Public Participation - Step 7

As mentioned in the ***Team Formation*** section, grassroots support is essential to the successful implementation and maintenance of a local wellhead protection plan. The Wellhead Protection Team may choose to utilize junior high and high school groups, church groups, senior citizen groups and community groups to help implement the program. These are just a few of the organizations available where you'll find willing and able volunteers. Also, retirees are known to be very effective in all aspects of wellhead protection plan implementation and maintenance.

Whoever you recruit, it cannot be stressed enough that grassroots support is imperative. Although it may seem as if your plan can be implemented using only the Wellhead Protection Team members, once Steps 1 through 6 have been completed, you'll have a much easier time maintaining your protection program with the help of all the people affected by such a plan.

Successful communication is paramount to an effective program. Publicity can be used to both inform and to build support. Take opportunities to meet with people who might be regulated by the program. Be prepared to answer questions and respond to complaints or requests. Talk with people who might participate in monitoring and enforcement. Provide them with clear and concise material on their responsibilities and the rationale for the program. These steps can increase the public's awareness of the program and their likely support for its goals. Involvement of the entire community will ease the burden on the utility.

In certain stages of the program's development, you will want to reach out to the community at large to communicate specific aspects of the program, its purpose, and involvement opportunities for citizens. To carry these messages, consider techniques such as:

- School or library newsletters
- Slide or video presentations
- Speakers
- Brochures
- Statement stuffers
- Signs or posters
- Advertisements
- Fliers
- Community or public meetings
- Press releases
- Press conferences

School or library newsletters are inexpensive ways to reach a large number of people. Usually you can contribute an article, an announcement for an upcoming meeting, or recruit volunteers for either of these publications at no cost to you.

Slide or video presentations are another wonderful method for describing in more detail to groups of all sizes what your protection program has accomplished so far, or what you hope to accomplish in the future. Presentations of this type can usually be produced for the cost of a camera and film. Enlist the help of the local amateur shutterbug or the high school camera/video club. These presentations can be used to recruit volunteers, explain hazards, and generate overall interest in compliance and enforcement of your new protection plan.

Speakers are always a good source of information. Invite one of the experts you may have used to help you develop parts of your plan. A speaker of this caliber can talk in more detail about some aspect of your plan you may be having a hard time explaining to your community. Organize a special coffee or council meeting, depending upon the topic and the number of citizens you'd like to interest.

Brochures are an excellent low-cost method for getting the word out to everyone affected by your wellhead protection program. Brochures can be created and mailed covering, for example, an overview of your program, describing the seven steps in your plan in more detail, and so on. Another popular brochure topic is one sent to landowners in the Wellhead Protection Area covering Best Management Practices.

Direct mailings, such as water **statement stuffers**, can be targeted to smaller groups or specific types of recipients, such as gas stations, dry cleaners, or other small businesses likely to engage in activities or handle hazardous substances that are subject to regulation. The detailed inventory form, found in Appendix Four, may be a good tool to include in direct mailings to such groups.

Signs posted within a community to identify entrance into a wellhead protection area are a good means of promoting the program, and raising overall awareness of your efforts. They may also cause people to think about their activities.

Advertisements in trade journals to reach certain professions can be useful. Advertisements in local newspapers, while less precisely targeted, may also prove effective, especially when local involvement is needed. Local media may also have public service announcement (PSA) time/space available for you to use at no cost.

Fliers, usually one letter-sized page, may be an effective way to reach a broad section of the population with minimal expense. This would be a good method to remind people that an upcoming event is occurring, such as a hazardous waste cleanup day.

Community or **public meetings** can be used to provide information to, and receive input from, members of the community who have a specific interest in groundwater issues. Some suggested topics are:

1. ***Nature and Magnitude of Risk***
   Which substances and business activities cause the greatest concern? What level of risk can be accepted by the community? How can you assess site specific risk? Participants will reconsider or reference this topic throughout the process as each potential protection measure is discussed and scientific data becomes available.

2. ***Wellfield Insurance Program***
   Could the city establish an effective program that requires a business in a protection area to maintain private wellfield insurance? Monitoring of ongoing business activities might

occur under this scenario because of the private insurance company's desire to protect its assets.

3. ***Voluntary Programs - Land Use Controls***
   Provide descriptions and examples of each for discussion. Also, determine what local resources are available to support each approach.

4. ***Permitting and Licensing - Health Codes***
   Provide descriptions and examples of each for discussion. Also, determine what local resources are available to support each approach.

5. ***Wellfield Protection Program Design and Subcommittee Formation***
   Determine what combination of wellfield protection measures is most appropriate for your town. Participants will consider the impact of each option, both positive and negative, on economic development.

6. ***Regional Coordination***
   Discussion and deliberation may result in the formation of a subcommittee.

Questionnaires, mailed to a large number of residents, are useful in getting a message out as well as obtaining feedback on groundwater issues. Although it should be noted that without some additional form of incentive, response to such questionnaire surveys is usually less than ten percent.

Seminars may be used to communicate detailed information to a small target group. Although seminars may involve greater effort and expense, this may be a useful way to inform industry of newly developed standards likely to affect their operations.

The Chamber of Commerce may also provide you with a means for reaching local businesses. Local Chambers are usually willing to give you access to their membership lists for mailings, or to their meetings for presentations.

These are some relatively low-cost public communication/participation strategies you may wish to consider. Most can be accomplished using utility staff and local business proprietors. Use the ***Public Participation Log Sheet*** to record details about each strategy you use.

Because the information to be presented with any of these tools would be very specific to your utility and community effort, it is difficult to provide samples for you to model from. However, should you need to prepare a press release, there are some common pieces of information and methods to follow. A sample press release is included at the end of this section for your reference.

In the ***Well No.*** section, record the specific number of the well this log sheet refers to.

In the ***Assigned Activity*** section, record the activity undertaken, such as "hearing on proposed contaminant inventory activities," or "organize field visits in the first 500-foot radius."

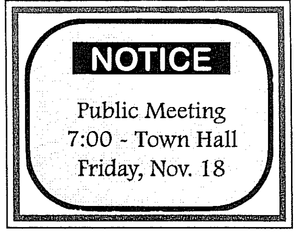
In the ***Name of Person Assigned to Activity*** section, record the name of the person who has volunteered or been appointed to complete or lead each specific activity.

In the ***Date Initiated*** section, record the date each specific activity is to begin. Use this date to document and keep track of the target dates for assigned activities, and keep your efforts always moving forward.

In the ***Date Completed*** section, record the date each specific activity is completed.

In the ***Evaluation of Activity*** section, make a notation as to whether the activity was successful or not, or whether you need to modify the methods used to accomplish the tasks.

Public Participation Log Sheet



Well No. ________________

Assigned Activity	Name of Person Assigned to Activity	Date Initiated	Date Completed	Evaluation of Activity

Sample News Release for Print Media

Office of Wellhead Protection

News Release

Date: December 1, 1996
FOR IMMEDIATE RELEASE
Page 1

Contact: James Smith
Affiliation
XXX/XXX-XXXX

TITLE OF CORRESPONDENCE

This announcement should be a simple WHO, WHAT, WHEN, WHERE, and WHY correspondence about your activities, people involved, an invitation to a special event, such as a seminar, etc. The news release should be double-spaced with at least a one-inch margin on all four sides.

The date should either read, as above, FOR IMMEDIATE RELEASE, or if you want it run in, for example, consecutive weekly newspapers, indicate what dates you would like these to be.

If your news release is longer than one page, at the bottom of the first page, and every successive page, except the last, put the word - MORE -, centered in the middle of the page. At the end of the news release, be sure to put either the symbol - ### - or the word - END -.

Implementation Strategy

Planning Wellhead Protection Training

By completing the fill-in-the-blank forms contained in the previous sections of this model plan, your utility and community can create its own unique wellhead protection plan. These same forms, particularly the ***Risk Assessment Table, Risk Consolidation Table, Contaminant Source Management Table,*** and ***Contingency Plan Table*** can serve as good indicators of the types of training that may be needed to prepare your Wellhead Protection Team for the responsibilities they must carry out. The ***Training Table*** has been developed for your use in tracking training activities as they are both planned and completed. The ***Training Table*** should identify who is to be trained, who will provide training, what types of training techniques are to be used, a schedule for training activities, and how the training will be evaluated to see if objectives were met. With a documented training plan, your utility can incorporate wellhead protection training into regular business processes and budgets as they are developed.

