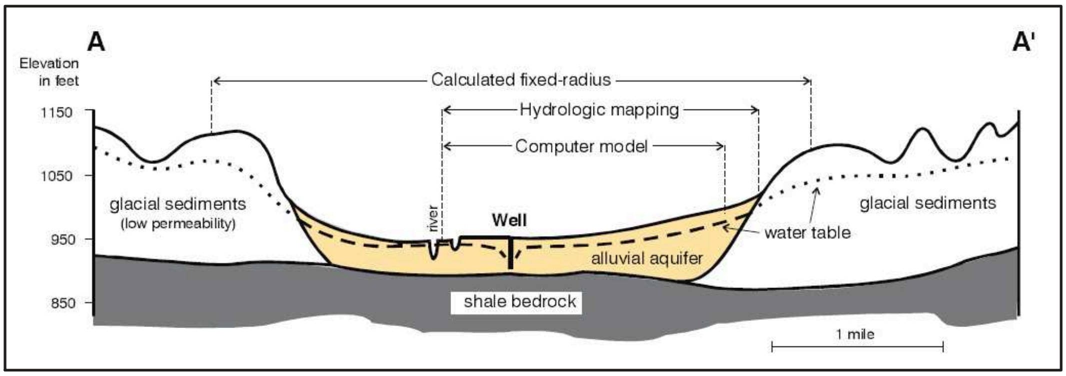
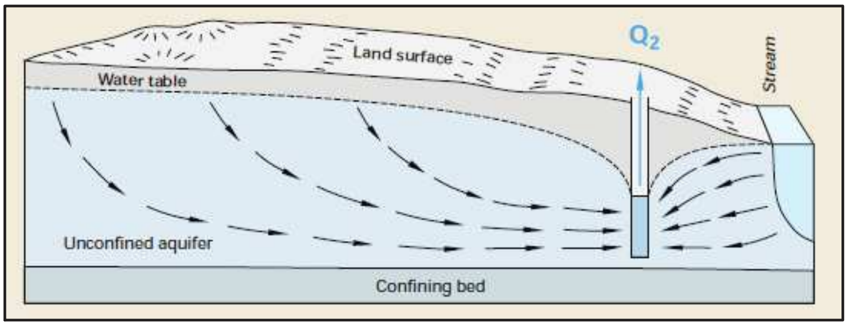


Source: *Keith and Howes, n.d.*

Figure 7-4 Cross section of the alluvial aquifer shows hydrogeologic conditions that affect groundwater movement and the cross-valley extent of each delineation method



Source: *Winter et al.* 1998

Figure 7-5 Example of surface water and groundwater interaction that would require conjunctive delineation

of groundwater contribution and the area of surface water contributing to the drinking water intake. For example, high-yield wells in alluvial or sand and gravel aquifers often draw water from the groundwater system and from overlying or adjacent rivers or lakes. As a result, the SWPA should include the groundwater system and upgradient surface waters through which contaminants could reach the drinking water intake.

Identifying contaminant sources. States are required to identify the sources of contaminants regulated under the SDWA for which monitoring is required (or any unregulated contaminants selected by the state that may present a threat to public health). These contaminants include those regulated under the SDWA (contaminants with a maximum contaminant level, and contaminants regulated under the various Surface Water Treatment Rules). A variety of regulated and unregulated contaminant sources can be found in SWA areas, including aboveground and underground storage tanks; animal feedlots; agricultural chemical applications and manufacturing; underground injection wells; chemical processing facilities; transportation and road maintenance facilities; septic systems and other onsite wastewater disposal systems; pipelines; and waste transport, storage, and disposal facilities. The range of potential contaminants and contaminant sources is described in several USEPA publications (USEPA 1991, 1993) and are available from numerous state and USEPA websites (e.g., USEPA 2014a, https://www.epa.gov/sourcewaterprotection).

