PROTECTING OUR WATER:

A Primer for Preventing Pathogenic Contamination of Drinking Water Sources

Acknowledgements

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Karen Edwards, Project Officer, United States Environmental Protection Agency Office of Groundwater and Drinking Water

Claire Reiss, Deputy Executive Director and General Counsel, Public Entity Risk Institute

Project Advisory Committee

Martin Allen, American Water Works Association Research Foundation
Stephen Edberg, Yale University of Medicine
Ann Marie Gebhart, Underwriters Laboratories, Inc.
Jeffrey Griffiths, Tufts University School of Medicine
Beth Hall, United States Environmental Protection Agency Office of Ground Water and Drinking Water
Marlin Kliewer, Gage County Planning and Zoning
Bob Kuzelka, University of Nebraska – Lincoln Environmental Studies Program
Kristina Mena, University of Texas – School of Public Health
Jonathan Patz, University of Wisconsin – Nelson Institute
Joan Rose, Michigan State University - Department of Fisheries and Wildlife

Workshops

Held April 25,2006 in Chadron, Nebraska
Host: Jason Moudry, Upper Niobrara White Natural Resources District
Speakers: Deana Barger, Nebraska Department of Environmental Quality
Robin Foulk, Nebraska Natural Resources Conservation Service
Jason Moudry, Upper Niobrara White Natural Resources District
Doug Woodbeck, Nebraska Health and Human Services

Held May 25, 2006 near Gretna, Nebraska
Host: Rodney Verhoeff, Lower Platte River Corridor Alliance
Speakers: Deana Barger, Nebraska Department of Environmental Quality
Jim Harder, Nebraska Natural Resources Conservation Service
Eric Lee, Lincoln Water System
Rodney Verhoeff, Lower Platte River Corridor Alliance
Doug Woodbeck, Nebraska Health and Human Services

Held June 19, 2006 in Manhattan, Kansas
Host: Abdu Durar, City of Manhattan
Speakers: Dr. George L. Marchin, Kansas State University
Ethan Kloster, City of Manhattan
Dr. G. Morgan Powell, Kansas State University

Held August 8, 2006 in Springfield, Missouri
Hosts: Loring Bullard and Mike Kromrey, Watershed Committee of the Ozarks
Speakers: Don Scott, Missouri Department of Natural Resources
Mike Kromrey, Watershed Committee of the Ozarks

Held September 27, 2006 in Attleboro, Massachusetts
Hosts: Clayton Commons, Rhode Island Department of Health and Kathleen Romero, Massachusetts Department of Environmental Protection
Speakers: Gabrielle Belfit, Cape Cod Commission
Marc Cohen, Atlantic States Rural Water Association
Clayton Commons, Rhode Island Department of Health
G. Timothy Cranston, North Kingstown Department of Water Supply
Lorraine Joubert, University of Rhode Island Nonpoint Education for Municipal Officials
Rebekah McDermott, Massachusetts Rural Water Association
Vandana Rao, Executive Office of Environmental Affairs
Kathleen Romero, Massachusetts Department of Environmental Protection

Held as part of the 2006 Groundwater Foundation Annual Conference in East Lansing, Michigan on November 2, 2006
Host: Ruth Kline-Robach, Michigan State University – Institute of Water Resources
Speakers: Morris Beaton, United States Environmental Protection Agency Region V
Jay Beaumont, Orange County Groundwater Guardian, NY
Elgar Brown, Michigan Department of Environmental Quality
Lee Drummond, Dayton Multi-Jurisdictional Wellfield Protection Program and Groundwater Guardian, OH
Ann Marie Gebhart, Underwriters Laboratories, Inc.
Rebecca Head, Monroe County Health Department
Ruth Kline-Robach, Michigan State University – Institute of Water Resources
David Lusch, Michigan State University
Kristina Mena, University of Texas – School of Public Health

Groundwater Foundation Staff

Lori Davison, Database Manager
Rachael Herpel, Community Programs Director
Jane Hogue, Administrative Assistant
Cindy Kreifels, Executive Director
Zoe McManaman, Events Coordinator
Jamie Oltman, Program Coordinator
Carla Otredosky, Graphic Designer
Doug Sams, Financial Services Accountant
Susan Seacrest, President
Jennifer Wemhoff, Program Manager

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Primer Review

Ken Alkerton, Cambridge Groundwater Guardian, Ontario
Rhonda Artho, North Plains Groundwater Conservation District, TX
Chris Barnett, Indianapolis-Marion County Groundwater Guardian, IN
James Beaumont, Orange County Groundwater Guardian, NY
Gabrielle Belfit, Cape Cod Commission /Barnstable County Groundwater Guardian, MA
Thomas Cambareri, Cape Cod Commission /Barnstable County Groundwater Guardian, MA
Susan Carmichael, Washington County Groundwater Guardian, PA
Kaylene F. Carney, United States Geological Survey Iowa Water Science Center, IA
Catherine Chertudi, Boise Public Works Department/Boise Groundwater Guardian, ID
Jarrod Christen, Detroit Lakes Groundwater Guardian, MN
Betty Conner, League of Women Voters of Pennsylvania, Water Resources Education Network, PA
Lisa Corbitt, Mecklenburg County Groundwater and Wastewater Services, NC
Robyn Doescher, Northern Regional Groundwater Protection Planning Committee, IL
Lee Drummond, Dayton Multi-Jurisdictional Wellfield Protection Program, OH
Jeremy Eschliman, Central District Health Department, NE
Kim Garrett, Mecklenberg County Groundwater Guardian Affiliate, NC
Jim Graham, Cambridge Groundwater Guardian, Ontario
Sherene Hess, League of Women Voters of Pennsylvania, Water Resources Education Network, PA
Joan Jessen, Washington County Groundwater Guardian, PA
Steve Kelley, Beatrice Groundwater Guardian, NE
Jamie Lien, Atascadero Mutual Water Company/Atascadero Groundwater Guardian, CA
Wayne Madsen, Trenton Groundwater Guardian, NE
Arnold Mancl, Milladore Area Groundwater Guardian, WI
Ellis Marples, Pompton Lakes Groundwater Guardian Committee, NJ
Kevin Masarik, Center for Watershed Science and Education, WI
Kimberly McSparran, Wright-Patterson Air Force Base Groundwater Guardian, OH
Ross Penhallegon, Lane County Water Quality Affiliate, OR
Enid Probst, Alabama Department of Environmental Management, AL
Todd Risius, Cargill Pork Groundwater Guardian Affiliate, AR
Ruth Roth, Winnebago County Health Department, IL
Chris Schuett, Cambridge Groundwater Guardian, Ontario
Dave Smyth, Cambridge Groundwater Guardian, Ontario
Robert Swanson, United States Geological Survey Nebraska Water Science Center, NE
Frank Waksmunski, Carbon County Groundwater Guardian, PA
Carrie Wiese, Technical Consultant, NE

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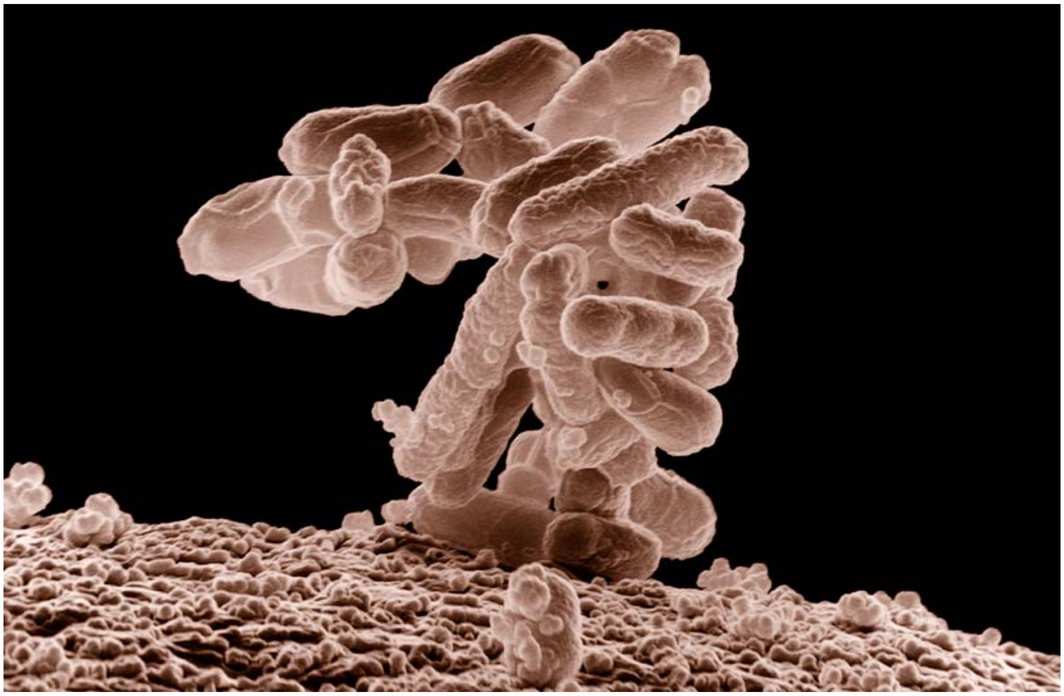


A cluster of *E. coli* bacteria viewed through a microscope.

1 Waterborne Pathogens: An Overview

Waterborne: *supported, carried, or transmitted by water <waterborne diseases>.*[1]
Pathogen: *a specific causative agent (as a bacterium or virus) of disease.*[2]

Despite modern advances in sanitation, waterborne pathogens still pose a threat to drinking water and recreational water in the United States. Large-scale outbreaks in recent history demonstrate this threat, from the Milwaukee *Cryptosporidium* outbreak of 1993, which made over 400,000 people ill, hospitalized over 4,000, and caused approximately 100 deaths;[3] to New York State's Washington County Fair *E. coli* outbreak of 1999, which made hundreds ill and killed two;[4,5] to the South Bass Island, Ohio multi-pathogen outbreak of 2004, which made over 1,400 people ill.[6] More recently, more than 88 attendees of a Wyoming bible camp reported gastrointestinal illness which has been attributed to *Campylobacter jejuni* and norovirus infections. Twenty family members of camp attendees also reported illness.[7]

The purpose of this primer is to provide information on common waterborne pathogens, their sources, how they contaminate water, and how to prevent pathogenic contamination of drinking water sources. Individual community case studies are included to showcase strategies for protecting sources of drinking water and lessons learned.

Waterborne pathogens can be broken into three primary groups: bacteria, parasites and viruses.[8] While certain bacteria are pathogenic, it is important to note that most bacteria do not cause disease. For more information about bacteria that do not cause disease, see Section 6 of this primer.

Bacterium: (condensed) *Round, spiral, or rod-shaped single-celled microorganisms that typically live in soil, water, organic matter, or the bodies of plants and animals, and that are noted for their biochemical effects and capacity to cause disease.*[9]

Parasite: *an organism living in, with, or on another organism in parasitism (Parasitism: an intimate association between organisms of two or more kinds; especially : one in which a parasite obtains benefits from a host which it usually injures).*[10]

Virus: ***a:*** *the causative agent of an infectious disease,* ***b:*** *any of a large group of submicroscopic infective agents that are regarded either as extremely simple microorganisms or as extremely complex molecules, that typically contain a protein coat surrounding an RNA or DNA core of genetic material but no semipermeable membrane, that are capable of growth and multiplication only in living cells, and that cause various important diseases in humans, lower animals, or plants.*[11]

An official outbreak of waterborne disease occurs when two or more people become ill and their illness is linked epidemiologically (by a medical professional dedicated to determining causation of disease) to contact with, or especially ingestion of, water.[12]

Since advances in sanitation, like the widespread use of chlorine, waterborne illnesses have decreased significantly in developed countries. However, as the rest of this primer will show, waterborne disease is still a threat in the United States, albeit a very preventable one.

For more information about the most common and noteworthy waterborne pathogens encountered in the United States, see Appendix A of this primer.

Modern advances in sanitation have improved drinking water quality and reduced the risks of waterborne disease, however prevention remains a key ingredient.

Surface water can become contaminated with animal fecal matter and pathogens, especially when used as a watering source for livestock.

2 How Do Pathogens Get Into Drinking Water?

Where do pathogens come from, and how do they get into drinking water? Ultimately, the source of waterborne pathogens is almost always fecal matter from infected humans and animals, whether they are exhibiting symptoms of infection or not. Fecal matter can come into contact with sources of drinking water in a surprising number of ways, including direct excretion into surface waters, raw sewage/combined sewer overflow, septic systems, sewer line leakage and livestock facility drainage.

Aside from wildlife contact with surface waters, all the sources of pathogenic contamination discussed here can be managed so that they do not pose a threat. Methods for preventing contamination will be discussed in Section 5 of this primer.

Vulnerability of Surface Water

Surface water can become contaminated with fecal matter from both animals and humans, especially when designated for recreational uses (e.g., swimming) or used as a watering source for livestock. Even when waters are not used for these purposes, wildlife will be in contact with surface waters, and so will their fecal matter. Because surface water is open to the environment, it will almost always be in contact with animals and/or humans (and their waste) and is thus highly susceptible to pathogenic contamination. It is also important to remember that surface water bodies supplied by other surface waters will reflect contamination that is occurring upstream. Lakes, for example, can harbor contamination that originated in a stream higher in the watershed.

Most public water systems using surface water in the United States are required to filter and all disinfect the water prior to distribution because of the vulnerability of surface water to pathogenic contamination. Surface water systems can avoid filtration if they meet certain criteria including maintaining appropriate disinfection. While the majority of systems filter, there are a few large population centers that use unfiltered water. [13]

Perhaps the most famous outbreak of waterborne disease in the United States was the result of a failure in the treatment of surface water serving Milwaukee, Wisconsin in 1993. Over 400,000 people became ill during this outbreak of Cryptosporidiosis, and about 100 died. The City of Milwaukee draws its drinking water from Lake Michigan, after which the water is processed for disinfection in one of two treatment plants. Before and during the outbreak, a change in the chemicals used for coagulation of certain contaminants (*Cryptosporidium* being one of these) prior to filtration had failed, allowing *Cryptosporidium* oocysts to pass through the filters and on into the distribution system. The ultimate source of *Cryptosporidium* for Lake Michigan was likely livestock and wildlife in the area, and when working properly, the Milwaukee treatment plants remove this and other types of contaminants.[14]

For more information about *Cryptosporidium*, see Appendix A: Waterborne Pathogens: "Bad Bug" Profiles.