It is important to prioritize training needs to address areas where your utility or community may be most vulnerable. The ***Risk Assessment Table*** rating will identify the contaminant sources most likely to put your utility at risk. Training needs associated with the highest priority risk should also be of highest priority. In prioritizing training needs, it is also important to consider the roles that each team member will fulfill, and areas where education may be needed. Roles could include routine responsibilities for, say, the Technical Coordinator, and also special responsibilities that person may be assigned in an emergency response to a contamination. If a team member isn't particularly strong in a skill needed for their position on the team, it is important to prepare them with the appropriate training before the need for them to act occurs. This preparation will help to minimize confusion in implementation stages and put forward a solid image to the community regarding the wellhead protection effort.

Conducting Wellhead Protection Training

Your utility does not have to spend large amounts of money to prepare Wellhead Protection Team members to fulfill their duties. Remember, utility personnel are often very knowledgeable about their community and the resources available in the utility or community to address an emergency. Use the resources available to begin training efforts, and bring in assistance from outside experts when it is needed.

Training can be provided in many forms. Organizations have used: orientation sessions, discussion groups, reading materials, tabletop exercises, scenarios, walk-through exercises or drills, demonstrations, external seminars, mock emergencies to test contingency plans, etc. Depending on the specific need, one form of training may be more effective than another. To help team members become more familiar with broader wellhead protection principles and to form a common background amongst the team, group question and answer sessions may work well. For specific emergency responses to a contamination, more of a “hands-on” method may be needed, such as tabletop scenarios or walk-through exercises. These are also extremely valuable tools to discover details not considered when preparing your ***Contingency Plan Table.*** Choose the tool that best fits the particular training need and the people to be involved in the training.

Once a training session has been conducted, it is important to determine whether it achieved what was intended. Every training activity should be concluded with an evaluation of the training materials and methods to allow for fine-tuning. Additionally, a means of follow-up should be in place to ensure training needs have been satisfied. For example, if the Regulatory Coordinator needed training on researching and writing ordinances, put in place quality checks to be sure the team member can demonstrate the new ability learned from the training.

Training records, in some form, should be maintained for all members of the Wellhead Protection Team. By keeping track of this information, your utility can easily identify someone to serve in a back-up capacity for another team member, or identify how duties can be shifted to others.

Updating and Administering the Plan

As with any business that experiences change, water utilities can expect their wellhead protection plans to become outdated. And, without up-to-date information, the plan will become useless as a preventive tool to safeguard the water system. Therefore, it is recommended the plan be reviewed, and potentially modified, at least on an annual basis. The annual process should include:

- Review of the ***Risk Assessment Table*** and ***Risk Consolidation Table*** - Be sure the priorities from the previous analysis are accurate, and rerank, if necessary due to successful control mechanisms, relocation of business or industry, or other changes. Is the ***Contaminant Source Inventory Table*** still complete, or should other potential hazards be added to it? If management strategies have been successful in offering the level of protection desired by your utility, these hazards may no longer pose as great a risk. In these situations, make the appropriate adjustments to the ***Risk Assessment Table*** and the ***Risk Consolidation Table*** reprioritize hazards. This will allow you to focus on hazards that were formerly not deemed as high a priority, but which will now offer additional protection for the water supply.

- Review the Progress of Contaminant Source Management Efforts - Determine if items listed on the ***Contaminant Source Management Log Sheet*** have been accomplished. Be sure adequate record keeping has occurred for management initiatives that have been accomplished or deemed no longer necessary due to changes in operation or land usage. For incomplete items remaining on the list, evaluate whether the measures are making satisfactory progress according to timelines projected for completion. If sufficient progress is not being achieved, bring your Wellhead Protection Team together to review how the initiatives might be changed to allow them to be implemented, and determine new priorities and schedules for completion. The team may also need to rethink a chosen control strategy and select another option, more appropriate for up-to-date community issues and climates.

- Review ***Contingency Plan Table*** - Consider how changes in team members, facilities, operational procedures, neighboring water suppliers, and community officials may have affected the information contained in this form. Update the form with appropriate information.

- Review ***Training Table*** and Individual Training Evaluations - Determine if activities listed on the ***Training Table*** have been accomplished. Delete items accomplished or no longer necessary due to changes in operation, personnel, or community resources. Consider the results of the training evaluations and determine changes needed in future programs to better meet the needs ofparticipants. For training activities which were not completed, evaluate why those activities were not conducted, make appropriate changes to allow them to be completed, and determine new priorities and schedules for completion based upon the revised ***Risk Assessment*** and ***Risk Consolidation Tables*** and ***Contaminant Source Management Log Sheet***.

The ***Wellhead Protection Team Coordinators*** form and ***Water Supplier General Information Sheet*** should be reviewed monthly for up-to-date names and telephone numbers. Additionally, both Wellhead Protection Team and Emergency Response Team members should be aware of their responsibility to notify the person responsible for maintaining the plan whenever this basic contact information changes. If team members move, obtain new telephone numbers, or are no longer available for after-hours contact, these forms should be updated immediately.

Specific events may also occur which should cause the plan to be updated (and appropriate training to occur) without waiting for the periodic review process. Examples may include: changes in water utility personnel, election of new utility or community officials, new business opportunities for the community, new facilities placed in operation, or significant operational changes.

Distribution of the Wellhead Protection Plan

The wellhead protection plan for your utility needs to be communicated in a variety of ways as stated in Step 7- Public Participation. First, it must be written and distributed to the appropriate people in the community. Copies of the plan should be provided to members of the Wellhead Protection Team and the Emergency Response Team, utility officials, community officials, other groundwater stakeholders, and representatives of emergency organizations in the community, such as fire and police departments. As your utility goes through the annual review and updating process, revised copies of the plan or individual pages should be distributed. Also, it is important that Wellhead Protection Team members have copies available not only at their business or day-time locations, but also in their homes.

Beyond circulation of the written plan, it is important to present the plan to your utility staff, community officials, and other community groups. Also mentioned in Step 7 - Public Participation, this educational effort cannot be minimized. The success or failure of your wellhead protection initiatives lies with the degree of acceptance or rejection offered by community residents.

Part of the wellhead protection presentation strategy should include identifying the people who will serve in each of the key team responsibilities. By introducing team members to the community, a first step is made in assuring the public that your utility will be prepared to do what is necessary to provide them with safe drinking water if a contamination emergency does occur. In sharing the plan, special attention should be paid to educating consumers about their roles in the wellhead protection initiatives. Identify how they can be involved.

The ***Training Table*** should also be presented to the Wellhead Protection Team and utility officials at least annually. This will ensure members and officials understand the priorities placed on training and encourage more support for achieving the training goals.

Instructions for Completing the *Training Table*

In the ***Name*** section, enter the name of the team member or volunteer who will be attending training.

In the ***Training Needed*** section, record the specific role, responsibility or function the training will address.

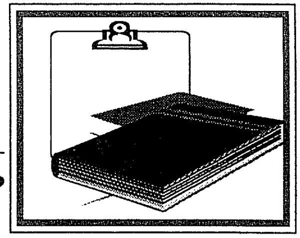
In the ***Trainer*** section, enter the name of the person conducting the training session.

In the ***Training Technique*** section, record the type of training being administered, for example, workshop, hands-on demonstration, classroom lecture.

In the ***Schedule*** section, record the month and year the training will be administered.

In the ***Evaluation Technique*** section, identify what method you plan to use to follow-up on the skills attained by the attendee.

Training Table



Name	Training Needed	Trainer	Training Technique	Schedule	Evaluation Technique	
(Staff/Community Member)	(Topic)	(Internal/ External)	(Workshop/Class)	(Month/Year)	(Post-Test/ Observation)	

Outcome

To meet the expectations of your customers, your utility and staff need to identify potential hazards that could jeopardize the drinking water supply and plan for such occurrences. Wellhead protection begins with selecting the right people to be involved; people who will support justifiable protective measures and remain committed to achieving an adequate level of protection for the drinking water wells and recharge areas, to the extent possible. Follow these steps to begin your wellhead protection program:

Choose the team. Canvass the community, get qualified reliable participants, and complete the ***Wellhead Protection Team Coordinators*** form to have handy information for contacting these individuals as you approach each step of the model plan.