More recent guidance on potential source water contaminants is not available through the USEPA, but information about emerging contaminants can be found in the scientific literature. The most current list of contaminants of concern can be found on the list of contaminants with Primary and Secondary Drinking Water Regulations, the Candidate Contaminant List, and as part of the Unregulated Contaminant Monitoring Program (USEPA 2009, 2014b, 2014c). Because of the wide variety of potential contaminant sources that may be found in SWA areas, a hierarchical approach to source identification is appropriate and most cost-effective. The information sources available to support this approach are summarized here.

Step 1. Search federal and state relational databases to identify regulated sources. The USEPA warehouse allows for online retrieval of environmental information from several USEPA databases:

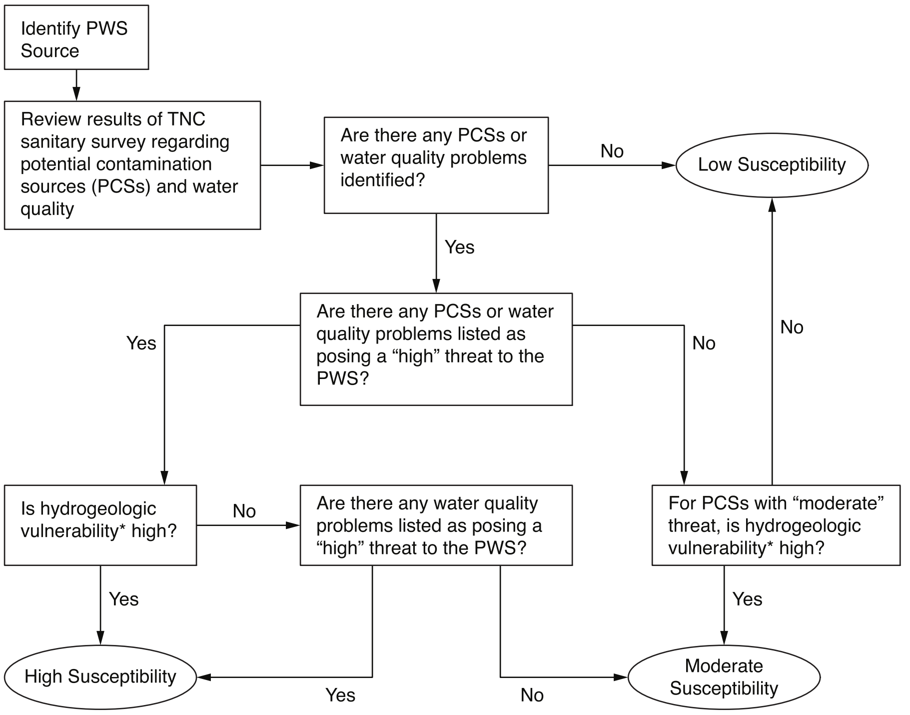
- Superfund sites—Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)
- Drinking water—Safe Drinking Water Information System (SDWIS)
- Toxic and air releases—Toxics Release Inventory (TRI)
- Hazardous waste—Resource Conservation and Recovery Information System (RCRIS)
- Water discharge permits—Permit Compliance System (PCS)
- Grants information

As a result, an Envirofacts (www.epa.gov/enviro/) and EnviroMapper (www.epa.gov/emefdata/em4ef.home) search allows water systems to rapidly identify existing and abandoned waste management facilities in the SWA area and other ongoing hazardous substance releases to the air, land, or water. In addition, certain states may maintain additional searchable data on underground injection wells, underground storage tanks, oil and gas wells, coal mines, and other potential hazards. USEPA maintains and updates a number of environmental databases. For example, the Superfund site information database (CERCLIS) was migrated to the Superfund Enterprise Management System (SEMS) in 2014 (USEPA 2014d). Leaking underground storage tank databases are maintained by state Departments of Environmental Quality or Natural Resources.

