and small construction sites to implement programs and practices to control stormwater runoff. Under Phase II, hundreds of urbanized communities, as well as institutions (e.g., public universities, state highway facilities, prisons) that have separate storm sewer systems are regulated. To comply, they must develop comprehensive stormwater management programs that include:

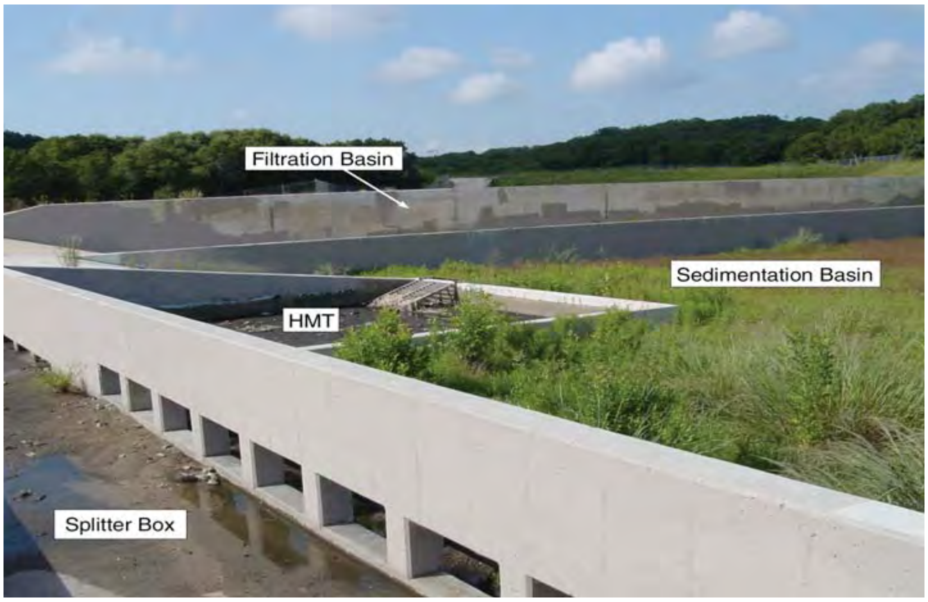
- Educating and involving the public.
- Finding and removing illicit discharge connections such as sanitary sewage being routed into storm sewers.
- Controlling runoff from construction sites during and after construction.
- Preventing stormwater pollution at municipal facilities.

WHO REGULATES STORMWATER RECHARGE?

States can and do play an important role in controlling and overseeing stormwater discharges to ground water. In a 2005 Ground Water Protection Council (GWPC) survey of state regulatory personnel, more than half of the states that responded indicated that they encourage stormwater infiltration, where feasible, over surface discharge.

The majority of responders indicated that some type of authorization is needed for installing units designed to direct stormwater into the subsurface, both infiltration systems and direct discharge systems. The type of authorization required ranges widely, from UIC rule authorization to different permitting mechanisms, such as sensitive area permits, stormwater general permits, or individual permits. Several states have enhanced protection/restrictions for introducing stormwater into the subsurface (more protective or otherwise segregated) in or near source water protection areas, wellhead protection areas, vulnerable aquifers, or other sensitive ground water areas.

Site-specific case studies have documented ground water contamination from stormwater drainage wells. States need this information in order to regulate stormwater discharges to ground water in a way that maintains ground water availability while preventing contamination. USEPA's current stormwater guidance, *Potential Ground Water Contamination*



Storm water structures along roadways can capture hazardous materials from catastrophic spills (either intentional or unintentional). This photo shows how a hazardous materials trap (HMT) can be sited within the footprint of the storm water control structure (a sand filter in this case) to both treat stormwater and collect hazardous material. Note that the invert of the openings from the splitter box to the HMT is set slightly lower than that of the openings into the sedimentation basin, allowing any hazardous spills as well as the first flush of runoff to be captured by the HMT. Once the HMT is full, the backwater level rises and allows the remaining runoff to enter the sedimentation basin directly. HMTs must be drained after a rain event (either manually or by use of an automatic siphon device).

Photo: USGS

Infiltration basins can be a very effective technique for controlling urban runoff quality and quantity problems. However, because of the potential for some types of urban runoff to contaminate ground water through infiltration, some restrictions are needed, including site-specific designs that consider soil characteristics.

from Intentional and Nonintentional Stormwater Infiltration (Pitt et al., 1994), developed under the NPDES stormwater program, is probably not sufficiently protective of ground water. For example, the guidance promotes the use of Class V stormwater drainage wells as BMPs to prevent the release of pollutants to surface waters. However, the placement of diverted stormwater underground via such wells may endanger underground sources of drinking water.

States need state-of-the-art technical and best management practices guidance to protect ground water from stormwater discharges. At a minimum, a complete compilation and synthesis of case studies on ground water contamination from stormwater discharges is needed. It is inefficient for the states to individually research this subject whenever they are revising their stormwater rules and/or guidance, when much of the same research could be applied nationally.

Another federal and state regulatory issue related to ground water impacts from stormwater is the definition of Underground Injection Control (UIC) Class V wells. Based on the definition published in the 1999 Class V Rule, stormwater Class V wells include stormwater drainage structures that are wider than they are deep, such as improved sinkholes and subsurface fluid distribution systems.

Yet there are still some categories of stormwater drainage structures that fall into a gray area as to whether they are considered Class V wells. Thus, they may present risks to underground sources of drinking water similar to those posed by Class V stormwater drainage wells. Federal and state UIC Class V Programs and NPDES Stormwater Programs must work together to clarify such issues and educate communities on how to best manage and regulate stormwater to protect all water resources effectively.

Photo: David Gleason - http://www.flickr.com/photos/mindfrieze/217930914/ Photo: Susanne Jespersen

Two green roofs in Chicago, Illinois. In addition to their ecological, aesthetic, and temperature-moderation values, green roofs dramatically reduce the volume of stormwater runoff and the peak flow rate. Rapid runoff from roof surfaces can result in flooding, increased erosion, and the discharge of contaminants directly into surface and ground water. A green roof can absorb stormwater and release it slowly over a period of several hours. The bottom photo shows a prairie twelve stories up on the roof of Chicago's City Hall.

THE STORMWATER UTILITY ALTERNATIVE

An alternative to private ownership with public oversight of stormwater BMPs is for the municipality to take ownership and maintenance responsibility for all stormwater BMPs, assessing an annual fee to cover all costs (e.g., maintenance, repair). A growing number of communities nationwide have established stormwater utilities so they can assess fees to fund their stormwater systems and annual maintenance costs and provide a wide range of services. The utility approach may, in fact, be one of the most effective ways to ensure BMP maintenance and consequently intended performance.

Washburn, Wisconsin's, Storm Water Management Utility

Until the heavy rainfalls of 2000 and 2001, which caused considerable public and private property damage, the City of Washburn, Wisconsin, was able to ignore stormwater management issues. With each passing storm, however, it became more apparent that existing stormwater conveyance systems could not handle regularly occurring runoff and that long-range plans and the use of appropriate BMPs were needed to minimize future problems.

Washburn needed a stormwater management system that would retain water on the properties that generate storm water, wouldn't overload conveyance and handling systems, and would eliminate flooding and minimize environmental degradation, thereby improving living conditions in the city. Regardless of their location in the watershed, the city recognized that all properties have an impact on stormwater drainage and that stormwater needed to be viewed from a total management perspective. Much research and deliberation made it clear that a stormwater utility would allow for such an approach.

The City of Washburn's Storm Water Management Utility went into operation in 2006. It is self-supporting, just like the city's water and wastewater utilities. Revenue collected from utility services is dedicated solely to stormwater management. The monthly utility fees pay for the operation, maintenance, and capital improvements of the system. The charge also provides an incentive for the largest generators of storm water—commercial, industrial, and institutional properties—to incorporate BMPs within their properties.

Source: http://www.cityofwashburn.org/storm.htm

One factor that may have a bearing on how states approach stormwater infiltration is a determination as to whether infiltration is considered to be an "aquifer recharge system" or a "stormwater disposal system." The GWPC survey indicates that the majority of states view stormwater infiltration as disposal, suggesting that recharge is not addressed with the same level of concern for ground water as it would if it were treated as a drinking water source. State drinking water, UIC, and stormwater regulatory programs need to coordinate the manner in which they control stormwater discharges to ground water. They also need stormwater monitoring (surface or ground water) requirements for units that infiltrate or directly discharge stormwater to ground water.

LOCAL REGULATION IS THE KEY TO STORMWATER MANAGEMENT

The day-to-day work of managing stormwater rests, for the most part, with local governments. In fact, communities may have several stormwater requirements that they must meet. For example, the federal NPDES Stormwater Phase II requirements require many urban communities to develop comprehensive stormwater management programs. States may also have comprehensive stormwater management policies or requirements that communities must meet. However, both must have a ground water component to be fully effective.

But when it comes right down to it, communities need to develop their own comprehensive stormwater management programs. Local governments are making the land-use decisions that will either make or break the health and well-being of their water resources. Local governments need to recognize that they have this responsibility and develop storm sewer management programs that address the following issues:

- How to assess existing stormwater patterns.
- How to mitigate existing runoff threats to source water areas.
- How to ensure that future development will not exacerbate stormwater impacts in the water supply watershed.
- How to take into account the cumulative impacts of runoff on the water supply region or watershed.
- How to change public and political attitudes toward the value of and need for an effective stormwater management program.
- How to fund an effective stormwater management program.

Abacoa, Florida's, stormwater runoff is managed within a greenway system that provides filtration and allows recharge locally. The higher density homes allow the developers to preserve more open space.

Source: http://www.epa.gov/smartgrowth/case/abacoa_p2.htm

Recommended Actions

To USEPA:

- **Establish better coordination among federal stormwater management, ground water protection, underground injection control (UIC), and water-quality monitoring programs so that programmatic overlaps and opportunities for collaboration in protecting surface and ground waters can be identified and initiated.**

- **Accord the protection and recharge of ground water and protection of surface water equal importance when regulating and providing guidance to state stormwater programs. For example:**
  - Develop and field-test BMPs specifically designed to manage stormwater in a manner protective of ground water in different hydrogeological settings (e.g., karst, sand and gravel).
  - Ensure that states may utilize §319 funds to conduct research and demonstration projects, and to develop and field-test BMPs specifically designed to manage stormwater in a manner that is protective of ground water.

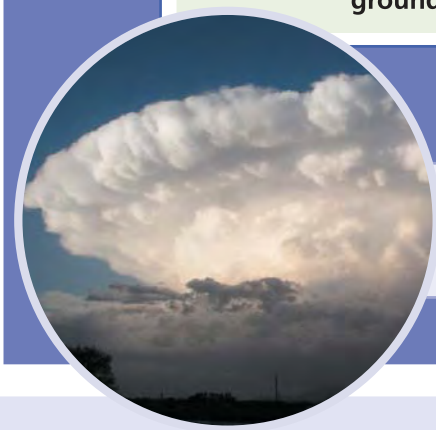
To State Agencies:

- **Establish better coordination among stormwater management, ground water protection, underground injection control (UIC), and water quality monitoring programs so that programmatic overlaps and opportunities for collaboration in protecting surface and ground waters can be identified and initiated.**

- **Review stormwater management plans and total maximum daily load (TMDL) determinations from a ground water program perspective to ensure protection and conservation of the resource.**

To Local Governments:

- **Protect all water resources through local stormwater management activities, and require the use of stormwater BMPs (including ongoing maintenance and monitoring), stormwater utilities, and stormwater management plans that are designed to conserve and protect both surface water and ground water and promote natural ground water recharge.**



A thunderstorm over Chaparral, New Mexico.

Photo: Greg Lundeen

Source: http://www.srh.noaa.gov/elp/swww/v8n1/Chaparral%20Supercell%202.JPG

Section 6 References: Ground Water and Stormwater Management

Fischer, David, E. G. Charles, A. L. Baehr. May 2003. "Effects of Stormwater Infiltration on Quality of Ground water Beneath Retention and Detention Basins" *Journal of Environmental Engineering* 129, no. 5.

GWPC. 2005. *State Regulation and Research on Storm Water Impacts to Ground Water.*

Harper, H. H. 1988. *Effects of Stormwater Management Systems on Groundwater Quality.* Final Report to the Florida Department of Environmental Regulation. Available at: *http://stormwaterauthority.org/assets/115PGroundwater.pdf* (accessed July 2007).

NHDES. 2001. *Managing Stormwater as a Valuable Resource* . Available at: *www.des.state.nh.us/dwspp/stormwater.pdf* (accessed July 2007).

Pitt, Robert, S. Clark, K. Parmer. 1994. *Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration.* USEPA. EPA/600/SR-94/051 Available at: *http://www.p2pays.org/ref/07/06744.pdf*

Stormwater-Related Websites:

USEPA Stormwater website: h*ttp://cfpub.epa.gov/npdes/home.cfm?program_id=6*

National Stormwater BMP Database: *www.bmpdatabase.org*

Bioretention and Stormwater ResearchPublications: *http://www.ence.umd.edu/~apdavis/LID-Publications.htm*

Low Impact Development Center: *http://www.lowimpactdevelopment.org/*

Stormwater journal: *http://www.forester.net/sw.html*

Stormwater Authority: *http://www.stormwaterauthority.org/*

Suggested Reading

Low-Impact Development Design Strategies An Integrated Design Approach. EPA 841-B-00-003.

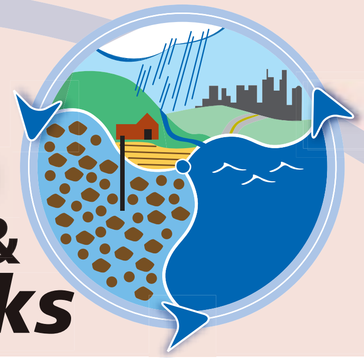
Low-Impact Development Hydrologic Analysis. EPA 841-B-00-002.

Using Smart Growth Techniques as Stormwater Best Management Practices. EPA 231-B-05-002.

Photo: Daniel Rehn

Ground water is a crucial resource for Hawaii. It provides over 90% of the fresh drinking water for island residents and is used for commercial, agricultural, recreational, industrial, and thermoelectric power activities. Precipitation, the source of Hawaii's fresh ground water, is naturally filtered as it infiltrates through the soil. Favorable geologic factors (i.e., the content, structure and extent of Hawaii's volcanic rock) and hydrologic factors (i.e., reliable rainfall, recharge capacity, recharge rates) contribute to the high quality of ground water. The state also manages stormwater quality through its nonpoint-source pollution control program, protecting ground water by controlling surface water pollution, recognizing the interconnection between surface and ground water.

Ground Water & Underground Storage Tanks



Underground storage tank (UST) systems that contain fuels, chemicals, and wastes are numerous and widespread and pose a significant threat to ground water quality in the United States. Currently, there are more than 640,000 federally regulated active USTs that store fuels or hazardous substances. These systems can and do leak, and when they leak they contaminate soil and ground water—even hydrologically connected surface water. These leaks often occur in populated areas, where public and domestic water supplies are concentrated, and it is difficult and expensive to clean them up, particularly if they involve a public source of drinking water.

Key Message

Since 1985, federal and state UST programs have significantly reduced the risk of new releases by implementing release-prevention and leak-detection requirements and establishing improved design, installation, and operational technical standards. Federal and state leaking underground storage tank (LUST) programs have overseen the cleanup of nearly 351,000 leaking tank sites. At the same time, states have had to respond to new contamination problems from fuel constituents such as methyl *tert*-butyl ether (MTBE). The continued widespread use of UST systems (including large numbers of heating-fuel storage tanks that are not federally regulated) requires that existing regulations be fully enforced and that additional regulatory, land-use, and engineering measures be developed and fully implemented to further minimize threats to public health and safety, the economy, and the environment.

Photo: Missouri PSTIF

A leaking underground storage tank is removed from gasoline-contaminated ground water.

When Buried Fuel Storage Tanks Leak

"We appreciate that the initial cause of the leak was a freak accident…and that someone was well aware of the losses that went unreported to the Maryland Department of Environment for over a month. We know what the impact has been on our community. We also know that we will all be living with this travesty and its lingering consequences for years to come"

Glenn A. Thomas | The Greater Jacksonville Association, Inc | *LUSTLine,* February 2007

why Underground Storage Tanks matter to ground water…

The majority of USTs contain petroleum products such as gasoline, diesel fuel, heating oil, kerosene, and jet fuel. In addition, substances classified as hazardous by the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act ("Superfund") are also stored in USTs—USEPA estimates that about 25,000 hold hazardous substances covered by the federal UST regulations. (USEPA, 2007)

Besides the 640,000 federally regulated USTs in operation nationwide (USEPA, 2007), there are millions more federally exempt tanks, such as heating-oil tanks and aboveground storage tanks (ASTs). The good news is that over the past 20 years, more than 1.6 million substandard tanks have been properly closed and are no longer in use (USEPA, 2007). But USTs and ASTs continue to be a concern because each installation has the potential to leak, threatening human health and the environment. Leaked product contaminates ground water used for drinking and other uses and, on occasion, enters surface water.

Of the federally regulated petroleum storage tanks, as of September 2006, there were about 465,000 con-

Photo: Missouri PSTIF

Gasoline-contaminated ground water visible after the removal of a UST indicates that there has been a release from somewhere in the UST system (e.g., piping, tank, joints, spill buckets).