Prepare to define your wellhead protection area and get help when needed. Collect and review facts about each of your wells; know what characteristics make them vulnerable. Record this information on the ***Wellhead Protection Information Table*** for each well. Have in mind qualified technical resources to contract with if formal delineation of the wellhead protection area becomes necessary.

Determine potential contaminants. Get input from your community to identify possibly threatening business activities, land uses, or properties -- existing and abandoned. Plot the possible hazards in relationship to the well(s) and record pertinent information on the ***Contaminant Inventory Table***.

Prioritize potential risks. Evaluate the contaminants identified according to the threats posed to public health, their mobility in groundwater, and their location to the well(s). Record ratings for each contaminant on the ***Risk Assessment Table*** and complete the ***Risk Consolidation Table*** to produce a prioritized list of potential threats to the water supply.

Identify management strategies for contaminants. Evaluate regulatory and nonregulatory options for minimizing the risk, or eliminating it altogether, and design measures to assure the water supply will be protected. Record the efforts needed in this process on the ***Contaminant Source Management Log Sheet.***

Prepare to respond when contamination emergencies cannot be avoided. Complete the ***Contingency Plan Table*** with strategies for providing both short- and long-term water sources to your community. Form an Emergency Response Team prepared to deal with contamination emergencies.

Keep your community educated and involved. Plan activities that will assure your community is aware and participating in the wellhead protection effort. Record your public participation initiatives on the ***Public Participation Log Sheet.***

Remember, wellhead protection is an effort needed today, to be sure the water environment will be safe for tomorrow's children.

Glossary of Definitions

A

ANALYTICAL EQUATION - A numeric calculation or formula involving multiple and various components or elements.

AQUIFER - A porous, water-bearing geologic formation. Generally restricted to materials capable of yielding an appreciable supply of water.

B

BEDROCK - The solid rock encountered below the mantle of loose rock and more or less unconsolidated material which occurs on the surface of the lithosphere.

C

CALCIUM CARBONATE - The principal hardness and scale-causing compound in water; found in nature as calcite and aragonite and in plant ashes, bones, and shells; used in making lime.

CONE OF DEPRESSION - The depression, roughly conical in shape, produced in a water table or other piezometric surface by the extraction of water from a well at a given rate. The volume of the cone varies with the rate and duration of withdrawal of water. Also called cone of influence.

CONFINED AQUIFER - An aquifer which is surrounded by formations of less permeable or impermeable material.

CONFINING LAYER - An impervious stratum or layer directly above or below one bearing water.

CONSOLIDATED - (1) In geology, any or all the processes whereby loose, soft or liquid earth materials become firm and coherent. (2) In soil mechanics, the adjustment of a saturated soil in response to increased load, involving the removal of water from the pores by increase in pressure and decrease in void ratio.

D

DEEP WELL - A well located and constructed in such a manner that there is a continuous layer of low permeability soil or rock at least five feet thick located at least 25 feet below the normal ground surface and above the aquifer from which water is to be drawn.

DELINEATE - To mark the outline of an area.

DELINEATION - The act or process of marking the outline of an area.

DISSOLVED-SOLIDS CONCENTRATION - Any material that is dissolved in water and can be recovered by evaporating the water after filtering the suspended material.

DOLOMITE - An equimolar combination calcium and magnesium carbonates which occurs in nature as a hard rock.

DOSE-RESPONSE - The relationship recognized between exposures to harmful substances over time and in varying concentrations (dose) and their subsequent impact upon public health (response).

DRAWDOWN - (1) The magnitude of the change in surface elevation of a body of water as a result of the withdrawal of water therefrom. (2) The magnitude of the lowering of the water surface in a well, and of the water table or piezometric surface adjacent to the well, resulting from the withdrawal of water from the well by pumping. (3) In a continuous water surface with accelerating flow, the difference in elevation between downstream and upstream points.

E

EPIDEMIOLOGIC DATA - Scientific medical information related to the study of the incidence, distribution, and control of disease in a population.

F

FIXED RADIUS METHOD - An approach used for establishing a wellhead protection area, applying constant distances to delineate a circular area of specific size.

FRACTURED AQUIFER - An aquifer in which water is stored and flows through relatively large openings, cracks, or crevasses.

G

GEOLOGY - The science that deals with the origin, history, and structure of the earth, as recorded in the rocks, together with the forces and processes now operating to modify rocks.

H

HYDROGEOLOGY - The branch of hydrology that deals with groundwater, its occurrence and movements, its replenishment and depletion, the properties of rocks that control groundwater movement and storage, and the methods of investigation and use of groundwater. Also called groundwater hydrology.

I

IMPERMEABLE - Not allowing, or allowing only with great difficulty, the movement of water; impervious.

J

K

L

LAND USE - (1) The culture of the land surface, which has a determining effect on the broad social and economic conditions of a region and which determines the amount and character of the runoff and erosion. Three general classes are recognized: crop, pasture or range, and forest. (2) Existing or zoned economic use of land, such as residential, industrial, farm, commerial.

M

MODELING - Computerized simulation of groundwater flow and pumping conditions.

N

NEGATIVE CONFINING BED - A confining bed that prevents or retards downward movement of groundwater where the overlying water has sufficient head to produce a resultant downward pressure.

O

OPEN CHANNEL - Any natural or artificial waterway or conduit in which water flows with a free surface.

P

PERMEABLE - Having a texture that permits water to move through perceptibly under the head differences ordinarily found in subsurface water.

Q

R

RECHARGE - Addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources.

S

SHALLOW WELL - A well located and constructed in such a manner that there is not a continuous layer of low permeability soil or rock (or equivalent retarding mechanism acceptable to the IDNR) at least 5 feet thick, the top of which is located at least 25 feet below the normal ground surface and above the aquifer from which water is to be drawn.

T

TIME OF TRAVEL (TOT) - The time required for water to travel from a given point to some other downstream point.

TOTAL DYNAMIC HEAD (TDH) - The difference between the elevation corresponding to the pressure at the discharge flange of a pump and the elevation corresponding to the vacuum or pressure at the suction flange of the pump, corrected to the same datum plane, plus the velocity head at the discharge flange of the pump, minus the velocity head at the suction flange of the pump.

U

UNCONFINED AQUIFER - An aquifer which is not restricted by formations of less permeable or impermeable material.

V

VELOCITY - The time rate of linear motion of groundwater in a given direction.

W

X

XERISCAPING - A landscaping practice which uses native plant materials having lower water and nutrient requirements than standard landscape plantings.

Y

Z

Appendix One

Iowa's Bedrock Aquifers

There are five principal bedrock aquifers used extensively in Iowa: the Dakota, Mississippian, Silurian-Devonian, Cambrian-Ordovician (Jordan) and Dresbach aquifers. These formations, comprised of porous, permeable sandstones and fractured carbonate rocks, are productive water-yielding units. They are usually separated by confining beds that slow the movement of water between the aquifers. At the bottom of the groundwater reservoir are Precambrian rocks in excess of 600 million years old. These rocks lie at a depth of about 5,200 feet in southwestern Iowa, rise to the surface in extreme northwestern Iowa, and to within 800 feet of the surface in northeastern Iowa. The Precambrian rocks are normally impermeable, and do not generally yield groundwater. The water-bearing rock formations are stacked, one on top of the other in layer-cake fashion, above these Precambrian basement rocks. The bottommost aquifer, and the first to be formed, is the Dresbach aquifer, which is estimated to be nearly 600 million years old. The Cambrian-Ordovician, the Silurian-Devonian, the Mississippian aquifers, and intervening units were all laid down in succession over the Dresbach aquifer. At some point, after formation of the Mississippian aquifer, geologic forces warped the bedrock so that these rock units slope downward from north-east to southwest at a rate of about 13 feet per mile. The Dakota aquifer of western Iowa was formed later, and lies relatively flat over approximately 20 percent of the state.

If the layers of overlying glacial materials (sand, gravel, till and soil) could be stripped off and the bedrock layer cake could be sliced from east to west, some interesting features of the bedrock system would be revealed. Figure 1A shows the slope of the bedrock. Because of the slope, bed-rock aquifers found at or near the surface in northeast Iowa are buried 2,000 or more feet below the surface in the southwest. Not only are these sloping bedrock layers higher in the northeast, they are also tapered off, becoming thinner and thinner until they become truncated in the eastern portion of the state. Each layer, in turn, becomes the uppermost surface of the bedrock, and it is in these areas, where the aquifers are exposed to the glacial materials which lie above, that the bedrock aquifers are recharged. The Dakota is the only bedrock aquifer which does not exhibit this noticeable slope.