Step 2. Collect information from local land records, sanitary surveys, and/or public health records. Information can be collected from local government records, including operating, discharge and disposal, construction, and other permitting information; zoning records; real estate titles and transactions; and health department records (e.g., septic and onsite wastewater disposal system permits). Maps, aerial photographs, telephone directories, and historic records can be used to locate particular land uses that have been or are currently threatening source water.

Step 3. Collect new information on past land-use practices or contaminant sources that have not been identified. Because many sources, such as product storage facilities, failing septic systems, or abandoned underground storage tanks, may not be tracked at the local level, additional information must often be collected to adequately characterize threats to source water. Such information can be collected by door-to-door canvassing within the SWA area, windshield surveys, mail surveys, or general public education and outreach to request and gather new information. A number of communities have successfully used local volunteers to collect such information. Many communities also regularly compile high-resolution aerial photographs that can be used to identify potential sources of contamination and to update old databases.

Step 4. Target significant sources for further investigation. USEPA (1991) provides worksheets to help target more significant contaminant sources based on the type and volume of materials managed at the sources, and the proximity and vulnerability of the drinking



* Hydrologic/Hydrogeologic Vulnerability High = all surface water sources and wells in unconfirmed and semi-confined aquifers; Moderate = wells in confined aquifers.

Note: Susceptibility determination findings will be accompanied by a discussion of the potential risks to the public of drinking water of impaired quality. The risk information breach system will include water quality, treatment, monitoring, and protection measures.

Source: *Massachusetts DEP 1999*

Figure 7-6 Massachusetts Department of Environmental Protection's approach to conducting susceptibility determination

water intake. For sources deemed most significant, the accuracy and reliability of the gathered information should be verified through field checks.

Assessing vulnerability and determining susceptibility. Susceptibility assessments are the least understood (and most important) aspect of source water protection. Assessments are intended to identify the contaminant sources that pose the greatest threat to the drinking water supply so they can be targeted for management. Assessment methodologies include simple, analytical techniques such as hydrogeologic and hydrologic mapping to identify the relative vulnerability of groundwater and surface water supplies, decision tree analysis (Figure 7-6), and complex contaminant transport models linked to risk assessment matrices. Surface water assessments have relied on predictive models such as Enhanced Stream Water Quality Model (QUAL2E), River and Stream Water Quality Model (QUAL2K), and the Storm Water Management Model (SWMM). Packaged assessment products, such as USEPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), provide an integrated approach to incorporate point source and nonpoint source pollution into SWAs. An inventory of hydrologic models, including links to their recommended uses and technical contacts, is maintained by Texas A&M University (TAMU 2014).

Making source water assessments available to the public. Source water protection initiatives require outreach, education, and other nonregulatory tools. Public outreach and education designed to influence behavior have been effective in preventing pollution, conserving water, and developing supplies. Involving the public at the earliest stages of the initiative (e.g., during the SWA phase) builds support for the entire source water initiative. Effective public involvement approaches have been developed as part of WHPPs for groundwater-based systems and for surface-water-based systems.

Public involvement and participation are needed for water systems attempting to implement source water protection and management measures. As the water supply and public utility industries adopt integrated resource planning, and watershed and source water management practices to ensure sustainable, long-term drinking water supplies, the need to build public support for and understanding of critical management issues becomes increasingly important. As discussed in chapter 2, water systems are developing new approaches for communicating with the variety of stakeholders and stakeholder groups that have an interest in water supply development, treatment, distribution, and demand management issues. Furthermore, other water systems and environmental programs are learning how to work with interested stakeholders in meaningful ways. By adopting these approaches, drinking water systems can build stakeholder alliances that will foster better communication with the public and informed water system decision making. The emerging challenges of new water supply development, source water quality management, and the consumer awareness and public outreach provisions of the SDWA make the need for such stakeholder involvement and alliance building especially critical.