SUBSURFACE VIEW OF AN UNDERGROUND STORAGE TANK SYSTEM PRODUCT RELEASE

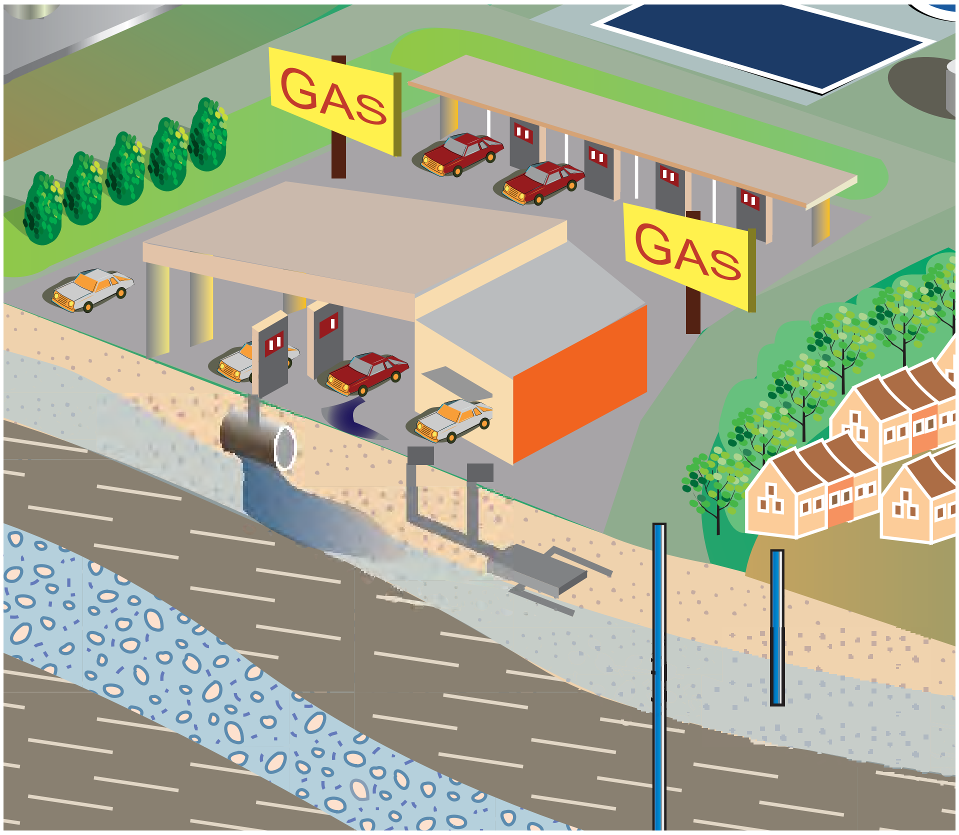


***Figure 1.** When gasoline leaks from a failed UST system, it moves from the backfill surrounding the tank or piping into the native soil and into ground water; volatile vapors often move upward into and around buildings and infrastructure. Over time, some of the leaked product either floats on top of the ground water table or dissolves into the ground water, where it moves downgradient with the ground water. If there are drinking water wells nearby, the leaked product can be drawn into the wellhead area.*

firmed releases (leaks) and 436,000 cleanups initiated, of which 351,000 had been completed (USEPA, 2007). However, cleanup efforts haven't even begun for more than 32,000 sites, many comprising what are considered to be abandoned tanks with no identified responsible party (USGAO, 2005). Many forgotten buried steel tanks have yet to be discovered that may still contain product or have leaked.

Given our dependence on internal-combustion engines, we'll continue to rely heavily on USTs to store our motor fuels, as well as other harmful substances. Today's improved UST systems are the product of federal and state requirements and programs, as well as improved technologies and a heightened awareness on the part of tank owners and operators. However, leaks still occur, albeit far less frequently, and we must stay vigilant in order to prevent tank systems from leaking in the first place and to ensure that leaking systems are reported immediately and cleaned up expeditiously.

UNDERGROUND STORAGE TANKS IN THE NATURAL SYSTEM

Most older petroleum UST sites have some contamination. The main chemicals of concern in gasoline are benzene, toluene, ethylbenzene, and xylenes (BTEX). Benzene, a known carcinogen, is the most hazardous

Petroleum product from a LUST that contaminated ground water and then impacted surface water. The white areas are absorbent materials used for soaking up the hydrocarbons in the water.

LOCATIONS OF USTs AND PUBLIC WATER SUPPLY (PWS) WELLHEADS

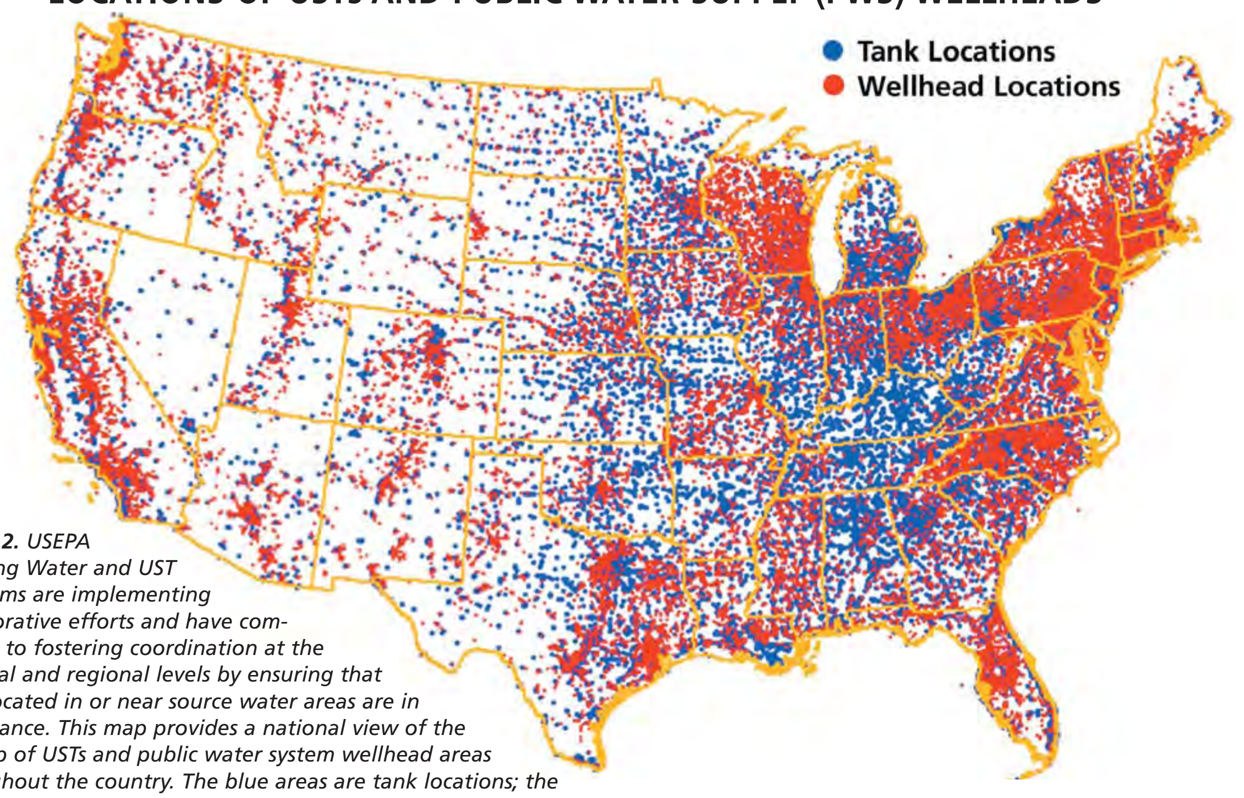


Figure 2. *USEPA Drinking Water and UST Programs are implementing collaborative efforts and have committed to fostering coordination at the national and regional levels by ensuring that USTs located in or near source water areas are in compliance. This map provides a national view of the overlap of USTs and public water system wellhead areas throughout the country. The blue areas are tank locations; the red areas are wellhead locations.* http://www.epa.gov/oust/swanust.htm
Source: USEPA

of these compounds. When gasoline leaks from a failed UST system, it moves from the backfill surrounding the tank or piping into the native soil and into ground water; volatile vapors often move upward into and around buildings and infrastructure. The fate and transport of gasoline in the environment is complex and depends on a number of local physical, chemical, and biological factors.

Over time, some of the leaked product either floats on top of the ground water table surface or dissolves into the ground water, where it moves downgradient with the ground water. Some of the product may also become trapped in the soil pores, evaporate upward through the soil, or cling to soil particles. Petroleum product held in the soil is released slowly over time.

It doesn't take much gasoline to contaminate drinking water. A spill of 10 gallons of gasoline contains about 230 grams of benzene. USEPA's Maximum Contaminant Level (MCL) for benzene is 5 parts per billion (ppb), or 5 micrograms per liter, in drinking water. The density of gasoline is about 0.8 grams per milliliter, so the benzene in a 10-gallon gasoline leak can contaminate about 46 million liters—or 12 million gallons—of water! *(http://bcn.boulder.co.us/basin/waterworks/lust.html)*

SERIOUS BUSINESS

Burying a tank that holds a hazardous substance is serious business. But we haven't always looked at it that way. In the past, once a tank was buried, it was out of sight and out of mind. Most tank owners didn't think much about their tank systems, and only large losses of inventory prompted a check for leaks. In 1984, there were more than 2.1 million buried tanks, many of which were leaking and contaminating

A bailer pulled from a LUST-site monitoring well shows that about a foot of free-product gasoline is present in the ground water.

SOURCES OF UST RELEASES

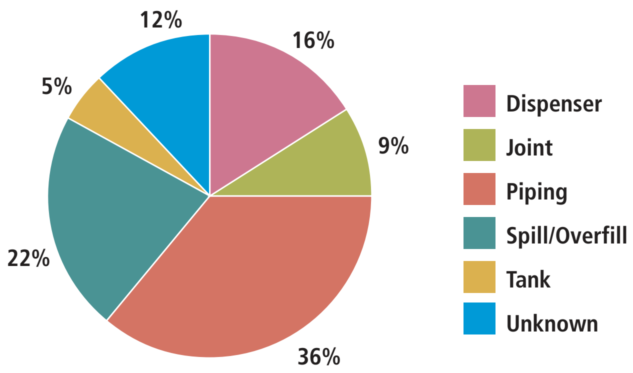


Figure 3. Based on the Missouri Petroleum Storage Tank Insurance Fund data from 76 releases, where there was an "identifiable release" from an operating UST system.

Source: Missouri PSTIF.

ground water. (USEPA, 2001) The majority of these were of single-walled, bare-steel construction—and highly susceptible to corrosion. To make matters worse, tanks were located without regard to their proximity to drinking water supplies.

UST releases are not limited to the tanks; leaks can be associated with any component of the storage system—piping, fittings, dispensers, sumps, vapor recovery. In fact, piping continues to be the number-one culprit in system failure. UST system failures can be the result of corrosion, structural deficiencies, improper installation, and/or loose fittings. Product delivery overfills and spills are another key source of contamination. (See Figure 3.)

Rules to the Rescue

In 1983, the CBS program *60 Minutes* aired a story called "Check the Water," which brought national attention to the problem of leaking underground storage tanks. In 1984, Congress passed the Subtitle I RCRA Amendments, directing USEPA to establish programs and regulations to prevent, detect, and clean up releases from petroleum or hazardous substance UST systems. The USEPA UST regulations used, in part, regulations already in effect in some states.

The federal rules, promulgated in 1988, triggered a sea change in the UST universe. Every phase of the life cycle of the storage system was addressed—design, construction, and installation of new systems; upgrading of existing systems; operation and maintenance; release cleanup; and closure. The UST rules set forth minimum federal standards and phased-in deadlines for leak detection, corrosion protection for both tanks and piping, and spill and overfill prevention. Owners and operators of existing tanks were given until 1998 to upgrade, remove, or replace substandard tanks. All releases had to be reported to the proper authority.

Because of the large tank universe, and the existence of some state regulations, USEPA designed the UST program to be implemented by the states. With the new federal regulations in hand, states were tasked to develop their own programs and seek federal program approval, which hinged on having adequate funding for their program and staff, regulations that were at least equivalent to federal regulations, adequate enforcement capabilities, and the capacity and willingness to carry out the program. As of August 2006, 35 states, plus the District of Columbia and Puerto Rico, had approved programs. (USEPA, 2007)

Photo: Pepijn Schmitz - http://www.flickr.com/photos/captainchaos/40136212/

This gas station from the Route 66 heyday is emblematic of many such facilities that are now abandoned along former busy highways. UST programs in many states are trying to address these sites in order to remove tanks that may have been leaking for years and facilitate necessary cleanups.

THE VERY ESSENTIAL UST/DRINKING WATER CONNECTION

The opportunity for cross-program integration couldn't be more obvious and necessary than in the realm of federal and state drinking water and UST programs. Given that more than half of the people in the United States rely on ground water for their drinking water and that contamination from LUSTs is a widespread threat to ground water sources, it makes a whole lot of sense for these programs to work together to maximize their effectiveness in protecting ground water sources.

While many state UST/LUST and drinking water programs have been working together for many years, it took a national initiative to really draw attention to the need for an interprogram communication process. In 2004, the USEPA Office of Underground Storage Tanks (OUST) made a commitment to protect drinking water by cosigning two memos with the USEPA Office of Ground Water and Drinking Water and holding collaborative state and regional meetings on the subject. Both memos are available on the OUST website *(http://epa.gov/oust/swanust.htm)*. They contain several tips for states interested in working with their drinking water program.

The state source water assessments (see Section 4 – "Ground Water and Source Water Protection") are a great place to begin this collaborative process. These assessments show, among other things, sources of drinking water most at risk for contamination from USTs. Drinking water programs, water suppliers, and local governments have this information or can create it from geographic information system (GIS) layers. Many state tank and drinking water programs are already actively sharing information through their GIS databases. These programs can be partners in preventing releases in source water areas and ensuring that releases that do occur are prevented from impacting drinking water supplies.

For example, as with many states, Massachusetts and Arkansas UST and drinking water programs are located in different agencies, yet they work together to prioritize UST inspections in source protection areas. Illinois recently passed a regulatory amendment requiring the identification of potable water wells in relation to LUST cleanup sites. The Louisiana Department of Environmental Quality has created a two-page fact sheet titled Best Management Practices for Underground Storage Tanks to Prevent Drinking Water Contamination, which is distributed by local parishes to UST owners/operators *(http://www.deq.louisiana.gov/)*.

Source: Kara Sergeant. February 2007. "A Marriage Made in Groundwater: How State UST, LUST, and Source Water Programs Can Work Together to Protect Drinking Water." LUSTLine, Bulletin 54. New England Interstate Water Pollution Control Commission.

Photo: USGS

Direct-push technology has allowed for more time-sensitive and effective field investigations at LUST sites. In this photograph, direct push is being used to investigate the discharge of MTBE-contaminated ground water into a surface-water body.

Cleaning Up

Ground water cleanup programs have come a long way since the 1980s. By today's standards, early cleanups were crude and protracted. Since then, many effective cleanup options have emerged. LUST cleanup often involves combinations of technologies, including monitored natural attenuation and a risk-based cleanup option. More careful siting of new USTs has also helped reduce future risk.

Accurate site characterization is critical to the development of an effective cleanup strategy. Hydrogeologists must determine the appropriate number and location of wells so that information retrieved is repre-

DISTANCING USTS FROM DRINKING WATER SOURCES

MAINE'S UST SITING LAW

Besides enforcing federal, state, and local UST program requirements, there is another highly effective way to ensure that the contents of underground and aboveground storage tanks do not contaminate drinking water sources—keep them away from those sources.

In 2001, the State of Maine passed the Act to Protect Sensitive Geologic Areas from Oil Contamination, which prohibits or modifies the installation of UST facilities in proximity to existing water supplies (public and private wells) and future water supplies (significant sand and gravel aquifers). The requirements apply only to motor fuel and bulk plant USTs, not to the expansion of USTs that existed at a site prior to the implementation date.

Under the law, tanks cannot be installed:

- Within 300 feet of a private well, other than the well used to supply water to the business with the UST.
- Within 1,000 feet (or within the source water protection area, whichever is larger) of a community water supply (e.g., municipal well, mobile home park well, condominium) or a school well.
- Over a high-yield (more than 50 gallons per minute) sand and gravel aquifer.
- Within 1,000 feet (or within the source water protection area, which ever is greater) of a transient (e.g., restaurant, highway rest stop) or non-transient (e.g., school, office park) public water supply.
- Over a mapped moderate-yield (between 10 and 50 gallons per minute) sand and gravel aquifer.

Photo: Scott Ruth, P.G. Bristol Environmental & Engineering Services Corp.

Arizona's Gila River Indian Community, along with USEPA, installed and activated this LUST site cleanup system to remediate hydrocarbon-contaminated soil and ground water. In what is expected to culminate in a 10-year cleanup effort, the final price tag may exceed $2 million.

sentative of what is happening in the subsurface. Portable direct-push technologies have allowed consultants to go out to a site, collect many samples, and obtain real-time results. With this initial information, monitoring wells can then be installed where they need to be and modeling can be used to predict plume behavior.

Risk-Based Cleanups

Besides the benefit of experience, cost has been a major driver in improving LUST investigation techniques. One of the most significant changes in LUST cleanup approaches has been the use of risk-based decision making. The process involves evaluating all aspects of a site and determining how much leaked fuel can "safely" be left in the ground, rather than trying to clean up a site to a one-size-fits-all predetermined cleanup number, such as an MCL.

Today, many sites are closed leaving some amount of product in the ground, with ongoing monitoring to validate the attenuation process. This process is dependent on a determination that receptors, such as homes or businesses, will not be impacted. Given the possibility that

As a UST is removed, gasoline released from the UST system becomes apparent in the tank pit. Discovering the contamination is only the beginning of a long and expensive process that includes site investigation, cleanup, monitoring, and often litigation.

new receptors could enter the picture in future development proposals, these sites are often closed with some kind of institutional control attached, such as a deed restriction.

Paying for LUST Cleanups

Paying for LUST cleanups, which can range from $100,000 to more than $1 million is a serious issue. A February 2007 report from the U.S. Government Accountability Office (USGAO) says it will cost at least $12 billion in state and federal funds to clean up known releases of gasoline and other hazardous substances from leaking underground storage tanks nationwide. USGAO estimates that EPA and the states have paid out more than $10 billion to clean up underground tank releases over the past 20 years.

To ensure they will be able to pay for remediation work, the federal Resource Conservation and Recovery Act requires UST owners and operators to demonstrate financial responsibility (FR) by obtaining some form of insurance or financial coverage for cleanup costs and third-party compensation for bodily injury and property damage caused by LUSTs. However, USGAO found that most states do not check regularly to see if coverage is current.

Most states have established financial assurance funds—capitalized through such devices as per-gallon or per-barrel fees on gasoline coming into the state—an important means for owners and operators to demonstrate FR. According to the 2007 Vermont State Funds Survey, 37 states have fully functioning funds, nine have transitioned to private insurance, three do not have funds, and one is being reestablished. During 2006, state funds paid out about $1 billion for LUST cleanups. As of May 2007, state fund programs had paid out a total of $15,453 billion. Yet, as USGAO noted, some state financial assurance funds are not sufficient to ensure timely cleanup work.

In the event of a release, tank owners covered by state financial assurance funds usually pay a relatively small deductible, while the funds can provide large sums of public financing to complete the required cleanup. Because the deductibles are small, USGAO noted that there might not be a sufficient incentive for tank owners to prevent releases from occurring.