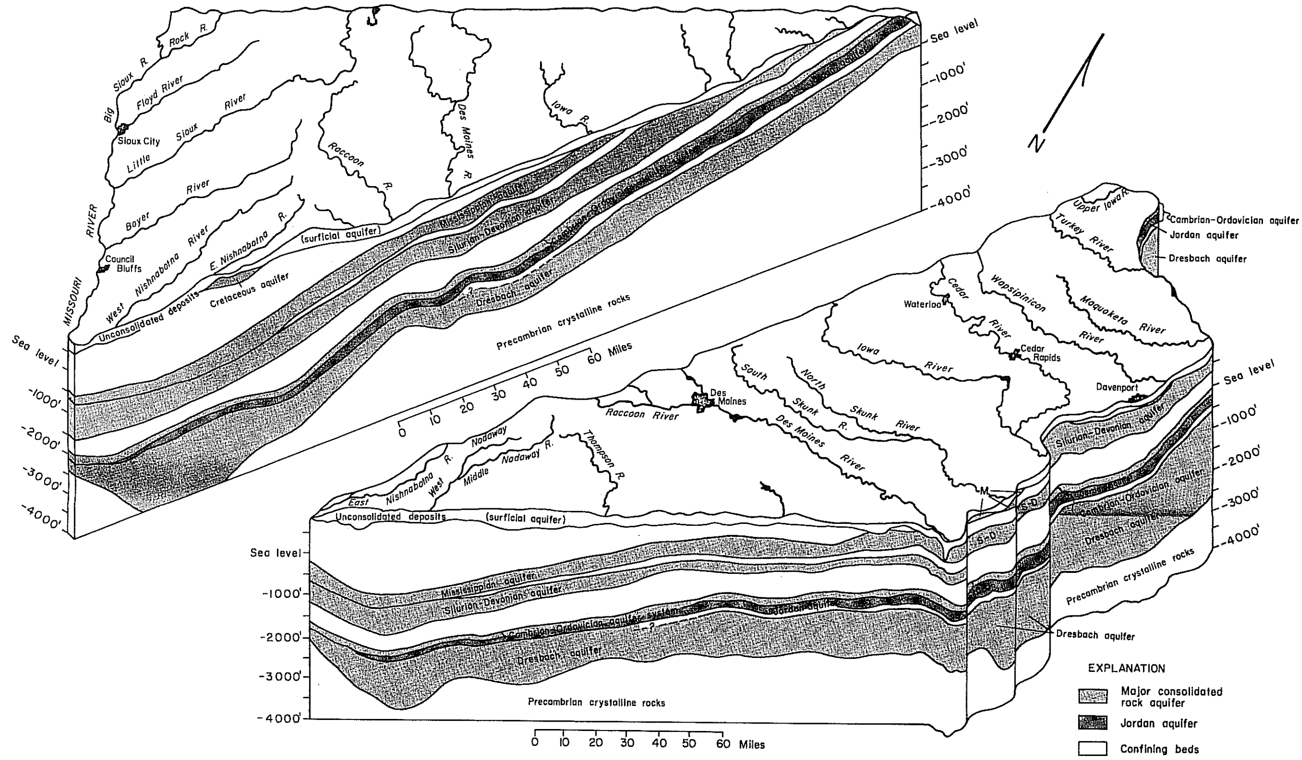


Figure 1A: Slope of Iowa's Bedrock and Aquifer Units

Many factors influence the overall value of each aquifer as a water source. Aquifer depth, thickness, permeability and water quality are just a few of the factors that must be considered. The following paragraphs provide information which can be used to understand differences between the bedrock aquifers in Iowa.

The Dresbach Aquifer

Physical Characteristics - The Dresbach aquifer, although present, is not really used in most of the state. It is the stratigraphically lowest aquifer in Iowa. The aquifer ranges in depth from less than 100 feet in some eastern counties to well over 3,000 feet in the western half of the state. Information regarding the Dresbach aquifer is limited to a stretch along the Mississippi River, from Allamakee to Clinton Counties. Some records, however, indicate thickness varies from less than 100 to well over 1,000 feet, with significant local variation. The aquifer consists primarily of sandstones in three formations: the Wonewoc Formation (top), Eau Claire Formation (middle), and Mount Simon Sandstone (bottom).

The Dresbach aquifer has generally been used as a water source only in northeastern and east central counties adjacent to the Mississippi River. In this area the aquifer has proven to be productive. Extreme depth, low yield, and poor water quality limit use of the Dresbach aquifer in other parts of the state.

Hydraulics - Water moves through the aquifer away from recharge areas outside the state. Discharge of water into the Mississippi River is likely, based on water levels in the area.

Yields of 500 gpm are common in far eastern counties. Even higher capacity wells have been developed in the aquifer in Dubuque, Clinton, and Maquoketa, where yields of 2,000 gpm are documented. Attempts to develop Dresbach wells in other parts of the state have met with little success. Yields of less than 50 gpm and water which was highly mineralized made successful development unlikely.

Water Quality - Acceptability of water from the Dresbach aquifer most often depends on its dissolved solids concentration. In the far northeastern counties, adjacent to the Mississippi River, water is suitable for most domestic use, with total dissolved solids concentrations of less than 500 milligrams per liter (mg/L). Concentrations increase to the south and west. Radium is also a consideration in some areas of use.

The Cambrian-Ordovician Aquifer (Including the Jordan Sandstone)

Physical Characteristics - The Cambrian-Ordovician aquifer covers more than 90 percent of the state, with the only exception being the extreme northwestern counties. Figure 1B shows the aquifer's extent in Iowa. A separate aquifer, known simply as the Ordovician aquifer, lies above the Cambrian-Ordovician aquifer and is used by some supplies in northeast Iowa. Its use is not, however, widespread, therefore, detailed information has not been provided about the aquifer. The Cambrian-Ordovician aquifer outcrops in the northeastern tip of the state and lies more than 3,000 feet below the surface in southwest Iowa. Depths range from 1,000 to 1,500 feet in the northern and northeastern counties to 2,500 to 3,000 feet in the central and south-central counties. The average thickness of the aquifer is from 400 to 500 feet. The aquifer consists of three water-bearing zones: the St. Peter Sandstone, the Prairie du Chien Group and the Jordan Sandstone (see Table 1).