Water systems have historically interacted with a variety of stakeholder groups. At the local level, water systems regularly deal with individual customer service and rate issues. Such local stakeholders may also be represented by developers, subdivision managers, or other bulk purchasers of residential water supply. High-demand users, such as industry or large public or private institutions, may also band together to represent the interest of such users. Finally, public utility commissions or citizens' utility boards are often charged with representing local residential water users to determine the adequacy of water supply rate structures and public utility spending plans.

On a regional level, water supply development and management initiatives intersect with the activities of municipal, township, and county governments; planning authorities; homeowners' associations; and agricultural and industrial trade groups. These stakeholder groups may become critically involved in developing and managing water supply watersheds or regional aquifers that encompass multiple political boundaries. Effectively communicating with such a diverse range of interests can drain the time and resources of even large water systems.

Finally, new monitoring and reporting requirements mandated under the SDWA will change the relationship of individual water systems with state and federal regulators and will require new approaches for communicating with the public. In addition, a growing number of water systems are choosing to work with national programs, such as Groundwater Guardian, which focus on community-based water supply protection.

The growing need for interaction with these stakeholders has led water systems to conclude that public awareness of utility concerns is a key to obtaining support for management initiatives and is critical when responding to the need for new resources and system improvements. Customers and other stakeholders are more likely to buy into management decisions when they are consulted early in the decision-making process. As a component of the SWA process, Congress requested that the results of the assessments be made available to the public. Because of sensitive information associated with various aspects of water systems (e.g., intake and well locations), some states decided to share the assessment results on an "as needed" basis after the terrorist attacks on the United States on September 11, 2001.

The SDWA Amendments of 1996 do not require management controls; however, many water suppliers and local governments are actively controlling contamination sources and preventing new contamination sources from threatening drinking water quality through various management controls. Because of the voluntary nature of SWPPs, in 2006, 13 national organizations united to form the Source Water Collaborative (SWC) to protect America's drinking water at the source—in the lakes, rivers, streams, and aquifers tapped for drinking purposes. The goal of the SWC is to combine the strengths and tools of a diverse set of member organizations to act together, and protect drinking water sources for generations to come. As of 2014, the SWC has grown to include 25 national organizations that have been working together to further the goals of protecting sources of drinking water—recognizing that resources are extremely limited, authorities are split, and the actors who can actually protect source waters are diffuse. Individually, SWC members promote the implementation of source water protection as a part of their overall mission. At the same time, each organization recognizes the synergy of coordinated actions and the need for leveraging each other's resources to increase the chances for success over the chances of each entity doing it alone. AWWA is one of the original founding members of the SWC. Valuable information in using a collaborative approach to foster source water protection can be found at www.sourcewatercollaborative.org/.

ANSI/AWWA STANDARD G300 FOR SOURCE WATER PROTECTION

AWWA's Utility Management Standards program provides a means for the user to assess service quality and management efficiency. The standards developed under this program are intended to improve a utility's overall operation and service by identifying appropriate practices, procedures, and behaviors whose implementation will promote effective and efficient utility operations and thus will contribute to protecting public health, public safety, and the environment.

The Utility Management Standards (also known as the G Series) are designed to serve water, wastewater, and reuse utilities and their customers, owners, service providers, and government regulators. The American National Standards Institute (ANSI)/AWWA G300, *Source Water Protection*, published in 2014, provides a framework through which the user can assess its effectiveness at source water protection. The standard was established as a general framework for a utility of any size and circumstance in developing SWPPs that are locally specific and variable in scope. Utilities that fully implement ANSI/AWWA G300 can be assured that they have met the minimum criteria for the initial barrier in the multiple-barrier approach to protecting drinking water. While there may be differences in the details of the programs, ANSI/AWWA G300 applies equally to either groundwater or surface water programs.

ANSI/AWWA G300 lists six essential elements of an SWPP. These six elements describe an adaptive management approach to source water protection (Figure 7-7). In 2010, AWWA published the *Operational Guide to AWWA Standard G300, Source Water Protection* for implementing ANSI/AWWA G300 at the water system level (Sham et al. 2010). The guidebook provided the following expanded description of the six essential elements.