Vulnerability of Groundwater Under the Direct Influence of Surface Water

Groundwater under the direct influence of surface water (GWI) is groundwater located near enough to surface water, such as a river or lake, to receive direct surface water recharge. Those groundwater sources most likely to be under the direct influence of surface water are:

- Infiltration galleries and horizontal collector wells located near surface waters.
- Poorly constructed springs.
- Shallow wells located near surface waters.[15]

GWI is more susceptible to pathogenic contamination and most often identified by the:

- Significant occurrence of insects or other macroorganisms, algae or pathogens, such as *Giardia lamblia*.
- Significant and relatively rapid shifts in water characteristics, such as turbidity and temperature.[16]

Because of GWI's vulnerability to pathogenic contamination, most public water systems using GWI in the United States are required to filter and all disinfect the water prior to distribution.[17]

For more information about *Giardia lamblia*, see Appendix A: Waterborne Pathogens: "Bad Bug" Profiles.

Combined Sewer Overflow

Combined sewer overflow can contribute significantly to pathogenic contamination. Combined sewers are those sewer systems that are connected with stormwater systems (which drain urban areas to prevent flooding) before arriving at a wastewater treatment plant. When significant storm events occur and the amount of stormwater entering the sewer

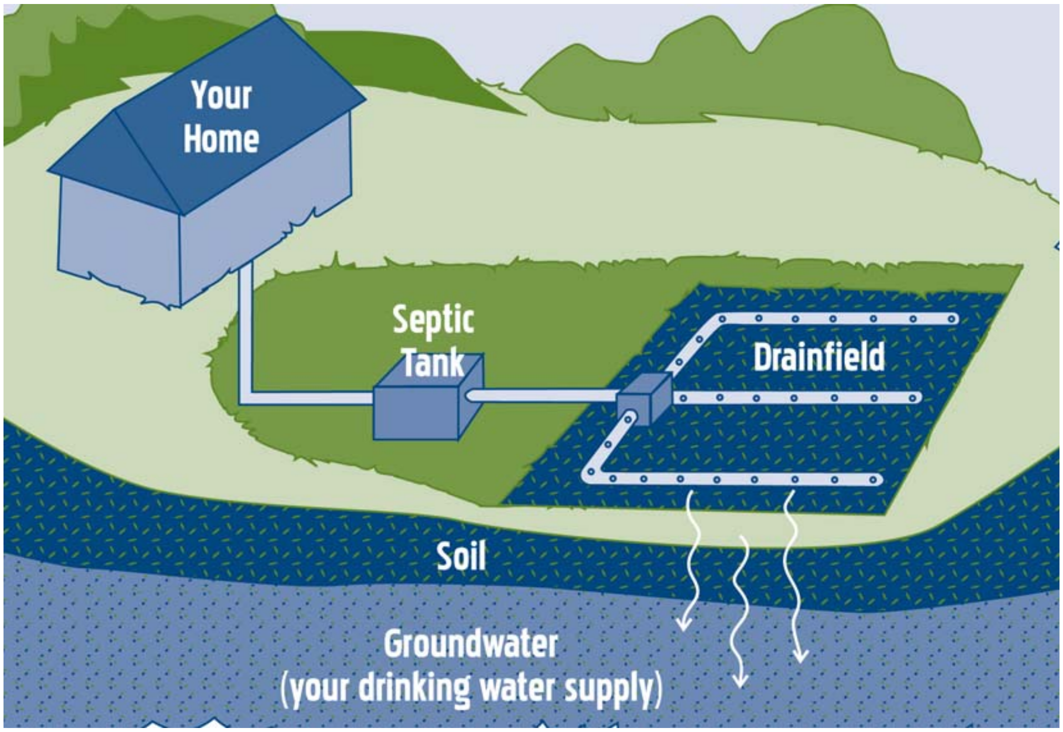


Diagram of a septic system - the most common type of on-site wastewater treatment system.

increases, the combined sewer system has a higher potential to overflow, in which case raw sewage also overflows and can then be directed into waterways untreated. The United States Environmental Protection Agency estimated in 1997 that 20% of the U.S. population is served by combined sewers.[18,19] For a map illustrating the locations of cities with combined sewers in the U.S., go online to http://cfpub.epa.gov/npdes/cso/demo.cfm?program_id=5.

On-site Wastewater Treatment Systems

Septic systems and lagoons can also be a source of pathogens, primarily when they are not functioning properly. These systems are used to treat waste on-site, especially for individual homes in rural areas where larger sewer systems and treatment are not available. A septic system allows solid wastes to settle in a tank and liquid wastes to be distributed into a leachfield in the soil, where waste is decomposed by soil organisms. A lagoon, which is a pond-like structure, uses bacteria to break down both solid and liquid waste.

There may be several reasons that treatment in a septic system would fail and could thus be a source of pathogenic contamination, especially in groundwater. A septic system could be poorly designed or installed for the type of soil it is in; for example, sandy soils are generally a poor choice for placement of a septic system. Sandy soils have large pore spaces through which contaminants (including pathogens) may easily pass, rather than adhering to soil particles where microorganisms and chemical reactions may render the contaminants harmless (or less harmful). In addition, a high density of septic systems (such as in rural acreage communities, lakeside communities, etc.) may lead to a high concentration of wastewater in an area, surpassing the capacity of the soil in that area to treat the wastewater.

An improperly maintained septic system may also lead to leakage of wastewater without treatment. Septic tanks must be periodically pumped to remove solid wastes to accommodate the collection of additional wastes. Failure to pump a septic tank may lead to an overflow of solid wastes into the leachfield which clogs the leach lines so that liquid and solid waste backs up in the system, overflowing into the home and in some cases even rising to the land's surface.[20,21] A failing septic system can be an even larger source of fecal contamination than a wastewater treatment plant, producing five to 150 million milligrams per liter of fecal effluent, as compared to 26 to 68 million milligrams per liter from a properly functioning wastewater treatment plant.[22]

Improperly managed livestock facilities, like this swine feedlot, may contribute pathogenic contamination to drinking water sources.

Septic systems were believed to have been part of the cause of the South Bass Island, Ohio gastrointestinal illness outbreak in the summer of 2004, during which about 1,450 visitors to the island became ill. The hydrogeology of the area is poorly suited for septic systems, with soils being thin or absent atop a karst setting. In karst hydrogeology, large fractures occur in limestone and provide direct conduits to groundwater without the benefit of soil filtration.[23,24,25]

A lagoon may be a source of pathogenic contamination when it overflows due to flooding, or if it is improperly lined and thus allows excess seepage into underlying soils. As with septic systems, proper siting, construction and maintenance can help to eliminate the potential for contamination.

Centralized Wastewater Treatment Systems

Although centralized wastewater treatment system, or sanitary sewer, lines are designed to keep sewage away from drinking water sources and distribution systems, leaks may sometimes occur. These leaks can be a source of contamination. Sewer lines may become compromised when the foundation (surrounding soil) is made unstable due to flooding, soil slippage, freeze/thaw action and from tree root invasion or seismic activity. Aged and corroded pipes may be especially susceptible to damage. When leaking sewer lines are located deep underground, below the soil zone where microorganisms and chemical reactions may assist in removing contaminants, pathogen-laden sewage may even enter groundwater directly.[26,27]

Livestock

Areas where livestock are kept, whether they are feedlots, pastures, or temporary holding facilities, can also be sources of pathogenic contamination. An outbreak of *E. coli* in recent history demonstrates this. During the summer of 1999, 921 people were infected with *E. coli* at the Washington County Fair in New York. Eleven of these people developed hemolytic uremic syndrome, and two died.[28] The source of *E. coli* in this case was manure piled outside a barn where cattle were kept during the fair. A heavy rain fell, washing manure away from the barn and into a shallow (20 feet deep) well located 83 feet away. Two days after the rain, the two patients that died from their infections visited the fair and consumed drinks and food from the same vendor, which was served by the contaminated well.[29]

For information on confined animal feeding operations (CAFOs), see Section 5: *Preventing Pathogenic Contaminaion*. For more information about *E.coli*, see Appendix A: Waterborne Pathogens: "Bad Bug" Profiles.

Even outhouses can contribute to pathogenic contamination.

Other Sources

Because pathogens can exist in the fecal matter of many different kinds of animals, as well as humans, there are other potential sources that should be considered, including:

- Pet waste, especially in areas where this may be concentrated such as exercise areas or boarding kennels.
- Fields where manure or sewage sludge is applied as fertilizer.
- Camping areas with primitive toilets.

As stated earlier, aside from wildlife contact with surface waters, all the sources of pathogenic contamination discussed here can be managed so that they do not pose a threat. Methods for preventing contamination will be discussed in Section 5 of this primer.

3 Identifying potential sources of pathogens

Knowing whether or not your source of drinking water is vulnerable to pathogenic contamination starts with identifying potential sources of pathogens in your area. Public water systems may identify these potential sources of pathogens by examining and field-verifying their sanitary surveys and source water assessments.

As a condition of managing a drinking water program, states must have a sanitary survey program and complete a sanitary survey at least every five years for all surface water systems and groundwater systems that are under the direct influence of surface water. The Ground Water Rule extends these requirements to groundwater systems. States must complete their initial round of sanitary surveys for most community water systems using groundwater by December 31, 2012. [30] For more information about the Ground Water Rule, see Section 6 of this primer.

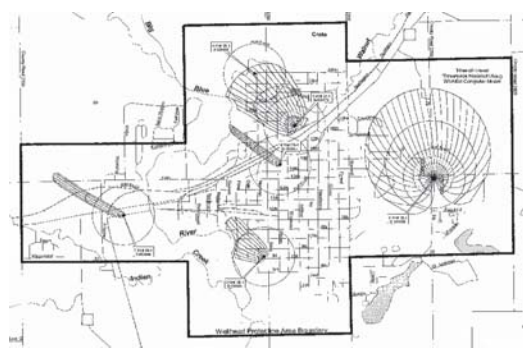
Sanitary Surveys

Sanitary surveys are regularly conducted by state agencies (often health departments) to evaluate the ability of a water system to consistently provide safe drinking water to their customers and verify the system's compliance with federal regulations. The sanitary survey is therefore designed to identify contamination threats to the drinking water system, whether these threats exist in the source water area or in the distribution system.[31]

The agency conducting the sanitary survey either conducts the survey with the operator of the water system present, or reports their findings to the water system. In cases where the system operator was not present for the survey, it may be necessary to field-verify the findings of the sanitary survey, especially to note any potential sources of contamination that may have been missed.

Source Water Assessments

Source water assessments also offer basic information about the source providing raw water to a public water system, but differ in that assessment information includes a description and/or map of the hydrologic area from which source water is drawn, an inventory of potential sources of contamination, and a determination of how vulnerable the source area is to potential contamination sources. The source water area is often shown as a land surface delineation of the groundwater body from which water is drawn, or as the delineated watershed contributing to a body of surface water.[32]



A source water area map identifies land that is linked to water supplies (groundwater or surface water).

All public water systems have a source water assessment completed by a state agency or other assistance organization, and are required to make source water assessments available for public review, as

Recording potential sources of pathogens can be as easy as tracking observations in a notebook or as technically-advanced as using a handheld GPS unit and GIS mapping software.

well as disclose information about the source water assessment's findings in the annual consumer confidence report made available to customers. Post 9/11 security concerns sometimes make obtaining a complete copy of a system's source water assessment difficult; nevertheless, understanding the information contained in the assessment is critical to any protection effort. Persistance, along with making one's intentions clear, can help make sure the assessment is available.

Field-verifying the information in source water assessments is also important, as the agency conducting the assessment may not have been familiar with past (but pertinent) activity in the area, or may have consulted a state database by mailing address and therefore may have included information on potential threats that are actually not present inside the source water area. The source water assessment is the primary source of information on the area from which source water is drawn, so field-verification need only happen in this area.

Reviewing and Field-verifying Sanitary Surveys and Source Water Assessments

Potential sources of pathogenic contamination to be aware of when reviewing, updating and/or field-verifying source water assessments and sanitary surveys include on-site wastewater treatment systems, wastewater treatment plants, livestock feeding facilities, areas of high concentration of wildlife, etc. Basically, any activity where contact with fecal matter of any sort is possible or probable should be included. It is also important to note that historical activity in the area may be relevant; for example, a now-inactive animal feeding area may contribute pathogenic (and other) contamination to source water as soils dry and become cracked, providing more direct surface runoff conduits to the water table.

Recording potential sources of pathogens can be as simple as writing down observations on a notepad, or as

Using technological tools to conduct a source water assessment.

technologically-advanced as using a Global Positioning System (GPS) receiver to mark those areas and load them into a Geographic Information System (GIS). Individual communities will operate on different budgets, which may limit the use of GPS receivers and a GIS program, but information can be recorded and tracked without them.

Some simple steps to field-verify sanitary surveys and source water assessments are:

- Identify the delineated source water area on a map. This information should be available from the water system, local government or state drinking water program.
- Develop a team of people from the community to assist with the inventory, such as community leaders, city employees, senior citizens, high school students, and anyone else who can serve as historians on the area.
- Walk or drive through delineated source water areas to determine which sources may have been overlooked by sanitary surveys and source water assessments, and verify that the sources listed in those documents are within the source water area.
- Consider including more detailed surveys of each property in the area, such as for individual farmsteads, wastewater treatment facilities, waste lagoons or any other area that might pose a pathogenic threat to source water.
- Establish a current database of information on the drinking water well(s) and potential sources of contamination in the source water area and update it as changes occur.
- Establish a map, hand-drawn or using a GIS, that shows accurate locations of all potential contaminant sources within the delineated source water area. This will help to identify which threats are more immediate (closer to the well[s]) than others.

These steps can also be used more generally to identify potential sources of other kinds of contamination, which is part of the process of developing a comprehensive source water protection plan.[33]

For more information about how to understand and use the information provided in a source water assessment:

- *Source Water Stewardship: A Guide to Protecting a Restoring Your Drinking Water* at www.cleanwaterfund.org/sourcewater/guide.html
- *Source Water Assessment and Protection Workshop Guide, Second Edition* at www.groundwater.org/gi/swap/swap.html.