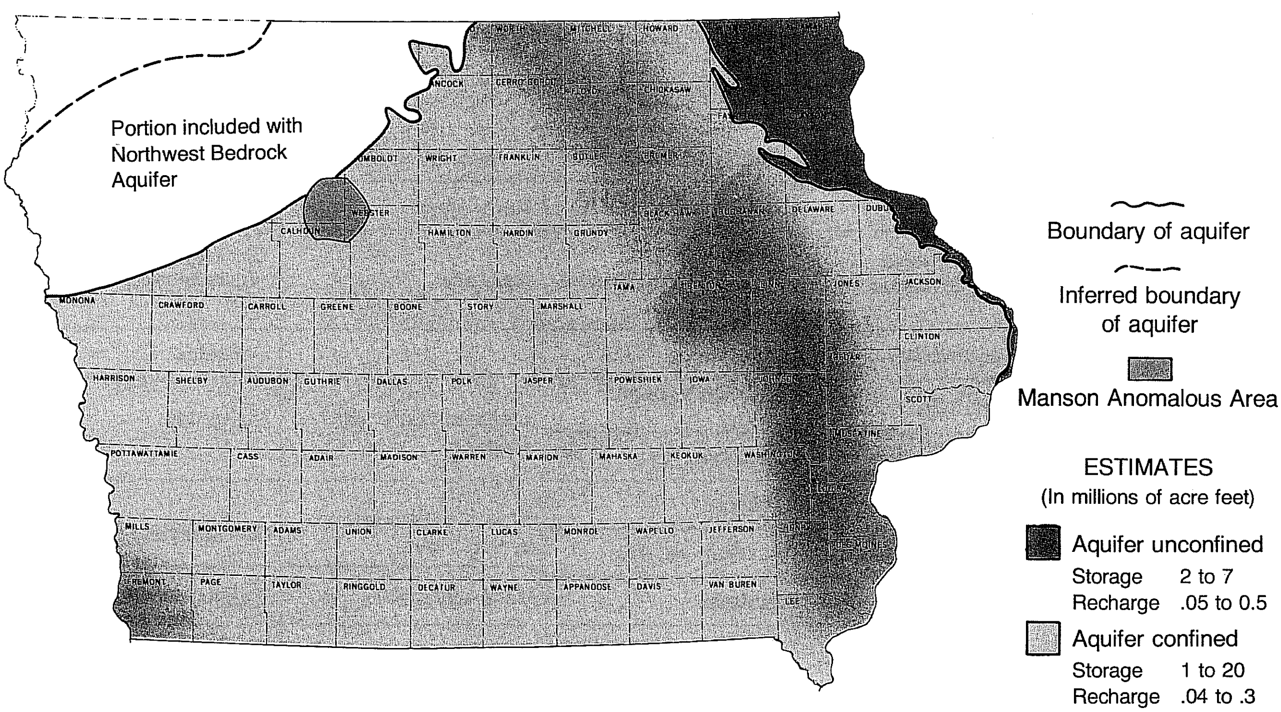


Figure 1B: The Cambrian-Ordovician Aquifer System

Table 1 - Geologic and Hydrogeologic Units in Iowa

AGE		ROCK UNIT	DESCRIPTION	HYDROGEOLOGIC UNIT	WATER-BEARING CHARACTERISTICS
Cenozoic	Quarternary	Alluvium	Sand, gravel, silt and clay	Surficial aquifer	Fair to large yields
		Glacial drift (undifferentiated)	Predominantly till containing scattered irregular bodies of sand and gravel		Low yields
		Buried channel deposits	Sand, gravel, silt and clay		Small to large yields
Mesozoic	Cretaceous	Carlile Formation Granerous Formation	Shale	Aquiclude	Does not yield water
		Dakota Group	Sandstone and shale	Dakota aquifer	High to fair yields
	Jurassic	Fort Dodge Beds	Gypsum, shale	Aquitard	Does not yield water
Paleozoic	Pennsylvanian	Virgil Series Missouri Series	Shale and limestone	Aquiclude	Low yields only from limestone and sandstone
		Des Moines Series	Shale; sandstones, mostly thin		
	Mississippian	Meramec Series	Limestone, sandy	Mississippian aquifer	Fair to low yields
		Osage Series	Limestone and dolomite cherty		
		Kinderhook Series	Limestone, oolitic, and dolomite, cherty		
	Devonian	Maple Mill Shale Sheffield Formation Lime Creek Formation	Shale; limestone in lower part	Devonian aquiclude	Does not yield water
		Cedar Valley Limestone Wapsipinicon Formation	Limestone and dolomite; contains evaporites in southern half of Iowa	Silurian-Devonian aquifer	High to fair yields
	Silurian	Niagaran Series Alexandrian Series	Dolomite, locally cherty		
	Ordovician	Maquoketa Formation	Shale and dolomite	Maquoketa aquiclude	Does not yield water, except locally in NE Iowa
		Galena Formation	Limestone and dolomite	Minor aquifer	Low yields
		Decorah Formation Platteville Formation	Limestone and thin shales; includes sandstone in SE Iowa	Aquiclude	Generally does not yield water; fair yields locally in SE Iowa
		St. Peter Sandstone	Sandstone		Fair yields
		Prairie du Chien Formation	Dolomite, sandy and cherty	Cambrian-Ordovician aquifer	High yields
	Cambrian	Jordan Sandstone	Sandstone		
		St. Lawrence Formation	Dolomite	Aquiclude (wedges out in NW Iowa)	Does not yield water
		Franconia Sandstone	Sandstone and shale		
		Dresbach Group	Sandstone	Dresbach aquifer	High to low yields
Precambrian		Sioux Quartzite	Quartzite	Base of groundwater reservoir	Not known to yield water except at center of Manson impact area
		Undifferentiated	Coarse sandstones; crystalline rocks		

The sandstones of the St. Peter Formation are very poorly cemented and tend to cave in, filling portions of the well with sand. For this reason, the St. Peter Formation is often cased-off or not used, and not allowed to contribute water to Cambrian-Ordovician wells.

There are a number of units in the Prairie du Chien Group. The two which contibute water to wells which tap the Cambrian-Ordovician aquifer are the Oneota Dolomite and Root Valley (New Richmond) Sandstone members. The Oneota is a drab-gray- to buff-colored dolomite that is locally cavernous and highly fractured. Its maximum thickness is about 235 feet. The Root Valley (New Richmond) consists of white- to buff-colored, fine- to medium-grained, quartz sandstone. It is loosely cemented in northern Iowa, becoming more tightly cemented to the south. It is as thick as 110 feet.

The Jordan Sandstone is the principal water-producing unit in the aquifer. It is a white- to buff-colored, fine- to coarse-grained, quartz sandstone that is loosely to moderately cemented. The thickness of the formation ranges from a maximum of about 145 feet in northeastern Iowa to about 30 feet in central and southwestern Iowa.

The Cambrian-Ordovician aquifer is used extensively as a water source by municipalities and industries in eastern Iowa. Many communities in central and southern Iowa also obtain their water supplies from the Cambrian-Ordovician aquifer, because in that region of the state the aquifers lying above the Cambrian-Ordovician either have low water yields or produce poor quality water.

Hydraulics - Water enters the Cambrian-Ordovician aquifer primarily through vertical leakage from overlying rocks in northwest, central and eastern Iowa. Water also enters through infiltration in areas where the aquifer is the uppermost bedrock unit. Water passes only through soil before it enters the aquifer in the northern most part of the recharge area but must pass through layers of sandstones, shales, and carbonate rocks in the rest of the recharge area. From the recharge area, the water moves by subsurface flow toward Illinois and Missouri. Water actually discharges from the aquifer into the Mississippi River and parts of the Illinois Basin.

Jordan wells are one of the most dependable groundwater sources for large capacity wells in Iowa. Generally, yields from these wells range from several hundred to 1,000 gpm, and occasionally 2,000 gpm in the southeastern part of the state. To some extent the variation in yield depends on the amount of cementation of the sandstones and the presence or absence of fractures in the dolomites.

Proper well construction and development are important in obtaining maximum yields from wells tapping the Jordan aquifer. The most successful wells usually have a bottom hole diameter of at least eight inches, and are cased from the surface into the upper part of the Prairie du Chien Group, with the full length of pipe grouted.

Water Quality - The best quality water in the Cambrian-Ordovician aquifer occurs in northeast Iowa, near the recharge area, where the concentration of dissolved solids is less than 500 mg/L. The mineral content of the water increases significantly southwest of a line running from Winnebago to Clinton Counties. Water that is classified as good-to-fair quality, with dissolved-solids concentrations of 500 to 1500 mg/L, is found in a broad belt through the central and southeastern parts of the state. In addition to high dissolved solids, the sodium and chloride concentrations increase significantly as the water approaches the southern and southeastern borders of the state. West and southwest of this central belt, the water generally is so highly mineralized as to be a poor-to-objectionable source for most uses.

Iron concentrations in water from Jordan wells vary considerably from 0.0 to 5.6 mg/L, with a mean value of 1.08 mg/L. Manganese concentrations range from 0.0 to 0.36 mg/L, with a mean value of 0.02 mg/L. Hydrogen sulfide exists in objectionable quantities in some areas, and the concentration of radium has an important bearing on the general acceptance of Jordan water supplies. Lower radium values generally occur in northeast Iowa, while higher values are found in central and western Iowa.

Nitrate concentrations in water from the Jordan wells throughout the state are very low. The concentrations range from 0.0 to 5.5 mg/L, with a mean value of 1.4 mg/L. Higher concentrations may occur in northeastern Iowa where the Jordan aquifer is close to the surface, thus subject to contamination from surface sources. The Allamakee, Clayton, and Winneshiek County areas, where the aquifer is the shallowest, are susceptible not only to nitrate contamination, but also to bacterial pollution from surface water infiltration.