1. **Vision.** A formalized vision guides the development and implementation of an SWPP. A vision statement explicitly expresses the policy of the organization as set forth by the decision-making body of the utility and helps to align priorities and resources. The vision or policy statement is the official declaration of the utility's commitment to source water protection.

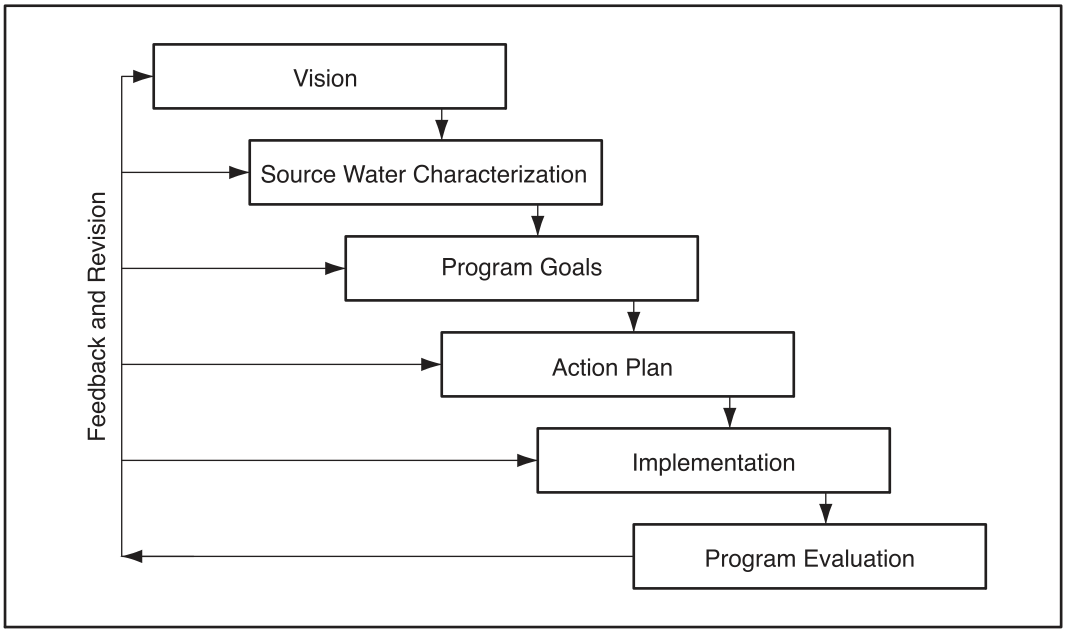


Figure 7-7 Six essential elements of an SWPP under ANSI/AWWA G300

2. **Source water characterization.** Characterizing and assessing both the source water and the land or subsurface area that the source water comes from is essential to obtain the understanding and knowledge needed to develop goals and plans that will realize the source water protection vision. In some cases, it will be appropriate and expected that users will have gone beyond state-performed source water assessments to better define watershed characteristics and will have obtained extensive public participation in defining components of the SWPP. It is also expected that in some cases, other stakeholders may be involved in the characterization process.
3. **Program goals.** Goals and objectives need to be formulated to guide the SWPP and its specific elements. The goals should be targets developed in response to specific problem areas identified through the source water and SWA area characterization and risk assessment processes. The goals should also address each of the drivers motivating the SWPP, including the source water protection vision. Goals may address both current and potential future issues. The goals should be prioritized to reflect the concerns of greatest importance and ideally should specify temporal and qualitative and/or quantitative dimensions (e.g., specific timelines and measurable goals). Both internal and external stakeholders should be involved in goal development.
4. **Action plan.** The action plan lays out a road map of activities to achieve the desired source water protection goals based on the vision, source water area characterization, and susceptibility analysis. The plan identifies required actions (regulations, agreements, practices, etc.) to mitigate existing and future threats to source water quality, and develops priorities and a timetable for implementation, identifying necessary resources and the means for obtaining those resources (e.g., funding), and metrics for measuring the success of each component of the plan. These priorities may be based on the perceived risk from different contaminant sources, the available resources to implement actions, the likelihood of success of different actions, and the obstacles to success that exist for different contaminant sources and action plans.