The federal LUST Trust Fund, created by Congress under the 1986 RCRA Subtitle I Amendments, provides money for overseeing and enforcing corrective action by a responsible party and for cleaning up abandoned tanks whose owners are unknown, unwilling, or unable to pay for cleanup. This fund is capitalized by a by a federal tax on gasoline of one-tenth of a cent per gallon. According to USGAO, the account had an unspent balance of $2.5 billion at the end of fiscal 2005. The surplus is expected to reach $3 billion by the end of fiscal 2008. Yet, USGAO noted, in fiscal year 2005, EPA distributed only $58 million to the states from the Fund.

WE'VE COME A LONG WAY

National attention to USTs has paid off. Most UST systems are now equipped with automatic tank gauges that monitor fuel levels and print out reports and sound alarms when a release is suspected. Steel tanks are required to have corrosion protection and/or reinforced-plastic jackets. Many states have adopted programs to ensure that UST systems are installed properly. By the 1998 deadline, which required UST owners/operators to upgrade, replace, or remove tanks, approximately 80 percent of the nation's tanks systems were in compliance, and that number has continued to rise. Several states went further by requiring double-walled tanks and piping. Many tank owners have independently made the move to double-walled fiberglass or steel systems.

Unfinished Business

In March 2003, USGAO reported that "89 percent of the 693,107 tanks subject to UST rules had leak-detection and -prevention equipment installed, but that more than 200,000 tanks were not being operated and maintained properly, increasing the chance of leaks." The report was undertaken in response to concerns expressed by members of Congress that the UST program was not effectively preventing leaks and that USTs continued to pose risks. Too many tank owners and operators are not familiar with state or federal requirements and need more training on how to operate and maintain their systems properly.

The majority of states have UST facility inspection backlogs; until very recently, some facilities hadn't been inspected since the 1998 upgrade deadline. Even though any suspected leak is supposed to be reported immediately, states often only find evidence that there may be a leaking system during a compliance inspection or an off-site impact such as a drinking water well. Many states are strapped for resources to effectively carry out inspection programs. Thus, even well-meaning tank owners and operators who think they are in compliance may have a tank system that is an accident waiting to happen—a situation that could be remedied by a visit from an inspector.

Some states have documented extensive problems with plastic flexible-piping systems introduced in the early 1990s to avoid problems with leaking unions and joints. Use of this piping is widespread and concerns continue. Also, spill buckets and under-dispenser sumps, which were not adequately addressed in the federal rules, have emerged as major sources of leaks.

The Concern over MTBE

Just when state UST programs were getting proficient at managing the cleanup of petroleum hydrocarbons, along came the gasoline additive methyl *tert*-butyl ether (MTBE), a monkey wrench in LUST cleanup programs. MTBE is an oxygenate that has been widely added to gasoline, first as an octane enhancer and later so that the gasoline would comply with reformulated gasoline (RFG) requirements of the 1990 Clean Air Act Amendments.

The unintended consequence of using MTBE to fix one environmental problem has led to another. MTBE has been detected at low levels in ground water in locations nationwide and at elevated levels in some public and private water supplies. MTBE is classified as a potential human carcinogen, but as yet, EPA has no MCL. In December 1997, EPA issued a Drinking Water Advisory of 20 to 40 parts per billion, based on taste and odor thresholds, to assist drinking water suppliers and LUST programs in making decisions about "acceptable" MTBE levels. Many states have adopted their own standards.

A new UST system is being installed. Leak prevention depends on the proper installation of a UST system that meets regulatory standards. This system must then be properly operated and maintained.

MTBE is very soluble and, once released, moves through soil and into ground water more rapidly than other chemical compounds present in gasoline. Once in ground water it is very persistent. The MTBE conundrum has given state programs pause about potential ground water contamination threats or issues associated with other gasoline constituents, such as ethanol, *tertiary*-butyl alcohol (TBA), *tert*-amyl methyl ether (TAME) and ethylene dibromide (EDB). For example, recent studies have shown that when ethanol is in a gasoline release, microorganisms prefer to feed on (degrade) the ethanol, causing the BTEX component to move farther, reducing its rate of natural biodegradation. (Mackay et al., 2006)

The Energy Policy Act

Title XV of the Energy Policy Act of 2005 created the Underground Storage Tank Act of 2005, which amends the original legislation that created the federal UST program. The Act addresses some of the pressing issues in the federal/state UST programs, including:

- Requiring secondary containment for new and replaced tanks and piping, or financial responsibility for tank installers and manufacturers.
- Inspecting tanks every three years.
- Prohibiting fuel deliveries at noncompliant UST facilities.
- Developing operator-training requirements.
- Cleaning up releases that contain oxygenated fuel additives.

The deadlines, however, are very tight, and the funding to accomplish these tasks, though authorized in the Act, may not get to the states until FY2008. The states are working on meeting these requirements under severe funding constraints.

The Act also made several alterations to the Clean Air Act RFG program, including removal of the 2 percent oxygenate mandate for RFG. In response to the law, USEPA promulgated a direct final rule to amend the RFG regulations in order to eliminate regulatory standards requiring the use of oxygenates (e.g., MTBE) in RFG.

MINIMIZING THREATS FROM USTS AT THE LOCAL LEVEL

Besides state requirements and statutes, there are a number of actions municipalities can take to minimize threats to their water supply sources from underground and aboveground storage tanks. These include:

- Establish a comprehensive program to prevent the contamination of present and future drinking water from fuel storage tank releases.
- Take advantage of readily available GIS map resources to inventory all storage tanks in your source protection area.
- Make a special effort to locate and remove or properly close all abandoned tanks.
- Contact your state UST program to find out:
  - which UST facilities in your community's source protection area are in the state regulatory database
  - when those facilities were last inspected
  - facility compliance records
  - how you can work with the state to address facilities of concern
- Develop municipal ordinances, overlay zones, best management practices, or regulations to address potential threats from petroleum storage tanks in your source water protection area. (NEIWPCC, 2004)

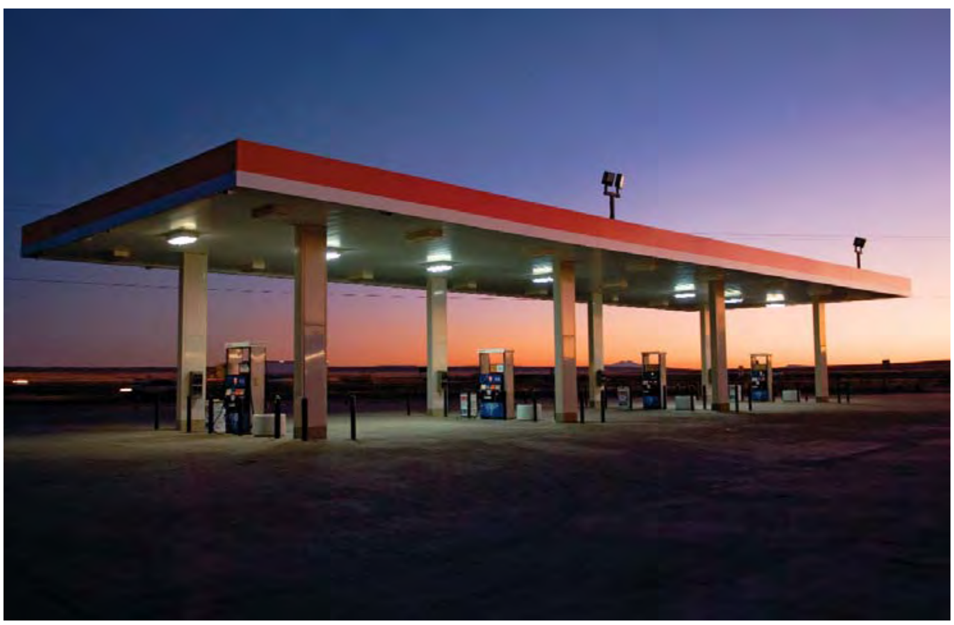


Photo: Steve Minor

A modern gas station in western New Mexico.

Recommended Actions

To Congress:

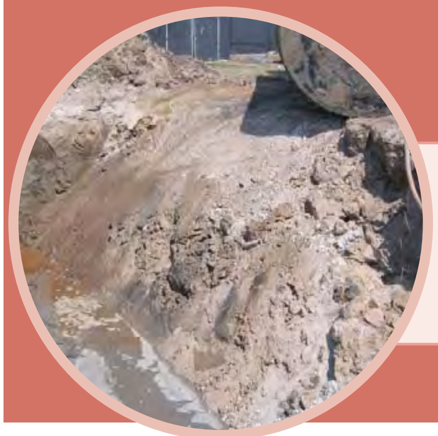
- Appropriate LUST Trust Fund money so that it can be sufficiently used for the purposes intended by Congress.
- Appropriate the funds necessary for states to carry out the new measures of the Energy Policy Act.
- Appropriate LUST Trust Fund money to the states for implementing the UST provisions of the Energy Policy Act (i.e., inspections, enforcement).
- Reevaluate the feasibility of including tank systems not currently covered by federal UST regulations, such as heating oil tanks and aboveground storage tanks not covered by Spill Prevention Control and Countermeasures rules.

To USEPA:

- Continue to encourage states to target UST enforcement and LUST response activities in areas of high-priority ground water (e.g., wellhead protection areas); over significant or single-source aquifers; near springs, sinkhole areas, and other karstic features; and in proximity to private wells.
- Modify the current UST regulations (40 CFR 280) so that standards meet today's technological capabilities.

To State Agencies:

- Adopt siting requirements for new UST facilities, including the establishment of minimum setback requirements in relation to water supply wells and high-priority ground water areas, and more protective requirements for existing tanks in high-priority ground water areas (e.g., site-grading requirements to keep storm water away from fueling areas).
- Prioritize UST inspections, compliance, and enforcement efforts for facilities within source water areas, near private drinking water wells, and over high-priority aquifers.



Leaks still occur, albeit far less frequently, and we must stay vigilant in order to prevent tank systems from leaking in the first place and to ensure that leaking systems are reported immediately and cleaned up expeditiously.

Photo: Missouri PSTIF

Section 7 References: Underground Storage Tanks

American Petroleum Institute (2003). *Answers to Frequently Asked Questions about Ethanol Impacts to Ground Water.* Available at: *http://www.api.org/ehs/groundwater/oxygenates/index.cfm*

Mackay, D.M., N. de Sieyes, M. Einarson, K. Feris, A. Pappas, I. Wood, L. Jacobson, L. Justice, M. Noske, K. Scow, J. Wilson. 2006. "Impact of Ethanol on the Natural Attenuation of Benzene, Toluene, and o-Xylene in a Normally Sulfate-Reducing Aquifer," *Environmental Science and Technology,* Volume 40,

NEIWPCC [New England Interstate Water Pollution Control Commission]. 2004. *Water Today, Water Tomorrow? Protecting Drinking Water Sources in Your Community: Tools for Municipal Officials.* Lowell, Massachusetts.

USEPA. February 2007. *UST Program Facts. http://www.EPA.gov/oust/pubs/ustfacts.htm.*

USEPA. *Overview of the Federal Underground Storage Tank Program http://www.epa.gov/swerust1/overview.htm* (Accessed February 24, 2007).

USEPA. 2001. U*nderground Storage Tanks: Building on the Past to Protect the Future.* EPA 510-R-04-001.

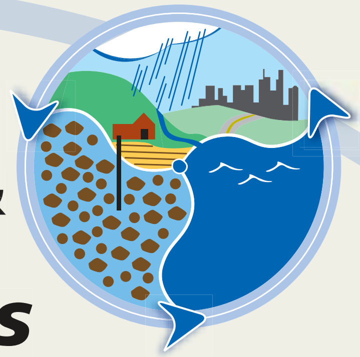
USGAO [U.S. Government Accountability Office]. 2005. *Environmental Protection: More Complete Data and Continued Emphasis on Leak Prevention Could Improve EPA's Underground Storage Tank Program.* GAO-06-45.

USGAO. 2007. *Leaking Underground Storage Tanks: EPA Should Take Steps to Better Ensure the Effective Use of Public Funding for Cleanups.* GAO-07-152.

Photo: Dave Belyea

This biofuels station in Eugene, Oregon, takes the whole business of fuel dispensing to a new level. Sited where a former gas station left behind petroleum-contaminated soil and ground water, the station is also a successful brownfield venture. It offers an assortment of biofuel blends for all gasoline and diesel vehicles, has a state-of-the-art double-walled fuel-storage system, is powered by 100% renewal energy, is bordered with grassy bioswales for stormwater runoff control, and has a "living roof" on the convenience store to reduce the flow of stormwater from what would otherwise be an impervious surface.

Ground Water & Onsite Wastewater Treatment Systems



Key Message

Onsite wastewater treatment systems (septic systems) have the potential to contaminate ground water and surface water resources, including drinking water supplies, with nitrates and other nutrients, chemicals, pathogens, and pharmaceuticals. However, when properly located, designed, constructed, and maintained, septic systems provide an effective and efficient means of treating domestic sewage and protecting water quality. Furthermore, there are economic and ecological advantages to managing wastewater within the watershed where it is produced.

Thousands of unsewered communities and rural residences will continue to depend on onsite systems for wastewater treatment and disposal. Today, as the population migrates farther from metropolitan areas, about one-third of all new development is served by decentralized treatment systems (USEPA, 2004). Onsite systems allow communities to develop while providing them with the means for adequately handling wastewater. To minimize the impacts of these systems on ground water, we need to:

- Ensure that onsite systems are properly designed, installed, and maintained.
- Take full advantage of innovative designs and sound science.
- Adopt effective management solutions.
- Actively educate the public on what wastes should not be put into their systems, and how these systems should be maintained.

Curlew Lake in northern Washington State showing eutrophication along the shore near densely spaced septic systems. (Photo from Curlew Lake Eutrophication Study, 1986, Washington State University.)

Minimizing the Impacts of Onsite Systems on Ground Water

"David Hayward came home one summer day to find brown, swampy puddles in his front yard. As he puzzled over the brown ooze, his neighbor strolled over and identified the problem: 'Looks like your septic system went.' Until that day, David didn't know septic systems died—he thought of his system as a simple underground tank that just made wastewater disappear."

Carol Steinfeld | "Septic System Basic" | *Mother Earth News* | October/November 2002

why Onsite Wastewater Treatment matters to ground water and surface water…

Nationwide, decentralized wastewater treatment systems (septic systems, private sewage systems, onsite sewage disposal systems) collect, treat, and release about 4 billion gallons of effluent per day from an estimated 26 million homes and businesses (USEPA, 2002). More than half of these systems were installed over 30 years ago, when rules were nonexistent, substandard, or poorly enforced. The percentage of homes and businesses served by these systems varies from state to state, from a high of about 55 percent in Vermont to a low of about 10 percent in California (USEPA, 2002).

Of concern is the fact that an estimated 10 percent to 20 percent of septic systems fail annually (USEPA, 2002), increasing the risk that pathogens (e.g., viruses, bacteria, cryptosporidiosis), nutrients (e.g., nitrates, phosphorus), pharmaceuticals, personal-care products, and household cleaning products will enter drinking water sources. Contamination of surface waters by fecal coliform bacteria is often associated with septic system infiltration. In fact, in USEPA's *Response to Congress on Use of Decentralized Wastewater Treatment Systems* in 1997, state agencies listed septic systems as the second most common threat to ground water resources. In November 2006, USEPA issued its final Ground Water Rule to provide increased protection against microbial pathogens in public water systems that use ground water sources. Microbial pathogens include disease-causing viruses and bacteria, such as E. coli and reach ground water from a variety of sources including failed septic systems. (See *http://www.epa.gov/safewater/disinfection/gwr/index.html*.)

A recent USGS Water Quality Assessment Program study on volatile organic compounds (VOCs) in ground water and drinking water supplies (Zogorski et al., 2006) found that VOC occurrence is widespread and can be attributed to the ubiquitous nature of many sources (including septic systems) and the

Photo: http://ndep.nv.gov/photo/carson.htm

Nevada's ground water protection strategy includes protecting all ground water as a potential source of drinking water and using strict contaminant source controls and monitoring. Ground water quality in Nevada is generally good enough for most uses. There have been relatively few detections of contaminants introduced by human activities in public water systems served by ground water. Even fewer systems have had detections that exceeded drinking water standards—nitrate is the most common contaminant found. Sources of nitrate include septic systems and livestock in suburban areas. Carson Valley has experienced rapid growth in areas that are outside those served by public water and sewage systems. This growth has led to the installation of septic systems at a rate of over 1,000 every 10 years.

vulnerability of many aquifers. Many people don't realize that some household products that are thoughtlessly tossed down the drain or flushed down the toilet contain VOCs or chemicals that form VOCs when added to water. Once in the environment VOCs tend to persist and migrate in ground water, potentially to drinking water supply wells.

The USGS study found that the factors describing the source, transport, and fate of VOCs were all important in explaining the widespread occurrence of VOCs. For example, the occurrence of perchloroethylene (PCE) was statistically associated with the percentage of urban land use and density of septic systems near sampled wells (source factors), depth to top of well screen (transport factor), and presence of dissolved oxygen (fate factor).

PCE, a chlorinated hydrocarbon solvent that can be found in numerous household products, moves easily through soil and ground water. While it does not dissolve easily in water, it can over time dissolve such that it can be a health risk (e.g., liver/kidney damage, liver/kidney cancer, leukemia). It is also very difficult to clean up PCE-contaminated ground water.

Despite the fact that these septic systems are known potential sources of ground water contamination, they are, as a whole, inadequately monitored and

FACTORS MOST COMMONLY ASSOCIATED WITH VOCS IN AQUIFERS

SOURCE FACTORS

- Septic systems
- Urban land
- Resource Conservation and Recovery Act (RCRA) hazardous-waste facilities
- Gasoline underground storage tank and leaking underground storage tank sites

TRANSPORT FACTORS

- Climatic conditions
- Depth to top of well screen
- Hydric (anoxic) soils

FATE FACTOR

- Oxic ground water (dissolved-oxygen concentration greater than or equal to 0.5 milligram per liter)

INDETERMINATE

- Type of well

Table 1. *Source: Zogorski et al., 2006*

SOURCES OF WATER-SUPPLY WELL CONTAMINATION

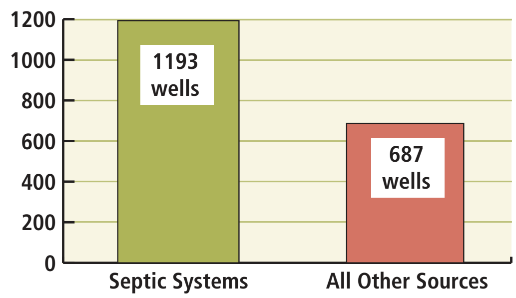


Figure. 1. *New Mexico Water-Supply Wells Contaminated by Onsite Septic Systems versus All Other Sources, Combined. (Modified from WQCC, 2002a)*

studied. In general, legal authority for regulating onsite systems rests with state, tribal, and local governments, and regulation may be divided in a variety of ways among jurisdictions. For example, the health department may regulate single-family systems, while the environmental agency may have jurisdiction over multiple-family or industrial septic systems.