New housing developments, especially where sanitary sewers and centralized wastewater treatment are not available, are important to assess as potential souces of pathogenic contamination.

4 Monitoring Land Use for Potential Sources of Pathogens

Once an initial assessment of potential sources of pathogens has been performed, it is important to keep updating the assessment. A variety of changes in the source water area may occur that pose a pathogenic threat to the source, and some of these changes may be obvious while others may not.

Identify New Potential Sources

New potential sources would include the introduction of livestock facilities, rural housing developments, etc. that may cause human or animal fecal matter to enter the source.

A new livestock facility over a certain size will usually be regulated by states because of the large amounts of waste generated by them (check with your state's department of environmental quality or natural resources to find out how large the facility has to be before it is regulated), but smaller, family farm-sized livestock facilities may not fall under waste management regulations. Regulated facilities may be required to implement waste management plans to minimize contamination threats while unregulated facilities will not fall under these requirements, so the threat of contamination may not be directly related to the size of the facility. Also, the addition of a new facility large enough to be regulated will often be quite obvious, while a smaller, family-operated facility may not be.

New housing developments, especially where sanitary sewers and centralized wastewater treatment are not available, are also important to assess. Often, rural housing developments will include septic systems at each home; areas with a concentrated number of septic systems are susceptible to pathogenic contamination, especially when these systems are not properly maintained. The soil and geologic conditions of the area are also important to understand, as illustrated in the example of South Bass Island in Section 2 of this primer.

Monitor Changes In Existing Conditions

Changes in existing conditions, such as the closure of a livestock facility or an accidental discharge from a waste treatment system, are also important to watch for.

For example, if a livestock facility closes, the likelihood of pathogenic contamination of groundwater from that facility may actually increase. While animals are kept in outdoor pens, the soils tend to be continuously compacted due to the tread of animal hooves, and kept continuously moist due to animal excretion. When these areas are abandoned, the soils may dry out and desiccation cracks may form, providing a more direct conduit from the ground's surface to groundwater, through which pathogens in the upper layers of soil may enter.

Conversely, the abandonment of such a facility may also represent a lessened threat to surface waters. Vegetation may sprout in the absence of soil compaction, creating a "roughening" of the surface that will slow runoff, thus reducing the amount of runoff reaching nearby surface waters.

Accidental discharges of human and animal waste from septic systems, sewer lines, waste lagoons and similar systems do happen. Sometimes, these discharges may be quite obvious as odors, wastewater streams or repairs to failing systems can be readily observed. However, a single failing septic system may not be quite as obvious.

Build Relationships With Facility Managers and Land Owners

While it might not be possible to be aware of all new or changing facilities within a source water area, a friendly rapport with landowners or officials of cities with facilities in the source water area can help landowners and officials feel comfortable sharing information. This can be especially important when an accidental discharge does happen.

One way to begin building a friendly rapport is to simply make stakeholders in the area aware of your efforts to identify potential sources of pathogenic contamination, and to share the information you have gathered. Since these stakeholders likely obtain their drinking water from the same area, it is also important for them to understand the potential sources of contamination.

New facilities and changes in existing conditions may occur at any time and there is a large range of possible sources of pathogenic contamination. Again, the main idea is to be aware of any new potential source or any change in existing potential sources involving human or animal waste, especially if these new or changing facilities pose a greater threat to discharge fecal matter. Refer often to your database of potential sources of contamination (discussed in Section 3), examine each listed source for changes, and add to the database as new potential sources emerge.

Keeping livestock out of surface water bodies can prevent pathogenic contamination.

5 Preventing Pathogenic Contamination

Although many pathogens can be safely removed from drinking water by disinfection, preventing the contamination from occurring in the first place is key to keeping treatment costs low. Some systems may even be able to avoid disinfection if they are able to sufficiently prevent pathogenic contamination from occurring. Preventing pathogenic contamination consists of maintaining separation between source water and pathogen sources (when possible), using best practices to successfully manage human and animal waste in the source water area, and preventing contaminated runoff from entering source water.

Maintaining Separation Between Source Water and Pathogen Sources

Perhaps the most obvious way to prevent pathogenic contamination in source water is to simply keep source water away from sources of pathogenic contamination, and vice versa.

Groundwater usually flows in a particular direction or gradient as it intercepts the well. For groundwater users, this means that wells should be located up-gradient (ususally upstream or uphill) of any potential source of contamination. That way, the water is captured by the well before it can become contaminated. Setback areas can also be used to maintain a safe distance between a well and a potential contamination source. For suggestions and regulations on setback distances, contact your state department of health or environmental quality.

For surface water users, this may be much more difficult. Bearing in mind that part of the source of water for any surface water body is a great distance away (i.e. at the "top" of the watershed), it may even be impossible. The best choices for locating surface water intakes are downstream of those portions of a watershed where little to no urban or rural development has occurred.

Surface water users may also help to keep pathogenic contamination from occurring in the immediate area by installing fences around the water source. Even simple, proactive actions like fencing will help keep large animals out of the area, and prevent their feces from directly entering the water.

Septic systems can become damaged, allowing hazardous wastewater to leak.

Since most water systems cannot afford to purchase all the land in their source water area (and thus, have complete control over what occurs on that land), keeping sources of pathogens away from drinking water sources often involves land use planning, zoning and legislative action. For example, North Carolina enacted legislation that allows counties to adopt zoning ordinances to regulate swine facilities of a certain size or capacity, and Iowa enacted legislation that allows counties to adopt stricter regulations (relating to confined animal feeding operations or CAFOs) than those of the state. Often, zoning regulations do not outright prohibit the introduction or expansion of a CAFO, but do set forth permitting processes or special conditions.[34]

Because it may be infeasible for both surface water and groundwater users to site water sources away from sources of pathogens entirely or to keep sources of pathogenic contamination away from source water, the following management strategies may be used within the source water area to prevent pathogenic contamination.

Managing Waste

HUMAN WASTES

On-site treatment: When wastes are properly managed on-site by septic systems, lagoons and alternative systems, the threat of pathogens entering source water is greatly reduced.

Septic tank and drain field maintenance: A septic tank/drain field system is the most common on-site wastewater treatment system. Wastewater flows through plumbing from the home to a septic tank. Here, heavy materials settle to the bottom of the tank, while liquids and suspended solids remain floating. Naturally occuring bacteria in sewage begins to break down organic materials in the wastewater in the septic tank. From here, wastewater travels through a pipe to a drainfield, which is often a trench filled with gravel and topped with soil. The effluent seeps through the gravel and into the soil, where it is treated by more bacteria in the soil, reducing the concentrations of nutrients like nitrogen and phosphorous and killing some pathogens. The soils surrounding the drainfield are quite important to the system's functioning ability, and the size of the drainfield is determined by the amount of wastewater moving through the system.[35]

Septic system maintenance involves regular pumping of the tank, water conservation, minimizing solids and hazardous materials in the waste stream, allowing the system to work naturally and protecting the drain field.

Many experts recommend pumping a septic tank every two to three years, though the number of people living in the home, water usage and whether a garbage disposal is used may cause the tank to reach capacity more or less frequently. To be safe, the septic tank should be inspected annually and pumped when the inspector deems it is necessary.

Conserving water and spreading out water usage can also help prevent septic system failure. Except immediately after a tank has been pumped, it is full of wastewater at all times. To allow solids to settle and thus prevent clogging of leach lines, wastewater should stay in the tank for at least 24 hours. Conserving water and spreading out water usage, such as washing one or two loads of laundry a day (instead of three or more), installing low-flow water fixtures, taking short showers, and turning off faucets when brushing teeth or shaving, can help maintain a balanced flow of wastewater through the septic system and prevent clogged leach lines.

Minimizing solids and hazardous materials in the waste stream is also important to properly maintaining a septic system, especially concerning those items that may damage the ability of the system to process wastewater. Items not to flush, wash down the drain or otherwise put into the septic system include: cigarettes, diapers, feminine hygiene products, paper towels, facial tissue, grease, oils, pesticides, paints, thinners,

Cigarettes, diapers, feminine hygiene products, paper towels, facial tissue, grease, oils, pesticides, paints, solvents, thinners, and medications should not be flushed into a septic system.

solvents and medications. Minimizing food wastes and powdered detergents can help to reduce solid waste in the septic tank, and minimizing the use of harsh cleaning products, including bleach, can help prevent damage to the bacterial population in the soil that breaks down septic system effluent. To further minimize solids in the waste stream and drainfield, install a filter on the washing machine discharge line to trap lint, and install an effluent filter at the septic tank's outlet.

Experts also recommend letting the system work naturally. Septic system starters, additives or feeders can actually cause materials to remain suspended in

Properly managing wastewater lagoons is an important factor in preventing pathogenic contamination.

wastewater and clog the drainfield; therefore their use is not recommended.

To ensure the function of the drainfield, it should not be inundated with water, nor should its structural integrity be compromised, damaged or threatened. Water from roofs, downspouts and any other surface water runoff should be directed away from the drainfield, and underground lawn sprinklers should not be operated in the drainfield. Vehicles and agricultural equipment, animal confinement units, driveways, sidewalks and buildings should be kept off of the drainfield, and trees and other deep-rooting plants should not be planted within five feet of the drainfield. Rodents and other burrowing animals should also be kept out of the area.[36]

Sewage lagoon maintenance: Sewage lagoons are an alternative for on-site wastewater treatment when soils are not properly suited to a septic tank/drainfield system. Wastewater goes through plumbing to the lagoon where algae and bacteria break down the waste. Similar to a septic tank, heavy solids settle to the bottom of the lagoon while fluids and suspended solids remain floating. Water evaporates from the lagoon, and some seepage from the lagoon into surrounding soils is sometimes allowed by state health and environmental agencies.[37]

Sewage lagoon maintenance includes tasks that must be performed at least monthly, as well as tasks that may be performed less frequently. Monthly tasks include checking and repairing lagoon structure, managing vegetation around and in the lagoon, observing the lagoon water's color and monitoring and managing the water level. Less frequent maintenance tasks include checking the depth of sludge, repairing leaks or seeps, removing sludge and, when necessary, properly closing the lagoon.

Checking lagoon structure includes checking both the fence around the lagoon (if one is present) and the lagoon itself. The fence should not have any holes or gaps that would allow children or animals into the immediate lagoon area, and any existing holes or gaps should be repaired immediately. The lagoon dike (the mound surrounding the lagoon) should be the same height and shape as when built, and any erosion or damage should be filled, compacted, leveled and reseeded with a perennial grass.

Managing vegetation around the lagoon includes maintaining grass height inside the dike to no more than six inches (taller vegetation will inhibit air circulation), preferably around three inches, and removing the grass clippings from the site. A vigorous perennial grass is the best vegetation to surround a lagoon. Grass outside the dike may be allowed to be a taller height than grass inside the dike, but should still be no taller than six inches.

Trees and woody plants taller than the dike should not be growing within 50 feet of the dike, as these will restrict air flow, and root action could damage the structure of the dike. Vegetation other than perennial grass should not be allowed to grow along lagoon edges. If the plants are too established to pull, applying a pesticide that will not harm algae is an option, but it should be applied with a wick directly to the plant and not broadcast sprayed as this may allow the chemical to get into the water, where it can damage algae and bacteria. Floating plants should not be allowed to grow inside the lagoon, as these will restrict the establishment of algae. These plants may be physically removed or treated with a herbicide specifically designed for them; again, be mindful not to harm the algae.

The lagoon water's color is a good indicator of lagoon health because the color is

Testing the efficiency of an animal waste lagoon constructed with a preventative geo-textile fabric liner.

directly related to the pH of the water, as well as dissolved oxygen levels. A bright, rich green color indicates a healthy lagoon with plenty of green algae. A dull green or yellowish color indicates that an undesirable type of algae has become dominant, indicating poor treatment conditions. A tan, brown or red color indicates that soil could be entering the water from bank erosion or that undesirable algae have become dominant. A gray or black color indicates that anaerobic conditions may exist, so the lagoon is not effectively treating wastewater; often, odor will also be present in these conditions. Monitoring and managing the water level provides information for lagoon operation, documents changes and trends, and provides a record in the event of a problem. The best water depth at which to operate a lagoon is two to five feet. When the lagoon is approaching the five-foot depth, divert or shut off supplemental water.

A bright, rich green color indicates a healthy lagoon with plenty of green algae.

Checking the depth of sludge can be done by wrapping a towel around the end of a stick and lowering the stick into the water, preferably near the center of the lagoon and always at the same place, and should be done annually. After a few moments, remove the stick slowly; solids clinging to the towel will show the sludge level and the water depth will be marked on the towel or the stick. There should be at least eighteen inches between the sludge level and the water surface level. If the sludge layer becomes closer to the surface than this, have a septage contractor remove a few loads of sludge from the bottom of the lagoon. Sludge can then be disposed of at a local wastewater treatment facility, or land-applied according to federal regulations, if allowed by local authorities.

Occasionally, the dike may leak due to faulty construction, erosion or damage from vegetation or animals. Any leak must be stopped by repairing the dike and/or sealing the lagoon's inside surface. If the lagoon should become dry, have a contractor remove sludge from inside the lagoon and rework the seal material in the liner to fill any cracks.

If the lagoon should stop functioning properly, become damaged beyond repair, or needs to be abandoned for any other reason, all liquids should be drained. All settled solids and liner material should also be removed and all waste should be disposed of at a local wastewater treatment facility or, if allowed, land-applied. The lagoon basin should then be filled with soil, which should be mounded to allow for settling.[38]

Alternative on-site treatment systems: In some areas, a septic tank/drainfield system or lagoon may not be appropriate. Some alternative systems include:

- Septic tank/pressure dosing
- Septic tank/mound system

Proper maintenance can extend the life of a septic system, preventing the inconvenience and cost of installing a new system (as seen here), as well as preventing pathogenic contamination.