5. **Implementation.** Implementing the action plan is the core of any SWPP. Planning without implementation does not provide results, and without this step, no actual protection takes place. Developing a comprehensive and implementable plan using an adaptive and iterative management approach to respond to unexpected challenges and barriers and adhering to an established timeline are integral to the success of implementing an SWPP.
6. **Program evaluation.** Administrative programs of any type require periodic (or continuous) evaluation and revision. A good SWPP will include provisions for reviewing and, if necessary, modifying the water system's source water protection vision, characterization, goals, action plan, and implementation elements. This should be done on a periodic basis and also in response to changes in the SWPA and contaminant sources, performance of implemented programs, and so forth. This step of the process is intended to measure the accomplishment or completion of projects, programs, and activities identified in the action plan and to identify obstacles to success and the means to overcome those obstacles. The evaluation and revision facets of the SWPP should be designed with the idea that source water protection is an iterative and interactive process, enabling the SWPP to be a living document, continuously undergoing improvement and updates.

The guidebook for implementing ANSI/AWWA G300 at the water system level (Sham et al. 2010) provides utilities with a detailed discussion of each of the six elements. The guidebook also contains numerous checklists that can be used to assess utilities' source water protection efforts and to develop and enhance their SWPPs.

There are direct benefits to a water utility for implementing an SWPP. USEPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), promulgated in 2006, includes a provision whereby a water utility may qualify for a 0.5-log disinfection credit as a result of an effective SWPP. Under LT2ESWTR, drinking water utilities that obtain their source water from relatively pristine surface water supplies that are protected by an effective SWPP may apply to the USEPA for a Filtration Avoidance Waiver, which if granted, would release them from the filtration treatment requirements of the SDWA. New York, Boston, Syracuse (New York), Seattle, and Portland (Oregon) are examples of some of the cities that have Filtration Avoidance Waivers.

GROUNDWATER PROTECTION

For most of the United States, groundwater is considered the most reliable and safest source of drinking water. Local governments and the water supply industry have traditionally been responsible for developing, managing, and protecting groundwater supplies in the United States. Today, public water systems (PWSs) that use groundwater sources are subject to the provisions under SDWA. Some states are more stringent than the federal requirements and thus regulate small water systems. Groundwater systems that regularly serve less than 25 individuals, or with less than 15 service connections, are considered private systems and are not subject to federal regulations.

Because of the general availability of groundwater across the country, many PWSs derive their sources from deep, confined aquifers that provide water that typically requires little to no treatment, although, as discussed chapter 4, may also provide little or no recharge. If groundwater treatment is applied, its purpose is typically to remove iron and manganese, for corrosion control or to reduce hardness.

Treatment for contaminants (such as industrial solvents) resulting from land-use activities, such as industry or commercial operations, may be necessary when a public supply well is contaminated. Groundwater contamination and water quality threats from land-use activities present a challenge for systems using groundwater. Groundwater is considered an economical source to develop because wells could be drilled near the areas to be supplied. Water quality threats from encroachment of land-use activities (such as agriculture, and residential, industrial, and commercial development) introduce organic contaminants, metals, nutrients, and biological pathogens to the land surface and subsequently into the groundwater through percolation and infiltration, or directly into the subsurface via underground injection wells and infiltration galleries. Groundwater contamination often is not evident or obvious and is discovered only after a considerable portion of the groundwater resource has become contaminated. Removing chemical contaminants from water is expensive, and the past practice of abandoning and replacing wells is no longer a viable option in areas with limited water resources and growing populations.

Groundwater protection is key to maintaining safe and reliable groundwater supplies. This section presents the regulatory framework for groundwater protection and outlines a stepwise process for groundwater source protection.