ONSITE WASTEWATER TREATMENT IN THE NATURAL SYSTEM

During the operation of a septic system, household wastewater is flushed into a large underground multicompartmented holding tank, where the solids settle to the bottom of the tank. Bacteria in the tank help break down some of the solids. The liquid effluent flows out of the tank and into a leachfield (drainfield) consisting of a series of parallel, underground, perforated pipes that allow wastewater to percolate into the surrounding soil, where the wastewater treatment actually occurs.

Through various physical and biological processes, most bacteria and viruses and some nutrients in wastewater are consumed as the effluent travels through the soil layers. By design, these systems allow water from the drainfield to percolate into the underlying soil layers and potentially into ground water. Proper design and placement of these systems help prevent nitrates from exceeding the assimilative capacity of the ground water. Some states and local jurisdictions are using advanced system design for vulnerable areas (e.g., mound systems) and increased monitoring schedules for larger systems.

Photo: DCvision2006 - http://www.flickr.com/photos/dcvision2006/534708375/in/set-72157594312514342/

View inside a septic system with clogged drainage.

For an onsite system to function properly and effectively, appropriate land conditions (e.g., soil, geology, hydrology) and system design, installation, and main-

EFFECTS OF CONCENTRATED HOUSING ON GROUND WATER LEVEL

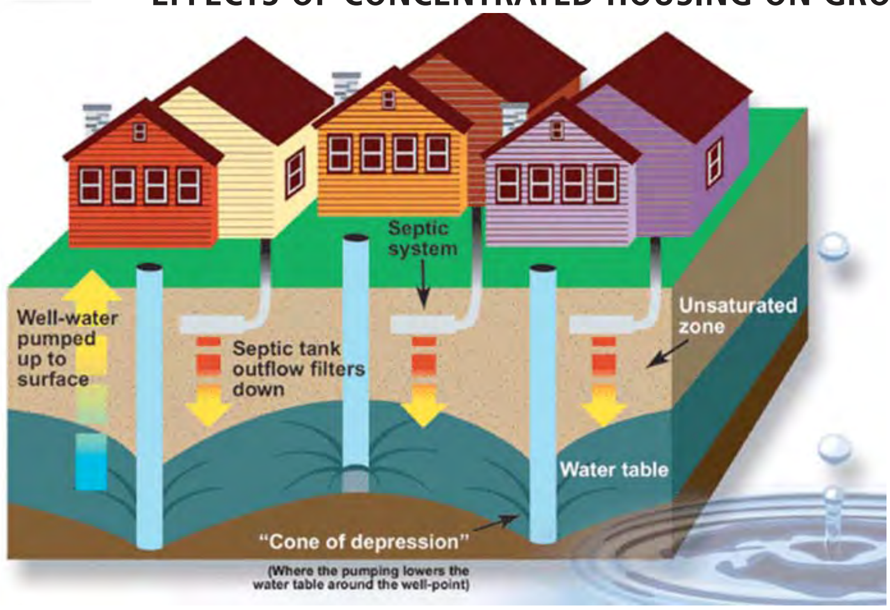


Figure 2. *Many onsite sewage disposal system regulatory programs have requirements for the setback distance between wells and onsite systems, minimum percolation rates, and/or absorption-field sizing to provide adequate dilution and attenuation of chemical and biological contaminants in order to prevent contamination of ground water and drinking water supplies. Housing developments with small lots and individual wells exist in many rural areas. If the aquifer is low yielding so that pumping causes a large drawdown, a cone of depression will develop around each well. Thus, several domestic wells close together can create a steady lowering of the water table if pumpage exceeds the natural recharge to the system (unless the withdrawn water is returned to the aquifer through septic systems).*

Source: http://cobweb.ecn.purdue.edu/~epados/septics/density.htm tenance are necessary. Effluent must move slowly through aerated soil or rock so organisms can feed on the drainfield effluent to remove the pathogens. Septic system technology now favors placing leaching structures so they are shallow enough to allow for higher oxygen availability and the benefit of evapotranspiration through root uptake to help treat the effluent. If the effluent moves through the soil or rock too quickly, the organisms cannot adequately digest it, and the wastewater can contaminate the aquifer underneath.

Improperly functioning systems pose a contamination risk to ground water and surface waters. Ground and surface water pollution is closely linked, since the baseflow of streams draining to lakes, ponds, and wetlands comes from ground water contributions.

Septic system function is typically impaired by:

- Improperly maintained, unpumped, sludge-filled septic tanks, which eventually cause clogged absorption fields and hydraulic overloading.
- Poorly or improperly sited leachfields (e.g., too many per acre, seasonally high ground water, unsuitable geology, poorly drained soils).

Photo: Ken Erney - http://www.flickr.com/photos/cryptik/302980912/

Installation of a drip irrigation system in Virginia. In addition to some control electronics in the house, the system includes the tanks you see in the photo as well as about an acre of land dedicated to a drain field. The drain field uses shallow buried tubing to disburse the treated water, in contrast to the standard depth fields used in conventional systems. The system is designed to handle about 600 gallons of sewage per day. The state estimates the size of the system based on the number of bedrooms at a rate of 150 GPD per bedroom.

- Discharged wastes (e.g., solvents, chemicals, household hazardous wastes) that can wipe out bacterial treatment processes.

The issue of septic systems and water quality is especially significant to ponds, lakes, and coastal estuaries. During wet periods, when water tables are high, a septic system may be more likely to contribute poorly treated sewage and nutrients to a water body. Water bodies contaminated by wastewater moving from ground water to surface water pose a health threat to people and aquatic life. Disease-causing organisms present in wastewater can cause dysentery, cholera, typhoid, and hepatitis A. Nitrates can contaminate drinking water and lead to illness in humans (for example, blue-baby syndrome, which affects an infant's ability to carry oxygen in its blood). Other nutrients, primarily phosphorous, can promote algae and weed growth in lakes, depleting oxygen levels and killing fish. (Tri-State Water Quality Council, 2005)

PHARMACEUTICALS AND PERSONAL-CARE PRODUCTS—AN EMERGING CONCERN

A 2002 USGS study (Kolpin et al., 2002) found that, of 130 waterways surveyed in 30 states, 80 percent contained trace amounts of pharmaceuticals and personal-care products (PPCPs). These products include prescription and over-the-counter drugs such as painkillers, antidepressants, lipid regulators, and contraceptive pills, as well as substances such as nicotine, caffeine, food supplements, cosmetics, sunscreen, antibacterial soaps, and cleaning products.

One of the largest sources of PPCPs is the typical household (NESC, 2007). PPCPs enter the environment primarily though household waste disposal systems—human excrement (e.g., ingested drugs), flushing of unwanted or expired pharmaceuticals, washing off externally applied drugs and chemicals. Septic systems are typically not designed to treat many of these products, and little is known about what PPCPs are doing to septic system performance. A disruption in the balance of bacteria in the system can affect performance and cause system failure.

Photo: Powell River Project, Virginia Tech

Certain onsite systems are regulated under the Underground Injection Control (UIC) Program if they (a) accept only sanitary wastes and are used by a multiple dwelling, community, or regional system; (b) accept only sanitary wastes, are used by a nonresidential establishment, and have the capacity to serve 20 or more people per day; or (c) accept anything other than sanitary waste, regardless of system size. Discharges from these onsite systems are authorized as long as they do not endanger underground sources of drinking water.

LARGE-CAPACITY SEPTIC SYSTEMS

Large-capacity septic systems are regulated as underground injection control (UIC) program Class V wells that receive solely sanitary waste and have the capacity to serve 20 or more people (e.g., schools, multiple dwellings, churches, office buildings, shopping malls). These systems fall within the federal UIC program, as authorized under the Safe Drinking Water Act of 1974, 1986, 1996, and regulated by UIC programs at the state or federal level. USEPA recognizes that different governmental offices in different states regulate septic systems of varying sizes. The UIC program is responsible for ensuring that these non-UIC programs meet UIC program requirements when regulating large-capacity septic systems.

In a May 2001 determination, USEPA concluded that federal regulations under the UIC requirements were not necessary at that time for large-capacity septic systems. The only onsite wastewater systems regulated under the Class V category are large-capacity cesspools, which are now illegal.

USEPA noted that existing state and local requirements are specifically tailored to local hydrogeologic conditions and therefore more effective than any additional federal UIC rules could be. The agency felt that any gap in environmental protection associated with large-capacity systems is due to a lack of effective and proper implementation, not a lack of standards, and encouraged local authorities to implement existing standards in an efficient and effective manner.

LIVING WITH SEPTIC SYSTEMS

Septic systems are sometimes considered to be temporary installations that will eventually be replaced by complex and expensive centralized wastewater treatment facilities. This mind-set has been eclipsed by the reality that in many places onsite systems are likely to be permanent approaches to treating wastewater for release and reuse in the environment.

Whether onsite systems are temporary or permanent wastewater treatment installations, each must be designed, operated, and maintained to ensure that it is going to function effectively and do no harm to human health and the water environment as long as it is in service. Approval of each proposed new system must take into account the cumulative impact of existing and future systems.

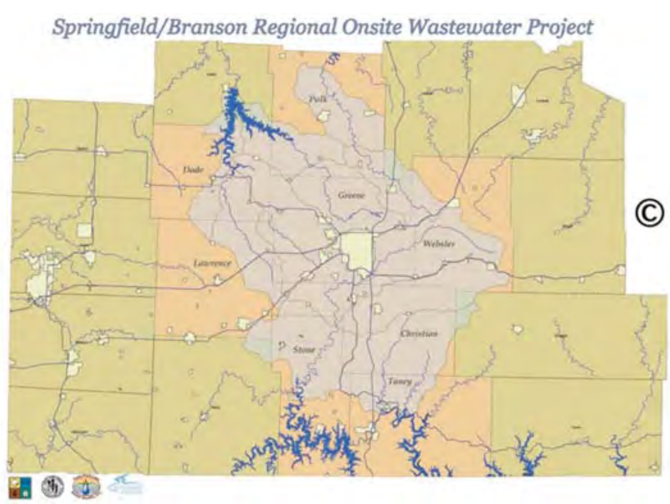


Figure 3. *The Watershed Committee of the Ozarks (WCO) is currently working with Table Rock Water Quality Incorporated (TRLWQ) to demonstrate the remediation of onsite wastewater treatment systems that have failed and pose a contamination threat to ground water. This project will provide design and installation services for the introduction of an alternative type of wastewater treatment system that can serve up to twenty homes in targeted areas to replace existing failing onsite systems.*

Source: Watershed Committee of the Ozarks

As stated in USEPA's voluntary national guidelines: "Although it is difficult to measure and document specific cause-and-effect relationships between onsite wastewater treatment systems and the quality of our water resources, it is widely accepted that improperly managed systems contribute to major water quality problems."

Septic Systems—a Local Concern

While design and construction standards for decentralized systems are typically established by state environmental agencies, responsibility for onsite wastewater oversight typically rests with local or regional boards of health, health directors, or sanitarians. Responsibility for ensuring the integrity of a septic system in the environment begins with approving the design of the system—will it function properly in a given subsurface environment?—and then overseeing the installation of that system according to design specifications. Many states have certification programs for installers. However, most communities do not routinely oversee septic system operation and maintenance or detect and respond to changes in wastewater loads that can overwhelm a system.

Responsibility for potential impacts on ground water from onsite systems also rests to some extent with local planning and zoning entities, whose zoning and subdivision requirements may or may not take into account the ability of the land to support a desired development density in a given area. Most health districts now restrict septic systems in vulnerable areas and have rules about spacing and density per acre. However, too few of these entities take into account the incremental effect of additional decentralized wastewater systems within a given water supply region or watershed. While the nutrient load from one septic tank system may be insignificant, the cumulative effect of adding more systems may trigger problems. Nutrients can build up in the soil and ground water over time to unhealthy levels. When surface runoff or ground water flow carry these pollutants to surface water, they can create an environment ripe for algal growth.

On the Home Front

Perfectly good septic systems can fail because the homeowner isn't giving them the attention they require. Examples of septic system abuse include:

- Failure to pump the tank on a regular schedule.
- Damage to the drainfield from compaction (e.g., caused by driving vehicles or performing construction activities on the drainfield), animal burrowing and tunneling in the leachfield, or tree and shrub roots.

Figure 4. *"Community" leaching fields serving multiple single-family homes, with their open space, environmental and aesthetic benefits, are now fully approvable in most states. This plat shows a proposed community leaching field in Connecticut that will be assessed by the Department of Environmental Protection for approval of the hydraulics of the proposed system, the treatment of nitrogen and pathogens, and the mixing of treated wastewater into the area's ground water system. The location of the proposed system's leaching fields, affected soils, the supporting ground water system, and adjacent uses are factors that will influence the design and feasibility of the system.*

The Biocycle system shown here is a full-treatment system comprised of two primary settlement chambers, two secondary-treatment tanks incorporating secondary settlement, and a final storage tank from which the wastewater is pumped periodically into a percolation area.

MANAGED DECENTRALIZED SYSTEMS PUT THE ONUS ON THE EXPERTS

The high rate of onsite wastewater treatment system failures is typically the result of poor system siting, design, and maintenance—not the inability of these systems to adequately treat and disperse wastewater. A septic system management program offers the best hope for ensuring that these decentralized systems do their jobs without harm to ground and surface water resources. Some communities have such programs but most do not. If a community does not want to take this responsibility on because of the cost, then a utility approach can provide a cost-effective solution by financing septic management services through collection of a dedicated fee assessed to system owners.

A septic utility can handle such activities as ensuring proper system siting, design, installation, performance, and operation and maintenance; providing public education and training and planning; and handling record keeping/reporting, financial assistance, and funding responsibilities. It can inspect and monitor systems regularly, pump out on an appropriate schedule, and make repairs in a timely fashion. The utility can also enforce existing regulations and establish any other necessary regulations.

Septic system utilities can be operated by local governments or by private entities. For example, the first regulated onsite system public utility company in Tennessee, Tennessee Wastewater Systems, Inc,, was established in 1993 to manage cluster-type wastewater systems across the state. In this case, developers pay the capital cost to put the systems in place and then the utility takes over from there.

- Disposal of household chemicals (e.g., paint thinner) into the system.
- Overloading the system by using a garbage disposal.
- Inability of the system to support the number of people in the household.
- Use of septic tank additives, drain cleaners, or harsh household chemicals.
- Planting inappropriate vegetation (e.g., trees, shrubs) over the drainfield.

Photo: Aaron Vincent

First cleanout for this septic system, which was installed in 1978. While it is difficult to measure and document specific cause-and-effect relationships between onsite systems and the quality of our water resources, it is widely accepted that improperly operating systems (resulting from inadequate siting, design, construction, installation, operation, and/or maintenance) contribute to major water quality problems. Improved operation and performance of onsite systems through better management will be essential if the nation's water quality and public health goals are to be attained.

The Management Approach to Wastewater

Since, for the most part, responsibility for conventional gravity-based septic systems rests with homeowners, who are often uniformed about the potential health risks of these systems, USEPA is promoting a management approach to ensure that septic systems perform effectively. Many community-development strategies are headed in this direction as an alternative to traditional centralized water and sewer lines that are costly and can give rise to unwanted sprawl, traffic congestion, and environmental degradation.

To promote the effective performance of any type of septic systems, state and local governments need to develop effective strategies that consider critical elements such as planning, site soil conditions, risk factors, system design, operation and maintenance, periodic inspections, monitoring, and financial support. Some neighborhood associations now impose annual fees to help support septic system maintenance.

Photo: sappyroo – http://www.flickr.com/photos/20018463@N00/1599982685/

A malfunctioning septic tank that is being cleaned out and repaired.

This new waste management paradigm involves a cooperative, coordinated, integrative approach to protecting public health and water resources. It includes the use of performance-based management techniques, rather than prescriptive code requirements (which don't take into account the potential for environmental degradation) for system siting, design, and operation.

Some communities are experimenting with performance-based approaches, in which onsite systems are designed for specific sites to protect water quality and public health. Many continue to rely on the more traditional but less flexible prescriptive requirements for technologies that have proven to be effective under a wide range of site conditions. Newer, or "alternative," onsite treatment technologies are often more complex than conventional systems, and incorporate pumps, recirculation piping, aeration, and other features that require periodic monitoring and maintenance.

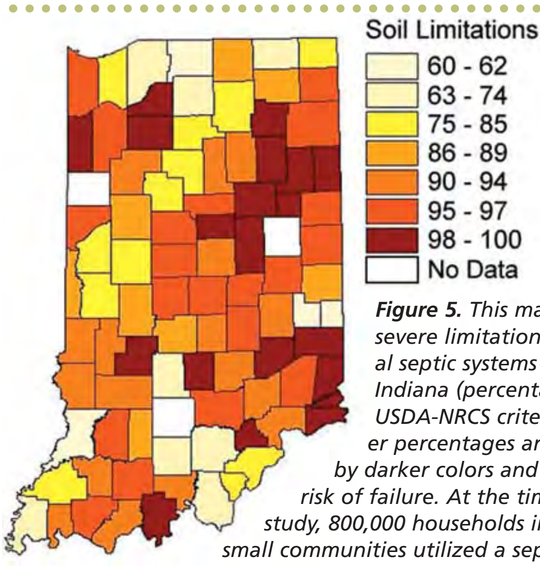


Figure 5. *This map shows severe limitations for traditional septic systems by county in Indiana (percentages based on USDA-NRCS criteria). The higher percentages are represented by darker colors and mean greater risk of failure. At the time of this study, 800,000 households in rural and small communities utilized a septic system. About 15,000 onsite wastewater disposal permits were approved annually, and county sanitarians estimated that failure rates were as high as 70 percent and that about 200,000 systems were operating inadequately. It is likely that such conditions have not improved since then, in Indiana or elsewhere.*

Source: C. Taylor, J. Yahner, and D. Jones. 1997. An Evaluation of Onsite Technology in Indiana. Purdue University, West Lafayette, IN.