- Septic tank/gravelless system
- Septic tank/constructed wetland
- Septic tank/evapo-transpiration system
- Septic tank/sand filter
- Aerobic unit or aerated tank
- Holding tank
- Waterless toilets

Septic tank/pressure dosing: Pressure dosing may be required when a long drainfield (e.g., more than 500 feet) is needed to treat wastewater. Effluent is pumped out of a dosing chamber (following the septic tank) at regular intervals, which forces wastewater along the entire line of drainfield, helping to make distribution more uniform. Maintenance of this type of system would be similar to that of a traditional septic tank/drainfield system.

Septic tank/mound system: Mound systems can be used when the water table is too close to the surface for a drainfield to not be inundated, or soil conditions are such that percolation is too slow for wastewater treatment. The septic tank effluent is pumped into a mound above the ground's surface, which is composed of materials that will provide proper treatment. Maintenance for this type of system would be similar to that of a traditional septic tank/drainfield system.

Septic tank/gravelless system: A gravelless system functions the same as a traditional septic tank/drainfield system, with the exception that the trenches in the drainfield are not filled with gravel. Instead, perforated pipes are surrounded by a filter fabric and effluent drains into the soil directly from these pipes. Often, these systems are easier to install because of their lighter components, and may even have a greater storage capacity. Maintenance for this type of system would be similar to that of a traditionial septic tank/drainfield system.

A constructed wetland can provide an alternative in areas where traditional septic systems are ineffective.

Septic tank/constructed wetland: A septic system with a constructed wetland can be an aesthetically pleasing alternative to a traditional septic tank/drainfield system. Effluent discharges from the septic tank into the wetland, which is planted with cattails, reeds and other aquatic plants that remove or take up nutrients and other contaminants, along with suitable soils and a natural microbe community. Effluent then flows out of the wetland into a drainfield or polishing pond where treatment and evaporation continue to occur. Maintenance would be similar to that of a traditional septic tank/drainfield system, but including maintenance of wetland plants. In addition, if the wetland discharges to surface water, the owner will need to obtain a permit through the National Pollutant Discharge Elimination System (NPDES), which is administered by the U.S. EPA and state agencies.

Septic tank/evapo-transpiration (ET) system: This type of system uses evaporation from soil and transpiration from plants to treat wastewater, and can be used in dry climates where precipitation does not exceed evaporation and transpiration rates. In this system, effluent flows out of the tank and into the ET bed which consists of perforated pipes in a crushed stone bed, which is covered with a shallow layer of topsoil planted with water-tolerant vegetation. Maintenance for this type of system would be similar to that of a traditional septic tank/drainfield system, including maintenance of water-tolerant vegetation.

Septic tank/sand filter: Sand filters can be used as a second step in on-site wastewater treatment (after the primary treatment in the septic tank) when a septic tank/drainfield system has failed or is restricted due to a high water table, shallow bedrock, inadequate soils or other similar conditions. A sand filter consists of a watertight box, usually lined with plastic or concrete, filled with sand material. Effluent from the septic tank is pumped in small doses into the filter box and distributed evenly over the top of the sand filter. Wastewater is collected at the bottom of the filter after it has trickled through the sand and is then taken to an effluent treatment system. If the wastewater is discharged to surface water, the owner will need to obtain a NPDES permit. Maintenance for this type of system will be similar to that of a traditional septic tank/drainfield system.

Aerobic unit or aerated tank: These units use aerobic digestion, which breaks down wastes with bacteria in the presence of oxygen, as opposed to the septic system, which is anaerobic. In this type of treatment, waste flows into a tank where an air compressor bubbles air through the wastewater, or a pump or stirring device introduces air. After treatment in the tank, effluent flows into a drainfield, mound system, subsurface drip irrigation system, or some other type of effluent treatment before being released into the environment. Maintenance of this type of system will be more expensive than a septic system because this system uses mechanical parts and energy.

Holding tank: A holding tank is an option for homes where conditions are not proper for septic systems, lagoons or aerobic units. Quite simply, waste is pumped into a holding tank, which has to be pumped out periodically. One person uses, on average, 75 gallons of water per day, so a home may require a rather large holding tank, or have the tank pumped frequently. Maintenance involves assuring the tank is not leaking, as well as the continual hiring of a contractor to pump out and haul away the waste.

Waterless toilets: Composting and incinerator toilets are two types of waterless toilets. These can be useful when water supplies are low, or when a homeowner wants to reduce the quantity and/or improve the quality of wastewater that does require treatment. In composting toilets, heat produced by bacterial activity will drive off excess moisture and reduce waste to about 5-10% of its original volume. Composting produces a residue that may be disposed of in a trash bin or garden, if it is permitted by local health departments. Incinerator toilets use energy to burn waste and reduce it to sterile ash. The ash box must be emptied periodically. Both of these types of waterless toilets do produce some odor and will consume energy either for burning or for venting odor and gases.[39]

Human wastes - centralized wastewater treatment systems: The proper operation and maintenance of wastewater treatment plants and their transmission systems (including sewer lines) are critical to preventing the pathogenic contamination of source waters in areas where they are both present. While the average person does not get involved in the operations and maintenance of a wastewater treatment system, the average person can do their part by recognizing the value of proper operation and maintenance of these facilities. Public support is critical, especially when proper operation and maintenance leads to higher utility bills. Recalling the potential for pathogenic contamination during combined sewer overflows, this is especially important when a municipality is updating its combined sewer system to separate stormwater and sanitary sewer lines.

ANIMAL WASTES

Managing animal wastes includes managing waste from livestock, pets and wildlife.

Livestock waste - Confined Animal Feeding Operations (CAFOs): Livestock operations larger than a defined size are governed under the U.S. EPA's CAFO Rule. According to U.S. EPA regulations, these operations include those that confine animals for at least 45 days in a 12-month period, have no grass or other vegetation in the confinement area during the normal growing season, and that have at least one of the following:

- 200 to 699 mature dairy cows, whether milked or dry;
- 300 to 999 veal calves;
- 300 to 999 cattle other than mature dairy cows or veal calves. (Cattle includes but is not limited to heifers, steers, bulls and cow/calf pairs.);
- 750 to 2,499 swine each weighing 55 pounds or more;
- 3,000 to 9,999 swine each weighing less than 55 pounds;
- 150 to 499 horses;
- 3,000 to 9,999 sheep or lambs;
- 16,500 to 54,999 turkeys;

Managing animal waste is an important step in preventing pathogenic contamination of water supplies.

- 9,000 to 29,999 laying hens or broilers, if the CAFO uses a liquid manure handling system;
- 37,500 to 124,999 chickens (other than laying hens), if the CAFO uses other than a liquid manure handling system;
- 25,000 to 81,999 laying hens, if the CAFO uses other than a liquid manure handling system;
- 10,000 to 29,999 ducks, if the CAFO uses other than a liquid manure handling system; or
- 1,500 to 4,999 ducks, if the CAFO uses a liquid manure handling system.

The above capacities apply to operations where pollutants are discharged into waters of the United States either directly (because a water body comes into direct contact with the animals confined in the operation) or through a man-made device such as a ditch or flushing system. Operations with greater numbers of animals than those listed above are considered CAFOs, regardless of their contact with waters of the United States. ***Also, states may individually regulate livestock facilities.*** Facilities that fall under state or federal regulations are managed under the NPDES to minimize their waste effluent stream. Managers of these facilities are responsible for adhering to state and federal rules for waste management.[40]

It is important to recognize that while a livestock facility may fall under state or federal regulations, accidents may still happen during which livestock waste containing pathogens is discharged into the environment. Building a friendly rapport with facility owners and managers in the area will help those individuals feel comfortable in sharing accident information so that the potential threat to drinking water supplies may be assessed.

Livestock waste - small operations:
Some facilities will, of course, not fall under state or federal regulations and so will not be required by law to follow any specific waste management techniques.

However, several waste management techniques can still be effective in reducing or eliminating the threat of pathogenic contamination in the areas surrounding these facilities.

Even a small number of animals (a few cattle or a horse) can produce enough waste to be a problem if runoff is not managed, especially in an area where stormwater runoff may wash feces into sources of drinking water. Diverting stormwater from animal pens or manure piles is therefore an important management practice. Construction of stormwater diversion dikes upslope of animal holding areas decreases the amount of stormwater entering those areas. Managing manure collection piles is also important. These piles should not be placed in the path of stormwater runoff, and can instead be composted to produce a valuable soil conditioner.[41]

Pet Waste: There are approximately 65 million dogs and 77.6 million cats owned in the United States. Over a third (39%) of U.S. homes have at least one dog, and about a third (34%) have at least one cat.[42] Outdoor pet waste can be washed into storm sewers and then into nearby streams or shallow water tables, thus contaminating water sources. The sheer number of these pets in the U.S. indicates that managing pet waste, especially in urban areas where pet populations are concentrated, is important to preventing pathogenic contamination.

Many municipalities have adopted ordinances requiring pet owners to pick up their pet's waste outside. Regardless of the adoption of an ordinance in your area, managing outdoor pet waste can be as simple as picking up waste in a bag or scoop and depositing it in an outdoor trash can. Waste digestion devices are available which may be installed in the ground in your yard, allowing pet waste to be converted into organic matter and absorbed into the soil.[43] Pet owners may also manage waste by not allowing their pets to roam outside, unsupervised. Some municipalities also have ordinances for this.

Preventing Contaminated Runoff From Entering Source Water

Sometimes even managing wastes on-site does not prevent contaminants from leaving the site, so preventing runoff, which may contain pathogenic contaminants, from entering source water is essentially the last step to preventing pathogenic contamination.

Rural prevention - riparian buffers and filter strips: In agricultural settings, preventing runoff from entering source water is largely a matter of planting vegetative buffers. Riparian buffers are planted parallel to streams to provide runoff interception, bank stabilization, aesthetic qualities and possibly even government payments to landowners through cost-share programs. Riparian buffers also provide wildlife habitat, which can contribute to pathogenic contamination if not properly managed.

Pet waste is a frequently overlooked source of pathogenic contamination.

A riparian buffer (made of trees, shrubs and native grasses) prevents sediment, nitrogen, phosphorus, pesticides, pathogens, and other pollutants from reaching a stream.

Installing a riparian buffer involves removal of existing weeds and managing weed growth, especially while grasses are being established. The buffer should include trees, shrubs and grasses. Trees and shrubs can be planted by hand or by machine, while grass seeds should be planted by drilling or by broadcasting the seeds and incorporating them with light tillage. In periods of dry weather, the buffer plants will need to be watered, especially the trees during the first few years. Generally, deep and less frequent watering is better for plant establishment than shallow and more frequent watering.

It is also important to control wildlife damage, especially to trees. Trees can be protected by installing plastic or woven-wire cylinders around their bottoms, and fencing around the buffer perimeter can be an effective means of protecting the entire buffer from deer. There are also various forms of repellents that may be sprayed to keep wildlife away from trees.[44] Wildlife may also be kept out of buffers through harassment tactics, such as the presence of predator decoys, noisemakers and scarecrows, or even a daily human presence. Pruning trees to reduce bird roosting, reducing or eliminating palatable plant species (when possible) and removing trash from the area are also effective means of discouraging wildlife occupation of the buffer.[45]

Filter strips are areas of close-growing vegetation on the gently sloped land surfaces immediately bordering a surface water body. They work to hold soils in place, allowing some infiltration, and filter solid particles out of the runoff from storm events. Filter strips should include plants with dense root systems, preferably native species. Maintenance includes mowing and removal of sediment build-up. Filter strips are most effective when the water flow is even and shallow (which will happen when the water is slowed first by a riparian buffer), and if the grass is allowed to regrow between rain events.

Urban prevention - stormwater management: A variety of practices are available to hinder stormwater pollution. Some of the most common practices include minimizing impervious areas; structural controls such as grassed swales, buffer strips, stormwater ponds, constructed wetlands, infiltration basins and trenches; and swirl-type concentrators.

Minimizing impervious areas, especially those that are directly connected to each other, can be accomplished by directing runoff from roofs, sidewalks and other surfaces over grassed areas, as well as using porous pavements in parking lots. All of these practices encourage stormwater to infiltrate into the ground rather than runoff into nearby streams.

Grassed swales are shallow, vegetated ditches that slow runoff and reduce its volume entering local waterways. Vegetative cover and integrity is key; grassed swales should be regularly mowed and weeded. To function properly, the inflow to the swale should be from a filter strip or impervious area, not from the end of a pipe.

Buffer strips (riparian buffers) and filter strips are discussed previously, under *Rural prevention- riparian buffers and filter strips* and may also be used to prevent contaminated runoff from entering urban streams.

Stormwater ponds consist of a permanent pond (where solids settle) and a zone of emergent wetland vegetation where dissolved contaminants are removed through plant biological and chemical processes. Constructed wetlands are similar to stormwater ponds, with more emergent vegetation and a smaller permanent pond. Maintenance consists of annual inspection of outlets and the shoreline, vegetation harvesting every three to five years, and sediment removal every seven to ten years.

Infiltration basins and trenches are long, narrow, stone-filled excavated trenches that are three to twelve feet deep. These should be combined with other structural processes such as grassed swales to prevent the basin/trench from clogging prematurely. Maintenance includes inspection after major storm events, and debris removal as needed.

Swirl-type concentrators are underground vaults that are constructed to create a circular motion as water flows through to encourage sediments, grease and oil to settle out of the stormwater before it flows on to treatment systems or receiving waters. The materials that are settled out may be treated.[46]

In addition, storm water permits can place a special priority for protection within a drinking water source area.

Proper well construction: Proper well construction is not only important for preventing contamination from entering the well (and the aquifer from which the well draws water), it is the law. Many states have grandfather clauses in their statutes, allowing wells that were constructed before the statute was enacted to still be considered legal, but it is really to the benefit of the landowner or community operating the well to ensure that it is in compliance with current well construction standards.

Many urban storm drains are marked to deter the public from dumping hazardous materials down city sewers.

Although specific well construction standards may vary from one state to the next, there are some basic features that

Private drinking water wells should be tested for pathogens and other contaminants on an annual basis. All public water systems are required to test for total coliform bacteria, indicators of waterborne pathogens, at least once per month.

will aide greatly in ensuring that contamination from the ground's surface does not enter the well directly. The basic construction standards featured here are from Nebraska (Title 178, Chapter 12), and are generally designed to prevent contamination from entering a well from the surface. Check with your state department of health or environmental quality for standards in your area.