Under the 1974 SDWA, two programs were put in place to help protect US groundwater resources: (1) the Sole Source Aquifer Protection Program, and (2) the Underground Injection Control Program.

The Sole Source Aquifer Protection Program is authorized by Section 1424(e) of the SDWA of 1974. It states the following:

> *If the Administrator determines, on his own initiative or upon petition, that an area has an aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health, he shall publish notice of that determination in the Federal Register. After the publication of any such notice, no commitment for federal financial assistance (through a grant, contract, loan guarantee, or otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health, but a commitment for federal assistance may, if authorized under another provision of law, be entered into to plan or design the project to assure that it will not so contaminate the aquifer.*

The Underground Injection Control (UIC) Program is authorized by Section 1421 of the SDWA of 1974. Part of the SDWA required USEPA to report back to Congress on waste disposal practices and develop minimum federal requirements for injection practices that protect public health by preventing injection wells from contaminating underground sources of drinking water (USDWs). A USDW is an aquifer, or a part of an aquifer, that is currently used as a drinking water source or may be needed as a drinking water source in the future. Specifically, a USDW supplies any PWS or contains a sufficient quantity of groundwater to supply a PWS, and currently supplies drinking water for human consumption, or contains fewer than 10,000 mg/L total dissolved solids (TDS) and is not an exempted aquifer. It should be noted that unless diesel fuel is used in the fracturing fluid, hydraulic fracturing is exempted from UIC regulations. The effects of unconventional oil and gas production using hydraulic fracturing and directional drilling on groundwater are being studied in shale gas production areas. Sole source aquifer protection and UIC programs are used at various levels to protect the USDWs in the United States. These programs should be integrated into any groundwater-based SWPPs, as appropriate.

Comprehensive State Groundwater Protection Programs

In 1992, the USEPA published guidance for comprehensive state groundwater protection programs (CSGWPP) (USEPA 1992). The goal of this approach is to achieve a more efficient, coherent, and comprehensive approach to protecting the nation's groundwater resources by coordinating operations of all relevant federal, state, and local groundwater programs in a state. Under CSGWPP, USEPA asks states to coordinate their groundwater protection actions through six strategic activities:

1. Establish a groundwater protection goal.
2. Establish priorities to guide program efforts.
3. Define authorities, roles, responsibilities, resources, and coordinating mechanisms.
4. Implement efforts to accomplish groundwater protection goals.
5. Coordinate information collection and management.
6. Improve public education and participation in all aspects of groundwater protection.

CSGWPPs are designed to focus pollution source control programs on preventing contamination of high-priority groundwater, facilitate coordination among the many intrastate programs that protect groundwater, and build a comprehensive approach to protect groundwater that includes all stakeholders. In addition, CSGWPPs strengthen state watershed approaches by providing an essential link between the state's groundwater and surface water protection programs. In some geographical settings, however, these plans may be too broad and there is a lack of resources to implement them. Thus, many PWSs that rely on groundwater for their source water maintain an active approach in maintaining and implementing their own SWPPs as discussed below.

Wellhead Protection Program. In 1986, amendments to the SDWA increased the authority and responsibility for drinking water protection. Section 1428 of the SDWA created the wellhead protection program (WHPP). Subsequent amendments in 1996 further strengthened drinking water protection by establishing the source water protection program (SWPP). Because of the duplicative nature of WHPP and SWPP, many states have replaced their WHPPs with the updated SWPPs or incorporated their WHPPs into their SWPPs. One of the subtle differences between WHPPs and SWPPs is associated with the extent of the aquifer under consideration and is discussed further below. The following paragraphs describe the components and operation of WHPPs and the corresponding SWPPs.