Only a few Jordan supplies are not treated in some way. The majority of the Jordan well water supplies used for municipal purposes require treatment for iron removal. A typical treatment system consists of aeration, filtration, and disinfection, in that order. Seventy-five to 80 percent of all municipal Jordan wells are treated in this fashion. A relatively small number of supplies are also softened as a part of their treatment process. Most of the softened supplies are located in the southeast quarter of the state. Fluoridation is included in several treatment systems in the northern part of the state, where the natural fluoride concentration of the Jordan water is less than 1.0 mg/L. About 25 percent of the Jordan municipal supplies add polyphosphate or alkali chemicals to the water for stabilization, to adjust the pH, for corrosion control, and to hold iron in solution. A few communities aerate the water to remove hydrogen sulfide odor.

The Silurian-Devonian Aquifer

Physical Characteristics - The Silurian-Devonian aquifer underlies approximately 90 percent of the state, except for the northeast and northwest corners. Figure 1C shows the boundaries of the Silurian-Devonian aquifer in Iowa. The depth to the top of the aquifer ranges from 0 to 400 feet in the outcrop area, where it is the uppermost rock unit, but it is usually between 50 and 250 feet deep. In the subcrop area, where the aquifer underlies other rock units, several hundred feet of drilling may be required before the aquifer is reached.

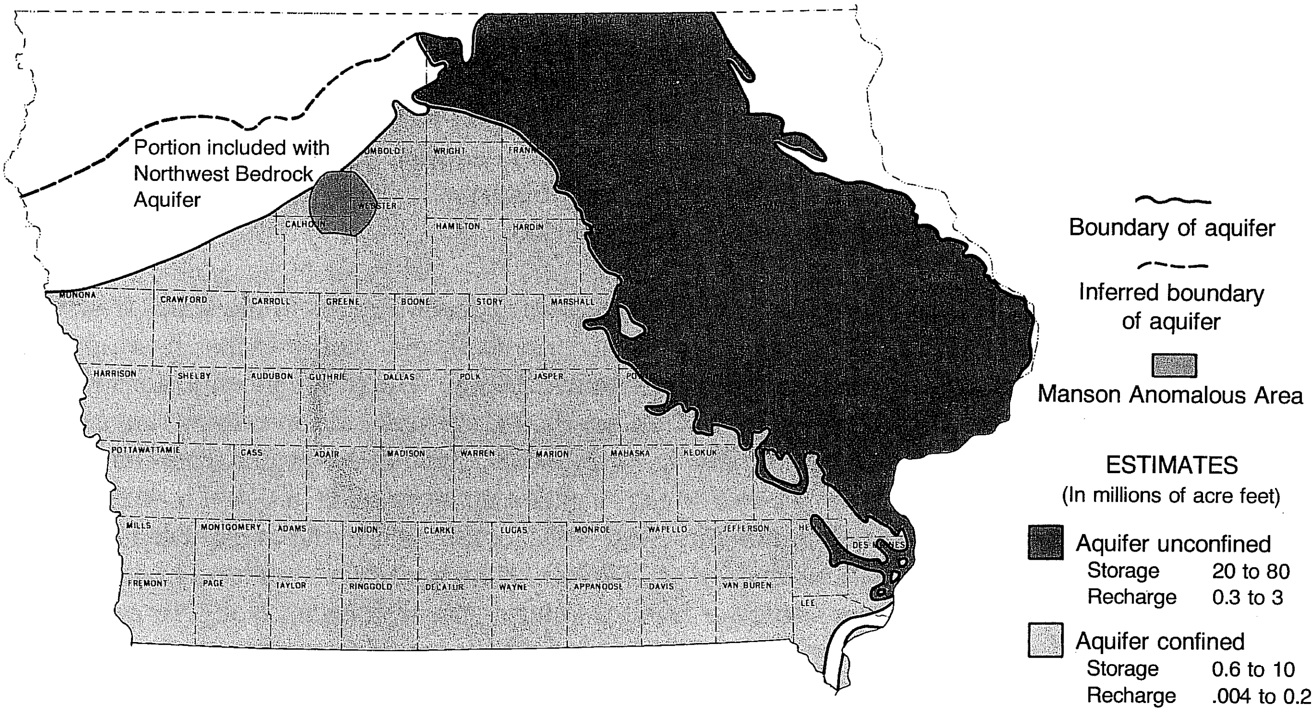


Figure 1C: The Silurian-Devonian Aquifer System

The aquifer is thickest in the southwest quarter of the state where it is generally 500 to 600 feet thick, reaching a maximum of 700 feet. Over most of eastern and northern Iowa, the Silurian-Devonian aquifer averages between 200 and 400 feet in thickness. However, because of surface erosion, the thickness of the aquifer in the outcrop area often is less than the average.

The Silurian-Devonian aquifer consists of a succession of thick carbonate rocks of Devonian and Silurian age. Dense limestones and dolomites, with significant secondary porosity (fractures, joints, bedding planes, and solution cavities), are the principal rock types. Locally, shales and clays fill large cavities in Silurian carbonates. Table 1 shows where these rock layers lie in relation to the other bedrock aquifers.

More than 15 percent of the municipal and rural populations of the state are supplied by wells tapping the Silurian-Devonian aquifer. The aquifer is used as a water source primarily in northeast and eastern Iowa where it lies beneath glacial drift only. The aquifer is also used to some extent in northwestern Iowa, where it is overlain by Cretaceous strata. In central and southern Iowa, the aquifer is highly mineralized. For this reason, the Silurian-Devonian aquifer is not used a great deal in central and southern Iowa. In western and southwestern Iowa, the aquifer is deeply buried beneath younger rocks and is not often utilized.

Hydraulics - Recharge to the Silurian-Devonian aquifer is directly in the outcrop area in the northeastern part of the state. Recharge is rapid in this area because the soil and glacial drift is less than 25 to 50 feet thick in many places, and highly porous. In the subcrop area of the aquifer, recharge occurs at a much slower rate.

The Silurian-Devonian aquifer is most productive in the outcrop area in northeastern Iowa, because the rocks near the surface have more fractures and solution-bearing cavities. The highest-capacity wells are usually found in or near river valleys, because the limestone and dolomite have dissolved to a greater extent in these areas, giving the aquifer greater water transmissivity and storage capacity. A number of municipal and industrial wells in northeastern and eastern Iowa obtain between 150 to 400 gpm from the Silurian-Devonian aquifer. A narrow strip along the Cedar River valley from Charles City to Waterloo is very cavernous. Yields in excess of 4,000 gpm have been recorded from wells at Cedar Falls and Waterloo.

Water Quality - Iron commonly occurs in troublesome concentrations in the water from the Silurian-Devonian aquifer. In fact, in most places it is practically mandatory to install equipment for iron removal or to stabilize the water to hold iron in solution. The iron concentrations range from 0.0 to 31.0 mg/L, with a mean value of 1.54 mg/L. Manganese concentrations range from 0.0 to 2.5 mg/L with a mean value of 0.9 mg/L. Nitrate concentrations in water from the Silurian-Devonian aquifer range from 0.0 to 300 mg/L with a mean value of 6.6 mg/L. Wells less than 50 feet deep show the most contamination, but wells located where the overburden is thin will show high nitrate concentrations as deep as 150 feet. If high nitrates are found in deeper wells it may imply that water from shallower levels is entering the well because of poor construction or corroded casing. Chloride concentrations in water from the Silurian-Devonian aquifer range from about 0.5 to 100 mg/L in the northern half of the state and from about 100 to 1000 + mg/L in the southern half. The dividing lines run roughly from Louisa to Polk to Pottawattamie Counties.

In central and southern Iowa, the aquifer contains a high concentration of sulfate ions. For this reason the Silurian-Devonian aquifer is not used a great deal in those regions. Total dissolved solids range between 2,000 and 5,000 mg/L in the subcrop area of the Silurian-Devonian aquifer, which is poor quality for most domestic purposes. Fluoride concentrations in the Silurian-Devonian aquifer range from 0.1 to 5.0 mg/L. The higher concentrations occur in most of the southwestern, southern and southeastern parts of the state. Water hardness levels in the Silurian-Devonian aquifer run from 200 mg/L to more than 2,000 mg/L, with values between 300 and 400mg/L common in the outcrop area in north-central, northeastern and east-central Iowa.

Where unconsolidated materials, less than 25 to 50 feet thick, overly the Silurian-Devonian (and all northeast Iowa aquifers), and where concentrations of sinkholes occur, groundwater may be severely polluted by nitrate. The upper bedrock in these areas is highly susceptible to pollution from farmland infiltration, or infiltration from point sources of pollution such as manure piles, barnyards, septic tanks, and refuse dumps.