General standards to prevent well contamination from the ground's surface are:

- Well should be capped with a secure cover when not attended.
- Earth surrounding the top of the well casing should slope away from the well and be firmly tamped to prevent seepage from the surface.
- Annular space (space between the borehole and the well casing) should be sealed with grout at and just below the ground's surface.
- Well casing should be a watertight, nontoxic, durable material suited for the chemistry of water that it may encounter (this includes groundwater as well as surface runoff).
- Plastic-cased wells should be protected from the frost line to above the surface grade, or may be located inside a pump house with a concrete floor sloping away from the casing.
- Well casing should extend at least 12 inches above the ground's surface (or higher if the well is constructed in a floodplain. Casing should rise enough above the ground's surface so that runoff or flood waters will not enter the well during a flood event).[47]

Non-transient non-community water systems serve at least 25 of the same people at least six months of the year and typically are operated by churches, schools, factories, hospitals, and daycare facilities.

6 Non-Community Water System Perspective and Case Study

Groundwater is the source of water for 91% of all the public drinking water systems in the United States.[48] Of these groundwater-sourced systems, nearly three-quarters are classified as non-community water systems, or those that serve a non-residential population. Non-transient non-community water systems serve at least 25 of the same people at least six months of the year and typically are operated by churches, schools, factories, hospitals, and daycare facilities. Transient non-community water systems serve at least 25 people at least 60 days per year and typically are operated by roadside stops, gas stations, commercial campgrounds, hotels, restaurants and other businesses.

Vulnerability of Non-Community Water Systems

Non-community water systems are not necessarily more likely to be exposed to pathogenic contamination than community water systems (those that serve at least 25 people or 15 service connections year round); but some non-community water systems are at more risk. Of particular note is that non-community water systems:

- Are less likely to treat the water before it is served.
- Are usually very small. Small systems sometimes lack the technical, managerial, and financial capacity to comply with drinking water regulations.

Preventing the pathogenic contamination of drinking water is the goal of every public water system. Prevention is especially important to those groundwater systems that do not disinfect the water, but deliver it directly to consumers after it is pumped from the ground. A study completed by the United States Environmental Protection Agency (US EPA) in 1996 found that nationally, 55% of community water systems using groundwater disinfected the water. In contrast, only 28% of non-transient non-community water systems and 17% of transient non-community systems disinfected the drinking water they served.[49] Of the 207 waterborne disease outbreaks that were recorded from 1991-2002, slightly more occurred in non-community water systems (42%) than either community (36%) or individual systems (i.e., private wells, 22%).[50]

Virtually all non-community water systems – 99.8% – are small and many serve less than 100 people.[51] These systems generally do not have the resources or expertise of larger systems and have higher rates of not complying with monitoring and reporting rules. When oversight and technical assistance resources are stretched thin, states may place greater priority on systems where a contamination problem could affect a larger population.

Total Coliform Rule

Total coliforms are a group of closely related bacteria that inhabit soil and surface water and are generally harmless (i.e., do not cause illness); however, when coliform bacteria are found in drinking water, it means that other, more harmful bacteria and other pathogens may also be in the water.[52] For more information on how pathogens get into drinking water, see Section 2 of this primer.

Since 1990 water systems have been required to monitor for coliform bacteria and take action if positive results are found. Large water systems may take many samples every day. In contrast, the Total Coliform Rule requires that all non-community water systems collect at least one water sample per quarter (i.e., three month period) so it may be tested for total coliform. If total coliform is found, additional samples must be taken and tested for fecal coliforms or *E. coli*. If these and other subsequent tests for total coliform are positive, the system poses a potentially serious public health risk. Both states or tribal governments and the public must be notified of this potential threat, and bottled water may be provided to consumers.[53]

Waterborne disease outbreaks have occurred in public water systems even when these systems are in compliance with the Total Coliform Rule; consequently, additional effort is needed to better identify those public water systems most vulnerable to an outbreak.[54]

Ground Water Rule

The Ground Water Rule, published by US EPA in November of 2006, is intended to further protect public health by targeting those groundwater systems most vulnerable to fecal contamination, and that as a result, may cause waterborne disease. Small systems must comply with the Ground Water Rule by December of 2009.

The rule requires that a comprehensive sanitary survey be conducted every three years for community water systems and every five years for non-community water systems. Any significant deficiencies found during a sanitary survey must be corrected. Significant deficiencies are anything that causes or has the potential to cause the contamination of the water delivered to consumers.[55] An estimated 17% of all non-community water systems will need to correct deficiencies found during their sanitary survey.[56]

Systems that are not treating their water to achieve 99.99% inactivation or removal of viruses must collect source water samples after any of the systems' routine samples test positive for total coliform. If the source water samples test positive for fecal contamination, systems must complete or develop a plan to complete corrective actions within 120 days of being notified of the contamination.[57]

Corrective actions for both significant deficiencies and positive groundwater source samples are to:

- Make repairs to water system infrastructure,
- Provide an alternative source of water,
- Eliminate the source of contamination, or
- Provide treatment to achieve 99.99% (4-log) inactivation and/or removal of viruses.[58]

The two most likely treatment methods are chemical disinfection and membrane filtration.[12] Estimates are that by annually implementing these corrective actions, anywhere from 533 to 4,308 illnesses originating from non-transient non-community water systems and 1,037 to 14,738 illnesses originating from transient non-community water systems will be avoided.[60]

Systems that fail to achieve 99.99% inactivation or removal of viruses must collect source water samples after testing positive for total coliform.

Taking Steps to Prevent Pathogenic Contamination

Non-community water systems, like community water systems, can keep treatment costs low or avoid treatment all together by preventing pathogenic contamination from occurring in the first place.

The first step in preventing source water contamination is to review a system's source water assessment (for more information see Section 3: *Identifying Potential Sources of Pathogens*). The assessment includes a map of the system's source water area, which are comparatively smaller for non-community water systems because they generally use and deliver less water to customers. For example, in West Virginia the source water area for non-community water systems with a pumping capacity of less than 2,500 gallons per day is a fixed radius of 500 feet around the well.[61] Consequently, any protection activities for these low capacity non-community water systems should be targeted within this 500 foot radius.

The same approaches detailed in Section 5: *Preventing Pathogenic Contamination* may be used by non-community water systems to achieve source water protection. Source water protection may even be easier for a non-community water system to achieve because protection activities may be integrated into the facilities' overall operation and maintenance. For example, campground managers generally have contracts with on-site wastewater professionals to periodically pump and inspect their on-site systems throughout the camping season. Roadside stops and restaurants often limit areas where people can walk their pets or require visitors to pick up pet waste. In both cases, visitors are more likely to behave responsibly

Implementing groundwater protection practices has enabled Bayside Golf Club to earn designation as a Groundwater Guardian Green Site during the program's pilot year.

knowing their actions protect the facilities' drinking water. On the other hand, if potential sources of contamination are not being actively managed or are located on neighboring properties, protection activities may not be given enough attention.

Non-Community Water System Case Study – Bayside Golf Club

Bayside Golf Club uses one well for drinking water and is considered a transient non-community water system with most visitors arriving in the summers months. The facility is actively managed so that the wells are protected from potential sources of contamination. In addition, although they are only 300-400 yards away from Lake McConaughy, Nebraska's largest reservoir, runoff from the course seldom reaches it. Implementing groundwater protection practices has enabled Bayside Golf Club to earn designation as a Groundwater Guardian Green Site during the program's pilot year.

Bayside Golf Club emerged from the arroyos, ruts, bluffs and rugged grasslands of the Sandhills in western Nebraska. The first nine holes opened in 2000, with the grand opening of additional facilities following in 2001. This mixed-use development includes an 18-hole golf course, a lodge with capacity for 375 people, a pro shop, and numerous maintenance buildings. Twelve townhomes and four cabins are also available for lodgers, with more planned for the future. The course is generally open for nine months of the year, which is close to the area's seven to eight month growing season.

The area's annual precipitation is only 13 inches, so precipitation and the course's irrigation water readily infiltrate into the porous soil. Prior to being developed, the land was used as pasture, with some areas of original prairie still remaining. Standing on the golf course greens today it is easy to imagine what the area looked like over 160 years ago when pioneers traveled nearby on the Oregon Trail. The area's beautiful landscape makes it prime for further resort development; the area's steady winds, which average between nine and thirteen miles per hour all year long, and low humidity mean even the warmest days are comfortable.

The entire Bayside Golf Club facility is served by a non-community water system and is actively managed so that its drinking water well is protected from potential sources of contamination. Protection activities include:

- Taking required water samples properly and sending the samples to a certified laboratory for analysis. No problems have been detected to date.
- Always storing fertilizers and pesticides (i.e., 8,000 pounds granular, 50 pounds liquid annually) on an impervious surface in a secured facility capable of containing spillage.
- Always mixing and loading fertilizers and pesticides on an impervious surface capable of containing spillage.

- Applying tank rinsate (less than 200 gallons per month) over an area of similar land use.
- Altering or ceasing granular and liquid fertilizer and pesticide applications when wind speed alters the distribution. This is a regular occurrence for Bayside; one year managers went for 22 days without applying a granular product!
- Having a licensed applicator inspect equipment prior to each application, about twice a month during the growing season.
- Calibrating fertilizer and pesticide application equipment at least quarterly during the growing season.
- Testing soil and using the resulting nutrient analysis to apply fertilizer; often the amount of fertilizer applied is less than what is recommended by the soil test.
- Following integrated pest management practices, thus reducing the volume of pesticides used by 50%.
- Adding or replacing plants with lower input requirements than previous plants; this practice enables the course to avoid using upwards of 300 pounds of fertilizer and 15 gallons of pesticides annually.
- Maintaining a fertilizer and pesticide no-application zone around the wells on the property.
- Selecting new plants adapted to the climate of the region, thus saving upwards of 10,000 gallons of water annually.
- Tracking irrigation water use and modifying practices to reduce water use, which could save upwards of ten million gallons of water annually.
- Disposing of or recycling toxic substances properly, which generally add up to 300 golf cart batteries, 50 other batteries, 200 gallons of oil, and 20 tires annually.
- Arranging for a certified professional to regularly pump or otherwise service the facilities' on-site wastewater treatment system.
- Maintaining parking areas with approximately 90% porous surfaces, 800 yards of native pasture and grasses between the parking area and adjacent surface water, and engineered slopes so run-off does not run directly into surface water. Parking areas cover approximately two acres.
- Storing approximately 6,000 gallons of fuel above-ground with secondary containment annually.
- Recycling.
- Managing the course to maintain and increase wildlife habitat in areas outside the source water protection area.
- Using surfactants to reduce surface tension and decrease water use by better utilizing the water that is available.

Implementing the practices described previously enabled Bayside Golf Club to earn designation as a Groundwater Guardian Green Site during the program's pilot year. To maintain the designation, these practices must continue and the application describing them updated every three years.

For more information about Bayside Golf Club, contact Elton Nolde at (308) 287-2653 or noldeeltono@hotmail.com. Also visit www.baysidegolf.com. For more information about how the Groundwater Guardian Green Site program may be used to promote and document groundwater-friendly practices for non-community water systems and other sites, contact Jennifer Wemhoff at (402) 434-2740 or jennifer@groundwater.org. Also visit www.groundwater.org.

Land use and management have a direct impact on the risk of drinking water source contamination by pathogens.

7 Case Studies

The following six communities hosted and/or participated in a series of pathogen education workshops held in 2006, during which much of this primer's content was developed and tested for its educational value and usefulness.

Some of these communities had been working to reduce pathogenic threats to their source water for over a decade; others were just getting started.

- Delaware River Watershed, Kansas - in this high priority watershed learning more about pathogens has helped local stakeholders as they develop a plan to reduce the amount of fecal coliform bacteria in streams.
- Greater Lansing Area, Michigan - an abandoned well program, business owner and manager education, and stormwater management have all been a part of comprehensive wellhead protection in the area.
- Greene County, Missouri - in a region dominated by karst geology, the Adopt-a-Spring program trains volunteers to conduct quarterly sampling and sinkhole clean-ups.
- Village of Hemingford, Nebraska - recent *E. coli* contamination has motivated local leaders to move forward with wellhead protection planning.
- Lincoln, Nebraska - in addition to source water protection, carefully managed operation and maintenance has enabled this city's public water system to keep costs as low as possible.
- North Kingstown, Rhode Island - adopted a wastewater management ordinance to ensure regular inspection and pumping (when necessary) of on-site wastewater treatment systems in the community.

All the communities featured here recognize the value of source water protection and are committed to making progress. The following are accounts of their concerns and efforts.

Delaware River Watershed, Kansas

The Delaware River Watershed in northeastern Kansas drains 1,157 square miles and terminates at the confluence of the Delaware and Kansas Rivers a few miles south of Perry Lake Reservoir. The watershed includes the communities of Holton, Sabetha, Horton, Valley Falls, Oskaloosa, Nortonville, Perry, Whiting, Wetmore, Goff, Circleville, Muscotah, Netawaka, Powhattan, Denison, Ozawkie, Huron and Fairview. Most of these communities are small, with the largest being Holton (population 3,500), Sabetha (population 2,500) and Horton (population 1,900). The largest industry in the area is agriculture; education, health and social services, manufacturing, forestry, recreation, mining and retail are also important to the watershed's economy.

There are 22 public water supply systems in the watershed, most of which use exclusively groundwater or a mixture of groundwater and surface water. Most groundwater resources in the watershed are found in alluvial aquifers, and thus can be affected by surface water quality.

The Delaware River Watershed ranked third among 92 watersheds prioritized for restoration and protection in Kansas. Eighty percent of the streams in the watershed are impaired, and fecal coliform bacteria is responsible for over 90% of this impairment. Other environmental concerns in the area include pesticide contamination, the lack of hazardous waste disposal programs, and sediment and nutrient loading.

To address the issue of total maximum daily loads (TMDLs) and other water issues in the state, the Kansas Department of Health and Environment (KDHE) implemented the Kansas Watershed Restoration and Protection Strategies (WRAPS) program. WRAPs is a planning and management framework designed to involve stakeholders in identifying watershed restoration and protection needs, establishing management goals, and creating and implementing cost-effective action plans to achieve these goals. At the state level the program is administered through KDHE and the WRAPS Work Group. The Work Group includes members from state and federal agencies involved in watershed protection activities and the Kansas Natural Resources Sub-Cabinet. Coordination of efforts in individual watersheds is carried out at the local (or watershed) level by WRAPS coordinators.