ELEMENTS OF AN EFFECTIVE DECENTRALIZED WASTEWATER MANAGEMENT PROGRAM

Local and regional governments or groups such as watershed associations can protect ground water resources and public health by adopting comprehensive decentralized wastewater management programs, including:

- Establishing permit and inspection requirements to ensure proper installation.
- Educating the public about septic system use and care.
- Establishing a septic system maintenance ordinance.
- Banning hazardous additives or cleaners for septic systems.
- Connecting homes and businesses to central sewers or decentralized treatment systems, such as package plants or cluster systems, when feasible.
- Requiring additional treatment, such as a sand filter, when needed.
- Establishing standards for design, installation, and siting new septic systems.
- Training and certifying/licensing septic system professionals.
- Requiring performance-based system monitoring.
- Establishing financial assistance and funding programs.
- Ensuring that septic systems undergo technical review during land-use planning and subdivision approval.

Source: USEPA. February 2002. Onsite Wastewater Treatment Systems Manual. EPA/625/R-00/008.

A SAMPLING OF STRATEGIES FOR MANAGING ONSITE SYSTEMS

Minnesota's 10-Year Plan to Upgrade and Maintain Onsite Treatment Systems

In Minnesota, approximately 86% of the state's full-time residents are served by onsite systems. In February 2004, the Minnesota Pollution Control Agency (MPCA) presented the state legislature with the *10-Year Plan to Upgrade and Maintain Onsite Treatment Systems,* in response to the legislature's charge to the agency to develop a plan to:

- Identify and upgrade all noncompliant Onsite Treatment Systems (ISTSs) within a 10-year period.
- Develop a maintenance oversight system that ensures that all ISTSs remain in compliance requirements of Minnesota Rules.
- Recommend enhanced funding mechanisms to assist homeowners in making necessary upgrades.

MNPCA identified the following activities, which are now being implemented, that would be necessary to meet these goals:

- Identify unsewered properties.
- Improve professional competency of ISTS professionals.
- Enhance baseline county programs (where standards are developed and program oversight and funding takes place).

For more information on the plan, go to: http://www.pca.state.mn.us/publications/reports/lrwq-wwists-1sy04.pdf.

Effluent Quality Requirements and Operating Permits in St. Louis County, Minnesota

In St. Louis County, many of the soils are very slowly permeable lacustrine clays, shallow to bedrock, and often near saturation—poorly suited for application of traditional onsite treatment systems. The state minimum code restricts onsite systems to sites that have permeable soils with sufficient unsaturated depths to maintain a 3-foot separation distance to the saturated zone. To allow the use of onsite treatment, the county adopted performance requirements that may be followed in lieu of the prescriptive requirements where less than 3 feet of unsaturated, permeable soils are present. In such cases the owner must continuously demonstrate and certify that the system is meeting these requirements, which is achieved through the issuance of renewable operating permits based on evaluation of system performance.

Permit renewal requires that the owner document that these requirements have been met. If the documentation is not provided, a temporary permit is issued with a compliance schedule. If the compliance schedule is not met, the county has the option of reissuing the temporary permit and/or assessing penalties. The permit program is self-supporting through permit fees.

The county has also adopted a performance code that establishes effluent requirements for systems installed where minimum standards cannot be met. For example, where the natural soil has an unsaturated depth of less than 3 feet but more than 1 foot, the effluent discharged to the soil must have no more than 10,000 fecal coliform colonies per 100 mL. On sites with 1 foot or less of unsaturated soil, the effluent must have no more than 200 fecal coliform colonies per 100 mL. These effluent limits are monitored prior to final discharge at the infiltrative surface but recognize treatment provided by the soil. If hydraulic failure occurs, the county considers the potential risk within acceptable limits. The expectation is that any discharges to the surface will meet at least the primary contact water quality requirements of 200 fecal coliform colonies per 100 mL. Other requirements, such as nutrient limitations, may be established for systems installed in environmentally sensitive areas.

Source: http://www.epa.gov/ORD/NRMRL/pubs/625r00008/625R00008chap3.pdf.

The Massachusetts Onsite Treatment System Inspection Program

In 1996, Massachusetts mandated inspections of Onsite Wastewater Treatment Systems (OWTSs) to identify and address problems posed by failing systems (310 CMR 15.300, 1996). The intent of the program was to ensure the proper operation and maintenance of all systems. A significant part of the program is the annual production of educational materials for distribution to the public describing the importance of proper maintenance and operation of onsite systems and the impact these systems can have on public health and the environment.

Inspections are required at the time of property transfer, a change in use of the building, or an increase in discharges to the system. Systems with design flows equal to or greater than 10,000 gallons per day require annual inspections. Inspections are to be performed by state-approved persons.

A system is deemed to be failing to protect public health, safety, and the environment if the septic tank is made of steel; if the OWTS is found to be backing

A SAMPLING OF STRATEGIES FOR MANAGING ONSITE SYSTEMS (continued from page 10)

up or if it is discharging directly or indirectly onto the surface of the ground; if the infiltration system elevation is below the high ground water level elevation; or if the system components encroach on established horizontal setback distances. The owner must make the appropriate upgrades to the system within two years of discovery. Failure to have the system inspected as required or to make the necessary repairs constitutes a violation of the code.

Source: Title V, Massachusetts Environmental Code.

Limiting Nitrogen from Onsite Systems by Performance Requirements in Massachusetts

Massachusetts also has requirements for nitrogen-sensitive areas. These areas are defined in state rules as occurring within Interim Wellhead Protection Areas, one-year recharge areas of public water supplies, nitrogen-sensitive embayments, and other areas that are designated as nitrogen-sensitive based on scientific evaluations of the affected water body (310 Code of Massachusetts Regulations 15.000, 1996). Any new construction using onsite wastewater treatment in these designated areas must abide by prescriptive standards that limit design flows to a maximum of 440 gallons per day of aggregated flows per acre. Exceptions are permitted for treatment systems with enhanced nitrogen removal capability.

Source: Title V, Massachusetts Environmental Code and http://www.epa.gov/ORD/NRMRL/pubs/625r00008/625R00008chap3.pdf.

Monitoring Requirements in Washington State

The state of Washington Department of Health has adopted a number of monitoring requirements that OWTS owners must meet. Because such requirements place additional oversight responsibilities on management agencies, additional resources are needed to ensure compliance. Among the requirements, the system owner is responsible for properly operating and maintaining the system and must:

- Determine the level of solids and scum in the septic tank once every three years.
- Employ an approved pumping service provider to remove the septage from the tank when the level of solids and scum indicates that removal is necessary.
- Protect the system area and the reserve area from cover by structures or impervious material, surface drainage, soil compaction (e.g., by vehicular traffic or livestock), and damage by soil removal and grade alteration.
- Keep the flow of sewage to the system at or below the approved design both in quantity and waste strength.
- Operate and maintain alternative systems as directed by the local health officer.
- Direct drains, such as footing or roof drains, away from the area where the system is located.

Areas of special concern are those where the health officer or department determines additional requirements might be necessary to reduce system failures or minimize potential impacts upon public health. Examples include shellfish habitat, sole-source aquifers, public water supply protection areas, watersheds of recreational waters, wetlands used in food production, and areas that are frequently flooded.

Source: Washington Department of Health, 1994 and http://www.epa.gov/ORD/NRMRL/pubs/625r00008/625R00008chap3.pdf.

Onsite System Inspection/Maintenance Guidance in Rhode Island

In 2000, the Rhode Island Department of Environmental Management published the *Septic System Checkup: The Rhode Island Handbook for Inspection,* an inclusive guide to inspecting and maintaining septic systems. The handbook, available to the public, is written for both lay people and professionals in the field. The guide is an easy-to-understand, detailed protocol for inspection and maintenance and includes newly developed state standards for septic system inspection and maintenance.

The handbook describes two types of inspections: a maintenance inspection to determine the need for pumping and minor repairs, and a functional inspection for use during property transfers. The handbook also includes detailed instructions for locating septic-system components, diagnosing in-home plumbing problems, flow testing and dye tracing, and scheduling inspections. Several Rhode Island communities use *Septic System Checkup* as their inspection standard. The University of Rhode Island offers a training course for professionals interested in becoming certified in the inspection procedures. The handbook is available free on-line at *http://www.dem.ri.gov/pubs/regs/regs/water/isdsbook.pdf*

Source: Rhode Island Department of Environmental Management.

In the document *Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems (http://www.epa.gov/owm/septic/ pubs/septic_guidelines.pdf),* USEPA recognizes that the disparate governmental units that regulate onsite systems need "a flexible framework and guidance to best tailor their management programs to the specific needs of the community and the needs of the watershed."

USEPA's guidelines include the following voluntary management models:

- **Model 1: The Homeowner Awareness Model**
  Ensures systems are sited, designed, and constructed in compliance with prevailing rules, and includes inventory and documentation of all systems by regulatory authority with voluntary maintenance. Appropriate for conventional systems in areas of low environmental sensitivity.
- **Model 2: The Maintenance Contract Model**
  This builds on Model 1 by ensuring that property owners maintain maintenance contracts with trained operators, including tracking and reporting functions to ensure that requirements of maintenance contracts are fulfilled. Appropriate for more complex wastewater treatment systems, small clusters, or restrictive site conditions.
- **Model 3: The Operating Permit Model**
  This builds on Model 2 by issuing limited-term renewable operating permits to individual system owners. Provides continued oversight of system performance (this may include scheduled inspections). Appropriate where large-capacity onsite systems or systems treating high-strength wastewaters exist, and in areas of heightened environmental concern (lakes, estuaries, or drinking water supplies).
- **Model 4: The Responsible Management Entity (RME) Operation and Maintenance Model**
  Similar to Model 3, except that after systems are constructed, operating permits are issued to a management entity that performs operation and maintenance activities. This model is appropriate where large numbers of onsite and clustered systems must meet specific water quality requirements because environmental sensitivity is high (e.g., shellfish waters or wellhead protection areas).
- **Model 5: The Responsible Management Entity (RME) Ownership Model**
  Similar to Model 3, except that the RME owns, operates, and manages the decentralized wastewater treatment systems in a manner analogous to central sewerage. This is appropriate where new or existing high-density development is proposed or exists near sensitive receiving water.

USEPA's website, *http://cfpub.epa.gov/owm/septic/home.cfm,* provides an excellent array of documents that communities can download to learn about managing decentralized wastewater treatment systems.

National Performance Code in the Works

The National Onsite Wastewater Recycling Association (NOWRA) is currently developing a model onsite system performance code to assist states and local regulators in addressing existing conflicts with the permitting and use of decentralized systems. This work is intended to accomplish the following objectives.

- Promote the rationalization of regulations across political boundaries with performance- and science-based code provisions.
- Establish an efficient method with which to evaluate and deploy new onsite wastewater treatment processes.
- Create a methodology to integrate decentralized wastewater treatment standard setting mechanisms within the USEPA Total Maximum Daily Load (TMDL) program.
- Advance the professionalism of industry participants through education, training, and certification.

Those involved in this process represented all geographic regions of North America, and the regulatory, service, and manufacturing segments of the industry. Funding for this effort was provided by self-funded volunteers, grants from USEPA, and contributions from business, industry, and state onsite associations. For more information, go to: *http://www.model-code.org/*

Recommended Actions

To USEPA and the Research Community:

- Fund and conduct demonstration projects to test the applicability of the various management models described in USEPA's *National Guidelines for Management of Onsite and Cluster (Decentralized) Wastewater Treatment Systems* (EPA 832-B-03-001) within a wide range of hydrogeologic and institutional settings (e.g., economic, legal, administrative, regulatory), including utilities that would install, manage, operate, and monitor performance-based septic systems located in areas of high-priority aquifers.
- Commission additional research regarding onsite system residuals, including emerging/unregulated contaminants such as pharmaceuticals, and the extent to which they are migrating to ground water, and compile and evaluate the latest advances in onsite wastewater treatment science and technology.

To USGS and State Geological Surveys:

- Conduct additional hydrogeologic and aquifer-vulnerability mapping at a scale that allows use by local and state governments for the purpose of siting onsite wastewater treatment systems and determining the need for advanced treatment for specific contaminants, including unregulated contaminants and pharmaceuticals and personal-care products.

To State and Local Agencies:

- Develop coordination protocols among all potentially involved agencies to promote more consistent regulatory oversight of both domestic and commercial onsite wastewater treatment systems.
- Encourage effective septic system siting, installation, inspection, and maintenance as described in USEPA's *National Guidelines for Management of Onsite and Cluster (Decentralized) Wastewater Treatment Systems,* and recommend that communities use one or more of the management models described in the guidelines.

To Homeowners:

- Operate your waste-disposal system according to recommended practices.
- Maintain your system on a regular schedule.
- If you sell your home, inform the new owner about your septic system and share maintenance records.

Section 8 References: Ground Water and Onsite Wastewater Treatment Systems

Kolpin, Dana W., E. T. Furlong, M. T. Meyer, E. M. Thurman, S. D. Zaugg, L. B. Barber, and H. T. Buxton. 2002. "Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in U.S. Streams, 1999–2000: A National Reconnaissance." *Environmental Science & Technology,* American Chemical Society. Web release date: March 15, 2002. *ks.water.usgs.gov/Kansas/pubs/abstracts/emt.est.v36.html*

NESC [National Environmental Services Center]. Winter 2007. "Pharmaceuticals and Personal Care Products: An Overview." *Pipeline* 18, no. 1. Available at: *http://www.nesc.wvu.edu/nsfc/pdf/pipline/PL_wi07.pdf*

Tri-State Water Quality Council. 2005. *Septic System Impact of Surface Water: A Review for the Inland Northwest.* Available at: *www.tristatecouncil.org/documents/05septic_system_impacts.pdf*

USEPA. September 2004. *Primer for Municipal Wastewater Treatment Systems.* EPA 832-R-04-001.

USEPA. March 2003. *Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems.* EPA 832-B-03-001.

USEPA. February 2002. *Onsite Wastewater Treatment Systems Manual.* EPA/625/R-00/008.

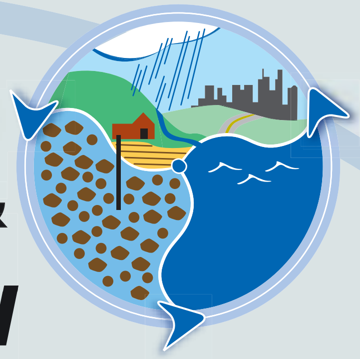
USEPA. 2005. *Handbook for Managing Onsite and Clusterd (Decentralized) Wastewater Treatment Systems.* EPA No. 832-05-001.

USEPA. 1997. *Response to Congress on Use of Decentralized Wastewater Treatment Systems.* EPA 832/R-97/001b.

Zogorski, J.S., J. M.Carter, T. Ivahnenko, W. W. Lapham, M. J. Moran, B. L. Rowe, P. J. Squillace, and P. L.Toccalina. 2006. *The Quality of Our Nation's Waters: Volatile Organic Compounds in the Nations Ground Water and Drinking-Water Supply Wells.* USGS Circular 1292. Available at: *http://pubs.usgs.gov/circ/circ1292/pdf/circular1292.pdf*

A newly installed septic tank at a lake-side cabin. The tank has been installed in a hillside, which requires tall and short access points to facilitate periodic inspection and maintenance and accommodate slope.

Ground Water & Underground Injection Control



Key Message

The success of the deep well Underground Injection Control (UIC) program in isolating massive volumes of pollutants from underground sources of drinking water and other parts of the ecosystem has led some national policy makers to assume that no additional federal funding is needed, even though new challenges and responsibilities continue to be added to the program.

The two most serious challenges and responsibilities confronting the UIC program today are:

- Some types of shallow injection wells, such as motor vehicle waste disposal wells, large-capacity cesspools, stormwater drainage wells, and some types of septic wells, continue to be among the most neglected sources of ground water contamination in the country.
- Technologies necessary for the management of residuals from water treatment and for the geosequestration of carbon dioxide (CO_2) will require very large numbers of new injection wells, far exceeding present program resource capabilities.

Without additional federal funding, federal and state UIC programs will not be able to eliminate the harmful impacts of high-risk types of shallow injection wells, nor maximize the benefits of safe underground injection to enable new technologies for providing safe drinking water and environmental protection.

Photo: Lindsay Taliaferro, Ohio EPA.

The threat to Underground Sources of Drinking Water (USDWs) posed by Class V wells is inherent in their general shallowness and the fact that they are often located over aquifers. Contamination incidents tend to be associated with the most prevalent of the high-risk types of Class V wells.

UIC—the Growing Pains

"We must change our lives, so that it will be possible to live by the…assumption that what is good for the world will be good for us. And that requires that we make the effort to know the world and to learn what is good for it. We must learn to cooperate in its processes, and to yield to its limits."

Wendell Berry | *The Long-Legged House*

why the UIC Program matters to ground water…

Underground injection refers to the placement of fluids into the subsurface through a well bore. The federal UIC program, designed to prevent contamination of underground sources of drinking water (USDWs), divides injection wells into five classes based on usage. (See "About UIC" page 9•5.) The practice of underground injection has become diverse in its many applications and is essential to activities such as petroleum production, chemical processing, food production, manufacturing, mining, operation of many small specialty plants and related businesses, and remediation of ground water contamination.

Underground injection is used to isolate more than 50 percent of the liquid hazardous waste and a large percentage of the nonhazardous industrial liquid waste generated in the United States. While other options exist, such as wastewater and chemical-specific treatment technologies, it would be very costly to treat and, in fact, questionable to release the billions of gallons of wastes produced each year to surface waters. In addition, the residuals from such treatment could have a negative impact on sensitive aquatic systems.

Whether in adolescent humans or regulatory programs, "growing pains" are symptomatic of fast or uneven growth that outstrips supporting resources. As the UIC program transitions from its origin in the early 1980s, it is experiencing significant new changes that are creating the kinds of problems that might be described as regulatory growing pains.

A "mature" regulatory program suggests that the major processes are working smoothly, the principal issues are well understood, and significant problems

Treated municipal wastewater is pumped more than 3,000 feet deep underground through a Class I injection well in South Florida.