The most frequently used methods of treatment for supplies developed from the Silurian-Devonian aquifer are disinfection by gas chlorination or hypo-chlorination, and iron and manganese removal by aeration and filtration. In addition, a few supplies are softened, however, the aquifer is not used extensively in areas where hardness exceeds 500 mg/L.

The Mississippian Aquifer

Physical Characteristics - The Mississippian aquifer underlies about 60 percent of the state, but it serves as a major drinking water supply in only about 15 percent of its total area. Figure 1D shows the limits of the Mississippian aquifer in Iowa.

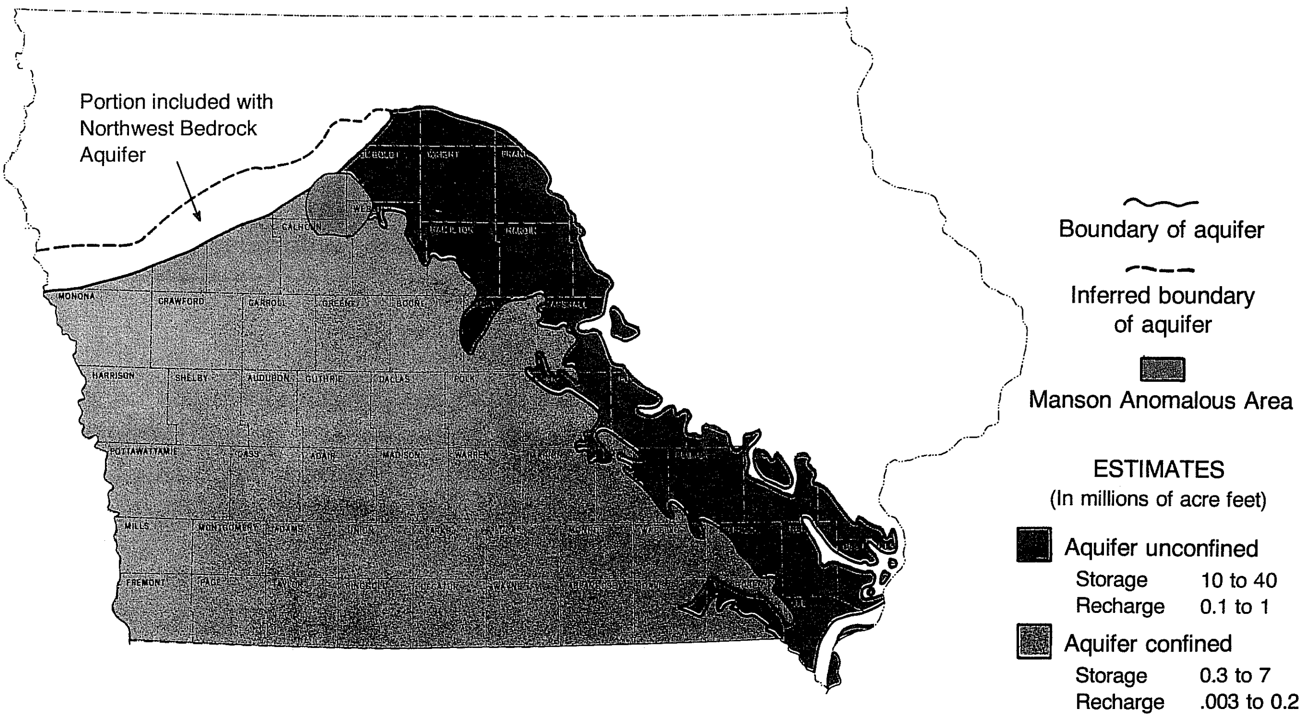


Figure 1D: The Mississippian Aquifer System

The depth of the Mississippian aquifer varies from 50 to 100 feet in north central regions of the state, to more than 500 feet in the southwestern quarter of the state. The maximum thickness of the aquifer is about 600 feet; however, in the outcrop area, the thickness generally ranges from less than 100 feet up to about 300 feet.

The Mississippian aquifer, consists principally of limestone and dolomite strata that are grouped into three mappable units: the Kinderhookian, Osagean, and Meramecian Series. The Kinderhookian strata are chiefly limestone and cherty dolomite, with some siltstone. In north-central Iowa, the series is characterized by carbonate beds which become more shallow to the south and southeast. The Osagean strata are chiefly dolomite and limestone with an abundance of chert; however, the only shale (Warsaw Shale) as an important aquiclide in Mississippian rocks occurs in this unit in southeastern Iowa. The Meramecian rocks are mainly sandy limestone and sandstone with some dense dolomite beds near the base, and shale locally near the top. This unit in south-central Iowa contains beds of gypsum and anhydrite at its base.

The principal area of development of the Mississippian aquifer is located in central and southeastern Iowa. This area comprises all or parts of 10 counties in the north-central part of the Mississippian outcrop belt, where the aquifer yields moderate to large supplies of good- to excellent-quality water. In this area, the aquifer is overlain by glacial deposits.

Hydraulics - Recharge to the aquifer is in the outcrop area and by seepage of water from the northwest. The water moves through the aquifer, which is confined by overlying and underlying confining beds, in a southerly and southeasterly direction. Some water moves into Missouri as underflow, but the Des Moines River is the principal discharge area for the aquifer. Other important discharge areas are the valleys of the Skunk, North Skunk, and South Skunk Rivers.

Water is stored principally in secondary openings in the predominantly carbonate-type rocks of the Mississippian aquifer. These openings occur randomly and vary in size and extent. Water is also stored in rock units that have primary porosity, such as the St. Louis Sandstone in the Meramecian Series. The storage and transmission characteristics of the Mississippian aquifer are variable from place to place.

Artesian conditions predominate in the Mississippian aquifer, even in the outcrop area where the aquifer is confined by glacial till. However, in many localities in the outcrop area, the artesian pressure is quickly depleted in the vicinity of pumping wells. Under these conditions, the aquifer is being dewatered.

In the subcrop area, specific capacities generally are much less than one gpm per foot of drawdown. However, because more room for drawdown generally is available in the deeper wells penetrating the aquifer in the subcrop area, yields of as much as 50 gpm may be obtained. Water yields from the aquifer are variable and range from more than 500 gpm in Wright, Hardin, and Story Counties to only a few gallons per minute in southeastern Iowa.

Water Quality - Chloride content generally is less than 20 mg/L in the outcrop area of the aquifer and, generally, less than 80 mg/L elsewhere. Higher concentrations occur locally in southern Iowa. These high concentrations are always associated with very high sodium concentrations, but not all water with high sodium content has a high chloride content. Nitrate content generally is less than 5 mg/L. Water with an unusually high concentration of nitrate is a good indication that the well is polluted. Iron and manganese concentrations vary considerably. Both constituents, however, are readily removed by treatment.

Water from the aquifer, with few exceptions, is extremely hard. The exceptions occur in a small area through central Iowa. High concentrations of fluoride are usually associated with the low-hardness water.

The Dakota Aquifer

Physical Characteristics - The Dakota aquifer of northwestern Iowa covers approximately 20 percent of the state. It is the chief bedrock aquifer in northwestern Iowa, and is occasionally used in western and southwestern Iowa, as well. Figure 1E shows the area of the Dakota aquifer. Depth to the top of the aquifer varies considerably, because its surface was weathered before the overlying materials were deposited. In the northwestern counties, the top of the aquifer can be as deep as 600 feet, while in other areas it may only be necessary to drill between 50 and 200 feet to reach the aquifer. The thickness of the aquifer varies from less than 50 feet to more than 200 feet, with an average thickness of about 75 feet.