The Glacial Hills Resource Conservation and Development Region, Inc. received financial assistance from KDHE through an EPA Section 319 Nonpoint Source Pollution Control grant for the Deleware River WRAPS project. Marlene Bosworth, the Delaware River Watershed WRAPS Coordinator, began work in the watershed in February 2006. Since that time, Bosworth has coordinated monthly meetings with watershed stakeholders so they may become more familiar with the watershed's water quality issues and their role as citizens of not only their communities but also of the watershed. Bosworth is also facilitating stakeholder involvement in creating a Watershed Restoration and Protection action plan, which is slated for completion in early 2007. To date the emphasis in management planning has been on voluntary protection strategies. Upon completion of the action plan, work to secure funds and implement the plan will continue.

Because fecal coliform is such a widespread water contaminant in the Delaware River Watershed, Bosworth felt it would be very beneficial to participate in a pathogen workshop held in Manhattan, Kansas on June 19, 2006. This workshop featured information from experts from Kansas State University and the City of Manhattan. Information collected and resources identified at the workshop have been used by Bosworth to inform the stakeholder team's planning efforts. The better understanding of pathogenic contamination she gained from the workshop will also be useful as the watershed plan is implemented.

This WRAPS meeting was designed to collect input from watershed stakeholders which is then considered when writing the action plan for the Delaware River Watershed.

Some of the challenges in coordinating the WRAPS program in the Delaware River Watershed have involved initial misconceptions on what the program actually entails and getting stakeholders to participate in the process. These challenges have been met, in part, by inter-agency coordination and outreach to community members. By working with the local conservation districts, Kansas State University Research and Extension, local watershed districts, cities in the watershed, county governments, the Kansas Rural Center, KDHE, the Kansas Alliance for Wetlands and Streams, the Natural Resources Conservation Service, the Kansas Water Office, the State Association of Kansas Watersheds, tribal nations and others, Bosworth has been able to educate stakeholders on the WRAPS process and get them actively involved in the creation of a Watershed Restoration and Protection action plan.

The planning process has already been beneficial to stakeholders in the watershed. They have learned more about issues directly pertaining to them and their role in protecting the resources of the watershed. The process has also helped to foster inter-agency cooperation and agency-stakeholder relationships.

For more information, contact Marlene Bosworth at mkbosworth@northwindts.com or visit www.kswraps.org and www.glacialhillsrcd.com.

Greater Lansing Area, Michigan

The Greater Lansing Area, located in south-central Michigan, is home to a growing population of about 480,000 residents. Major employers include state government, Michigan State University, services, wholesale and retail trade, and manufacturing (primarily of transportation products). Area land use is primarily urban with several parks and recreation areas; highly productive agricultural land is also present.

The Greater Lansing Area is served by approximately 225 public water supply wells, along with thousands of private wells. The primary aquifer in the region is the Saginaw Formation. The water within the Saginaw moves at a rate of less than one foot per day. Over the years a number of private wells have been abandoned and fallen into disrepair, thus providing a direct conduit for surface contamination to reach area groundwater supplies. Chloramines are regularly used by area public water systems as a disinfectant.

Since 1990 the Tri-County Regional Planning Commission (TCRPC) has taken the lead in facilitating the wellhead protection efforts of the area's local governments. Since 1995 the TCRPC has utilized The Groundwater Foundation's Groundwater Guardian Program to organize support for area groundwater protection efforts. The Greater Lansing Area's Groundwater Guardian team currently includes representatives from local government, a local watershed group, a local water utility and the TCRPC. Over the years the team has implemented several programs that have brought groundwater protection into the public eye and protected local groundwater resources.

One of the earliest activities implemented by the team, an annual Children's Water Festival, has involved over 22,000 area children in hands-on activities designed to teach them about the importance of groundwater and environmental protection. Festival volunteers leading activities have included the United States Geological Survey, Michigan Department of Environmental Quality, Michigan State University, local governments and private companies. In recent years, high school students who attended the festival as elementary students have also volunteered, thus demonstrating their continued commitment to groundwater education and protection.

Another activity implemented early on is the annual Holiday Breakfast, which is held in mid- to late December. The breakfast continues to provide a wonderful opportunity for federal, state and local government representatives to network with one another, as well as private supporters of groundwater protection. The breakfast includes a brief program on groundwater protection, but perhaps more importantly, it also generates positive media attention for the ongoing efforts of the Groundwater Guardian team.

In 1999 the team began to implement an abandoned well survey program, which included door-to-door visits with area residents to identify abandoned wells. Out of the approximately 12,000 homes that were visited, over 600 abandoned wells were identified. Grant funds were used to properly decommission over 130 wells.

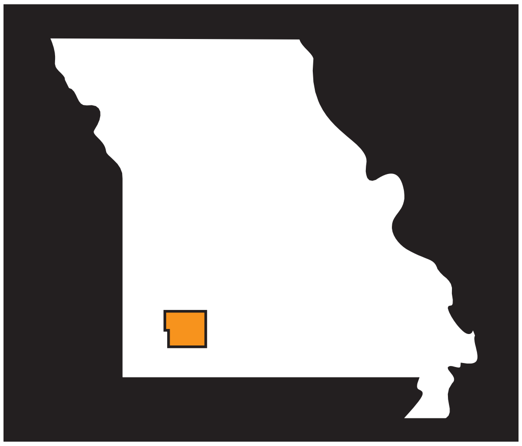
In 2005 a new program was initiated to educate local business owners and managers about the potential for their business to contaminate the water supply in their area. They were also introduced to a scoring system developed by the wellhead protection team for ranking the relative risks posed by various businesses. They were also educated in how they could improve their stewardship of the environment through their business practices. These business education seminars served to introduce attendees to the importance of wellhead protection, causing many to express interest in becoming active members of their local government's wellhead protection team.

This abandoned well was properly decommissioned as part of the Greater Lansing Area's wellhead protection activities.

Because the potential for pathogenic contamination of local groundwater supplies is a concern for the Greater Lansing Area, members of the Groundwater Guardian team participated in the pathogen workshop held there as part of The Groundwater Foundation's 2006 Annual Conference on November 2nd. Team members recognized that the significant work done to properly decommission abandoned wells and manage area stormwater has protected local groundwater resources. The workshop also served to strengthen their commitment to the on-going comprehensive wellhead protection efforts being implemented in the area.

For more information, contact the TCRPC's Christine Spitzley at (517) 393-0342, cspitzley@mitcrpc.org, or cvspitzley@hotmail.com. Also visit www.tn-co.org or www.capitalgroundwater.org.

Greene County, Missouri



Greene County in southwestern Missouri is home to a growing population of approximately 261,000 residents, over half of which live in the City of Springfield. Major employers in the county include educational, health and social services, retailers and manufacturers. About 30% of the land in the county is used for farming, with major crops being corn, wheat and soybeans; the major livestock raised is cattle. The city was founded by John Polk Campbell, who chose his homestead by a spring that settlers described as "a natural well of wonderful depth." Groundwater resources are still relied upon for municipal and private use, and require active stewardship, because the geology of the area makes groundwater susceptible to pollution from the surface.

Approximately 80% of the water used for domestic and municipal purposes in Greene County comes from surface water sources; the other 20% from groundwater. Since 1957, City Utilities of Springfield has managed the city's water supply and treatment. Two drinking water treatment plants serve over 69,000 residential meters and 7,000 commercial meters. Three reservoirs, a river, deep wells, and a large natural spring provide water to the city. Areas outside municipalities rely almost exclusively on groundwater. Private wells are threatened by groundwater depletion and pathogenic contamination from thousands of on-site septic systems.

The region is dominated by a karst geologic setting, an important factor for private and public water supplies in the area. In karst areas, porous bedrock is dissolved by weakly acidic water percolating through the ground over time. Water moves relatively freely from the surface, often flowing through caves and other large openings, resurfacing again in springs, or discharging to groundwater from losing streams. In this type of setting, groundwater is particularly susceptible to contamination of all sorts, including pathogenic contamination.

Greene County has been recognized in The Groundwater Foundation's Groundwater Guardian program since 1995. To earn this designation, the local Groundwater Guardian team, consisting of local citizens, city officials, and the Watershed Committee of the Ozarks, has coordinated activities each year to attain water quality protection results.

The Greene County Groundwater Guardian team's activities have covered a range of water quality-related topics, and several have addressed concerns relating to pathogenic contamination. The team began its work with volunteers going door-to-door to conduct an inventory of active and abandoned private wells, which were entered into a Geographic Information System (GIS) database, as

Failing on-site wastewater systems threaten groundwater resources.

well as to speak with landowners about the importance of proper installation and maintenance of septic systems.

The team also established an Adopt-a-Spring program. This volunteer program conducts quarterly sampling of all the major area springs for total coliform bacteria, *E. coli*, nutrients, dissolved oxygen, and temperature. This sampling and analysis provides excellent background information and serves as a database of indicators for groundwater contamination. The program has been promoted through brochures developed by the Groundwater Guardian team.

Cleanup of sinkholes in the county is another issue that the Groundwater Guardian team has tackled. Because sinkholes are common in karst settings and provide direct conduits to groundwater, the team educated and coordinated volunteers to assist in cleaning up sinkholes which had been used for illegal trash dumping. During one sinkhole cleanup, two local television stations were on site and broadcasted the cleanup.

Through volunteer coordination and publicizing events, the Greene County Groundwater Guardian team has fostered excellent working relationships with the local residents and provided information to these stakeholders, which is vital to the overall protection of water resources. Since beginning their work, the team has trained and worked with over a dozen active volunteers, collected about 40 spring samples per year, and has cooperated with the local health department to do weekly swimming hole sampling for bacteria throughout the summer.

In order to bring more attention to the health benefits of source water protection, the team also hosted a pathogen workshop on August 8, 2006. Attendees included environmental educators, local activists, and drinking water and public health experts. The workshop reinforced the fact that vigilence is needed to protect local drinking water supplies.

As with any grassroots organization, the team has faced challenges when implementing programs. One of the biggest challenges has been sustaining programs through changes in local leaders and participants. Through cooperation with other agencies and by continuously fostering partnerships, the Greene County Groundwater Guardians have maintained commitment to their projects and ensured their overall longevity.

For more information, contact Mike Kromrey with the Watershed Committee of the Ozarks at (417) 866-1127 or mike@watershedcommittee.org. Also visit www.watershedcommittee.org.

Village of Hemingford, Nebraska

The Village of Hemingford lies 59 miles northeast of Scottsbluff in Box Butte County and was first settled by Canadian immigrants during the summer of 1885. The primary commerce in the area includes farming, ranching, cattle feeding and retail. Land in the region is primarily used for agriculture and grazing.

Hemingford's 997 residents are served by about 430 residential and 90 commercial service connections, which are supplied by five regularly used wells and one backup well. All service connections are metered and have backflow prevention devices installed. For backflow prevention, dual check devices on all residential service connections and double checks and reduced pressure zone devices on commercial service connections are required. The community's water supply is not regularly treated to remove or inactivate contaminants.

The Village of Hemingford has a board of trustees form of government, with a chairperson and four board members. The village utilities superintendent is also the water system operator. Box Butte County lies within the Upper Niobrara White Natural Resources District (UNWNRD), which is governed by a board of eleven directors. Each director serves on one of several committees within the board, including one committee specifically dedicated to water resources. The UNWNRD also employs a water resources manager and a wellhead protection coordinator.

The Village of Hemingford experiences total coliform "hits" nearly every summer, which means that the water supply tests positively for total coliform. Total coliform is an indicator used by Nebraska Health and Human Services (NHHS) to determine bacterial contamination of a water supply. For the first time in July of 2006, Hemingford also had a "hit" for *E. coli*, which is the indicator that NHHS uses to determine fecal bacteria contamination of a water supply. The village issued a boil-water warning to its customers and continued testing for *E. coli*. Another "hit" occurred the following month. The village immediately began chlorinating the water supply and continued chlorinating for about a month, beyond the required time period, to ensure that the water supply was disinfected and safe. No illnesses relating to the bacterial contamination were reported.

In a proactive effort to reduce the risk of pathogenic contamination as well as other kinds of contamination, Hemingford's utilities superintendent, Dan Swanson, began working with the UNWNRD's wellhead protection coordinator, Jason Moudry. The pair began discussing wellhead protection planning early in 2006, and both attended a pathogen workshop hosted by the UNWNRD on April 25. Moudry and

Swanson began incorporating pathogenic contamination prevention measures into the plan and, with the assistance of the Nebraska Rural Water Association and NHHS, researching possible sites causing the *E. coli* contamination.

The obvious benefit to preventing pathogenic contamination in Hemingford will be reducing and even eliminating the water system's total coliform and *E.coli* contamination incidents. Although no illnesses have been reported in association with contamination, the water system is subject to administrative action from NHHS for repeated positive *E. coli* results. There are additional state regulations on disinfection byproducts, so the water system must also be in compliance with these when disinfection with chlorine is necessary. Chlorination and testing for disinfection byproducts represents an additional financial burden upon the community, as well as additional time spent by the water operator for disinfection and sample collection.

Downtown Hemingford, Nebraska.

So far the main challenges Moudry and Swanson faced while working on Hemingford's wellhead protection plan were time constraints, especially in the summer months which are filled with other duties for both. Until very recently there was also little support for wellhead protection planning on the Hemingford board of trustees; however, with some changes in the local leadership and additional discussion, Swanson was able to garner the necessary support from the board to move forward with wellhead protection planning.

For more information, contact Dan Swanson at 308-487-3465 or Jason Moudry at 308-432-6190 or moudry@unwnrd.org. Also visit www.unwnrd.org.

Lincoln, Nebraska

The City of Lincoln in Lancaster County, Nebraska is home to a growing population of about 236,000 residents. Major employers are government agencies; education; health services; trade, transportation, utilities, professional and business services providers; leisure and hospitality businesses; and manufacturers.