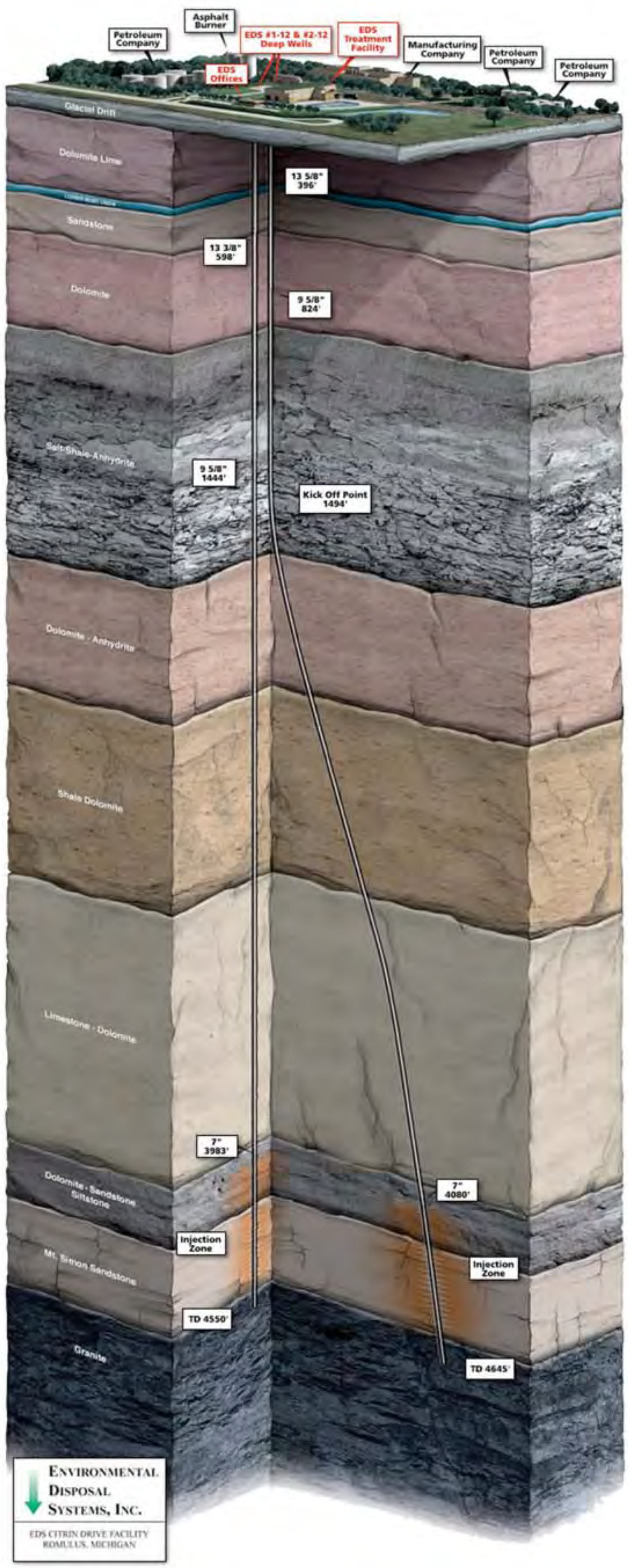


Figure 1. *A simplified earth cross section showing Class I injection wells. Source: Class I injection well permit application, USEPA Region 5*

encountered have been solved. For Class I, II, III, and IV types of UIC wells, this is true. However, the Class V category of the UIC program has not kept pace with the maturation of the rest of the program. Additional financial resources are needed to conduct essential inventories, inspections, and compliance monitoring.

Historically, the general public (and many regulators) assumed the greatest environmental risks existed in the Class I, II, and III programs. This has a negative effect on the substantial resource needs of the larger Class V shallow injection well program, where it has become apparent that most of the environmental risks exist.

There is a serious lack of appreciation for the fact that the level of federal funding for the UIC program has remained at approximately $10.5 million for the past 16 years, and has, in effect, been diminished by inflation. During these years, state agencies responsible for the UIC program have faced increased federal compliance and reporting requirements and significantly more administrative paperwork, not to mention severe individual state budget deficiencies. The result has been that while the workload and responsibilities for oversight of this federal UIC program have been substantially increasing, the financial capacity to carry them out has been decreasing.

The UIC program's "growing pains" in regard to Class V injection wells are illustrated by a 2004 survey of state UIC programs conducted by the Ground Water Protection Council (GWPC), which concluded that the shortfall of funds for Class V permitting and enforcement programs for these high-risk types of wells is much greater than originally thought. Specifically, the survey indicated that full implementation of the Class V regulations would require an additional $56 million above FY2003 and subsequent USEPA budget levels of $10.2 million. Based on the results of the survey, GWPC estimated that there were at least 1.5 million Class V wells nationwide, many of which existed without permits or the

Photo: 1986, CH2M Hill and Sterling Fibers

Neale Sharitz at an industrial primary injection wellhead that Sterling Fibers, Inc. constructed in 1971 in Milton, Florida. This wellhead configuration is typical of a Class I disposal well at an industrial facility.

knowledge of state or federal regulatory agencies. (GWPC, 2004)

In addition to Class V concerns, a new UIC-related financial need is surfacing with the advent of new technologies, such as drinking water treatment resulting in residuals (e.g., desalination concentrate) and carbon dioxide (CO_2) geosequestration, that are important for providing new drinking water supplies and reducing greenhouse gas emissions. These will likely require thousands of new injection wells, straining already inadequate regulatory program resources. State permit requirements to implement these new technologies will, no doubt, compete with the need to find and eliminate high-risk types of Class V wells in the allocation of limited program funds. Environmental oversight and compliance tracking cannot be sustained without additional funds.

CLASS V SHALLOW WELLS

By far the largest numbers of injection wells in the United States fall into the Class V category—a catchall class used to define injection wells that do not fit into any of the other four classes. Because many Class V injection wells are not regulated, the exact number is unknown. However, there may be more than one million such wells in the United States. Because there are minimal requirements associated with the construction, monitoring, and testing of many types of Class V wells, and because they are often used to dispose of a wide variety of fluids, some of which may be harmful, Class V wells can pose a substantial risk to ground water.

Class V wells can be used for both beneficial and harmful injection activities. They are used to inject or dispose of nonhazardous fluid into or above a USDW. The beneficial activities can include remediating

Photo: USEPA

Photo: Oregon DEQ

Photo: USEPA

Floor drains and open pits such as these pose a substantial threat to ground water.

ABOUT UNDERGROUND INJECTION CONTROL (UIC)

When Congress passed the Safe Drinking Water Act (SDWA) in 1974, oil and gas operators had been injecting saltwater into deep rock formations to increase oil recovery for more than a quarter century. Until 1974, however, the practice was managed under a variety of regulations, state by state. It took nearly a decade after passage of the SDWA for USEPA to implement a standardized program governing underground injection.

The purpose of the UIC program is to ensure that underground injection of fluids is managed so as to protect USDWs. This goal is accomplished by setting the physical and operational standards that apply to the practice. The UIC program establishes requirements for well construction, operation, monitoring, and testing. When these requirements are met, injection wells can be a valuable tool for protecting ground water and other environmental components by securely isolating wastes and enabling the cleanup of existing shallow ground water contamination.

The SDWA divides injection wells into the following five classifications based on use:

Class I

Isolating hazardous, industrial, and municipal waste through deep injection.

U.S. facilities produce billions of gallons of hazardous, industrial and municipal waste every year. Some of the waste is injected deep below any drinking water source, protecting the public.

In the 30 years of the SDWA, Class I wells have isolated more than ***4 trillion gallons of waste fluid***—the amount of water that flows down the Mississippi River into the Gulf of Mexico every 17 days.

Class II

Preserving drinking water resources by injecting oil and gas production waste.

Each barrel of oil produced in the U.S. includes an average of about 10 barrels of produced water (brine). Most brine, about 24 billion barrels annually, is injected into oil and gas bearing formations to increase production. This practice preserves streams and rivers and protects USDWs.

In the 30 years of the SDWA, Class II wells have injected nearly ***720 billion barrels of brine***—enough barrels to stretch from Earth to Mars about 10 times.

Class III

Minimizing environmental impacts from solution mining operations.

Solution mining operations produce 50% of the salt used in the U.S., as well as uranium, copper, and sulfur. These injection wells provide needed minerals while limiting the impact on the environment.

In the 30 years of the SDWA, Class II wells have safely mined ***330 million tons of salt***, or enough salt to fill a salt shaker 7 times higher than the Statue of Liberty.

Class IV

Preventing ground water contamination by prohibiting the shallow injection of hazardous waste (except as part of an authorized cleanup).

Shallow injection wells used by large and small businesses to dispose of radioactive waste threaten drinking water resources. About 50% of Americans rely on ground water for drinking water, and the need for safe, reliable sources in the future is increasing. Therefore, Class IV injection is prohibited outside approved remediation programs.

Class V

Managing the injection of all other fluids to prevent contamination of drinking water resources.

More than 600,000 shallow injection wells are used for disposal, ground water storage, and prevention of salt-water intrusion. When properly managed, these wells offer communities an option for wastewater disposal.

In the 30 years of the SDWA, the Class V Program has ***identified and managed more than 300,000 of an estimated 1.5 million injection wells.*** The challenge for the future is to identify the remaining wells and work with their owners to keep injection safe.

***TOTAL INJECTION WELL NUMBERS** (approximate)*

◆ ***Class I: 488 wells (121 hazardous, 255 nonhazardous, 112 municipal)*** [Texas World Operations, Class I Inventory of the U.S., September 2006] ◆ ***Class II: ~167,000 wells*** [www.epa.gov] ◆ ***Class III: ~20,000 wells*** [Subsurface Technology, Inc. Class III Well Inventory, January 2004] ◆ ***Class IV: Banned for other than EPA-approved remediation purposes*** ◆ ***Class V: ~1.5 million wells (projected inventory)*** [GWPC Class V Inventory, The Cadmus Group, 2004]

A BAD SITUATION NIPPED IN THE BUD

Here's a story that has a positive ending because state UIC inspectors noticed a problem, acted quickly, monitored the ground water, and prevented a contamination incident.

A trucking company's maintenance facility is located just outside an unsewered small town in east central Ohio, where all residences are on private wells and septic systems. Several private wells are within 100 yards of the trucking company operation and dry wells. The town is underlain by a highly productive sand-and-gravel aquifer, and trucking company operations are upgradient of neighboring wells. Ohio Environmental Protection Agency UIC inspectors noticed the facility while inspecting a nearby site, but until that day they had no knowledge of the site.

The inspection found floor drains in the maintenance area that directed spilled motor oil and other wastes to several dry wells. The dry wells were oil-stained and had free oil floating in them. After several years of enforcement, the company owners agreed to remove the dry wells and the contaminated soil around them. Ground water monitoring around the facility determined that no residual ground water contamination was left after the dry wells were removed. Luckily, none of the surrounding private wells were found to be impacted by ground water contamination.

Unfortunately, situations like this are all too common, but more typically go unnoticed until contaminants are discovered in somebody's drinking water.

Source: Lindsay Taliaferro, Ohio EPA.

contaminated ground water, aquifer storage and recovery, aquifer recharge, subsidence control, and geothermal resource development. But there are also unknown numbers of shallow wells throughout the country used to inject wastes and contaminated runoff water directly into or above USDWs.

The risk Class V wells pose to ground water depends on various factors, including the types of waste fluids injected, well construction, local geology, and proximity to local water supply with regard to well location and depth. But since shallow Class V injection wells have the greatest potential to adversely impact drinkable ground water, it is reasonable to expect that they should be located and either permitted or closed.

Class V wells can be located anywhere, but they are especially common in areas without sewers—areas that are also most likely to depend on ground water for their drinking water source, typically from private wells. In addition, Class V wells are often used in sewered areas to dispose of stormwater. In municipalities that prohibit increased surface water discharge from new development, Class V wells are used to dispose of runoff.

State UIC programs are generally constrained by the lack of resources. This means that they are often unable to implement their programs as vigorously as desired. For this reason, some programs may sometimes be more reactive than proactive. This is particularly true in the regulation of Class V wells. Because of the prevalence of Class V wells and their increased use for waste disposal as well as a drinking water storage and recovery solution, federal, state, and local governments must act quickly to become more proactive in finding and assessing these wells, so they don't become a health threat and an economic liability.

Fuel spills flowing into drains at refueling stations like this one are a common source of ground water contamination.

RULES AND STRATEGIES FOR MANAGING CLASS V WELLS

Under the existing federal regulations, Class V injection wells are "authorized by rule" (40 CFR 144). This means that Class V wells do not require a permit if they do not endanger underground sources of drinking water and they comply with other UIC program requirements. These requirements include: (1) submitting basic information about Class V wells (e.g., location, legal contact, nature of the disposal activity) to USEPA or the state primacy agency, and (2) constructing, operating, and closing Class V wells in a manner that protects underground sources of drinking water.

Because of the large population and diverse types of Class V wells, USEPA and the states have targeted the Class V wells that pose the greatest environmental risks for regulatory development, education and outreach, and enforcement where necessary. Particular attention is given to wells located in source water protection areas.

In its 1999 Class V Rule, Phase I, USEPA established minimum standards specific to two types of wells that pose a high risk to USDWs: large-capacity cesspools and motor vehicle waste disposal wells.

In June 2002, USEPA issued a blanket regulatory statement for the rest of the universe of Class V wells, determining that, for the time being, additional federal requirements were not needed. It was noted that the use and enforcement of existing federal UIC regulations were adequate to prevent Class V wells from endangering USDWs.

In its determination, the agency set forth a strategy that would prioritize Class V program actions to ensure that these wells are constructed, operated, and maintained to protect USDWs. These actions include continuing to implement the long-standing UIC regulations and assisting well operators on using best management practices and compliance tools, exploring nonregulatory approaches for voluntary practices, and coordinating with other USEPA programs and authorized state UIC programs to educate and inform as many facilities owner/operators as possible. Clearly, the involvement of state and local governments and the public is essential to the success of this strategy.

The Problem with Shallow Wells

The threat to USDWs posed by Class V wells is inherent in their general shallowness—bottom-hole depths are at or above USDWs. These shallow wells, many of which are used to drain, discharge, or dispose of unwanted fluids, are difficult to regulate because they are inconspicuous, extremely diverse, and large in number.

Photo: USEPA

Existing motor vehicle waste disposal wells like the one in this photo can provide a direct contaminant pathway to ground water.

There are approximately 30 types of Class V wells and—besides large-capacity cesspools and motor vehicle waste disposal wells, which are both prohibited by regulation—many are either underregulated or not regulated at all. The overwhelming majority of these wells are shallow, low-tech systems such as drywells, improved sinkholes, mine drainage and backfill wells, seepage pits, catch basins, French drains, and retention ponds. Not all these "wells" pose a threat to ground water; however, it is important to understand what goes into them. While some Class V wells are technically sophisticated in design and operation (e.g., geothermal Class V reinjection wells), their numbers are small by comparison to the total number.

Most Class V wells are used for disposal of low volumes of liquid. However, some are used for high-volume liquid injection, such as for aquifer recharge or subsidence control. Except for (septic) disposal tanks serving single families or systems serving fewer than 20 persons, sumps, septic systems, cesspools, and drain fields are classified as injection wells. Any business or operation that provides a product or service and whose sinks or drains are not connected to a sewer could have a shallow injection well. Communities without stormwater sewer systems often use shallow injection wells to control flooding during storm events.

In general, contamination incidents tend to be associated with the most prevalent of the high-risk types of Class V wells. For example, stormwater wells are typically located along roads and in parking lots, where spills of oils, gasoline, and other contaminants can occur. States typically lack the resources to adequately inventory Class V wells or search for associated contamination.

A SENSE OF DISARRAY

We know much more about underground injection now than we did when the federal UIC program began in the mid-1980s. Yet that knowledge is not adequately reflected in our regulatory approach to injection wells in general, and to Class V wells in particular. As a result, some Class V injection wells are falling through the regulatory cracks, and a general sense of disarray prevails. There are several reasons for this, including:

- The severe shortfall of UIC program resources has been an obstacle to enabling USEPA to develop a more flexible well-classification system to better address real problems.
- So many different activities and injection liquids fall into the Class V category that, with limited resources, it is very difficult to formulate regulations for specific activities.
- Regulatory authority over Class V wells varies widely among states. Some of the same injection activities regulated within the UIC program in one state are regulated within another program in other states; and in some states these same injection activities may not be regulated by any program.
- Class V inventory databases are fragmented and difficult to compare among states. States and USEPA regions can have different well subclassifications and construction criteria.
- Overlapping regulatory programs, such as UIC Class V wells, septic systems, and stormwater, have historically lacked coordination at both federal and state levels.
- Some owners of existing or proposed underground injection wells that technically fit into one of the other three (Class I, II, III) categories seek to have these wells placed into Class V to avoid more complicated and costly operational requirements. This is owing in part to the fact that some of the UIC regulations are unnecessarily burdensome and have no environmental benefits—and thus place impediments on beneficial new technologies that provide new sources of safe water supplies and the ability to capture and sequester CO_2.

What We Don't Know Could Hurt Us

The universe of Class V wells has expanded and is manifesting unique differences in various parts of the country. As of FY2007, there are little, if any, resources at the state level for a systematic search to find all Class V wells; many states have only partial or even no databases, providing a very incomplete national picture of the Class V well inventory. Yet, knowing what you have is the first step in figuring out where you need to put your resources. Until these wells are located and inventoried, it will be difficult to even estimate their potential to contaminant drinking water.

NEW INJECTION STREAMS

There are a number of new injection practices associated with environmentally important technologies that are in competition with other Class V wells for limited program oversight resources. When the SDWA was passed and wells were placed into the five UIC classes, it was difficult to predict the evolution of industrial practices and the future need for flexibility in the well-classification scheme. However, within the past several years many technological changes have occurred that highlight the pressing need for reconsidering well classifications—either developing new classifications or modifying existing classes to handle new waste streams.

Providing flexibility in the UIC well-classification system must begin with the federal UIC regulations. Although a primary purpose of these regulations has been to provide consistency to UIC activities across the nation, the regulations are inflexibly grounded in technology that is at least 25 years old. In a number of ways, these regulations impede the development and implementation of new drinking water treatment technologies that require use of underground injection by weighing them down with permitting burdens that have no environmental benefit.

Without streamlined regulatory requirements and procedures, the large number of new wells needed for new technologies will overwhelm the resources available for well construction review and approval, creating severe backlogs in permit-application processing. Consequently, there is a need to step back and consider establishing a new, more flexible, comprehensive, and systematic approach to UIC and related programs. One reason this effort has not been undertaken by program regulators is that the preliminary work and the formal rulemaking involved are both very resource-intensive.

Among the new technologies that will need cost-effective forms of underground injection for managing byproduct streams are carbon capture and storage (geosequestration), to assist in decreasing greenhouse gas emissions, and water treatment by membrane and ion exchange methods to convert salt or brackish water into drinking water. The new waste streams associated with these technologies are CO_2 and drinking water treatment residuals, such as desalination concentrate.