WHPPs emphasize pollution prevention rather than treating drinking water contamination and taking remedial actions once groundwater is contaminated. Each state has developed a program tailored to the specific physical, cultural, and administrative conditions of the area to protect its groundwater supplies. Variability in hydrology, geology, land use, and management approaches have resulted in a wide range of programs to protect public water supply wells. For a state to have an approved WHPP, it must meet the following requirements:

1. Specify the roles and duties of state agencies, local government offices, and public water suppliers regarding development and implementation of the program. Many states have worked cooperatively with public water suppliers and local governments to form local teams to plan and implement wellhead protection efforts. A comprehensive approach, including stakeholders and the public, is recommended to achieve maximum results. A typical planning team could include representatives from local public interest groups (including environmental groups, community service organizations, and public representatives), regulatory organizations (such as health, planning, and public works), public service organizations (water utility, fire department, and extension service), and private organizations (including businesses, farmers, and developers). In some instances, larger water utilities are fully responsible for implementing and periodically revising a WHPP.

Stakeholder involvement is garnered through the public meeting process and sometimes by maintaining a citizen's advisory board.

2. Delineate a wellhead protection area (WHPA) for each wellhead based on hydrogeologic and other relevant information to define the boundaries of the most critical land areas that provide recharge to the well. The techniques used to delineate WHPAs depend on the well type, hydrogeology, management approach, and budget. Areas that receive recharge that contribute water to a pumping well are referred to as zones of contribution (ZOCs). These ZOCs are affected by recharge rates, pumping rates, and hydrogeologic boundaries.

   The methods used to delineate WHPAs include arbitrary fixed radius, calculated fixed radius, simplified variable shapes, analytical methods, hydrogeologic mapping, and numerical modeling. If stringent land-use controls are to be developed and enforced in WHPAs, more detailed and scientifically accurate methods should be used to delineate the area. If the management approach is only to educate the public and landowners of the connection between their land-use activities and water quality in the well, the simple arbitrary fixed radius or analytical methods may be sufficient. Details and examples of delineation methods can be found in several USEPA publications (USEPA 1987, 1988, 1997a, 1997b). An inventory of hydrologic models and technical contact information is maintained by Texas A&M University (TAMU 2014). Individual states have issued more recent guidelines for WHPA delineation including Minnesota (MDH 2009) and Wisconsin (WDNR 2012), two states that, on average, rely heavily on groundwater sources. As one can note, these methods were passed on for use in SWPPs under the 1996 SDWA Amendments. Advantages and disadvantages of various delineation methods are summarized in Table 7-1.

   In the current WHPPs for one midwestern utility, many ZOCs are considered simultaneously and include fixed radii of 1,200 ft (366 m) and ½ mile (4,250 km) and hydrologically modeled time of travel radii for 5, 50, and 100 years. Activities within each of these radii are managed through zoning and cooperative agreements with decreasing stringency as the activity moves further from the well.

3. Identify sources of contamination in each WHPA. The delineated WHPA becomes the boundary within which a land-use inventory can be conducted to identify and map potential contamination sources. While not considered as direct sources of contaminants, abandoned wells and drainage wells should be included in ZOC delineation because they may act as direct conduits for pollutants from the surface to enter an aquifer.

   Not only should current land uses be mapped and assessed for their potential threat to water quality but also for areas of future intended uses on the land. Distance from the well, contaminant type, and contaminant severity are important considerations when assessing water quality threats.

   For example, a few septic systems or onsite wastewater disposal systems in a WHPA may present very little threat to water quality. However, hundreds of onsite systems will definitely create a threat that will most likely result in lowering water quality. Many governmental sources are available to provide data on land-use threats. States and USEPA regional offices have extensive databases providing information on large permitted facilities, such as wastewater treatment plants, landfills, waste sites, and drainage wells. Local and state agencies may also maintain records of gas stations with underground storage tanks.

   Most water quality threats can be identified only by conducting field surveys and inventories. Small commercial operations that handle small quantities of hazardous materials, private septic and onsite wastewater disposal systems, roadway drainage, and underground petroleum storage tanks are all activities