The Lincoln Water System's wellfields draw groundwater from the alluvium of the Platte River. All water is treated in one of two facilities. The water from vertical groundwater wells is treated via aeration, chlorination, and filtration where long disinfectant contact times and strict compliance to stringent turbidity standards are used to ensure inactivation and removal of any pathogens that might exist in the raw water. This "groundwater treatment plant" can meet requirements for surface water treatment, if needed. A second plant treats the water from two horizontal collector wells on an island in the Platte River; one of these two wells has been determined by Nebraska Health and Human Services to be under the direct influence of surface water. In the "surface water treatment plant," water is treated with ozone as the primary disinfectant and oxidant, followed by chlorine. These disinfectants, in combination with strict compliance to stringent turbidity standards, are used to ensure inactivation and removal of any pathogens that might exist in the raw water. Both plants use chloramines as a secondary disinfectant.

The City of Lincoln has protected groundwater in its source water area by owning and controlling about 1,200 acres of land that surrounds the wells. Hazardous practices and materials, such as fuel or agricultural chemical storage, feedlots or any other potential contamination sources, are not permitted in this area. All "active production" wellfield land owned by the city is planted with grass, and no application of fertilizers or pesticides is allowed. The city also owns an additional 800 acres of land which is set aside for possible future development of wells to meet growth demands.

Anticipating the possibility that the horizontal collector wells could be classified as "groundwater under the direct influence of surface water," the treatment facility was designed and built to comply with Surface Water Treatment Rule standards, ensuring that no additional treatment and capital costs would be incurred in order to meet Surface Water Treatment Rule compliance. This "groundwater under the direct influence" designation has also meant that the source water area delineated for the city encompassed much of the state of Nebraska, as the entire Platte River watershed contributes water to this well during the time-of-travel periods typically used by the state for delineation mapping. This is obviously an area that is outside the city's jurisdiction to manage, so the Nebraska Department of Environmental Quality used models to develop more realistic time-of-travel maps for the city to utilize.

Lincoln Water System draws groundwater from the alluvium of the braided Platte River.

Because the Lincoln Water System has done so much to protect its source water and system from pathogenic contamination, Eric Lee, the system's Assistant Superintendent of Water Production and Treatment-Operations, was invited to describe this work at a pathogen workshop held near the Platte River. The workshop was hosted by the Lower Platte River Corridor Alliance (LPRCA), a consortium of three natural resources districts and six state agencies dedicated to working with people to protect the long-term vitality of the Lower Platte River Corridor. Individuals representing a number of public water systems located along the corridor used the workshop to begin developing their own source water protection plans.

The City of Lincoln has been recognized in The Groundwater Foundation's Groundwater Guardian program since 1995. To earn this designation in 2006, the city's activities included sponsoring an elementary school water conservation poster contest (the winning poster is enlarged and placed on public transport buses and billboards around the city), presenting a children's activity at the annual Earth Wellness Festival, sending bill inserts promoting rain sensors and water facts to customers, and hiring a student intern to develop water conservation reports for area businesses.

Because of the costs of operating such a large system, budget concerns are the largest challenges the city faces with regards to its water system. However, the city has risen to budget challenges without extending excessive costs to customers. The city cites planning ahead, agency partnerships, and carefully managed operation and maintenance strategies as the main components of keeping operational costs as low as possible. Besides planning ahead for the surface water treatment plant design, the city has participated in several cooperative studies with the United States Geological Survey, University of Nebraska, and others to identify potential source water protection issues. The money and effort spent on these projects has saved the city millions of dollars in treatment costs.

By having staff available to answer customer questions and complaints via the city website, phone and on-site visits, and distributing annual consumer confidence reports, the city has been very effective at maintaining customer satisfaction. The rare complaints that customers have usually relate to taste, odor or water pressure. The city also regularly provides opportunities for consumer involvement in public meetings regarding facilities changes and updates.

For more information, contact Eric Lee at elee@lincoln.ne.gov or 402-944-3306 and LPRCA Coordinator Rodney Verhoeff at rverhoeff@lpsnrd.org or 402-476-2729. Also visit www.lincoln.ne.gov or www.lowerplatte.org.

North Kingstown, Rhode Island

North Kingstown, Rhode Island, lies south of Providence on Narragansett Bay and is home to a growing population of approximately 27,000. Incorporated in 1674, early industries included textiles, farming, fishing and boat building. In 1941 nearby Quonset Point and Davisville became major naval installations; these facilities were closed in 1973 and are now being developed as a major industrial park.

Land use in the North Kingstown area is primarily residential and features an extensive coastline with numerous poorly flushed coves and estuary environments. The western portion of the town overlays an extensive groundwater aquifer which is the sole source of drinking water for the community.

North Kingstown's population is served by ten water wells and over 9,000 service connections which are operated by the town's Department of Water Supply. While the groundwater drawn by these wells is currently pure enough to not require disinfection, the town instituted a disinfection pilot program in 2005 in response to problems in portions of the distribution system.

North Kingstown has been recognized in The Groundwater Foundation's Groundwater Guardian program since 1995. Since then North Kingstown's team has implemented several activities in the community and region to address contamination issues.

Early in their work, the North Kingstown team focused on providing local teachers with regional groundwater information to be included in classroom curriculum. The team also conducted an inventory of potential sources of contamination in the wellhead area, and worked to assemble a local committee, including representatives of two other area communities, to work on wellhead protection planning.

Over the years, the North Kingstown team has continued their community education efforts and work with the wellhead protection planning committee. One of the ways the team meets its community education objectives is by holding an annual environmental fair, which they have done since 1998. Fair activities are designed to teach citizens about environmental, especially groundwater, protection. The event reaches 1,200 to 1,500 participants each year.

Community education paid off for North Kingstown when its residents passed a wastewater management ordinance, requiring property owners to have their on-site wastewater treatment systems regularly inspected and pumped when necessary. Members of the community understood the value of wastewater management and knew what to expect;

thus the ordinance met with minimal opposition. Since the beginning of the team's work, over 3,600 septic systems have been inspected and pumped and the town has paid for over 60 homeowners to have failing septic systems repaired or replaced.

Because North Kingstown has been proactive and has successfully managed pathogenic threats to its source water and water system, G. Timothy Cranston, Water Quality Specialist for the North Kingstown Department of Water Supply, was invited to describe this work at a pathogen workshop held in Attleboro, Massachusetts on September 27, 2006.

The community environmental fair reaches 1,200 to 1,500 participants each year.

The workshop also featured presentations from Gabrielle Belfit with the Cape Cod Commission, Marc Cohen with the Atlantic States Rural Water Association, Clayton Commons with the Rhode Island Department of Health, Lorraine Joubert with the University of Rhode Island Nonpoint Education for Municipal Officials (NEMO), Rebekah McDermott with the Massachusetts Rural Water Association, Vandana Rao with the Executive Office of Environmental Affairs, and Kathleen Romero with the Massachusetts Department of Environmental Protection. All described the work they do to reduce pathogenic threats to source water.

The main benefit of the North Kingstown Groundwater Guardian team's activities has been preventing contamination of their sole source aquifer. The primary challenge the team has faced has involved funding. There is some difficulty in tracking and administering their program; however, they have been able to continue their work, despite funding issues, by cooperating with area stakeholders and volunteers.

For more information, contact G. Timothy Cranston at (401) 294-3331 ext. 233 or gcranston@northkingstown.org. Also visit www.northkingstown.org, www.capecodgroundwater.org, www.asrwwa.org, www.health.ri.gov/environment/dwq/swap/index.php, www.uri.edu/ce/wq/NEMO, www.massrwa.org, www.mass.gov/envir/, www.mass.gov/dep/water/drinking/sourcewa.htm.

Appendix A: Waterborne Pathogens "Bad Bug" Profiles

The following are profiles of common and noteworthy waterborne pathogens encountered in the United States.

Campylobacter

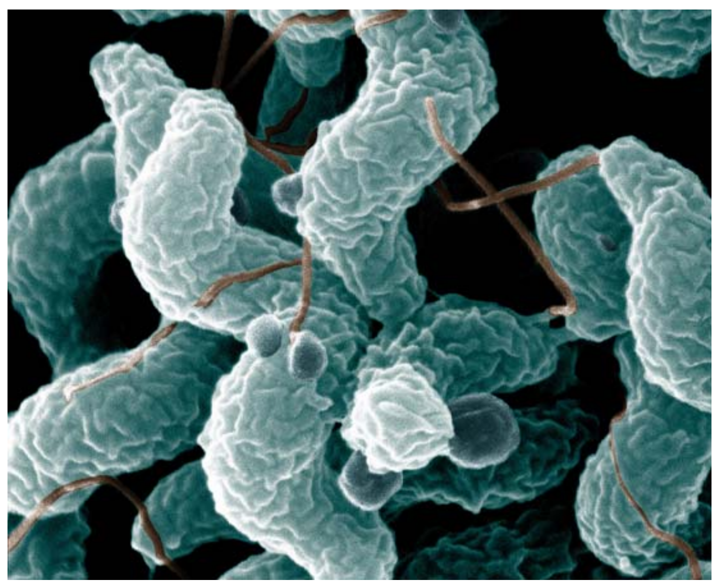
Campylobacter is a genus of the Vibrionaeceae family and contains at least fourteen species. The species of concern for human infection include *C. jejuni*, *C. coli*, and *C. upsaliensis*.[62]

Bacteria of the genus *Campylobacter* cause the infectious disease campylobacteriosis, which causes diarrhea, cramping, abdominal pain and fever. Diarrhea may be bloody, and may be accompanied by nausea and vomiting. These symptoms usually appear in humans within two to five days of contact with the organism, and typically last one week. While some infected with *Campylobacter* exhibit no symptoms at all, others who are immuno-compromised can develop a life-threatening blood infection.[63]

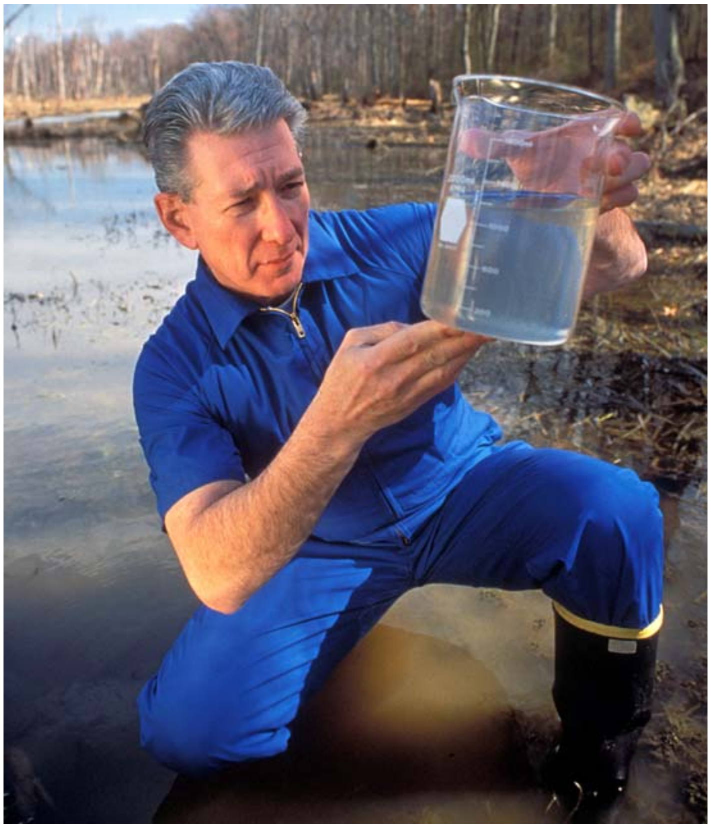
Campylobacters are quite commonly found in birds and are particularly prevalent in poultry, which is likely a major source of human infection. *Campylobacters* are also commonly found in natural fresh waters, even in remote areas, with their occurrences being highest in the fall and winter months. They are also found in high numbers in sewage. *C. jejuni* appears to be the dominant species in water and arrives there primarily through sewage and wildlife (especially birds).[64] While the bacterium is fragile and can be killed by oxygen, it can survive well in water.

Boiling water will kill *Campylobacter*. Drinking water should be brought to a full boil for at least one minute (three minutes for elevations above approximately 6,000 feet). Boiled water should then be kept in a clean container with a lid, and refrigerated. Private well owners may also disinfect their well against *Campylobacter*, and should contact their local health department for recommendations.[65]

Campylobacter is one of the most common causes of bacterial diarrheal illness in the United States. It does not commonly cause large outbreaks, and many cases go unreported or undiagnosed. Most people infected with *Campylobacter* will recover without any treatment, though patients are advised to drink plenty of fluids to prevent dehydration. In severe cases, antibiotics are sometimes prescribed and can shorten the duration of symptoms if administered early in symptomatic stages.



Campylobacter is one of the most common causes of bacterial diarrhea.