Carbon Dioxide Geosequestration

Global climate change has become generally accepted as an environmental threat, believed to be, in part, the result of CO_2 released into the atmosphere through activities such as fossil-fuel burning. In order to mitigate the impacts, new technologies are being developed to capture CO_2 before it is emitted into the atmosphere. Major multinational corporations, universities, USEPA, and the U.S. Department of Energy have joined in efforts to slow the rise in global warming.

The principal challenge with capturing CO_2 is that, once captured, it must be kept out of the atmosphere. Estimates of the volumes that could eventually be generated from this process are in the trillions of metric tons annually. While other potential isolation methods are being investigated (e.g., deep-ocean and terrestrial isolation), one of the most promising is geosequestration by underground injection into deep subsurface rock formations.

CONCENTRATE DISPOSAL APPLICATION

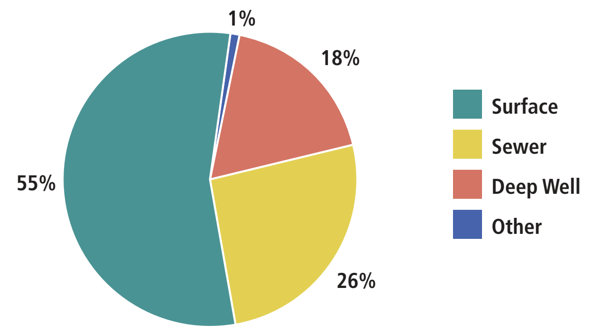


Figure 2. *This pie chart shows the distribution, by volume, of various concentrate-disposal options (a 2005 two-state snapshot).*

Source: Sandia National Laboratories

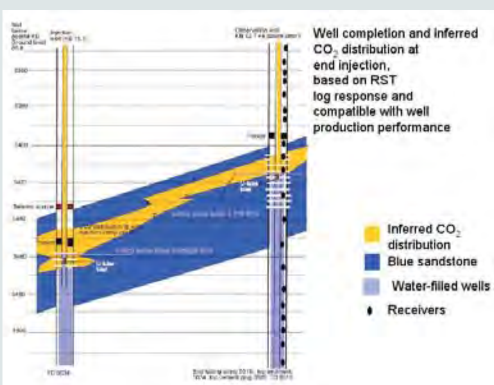
However, a number of technical and regulatory issues must be resolved before this technology can be effectively used to isolate large quantities of CO_2. Among these are ownership of the injection zones, cost of injection, the propensity for CO_2 to migrate underground more readily than conventional fluid-injection streams, prevention of leakage from the injection zones, the effect that CO_2 may have on the injection zones, and the long-term consequences of exposing well components to CO_2.

When fully implemented, the number of wells needed for effective CO_2 sequestration could ultimately be many thousands—and that is only for the United States! Such large numbers of wells, if regulated using the traditional Class I approach for deep-well injection of an industrially generated by-product, would bog down the UIC permitting process. Many of those working on this problem believe that a new specialized class or subclass of injection well is needed that has proper environmental safeguards along with streamlined authorization requirements.

An efficient option is injecting CO_2 for enhanced oil recovery (EOR) in Class II injection wells, as used successfully in the Permian Basin of west Texas since the 1970s (see “Frio Brine Project” page 9•10). Class II wells are notably faster to permit than Class I wells. However, the EOR option, alone, is not sufficient in reservoir capacity, geographic distribution of wells, or

THE FRIO BRINE PROJECT YIELDS POSITIVE FEEDBACK FOR LARGE-VOLUME CO_2 INJECTION

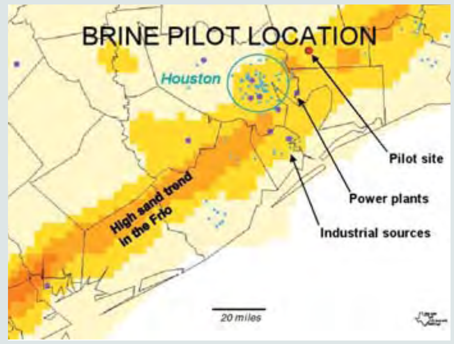
The U. S. Department of Energy funded a unique $4.14 million field experiment to test whether carbon dioxide (CO_2) can be sequestered in underground brine-bearing sandstone. The Frio Brine Pilot Project is part of an ongoing research initiative of the Gulf Coast Carbon Center (GCCC) to develop new capabilities to enable cost-effective sequestration of CO_2. Researchers selected a well-known high-permeability, high-volume sandstone, the Frio Formation, as the CO_2 injection interval. This formation is representative of a broad area of the Gulf Coast, an ultimate target for large-volume CO_2 geosequestration.



Above and right: Frio Brine Pilot Project: CO_2 injection/ observation wells and cross-section schematic.

Source: The University of Texas at Austin, Bureau of Economic Geology

The Frio Formation in the project area is brine saturated (i.e., not productive of oil or gas). This distinction was of primary importance in the project design. Through the pilot project, investigators hoped to increase knowledge concerning the potential for CO_2 geosequestration using similar brine-saturated formations worldwide. This would be a longer-term and more volumetrically significant option than that provided in the existing precedents for CO_2 injection for enhanced oil or gas recovery.



Map showing the location of the Frio Brine Pilot Project along the Gulf Coast.

Source: The University of Texas at Austin, Bureau of Economic Geology

Project goals included the development of monitoring protocols and predictive models to provide a better understanding of the fate and transport of injected CO_2 in the subsurface, including the trapping mechanisms that determine the effectiveness of geosequestration in keeping CO_2 isolated from the atmosphere.

The initial phase of the project involved detailed characterization of the local and regional geology of the project site in Liberty County, Texas, for use in constructing models and interpreting test results. Since 2004, two successful episodes of injection have been completed (injecting 1,600 tons and 300 tons of CO_2, respectively) with extensive monitoring within the injection interval and the overlying formations. Monitoring during the injection and postinjection periods included pressure and temperature measurement, wireline logging, seismic data collection and analysis, and two-phase fluid sampling.

Good matches were obtained between the observed and modeled evolution of the injected plumes. Over the monitoring period, plume stabilization was observed, suggesting that modeling predictions of arrested movement (trapping) of CO_2, limiting buoyant migration “updip” are correct.

More information on the Frio Brine Pilot Project is available at *http://www.beg.utexas.edu/environqlty/co2seq/fieldexperiment.htm*

CO_2 CAPTURE AND SEQUESTRATION

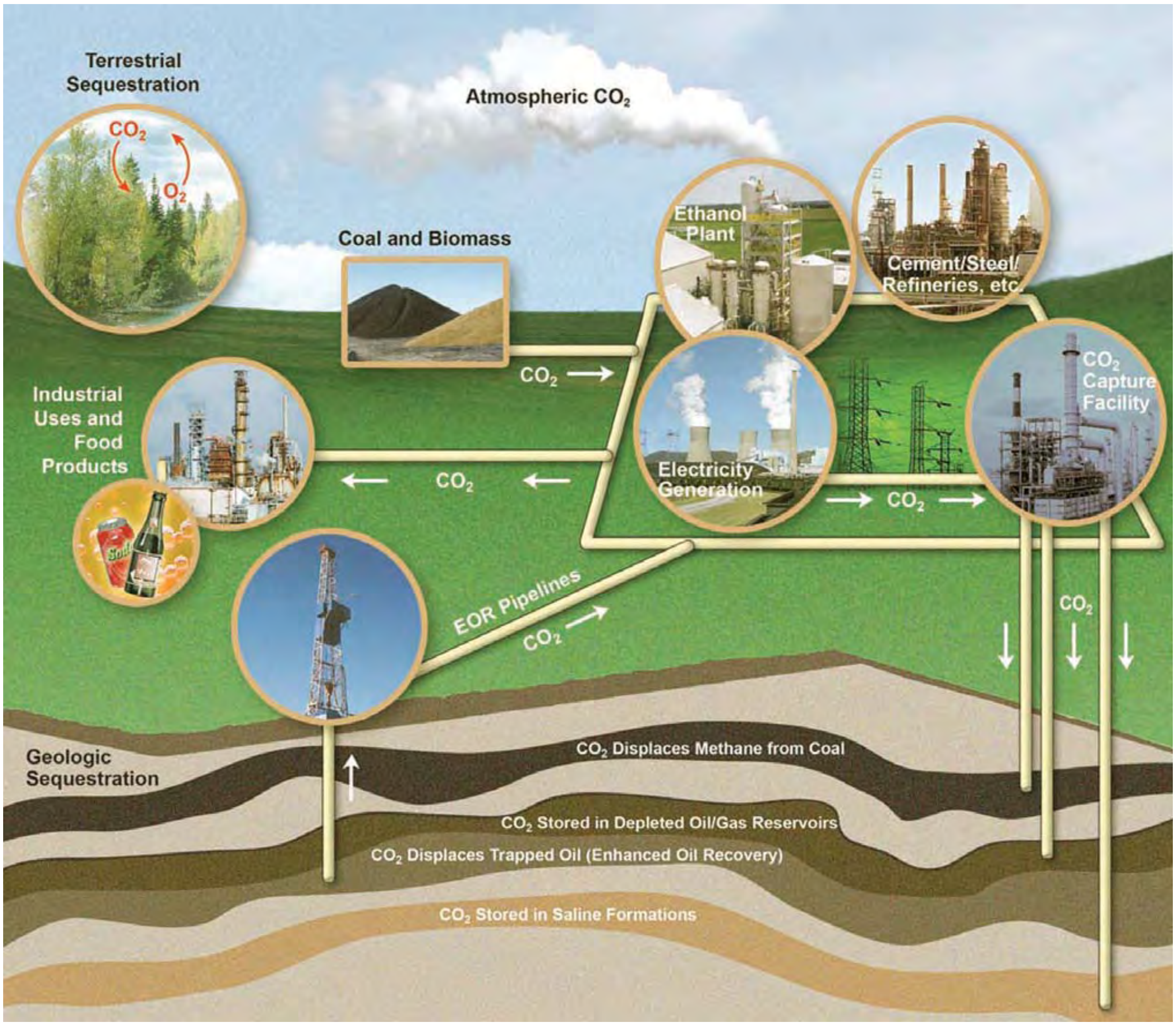


Figure 3. *Flow diagram showing sources of CO_2 and their pathways to sequestration.*

Source: Carbon Sequestration Atlas of the United States, USDOE

available timeframe for remaining oil production to solve the overall CO_2 sequestration challenge.

Disposal of Drinking Water Treatment Residuals

Properly designed and operated underground injection wells provide an ideal method of isolating drinking water treatment residuals, including highly concentrated salts from desalination operations, metals (e.g., arsenic), radionucides (e.g., radium), and known carcinogens (e.g., perchlorate) from USDWs. The traditional UIC approach for injecting such water treatment residuals uses a Class I well. However, the greater regulatory burdens associated with this well class, in the timeframes required for permitting and the costs of construction and operation, constitute significant impediments to its widespread use for injecting these residual streams.

In 2006, USEPA issued *Drinking Water Treatment Residual Injection Wells: Technical Recommendations,* a report authored by the UIC National Technical Workgroup to evaluate the technical aspects of and develop recommendations on the use of underground injection wells for disposal of drinking water treatment residuals. The report identifies 101 drinking water treatment residual injection wells that are currently permitted or authorized. These wells are classified as Class I nonhazardous or Class V wells, and the permit requirements, where specified, are generally similar to federal Class I requirements. The report addresses several data gaps and other areas where follow-up actions are recommended.

Other less burdensome options receiving consideration include Class II enhanced oil recovery (EOR) and deep Class V injection wells. However, each of these approaches has its drawbacks. In particular, the Class II EOR option will not be economically practical in areas distant from oil production, and the Class V option will require the conjunction of rather unusual geologic and hydrologic conditions.

FUNDING—THE ULTIMATE UIC IMPEDIMENT

As explained earlier, two great challenges facing the UIC Program are the need for more effective regulation of Class V wells and improved readiness to regulate waste streams associated with new technologies. The principal obstacle to meeting either of these challenges is the lack of sufficient funding for the state regulatory agencies.

Locating, inspecting, closing (if necessary), and/or remediating the higher-risk types of mostly shallow Class V wells is critical. If improperly used and left unchecked, such wells can cause ground water and drinking water contamination. Therefore, the future success of this critical part of the UIC program is in increasing jeopardy if more funds are not added at the federal level and passed onto the state-primacy programs. Neither USEPA nor the state-primacy agencies can continue to implement this federal program effectively without additional resources.

Similarly, without large increases in UIC Program funding, progress in implementing new technologies for addressing global climate change and developing new water supplies for growing populations will be impeded. However, if funds are provided to the new technologies/waste streams initiatives, it cannot be to the detriment of the Class V well problem. Both need to be addressed.

If these issues are not addressed, Class V wells will remain the program's stepchild, leaving some drinking water at substantial risk for years to come. Even so, at present funding levels, the initiatives associated with new technologies will hardly be the winners, because resources will be insufficient for their optimal development as many proposed projects become stalled in the permitting-process backlogs described earlier. Without additional funding, in the competition between Class V and the new technologies and streams, a lose-lose outcome is likely.

Key Term

USDW—UNDERGROUND SOURCE OF DRINKING WATER

An Underground Source of Drinking Water as defined in Title 40, *Code of Federal Regulations* (40 CFR) Section 144.3 is an aquifer or part of an aquifer that:

a. Supplies any public water system, or contains a sufficient quantity of ground water to supply a public water system and currently supplies drinking water for human consumption or contains fewer than 10,000 milligrams/liter of Total Dissolved Solids (TDS); and

b. Is not an exempted aquifer. An exempted aquifer is part or all of an aquifer which meets the definition of a USDW but which has been exempted according to the criteria found in 40 CFR.

Recommended Actions

To Congress:

- Increase annual funding for the national UIC program to $56 million to allow for more reasonable regulation of current UIC facilities, and provide additional funding for new injection streams that require safe management.

To USEPA:

- Revise the current injection well classification scheme to make it more consistent with current and future program needs and to provide greater flexibility for cost-efficient regulation of new injection streams.

Underground injection control is all about protecting underground sources of drinking water!

McFarland dry spring cave, Jackson County, Alabama.

Photo: Alan Cressler, USGS

South Charleston, Ohio, water tower.

Photo: Alan Cressler, USGS

Section 9 References: Ground Water and Underground Injection Control

GWPC [Ground Water Protection Council]. September 2004. *Class V Resource Needs Survey.* Available at: *http://www.gwpc.org/e-library/e-library_documents/e-library_documents_uic/Summary%20Class%20V%20Resource%20Needs%20Survey.doc*

USEPA. 2006. *Drinking Water Treatment Residual Injection Wells: Technical Recommendations.* Available at: *http://www.epa.gov/region5/water/uic/ntwg/dwtr_final_report_01-19-07.pdf*

Suggested reading and viewing:

GWPC Training video on Class V Service Station Wells.

Injection Wells: An Introduction to Their Use, Operation, and Regulation, GWPC. *http://www.gwpc.org/e-library/e-library_documents/e-library_documents_uic/uic%20brochure%208-2005.pdf*

Small Entity Compliance Guide—New MV Waste Rules, USEPA.

Using the Class V Experimental Technology Well Classification for Pilot Carbon Geologic Sequestration Projects, October 2006. EPA 816-B-06-008 Available at: *www.epa.gov/safewater/uic/ wells_sequestration_guidefactsheet.html*

Ground Water & Abandoned Mines

Key Message

Current mining operations are generally permitted and managed according to stringent standards designed to prevent the creation of new AMD problems. Therefore, this report will focus on the most significant mining-related environmental issue—ground and surface water problems associated with abandoned mines. Issues associated with current mining operations may be addressed in future reports.

Abandoned mines with associated acid mine drainage (AMD) discharges are among the greatest threats to ground and surface water quality in many areas of the United States. While mining is extremely important to our standard of living, energy production, and national security, it can disturb the land and alter the hydrologic balance—affecting the quality and quantity of ground and surface waters in the vicinity of mining operations. Most modern mines are now reclaimed during and after completion of mining activities; but prior to the enactment of environmental laws in the 1970s, most abandoned mines were not reclaimed after it was no longer profitable to retrieve the mineral or coal resources.

Abandoned mine sites, along with associated acidic discharges, must be remediated. To optimize remedial work, state officials should use all available funding sources, develop new funding sources, build partnerships, and remove obstacles that prevent third parties from undertaking activities that address ground water contamination problems. Future mining and reclamation activities must be planned with a critical eye to environmental and ecological circumstances, using information that incorporates adequate hydrological data, to prevent creation of new acidic discharges.

Such plans should evaluate the impacts or ramifications of mining before the fact and assist the industry in implementing mitigating measures. States should also adopt full-cost bonding requirements, or an equally effective alternative, to reduce the number of mine sites added to the abandoned mine lands inventory through bankruptcy.

Photo: Copyright Stuart Jennings, Montana State;

Acid mine water discharge from historic underground workings (Fisher Creek, Montana).

The Spoils of Abandoned Mines

"While mine pollution problems also appear occasionally as a quick visible pulse that suddenly kills lots of fish or birds…more often they take the form of a chronic leak of toxic but invisible metals and acid that don't degrade naturally, continue to leak for centuries, and leave slowly weakened people rather than a sudden pile of carcasses. Tailings dams and other engineered safeguards against mine spills continue to suffer from a high rate of failure"

Jared Diamond | *Collapse: How Societies Choose to Fail or Succeed*

why Abandoned Mines matter to ground water…

Many abandoned coal mines and hardrock mines emit acid mine drainage (AMD). This takes place because the rocks associated with both types of mines often contain metal sulfides, such as pyrite. When the rock or coal deposits are excavated, the sulfides are exposed to water and oxygen and react to form sulfuric acid. Many abandoned surface and underground mines, and their associated spoil and refuse piles, provide an ongoing source of AMD and toxic heavy metals that can have long-term devastating impacts on ground water, community water supplies, rivers, and streams. AMD turns surface waters red and can coat creek beds with white aluminum and other metallic deposits, a deadly combination for aquatic life. (See Trout Unlimited's *Restoring the Wealth of the Mountains,* 2005)

More than a million abandoned hardrock and coal mine sites are scattered throughout the United States. The Mineral Policy Center evaluated state and federal inventory data in 1995 and concluded that there were more than 557,000 abandoned hardrock mines nationwide, the majority in the western states. While most states have not completed detailed inventories or environmental impact assessments, the Western Governors

Photo: Vivian Stockman / SouthWings / www.ohvec.org

A mountaintop removal coal mine encroaches on a small southern West Virginia community.