Sampling surface water for *Cryptosporidium.*

Campylobacteriosis can sometimes, although rarely, lead to the development of Guillain-Barré Syndrome, which can cause paralysis for several weeks and require treatment in intensive care. About one in 1,000 Campylobacteriosis patients are estimated to develop Guillain-Barré syndrome.[66]

For more information about Guillain-Barré syndrome, visit the following websites:

- http://www.mayoclinic.com/health/guillain-barre-syndrome/DS00413
- http://www.gbsfi.com/

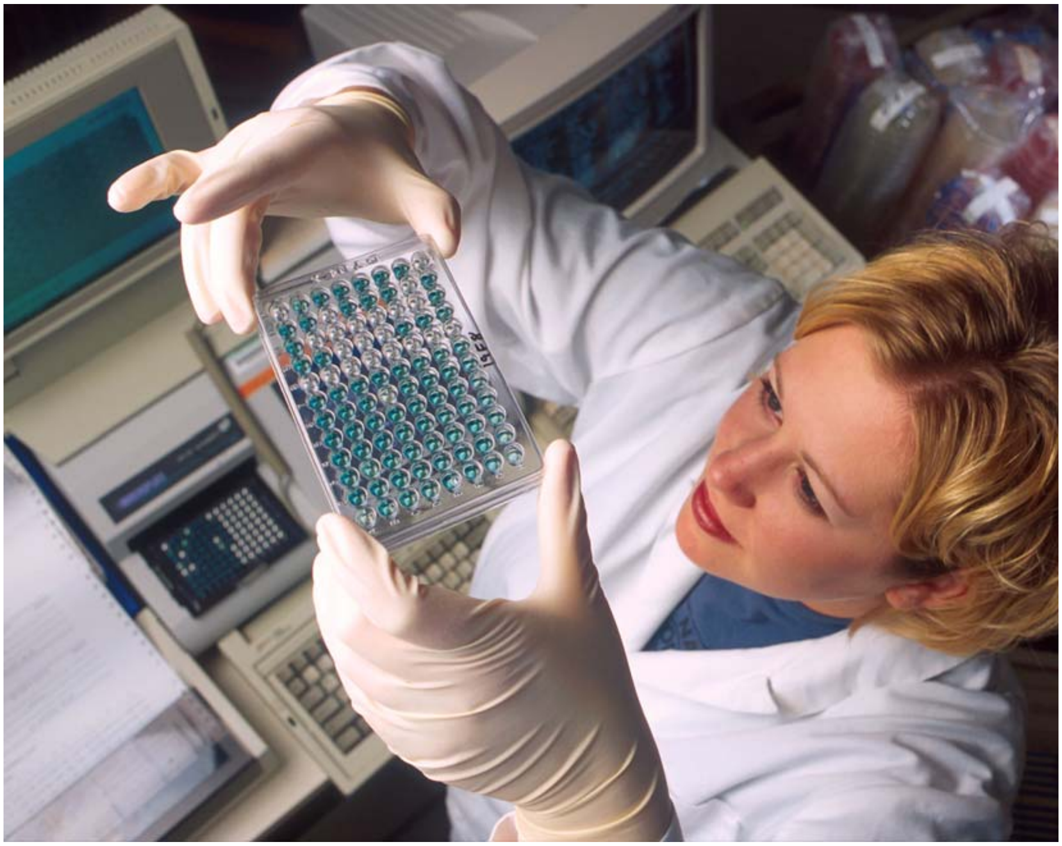
Cryptosporidium

The genus *Cryptosporidium* includes several species of protozoan parasites which cause human and animal disease, with those of most concern for drinking water being *C. parvum* and *C. hominis*. *C. parvum* can infect both humans and animals, while *C. hominis* infects only humans. *Cryptosporidium* has several life stages, the transmissible stage being the oocyst (an organism in the oocyst stage has a protective outer shell). When oocysts are ingested, they open (excyst) and release sporozoites that attach to and invade cells in the gastrointestinal tract. Excystation often requires specific conditions (presence of pancreatic enzymes and bile salts) but can occur without any such stimulus.

Cryptosporidium oocysts are widely distributed in water; they have been reported in 87 percent of source water samples and are present in nearly all surface waters. Numerous outbreaks of *Cryptosporidium* in swimming pools have been reported. *Cryptosporidium* caused the largest and most famous drinking water disease outbreak in the United States, where in 1993 over 400,000 people in Milwaukee, Wisconsin became infected.[67]

Cryptosporidiosis, the illness caused by *Cryptosporidium* (both the illness and pathogen are often referred to as "crypto"), includes watery diarrhea and sometimes vomiting, which may lead to dehydration and weight loss. Fever and stomach cramps are also common. The symptoms usually last one to two weeks and may go in cycles where the patient feels well for a few days and then becomes ill again.[68]

The oocyst stage makes *Cryptosporidium* quite environmentally stable. Oocysts can survive for months in cold, moist environments, making them particularly suited to survival in lakes and streams. Oocysts are also particularly difficult to inactivate with chlorine-based disinfectants, and consequently may persist



Testing for *E.coli,* a well-known bacterium and cause of both waterborne and foodborne illness.

in water systems which use only chlorine disinfection without filtration. However, oocysts can be made non-infectious when held at water temperatures at or above 64.2 ºC (about 148 ºF) for two minutes or longer; in other words, boiling can inactivate the oocysts.[69]

E. coli O157:H7

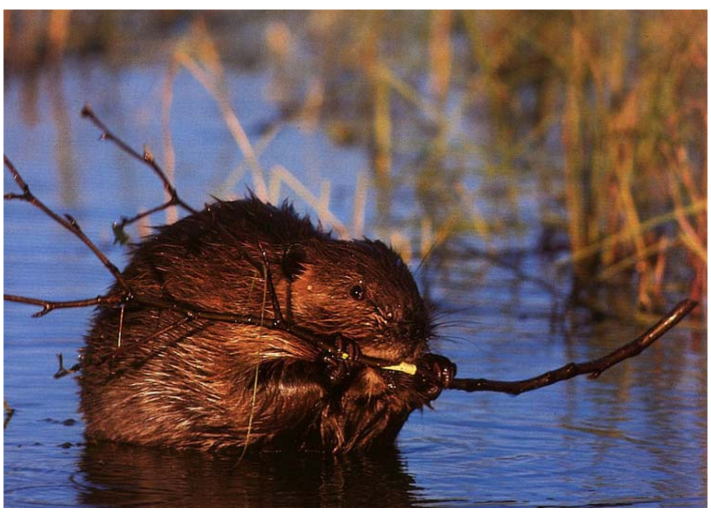
Escherichia coli O157:H7 (or *E. coli* O157:H7) is one strain of a large family of bacteria known collectively as *E. coli*, which includes five classes: enterotoxigenic, enteroinvasive, enterohemorrhagic, enteropathogenic and enteroaggregative. *E. coli* O157:H7 is of the enterohemorrhagic class, meaning that it causes internal (intestinal) bleeding.[70]

E. coli O157:H7 is perhaps best-known as an emerging cause of foodborne illness, with an estimated 73,000 cases and 61 deaths in the United States each year. Most illnesses are associated with the consumption of undercooked, infected ground beef. Infection results in cramping and profuse diarrhea, sometimes bloody (the bleeding is caused in the intestines by enterotoxins, which are emitted by the bacteria, attacking the intestinal lining).[71]

One life-threatening side effect of infection with *E. coli* O157:H7 is the development of hemolytic uremic syndrome (HUS), which is especially problematic for children. HUS may lead to kidney failure and even death. *E. coli* O157:H7 produces the aforementioned enterotoxin, which is similar to the toxin produced by *Shigella* bacteria, and it is the intense inflammatory response produced by this toxin that may explain the bacteria's ability to cause HUS.[72]

While *E. coli* O157:H7 is more commonly a problem in undercooked ground beef, it has recently emerged as an important waterborne pathogen. Outbreaks in Washington County, New York and Ontario, Canada (in 1999 and 2000, respectively) caused over 1,500 illnesses and nine deaths combined. Enterohemmorhagic *E. coli* (EHEC) has been detected in both recreational and drinking waters. It is widely accepted that EHEC originates primarily from agricultural animals (cattle), so waters near these sources are at risk for contamination. *E. coli* O157:H7 is also quite persistent in the environment, with the ability to survive in a range of temperatures and in both aerobic and anaerobic conditions (with or without oxygen).[73]

Water can be disinfected from *E. coli* by chlorination and/or boiling. Drinking water should be boiled for at least one minute (three minutes for elevations above approximately 6,000 feet) and then refrigerated in a clean container with a lid.



Wildlife excrement, especially from beavers, is a source of *Giardia.*

Private well owners may disinfect their well using chlorine, ozonation or ultra-violet light, and may contact their local health department for specific information on disinfection.[74, 75]

Giardia lamblia

Giardia lamblia is a protozoan parasite that infects numerous mammals, including humans, beavers and domesticated pets like cats and dogs. In the environment, *Giardia* is in the cyst stage and once inside the host animal, the cyst is stimulated to excyst and releases a trophozoite, which means it is ready to feed, grow and reproduce. Stimuli in the gastrointestinal tract will induce *Giardia* to return to the cyst stage, which can then be passed out through excrement.

Giardia lamblia occurs all over the world, in temperate and tropical climates as well as in the arctic. It is the most frequently identified protozoan parasite in the United States.[76] Giardiasis, the illness caused by *Giardia*, is sometimes referred to as "beaver fever" due to the spreading of *Giardia* into water by droppings from wildlife, including beavers.[77]

Giardiasis includes many intestinal symptoms, such as diarrhea, flatulence, stomach cramps and nausea. These symptoms may lead to weight loss and dehydration.[78] Patients may exhibit symptoms from none at all to a severity requiring hospitalization.[79] While no particular demographic of the population appears to be especially susceptible to infection, pregnant women and children should take special care to not become dehydrated from the illness. *Giardia* infections are also highly contagious, but can be contained by frequent hand-washing and by avoiding swimming during infection and for at least two weeks after diarrhea has stopped.[80]

Like *Cryptosporidium*, *Giardia* is particularly difficult to inactivate with chlorine-based disinfectants; ultraviolet radiation or ozonation are more commonly used.

Water can be also be disinfected from *Giardia* by boiling. Drinking water should be boiled for at least one minute (three minutes for elevations above approximately 6,000 feet), and then refrigerated in a clean container with a lid. If water is cloudy, it should be allowed to settle and then be filtered through clean cloths before boiling.[81, 82]

Legionella

Legionella are small bacteria of the family Legionellaceae. The genus consists of at least 46 species, about half of which have been implicated in causing human disease; the species *L. pneumophila* causes most *Legionella* infections.

Legionella bacteria appear most commonly in both natural and artificial aquatic environments, including lakes and streams as well as water tanks, whirlpool spas and decorative fountains. These bacteria thrive in freshwater environments under a wide range of temperatures and pH, and can become attached to surfaces, forming a biofilm and protective barrier. They may also survive inside free-living protozoa (such as amoebas) and so may evade water treatment systems. *Legionella* are not transmitted through consumption of water, but by inhalation of moist aerosols.[83]

The infection caused by *Legionella* is called Legionellosis, and can appear in two different forms: Legionnaire's Disease and Pontiac Fever. Legionnaire's Disease is the more severe form of infection and leads to pneumonia, while Pontiac Fever is a milder, influenza-like respiratory infection. Legionnaire's Disease got its name in 1976, when attendees of a Legionnaire's conference in Philadelphia contracted pneumonia; the bacteria causing the disease was first discovered then, and named *Legionella*.[84] An estimated 8,000 to 18,000 cases of Legionnaire's Disease occur in the United States each year.[85]

Legionella is transmitted by airborne moist particles from water fixtures, such as those associated with showers, air conditioners, whirlpool spas, decorative fountains, and misters in the produce section of a grocery store.

Most people who are exposed to *Legionella* do not become ill. However, those who have compromised immunity, the elderly, smokers, and those who have chronic lung diseases are susceptible to infection.[86]

Water can be disinfected from *Legionella* by chlorination and/or boiling. Drinking water should be boiled for at least one minute (three minutes for elevations above approximately 6,000 feet) and then refrigerated in a clean container with a lid.[87, 88]

Noroviruses

Norovirus is a genera of the *Caliciviridae* family of viruses. Early literature on the subject may also refer to this type of virus as SRSV, Norwalk virus, or Norwalk-like virus. Noroviruses are the most common non-bacterial cause of acute gastroenteritis (inflammation in the stomach and intestines) worldwide and can

Testing for norovirus, a virus named after the city of Norwalk, Ohio, where the original strain caused an outbreak in 1968.

infect all age groups. There are more than 100 known strains of human noroviruses, though they can be difficult to characterize because they are difficult to grow in culture. This has also made it difficult to study whether the viruses can be transmitted from one species to another.

Noroviruses are mainly transmitted through the fecal-oral route (meaning infected excrement is somehow ingested). Contamination has occurred in private wells, water systems, recreational waters and even ice cubes. Cold food items contaminated by infected food handlers and consumption of contaminated shellfish have also been documented as modes of transmission for these viruses.[89]

Noroviruses cause viral gastroenteritis (commonly referred to as "stomach flu"), which may include vomiting, diarrhea, stomach cramps, low-grade fever, chills, headache, muscle aches and fatigue. The illness often appears suddenly (sometimes within twelve hours of ingestion of the virus) but typically lasts only a day or two. Noroviruses are highly contagious - both stool and vomit are infectious. People are contagious from the onset of illness to at least three days, and as much as two weeks, after recovery. Additionally, the many different strains of norovirus make it difficult for a person to develop long-lasting immunity to the illness. Fortunately, the *most* serious health effect of viral gastroenteritis is dehydration, which can be prevented by the consumption of fluids. Spreading infection can be prevented by frequent hand-washing (especially after changing diapers of infected infants), steaming shellfish before consumption and avoiding recreational water contact when infected.[90]

Almost all outbreaks of non-bacterial gastroenteritis can be attributed to norovirus infection, with an estimated twenty-three million cases in the United States each year. At this time, the effectiveness of disinfection methods for drinking water are not well known and noroviruses appear to be resistant to chlorine disinfection.[91]

Appendix B: For More Information

Clean Water Action

Source Water Stewardship — a Guide to Protecting and Restoring Your Drinking Water
http://www.cleanwaterfund.org/sourcewater/guide.html

The Groundwater Foundation

Source Water Assessment and Protection
http://www.groundwater.org/gi/swap/swap.html

Source Water Collaborative

A web portal of the eighteen national organizations united to protect America's sources of drinking water.
http://www.protectdrinkingwater.org

Check these websites for the latest information.

United States Environmental Protection Agency (US EPA)

Consider the Source: A Pocket Guide to Protecting Your Drinking Water (Drinking Water Pocket Guide #3) - provides states, local governments, and consumers with resources to enhance existing source water protection programs and future drinking water protection plans. This guide includes an overview of Clean Water Act and Safe Drinking Water Act based regulatory and voluntary resources, tools, management measures, and financing sources.
http://www.epa.gov/safewater/sourcewater/pubs/guide swppocket 2002.pdf

US EPA: Ground Water & Drinking Water
http://www.epa.gov/safewater/

US EPA: Ground Water Rule
http://www.epa.gov/safewater/disinfection/gwr/index.html

US EPA: Source Water Protection
http://cfpub.epa.gov/safewater/sourcewater/

US EPA: Water
http://www.epa.gov/ow

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The Groundwater Foundation
PO Box 22558, Lincoln, NE 68542
www.groundwater.org
1.800.858.4844