Photo: savethewildup - http://www.flickr.com/photo_zoom.gne?id=469368925&size=o

Acid mine drainage (AMD) at a sulfide-rich nickel and copper ore deposit

Association estimates that up to 20 percent of these mines pose a threat to the environment.

More than 200 years of coal mining (preregulation) in the Appalachian region have left a legacy of abandoned, unreclaimed mine lands. USEPA Region 3 regards AMD as the single greatest threat to surface water in the Appalachian environment, and identified more than 4,500 miles of streams that fail to meet aquatic use designation as a result of AMD in Pennsylvania, West Virginia, Maryland, and Virginia. (USEPA, 2007) There are 3,000 miles of streams degraded by AMD in Pennsylvania alone. (USGS, 2006) In neighboring Ohio, the Ohio EPA has inventoried over 1,300 miles of streams degraded by AMD. (Ohio Environmental Council, 2006)

In 1977, Congress enacted the Surface Mining Control and Reclamation Act (SMCRA) to address public health and safety and environmental problems associated with inadequate reclamation of coal mining sites. Information on the actual cost of cleaning up abandoned mines sites is not readily available to the public. However, according to the September 2004 *Reference Notebook* by the USEPA Abandoned Mine Land Team, as of April 2002, USEPA's estimated and actual costs at 88 National Priorities List mining sites were more than $2.8 billion. The document cites several studies that address possible costs associated with restoring abandoned mine sites. Costs run well into the billions. For example, in 1993, the Mineral Policy Center estimated that the worst 363,000 (out of the 557,000) abandoned mine sites would require between $32 and $72 billion for reclamation—and that was then.

In the absence of comprehensive federal or state inventories, the current total number of abandoned mines and the number that are degrading ground and surface water quality can only be estimated. There are currently 25 abandoned mine sites on USEPA's Superfund list. The impacts of AMD from discontinued operations, and in some cases ongoing operations, are well documented,

ACID MINE DRAINAGE IN THE NATURAL ENVIRONMENT

AMD from abandoned underground mines or seeps from spoil or waste piles is caused by a variety of processes associated with unreclaimed abandoned mines, including:

- Underground and surface mines with workings below the water table must pump and discharge ground water from the active mining area throughout the operative life of the mine. Upon abandonment, pumping ceases, and ground water accumulates, interacts with the metal sulfides in the unmined ore or coal deposit, and eventually rises to the level where it discharges into local streams and rivers.
- Sinkholes that form as a result of mine roof collapse can capture water from streams, diverting

Photo: courtesy of the Oklahoma DEQ

Acid mine drainage has left a toxic legacy in this stream in the Tar Creek area of Oklahoma.

surface flow into abandoned underground mines. Diverted water reacts with metal sulfides in the underground mine environment and eventually resurfaces as an acidic ground water discharge.

- Piles of mine waste, also called "gob" or "refuse," are often found in unreclaimed piles near abandoned mines or in impoundments. When precipitation infiltrates the mine spoil, the underlying ground water becomes acidic and discharges at the base of these piles through seeps or springs.
- At some abandoned above-the-water-table surface mines, precipitation reacts with ore or coal-seam exposures created by mining. This can create acidic runoff or impoundments that discharge AMD.

SOLUTIONS—READY AND WAITING

Research is ongoing to develop both active and passive treatment technologies to reduce AMD and metal loadings in streams. Passive treatment involves the installation of limestone channels, wetlands, and successive alkalinity-producing systems (SAPS) at AMD discharge areas. The SAPS neutralize acid, while the wetlands provide the wherewithal to capture precipitated metals that would otherwise be discharged into local streams and rivers. Passive systems must be monitored, and accumulated metal precipitates must be removed periodically. Materials that generate alkaline conditions must also be replaced periodically.

Technologies have also been developed to increase the alkalinity of waters in recharge areas overlying acid-forming spoil or underground mine voids. Trenches filled with alkaline materials can neutralize acidic ground water before it discharges to surface water.

The most effective AMD solutions prevent the formation of acidic drainage through source control by reducing or eliminating air and water contact with

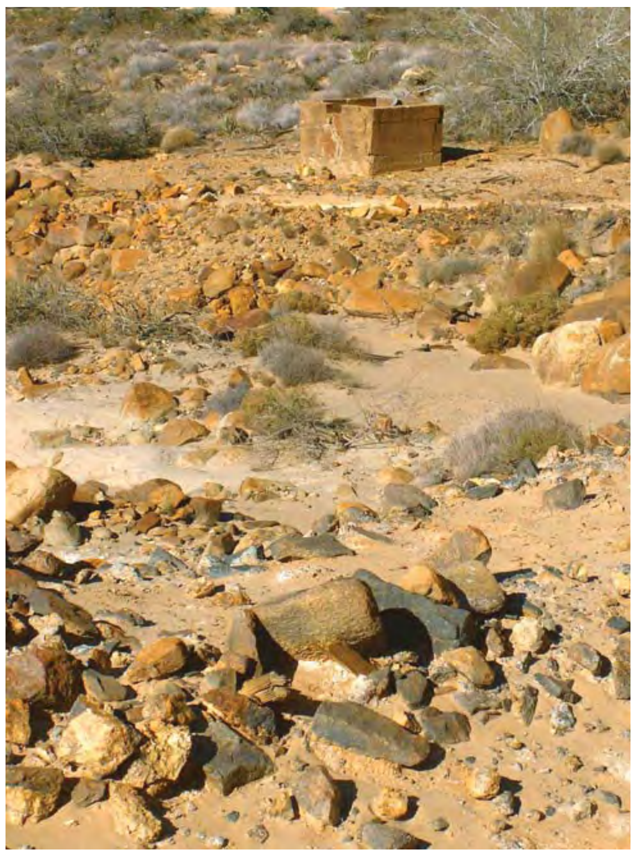


Photo: cobalt http://www.flickr.com/photos/cobalt

An abandoned mine in Chloride, Arizona.

A pipe driven into the hillside drains acidic water from a mine in Pennsylvania.

Photo: Kevin A. Geiselman

the underlying AMD-forming minerals. This can be accomplished by reducing recharge through these materials. Eliminating impoundments and diverting surface flow from recharge areas can reduce surface water infiltration through AMD-forming spoil. Capping recharge areas with impermeable materials also reduces recharge and hence the rate of AMD discharge. In addition, collapse features that capture surface water flow from streams can be filled and sealed, thereby reducing recharge of the underlying mine voids.

FUNDS AT WORK AND WORK NEEDING FUNDS

The SMCRA established the Abandoned Mine Land (AML) Program to reclaim previously mined areas that posed significant health, safety, and environmental problems to the public. Since SMCRA was enacted, the federal Office of Surface Mining has distributed approximately $3.5 billion to states and tribes for AML project work.

Funded by a severance tax of $0.35 per ton of surface coal and $0.15 per ton of underground coal, the AML program has reclaimed more than 285,000 acres of abandoned coal-mine sites through the grants to states and tribes. According to the National Association of Abandoned Mine Land Programs (NAAMLP), hazards associated with more than 27,000 open mine portals and shafts, 2.9 million feet of dangerous highwalls, and 16,000 acres of dangerous piles and embankments have been eliminated and the land reclaimed. (NAAMPL, 2006).

Despite this record of accomplishment, NAAMPL reports that “over $3 billion worth of listed health and safety coal problems remain, as well as another $3.6 billion worth of identified high priority coal problems affecting the general welfare of individuals in the coalfields and numerous environmental coal-related problems.” Fee collections for the AML Program were due to expire on September 30, 2004.

After a series of short-term fee extensions, on December 9, 2006, the 109th Congress passed the Surface Mining Control and Reclamation Act Amendments as part of the Tax Relief and Health Care Act of 2006. The legislation reauthorizes the collection of the coal severance tax for 15 years and directs more money to states with the greatest number of AML problems. The legislation also allows states to set aside up to 30 percent of their grant money for abatement of acid mine drainage problems. The 109th

Photo: Copyright Stuart Jennings, Montana State

Waste rock revegetation at Zortman-Landusky Mine, circa July 1996. This gold and silver mine used cyanide to process the ore. A 50,000-gallon spill of cyanide solution contaminated a public water supply well. (http://www.bettermines.org/zortman.cfm)

Photo: Copyright Stuart Jennings, Montana State

Slag placement as part of the Central Impoundment Area Repository cover system, Bunker Hill Superfund site near Kellogg, Idado. The site is located in the silver, lead, and zinc mining district. (Image circa June 2000.)

Congress is to be commended for its decisive action in addressing this significant issue.

Western hardrock abandoned mines have received less attention, largely due to the lack of a dedicated federal funding source and varying levels of commitment at the state level. The Mineral Policy Center reports that "few projects are undertaken without some sort of partnership with, and funding from, federal land management agencies and the Environmental Protection Agency."

OHIO BUILDS AN AMD OFFENSIVE THROUGH COOPERATION

The AML Program has built an impressive coalition of partners dedicated to abandoned-mine reclamation and restoration. With the cooperation of private land owners, industry representatives, federal agencies, local officials, and watershed groups, thousands of acres of abandoned mined land have been transformed into productive land, and healthy fish and macroinvertebrate populations are returning to streams once considered dead and unrestorable.

For example, in 1998, Ohio created a section within its AML Program to focus on water quality issues caused by AMD. In cooperation with the Ohio Environmental Protection Agency and the Department of Natural Resources, Division of Soil and Water Conservation, state AML funds are used to support coordinators in mining-impacted watersheds. These coordinators, working with AML Program hydrogeologists, academics, and local citizens, monitor stream water quality, characterize AMD discharges, locate stream captures, and inventory toxic spoil piles and other sources of water quality impairment in order to develop acid mine drainage abatement and treatment (AMDAT) plans.

AMDATs are essentially mining Total Maximum Daily Loads (TMDLs) that establish watershed treatment and remediation priorities within a watershed. They have enabled the AMD Section to leverage over $1 million annually from federal agency partners, including the U.S. Forest Service, USEPA, U.S. Army Corps of Engineers, and the Office of Surface Mining, to design and construct AMD treatment systems.

The AMD Section has established an invaluable working relationship with a faculty group at Ohio University (OU) known as the Appalachian Watershed Research Group, which consists of researchers from a variety of academic disciplines, including faculty from the Departments of Geology, Geography, Biology, and Civil Engineering. Coordination for much of this work has occurred through a partnership with OU's Voinovich Center for Leadership and Public Affairs, which leverages the resources of the university to meet the research needs of state agencies.

The Appalachian Watershed Research Group is currently developing a long-term monitoring plan that will include a scorecard and annual report for watershed projects. OU is also establishing an Appalachian Region Water Resources Center to provide technical support and a graduate degree program in Mineral Resource Extraction and Restoration Practices.

SMCRA funds cannot be used for non-coal environmental restoration projects, except in states where all coal projects have been completed, such as Wyoming and Montana. These two states, with secure annual funding of $28.8 million and $3.7 million, respectively, are in the best position to undertake water quality remediation projects at abandoned hardrock mines.

Other states fund water quality projects by tapping into federal sources of funding, such as USEPA grants to states for nonpoint-source pollution control under Section 319 of the federal Clean Water Act. Funding is sometimes available through other federal land management agencies, Clean Water Act 104b3 Water Quality Cooperative Agreements, Brownfield Grants, and the Restoration of Abandoned Mine Sites (RAMS) Program within the federal Water Resources Development Act (WRDA).

Different states have developed unique strategies for securing funds to remediate abandoned mine sites. Indiana, through its Partners for Reclamation Program, receives significant private sector contributions. In 1999, Pennsylvania established its Growing Greener Program, which provides $650 million in general funds over five years to remediate serious environmental problems, including AMD discharges from abandoned coal mines.

USEPA REMOVES DISINCENTIVES TO RE-MINING AND RECLAMATION

In 2002, USEPA amended its Effluent Limitations Guidelines and New Source performance standards to allow coal operators, under specific circumstances, to re-mine previously mined areas subject to modified effluent standards under a National Pollutant Discharge Elimination System (NPDES) permit. Under the changes, an operator gathers data on the quality and quantity of the preexisting pollution discharge to establish a baseline of the pollutants being discharged. In the mining permit application, the operator must demonstrate that re-mining and reclamation of the site is likely to improve or eliminate the preexisting discharge in order for the permit to be issued.

An old coal strip mine south of Victoria, Illinois.

PENNSYLVANIA: A NATIONAL MODEL FOR SUCCESSFUL RE-MINING

Pennsylvania serves as a national model for managing a successful re-mining program since enacting its re-mining laws in 1995. In a 2000/2001 study of 112 abandoned surface mines containing 233 preexisting discharges that were re-mined and reclaimed, 48 discharges were eliminated, 61 discharges were improved, 122 showed no significant improvement, and two were degraded. These environmental improvements occurred at no cost to the government or taxpayers because the operator's potential liability was limited and the operators were able to recover the coal that remained on the site.

At a site in Schuylkill County, the state and private sector are working together to implement an innovative re-mining solution that creates clean, zero-sulfur diesel fuel while restoring the environment. Waste coal from spoil piles associated with abandoned mines will be the feedstock to create clean diesel fuel at the nation's first coal-gasification-liquefaction plant.

Pennsylvania has over 8,500 acres of unreclaimed refuse piles containing an estimated 2.1 billion tons of waste coal that currently release AMD into local streams, rivers, and ground water. By 2009, a state-of-the-art power plant will be generating 40 million gallons of clean diesel fuel and generating enough electricity to power 40,000 homes, while eliminating an ongoing threat to the environment and a hazard to public health. (See April 2006; *Governing; www.governing.com/articles/4coal.htm*)

(Left) Over 40 acres of abandoned minelands were restored on formerly productive farmland in North Liberty, Pennsylvania. (Right) Volunteers planted 3,000 wetland plants in just a few hours as the final step in a mining reclamation process. The site was mined extensively in the 1940s. It was originally reclaimed in 2001 through a public-private partnership effort. Two ponds were built as part of the erosion and sedimentation control plan, a portion of the ponds was converted into wetlands. It was completed on October 18, 2003.

This revision is designed to encourage operators to re-mine previously mined lands to remove remaining reserves and waste coal from abandoned lands, thereby eliminating sources of AMD without spending tax dollars. Absent the modified limitations, operators are reluctant to mine areas with AMD discharges because they would be unable to meet NPDES standards while conducting mining operations.

LEGISLATIVE INITIATIVES

Good Samaritans

There are many volunteers ("Good Samaritans") who are interested in helping restore watersheds impaired by abandoned mines. However, the threat of liability pursuant to the Clean Water Act (CWA) and/or the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) discourages such third-party cleanups. A volunteer conducting a partial cleanup could become liable for the entire cleanup or could be obligated to obtain a discharge permit that requires compliance with strict water quality standards in streams that are already in violation of these standards. Liability may be assigned even though the volunteer did not cause the pollution.

If this threat of liability were removed, volunteers would have an incentive to restore watersheds impacted by AMD. "Good Samaritan" legislation has been introduced aimed at removing barriers to

Photo: Copyright Stuart Jennings, Montana State

At the Yankee Doodle tailings pond in Montana, a mix of clean influent water from upgradient (left) with mine tailings (right) can be seen.

voluntary cleanup of abandoned mine sites. Good Samaritans include federal, state, or local government agencies, citizen groups, and mining companies. The legislative concept has broad support from organizations, including the National Mining Association, Western Governors Association, Western States Water Council, Interstate Mining Compact Commission, Trout Unlimited, National Environmental Trust, and many others. (Refer to EPA website *http://www.epa.gov/water/goodsamaritan/*)

Photo: Copyright Stuart Jennings, Montana State

Iron precipitation in a wetland at the toe of the Opportunity Tailings Pond, Anaconda, Montana.

Recommended Actions

To Congress:

- Enact Good Samaritan legislation to encourage third-party efforts to remediate AMD problems without the risk of penalties and liability.
- Work with interested parties to enact an Abandoned Hardrock Mines Reclamation Act that would attempt to address problems caused by abandoned hardrock mines. This would essentially be the hardrock equivalent of the Surface Mining Control and Reclamation Act (SMCRA).
- Continue to appropriate funds for remediation of contaminated abandoned-mine sites that pose an immediate threat to human health under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

To Governors and State Legislatures:

- Increase the level of state commitment to address and resolve the problem of abandoned mines and AMD; recognize AMD and environmental issues as a use of funds under the Abandoned Mine Land Program; and establish funds dedicated for cleanup of abandoned mine sites that are not covered under SMCRA or CERCLA.

To State Agencies:

- Establish comprehensive inventories of abandoned mines and AMD-degraded aquifers, underground mine pools, and streams, and develop a strategy to address identified abandoned mines and AMD discharges on a priority basis.

If not adequately reclaimed, abandoned surface and underground mines, and their associated spoil and refuse piles, provide an ongoing source of acid mine drainage and toxic heavy metals that can have long-term devastating impacts on ground water, community water supplies, rivers, and streams.

An open-pit copper mine in Morenci, Arizona. This mining complex is over nine miles long and includes an open-pit mine, tailings impoundment, and waste piles.

Photo: Copyright © Michael Collier

Section 10 References: Ground Water and Abandoned Mines

National Association of Abandoned Mine Land Programs. July 2006. *Safeguarding, Reclaiming, Restoring. http://www.onenet.net/~naamlp/index.html*

Ohio Environmental Council. 2006. *Ohio Environmental-Conservation Briefing Book* 2007-2007. Available at: *http://www.theoec.org/PDFs/Legislation/hottopics_events_ld2006book.pdf*

USEPA. *MidAtlantic Integrated Assessment: Acid Mine Drainage*. Available at: *http://www.epa.gov/maia/html/AMD_issue.html* (accessed July 2007).

USEPA, September 2004. Abandoned Mine Land Team *Reference Notebook.* Available at: http://www.epa.gov/superfund/programs/aml/tech/amlref.pdf

USGA. Updated on Web 2006. *Coal-Mine-Drainage Projects in Pennsylvania: Restoration of Stream Water Degraded by Acid Mine Drainage*. Available at: *http://pa.water.usgs.gov/projects/amd/restoration.html*

Ohio DNR. *http://www.dnr.state.oh.us/mineral/aml/acid.htm*

Photo: savethewildup - http://www.flickr.com/photo_zoom.gne?id=469368925&size=o

Acid mine drainage is a byproduct of mining ore, which contains sulfides (e.g., pyrite) and has been deemed one of the most serious threats to water quality by USEPA. (http://www.epa.gov/region3/acidification/what_is_amd.htm)