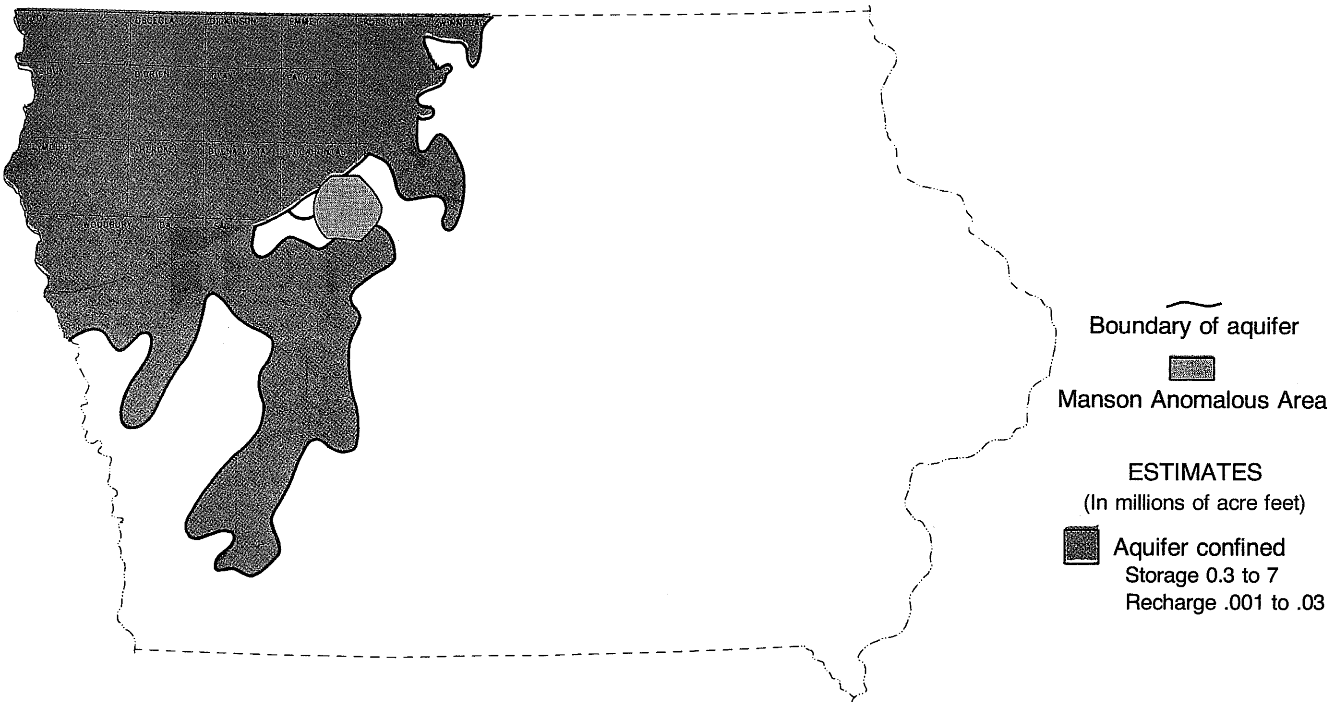


Figure 1E: The Dakota Aquifer System (Northwest Bedrock Aquifer System)

The aquifer is made up of many layers, most of which are Dakota sandstones. The sandstone which forms the Dakota aquifer is generally fine-grained and poorly cemented. These characteristics can result in problems if proper well construction and aquifer development techniques are not used.

Hydraulics - The Dakota, a confined aquifer, is recharged primarily in southwestern Minnesota and northwestern Iowa. Water tends to move from the northwest and north-central part of the aquifer to the southwest, south, and east. Water discharges from the aquifer into the Big Sioux and the Missouri Rivers, interior rivers and streams, and other geologic units.

The Dakota aquifer provides water for rural and municipal needs in northwestern Iowa. In Sioux City, yields of more than 1,500 gallons per minute have been obtained. Some municipal wells in the Dakota aquifer in O'Brien and Cherokee Counties have been shown to produce from 350 to 750 gpm. Even where the aquifer is only moderately thick, many wells have been developed that yield 50 to 100 gallons of water per minute.

Water Quality - The quality of water in the Dakota aquifer varies somewhat depending on location. Dissolved-solids concentrations vary from less than 500 to more than 2,000 mg/L. Sulfate concentrations, which are less than 250 mg/L over much of the area, exceed 1,000 mg/L in some areas. Concentrations of dissolved solids and sulfate both seem to be elevated in areas where the aquifer is recharged.

Appendix Two

Choosing a Method of Delineation

Several methods for delineation of wellhead protection areas (WHPAs) are commonly used. Again, the intent is to choose the method which offers each community the degree of accuracy desired in determining the area which must be monitored for potential threats to the water supply. The most common methods can be grouped into three general categories including the fixed radius method, the analytical equations method, and numerical flow and transport modeling. A brief description of each is included in this appendix.

When going beyond a simple fixed radius approach, selection of a delineation method is based on factors such as radius of influence around a well, depth of drawdown by a well at a given point, the time of travel of contaminants in various hydrologic conditions, and distance from the well. EPA has established these factors as "criteria" because they can represent the conceptual standards that form the technical basis for WHPA delineation. Four common types of criteria are identified: distance, drawdown, time of travel, and flow boundaries. In using these criteria for WHPA delineation, a threshold value or set of values must be selected to represent the limits above or below which a given criterion will cease to provide the desired degree of protection. These values are referred to as "criteria thresholds." In general, EPA has indicated protection from chemical threats is usually covered over the following criteria threshold ranges:

Distance:	less than 500 feet to more than 2 miles
Drawdown:	0.1 to 1.0 foot
Time of travel:	Tens of days to years (typically years)
Flow boundaries:	Physical and hydrologic

The selection of a method and criterion, or combination of criteria, will likely depend upon a blending of technical and non-technical (administrative, policy, etc.) considerations. The method used will also depend on budget, availability of data, required precision, and time available for implementation. Ultimately, the approach which satisfies your community's overall protection goal for the WHPA should be chosen.

Fixed Radius Method

The fixed radius method is used to delineate a circular area of specific size for use as a WHPA (See Figure 2A). The size can be based on arbitrary guidelines or generalized hydrogeologic conditions.

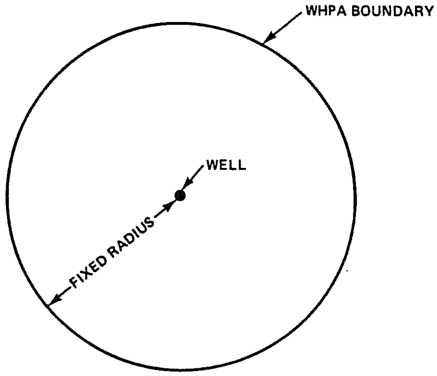


Figure 2A: Wellhead Protection Area Delineation Using the Fixed Radius Method

Arbitrary or non-hydrogeologic guidelines such as regulatory statute are often used in the fixed radius method. This is currently the case in Iowa, where the Iowa Administrative Code requires that all public wells have a minimum lifetime protected zone extending 200 feet from the well. This requirement is meant to restrict activities and potential sources of pollution in the vicinity of the well. In addition, the Code addresses groundwater vulnerability as a function of distance to potential contamination sources, and provides minimum lateral setback distances from selected sources of contamination (e.g., landfills, lagoons, etc.), as shown below. Though partially effective in some cases, it is important to understand that an arbitrary selection of a distance can be inaccurate and, unless very large, can fail to protect recharge areas.

Sources of Contamination	Shallow Wells as Defined in 567--40.2(455B)	Deep Wells as Defined in 567--40.2(455B)
Wellhouse floor drains (point discharges)	5 ft.	5 ft.
Water treatment plant wastes (point discharges)	50 ft.	50 ft.
Sanitary and industrial point discharges	400 ft.	400 ft.
Wellhouse floor drains to surface	5, 10, 25 or 75 ft. depending on pipe materials	5, 10, 25 or 75 ft. depending on pipe materials
Wellhouse floor drains to sewers	25, 75 or 200 ft. depending on pipe materials	25, 75 or 200 ft. depending on pipe materials
Water plant wastes	25, 75 or 200 ft. depending on pipe materials	25, 75 or 200 ft. depending on pipe materials
Sanitary and storm sewers, drains	25, 75 or 200 ft. depending on pipe materials	25, 75 or 200 ft. depending on pipe materials
Sewer force mains	75 or 400 ft. depending on pipe materials	75 or 400 ft. depending on pipe materials
Land application of solid wastes	200 ft.	100 ft.
Irrigation of wastewater	200 ft.	100 ft.
Concrete vaults and septic tanks	200 ft.	100 ft.
Mechanical wastewater treatment plants	400 ft.	200 ft.
Cesspools and earth pit privies	400 ft.	200 ft.
Soil absorption fields	400 ft.	200 ft.
Chemical application to ground surface	200 ft.	100 ft.
Lagoons	1,000 ft.	400 ft.
Chemical and mineral storage (above ground)	200 ft.	100 ft.
Chemical and mineral storage including underground storage tanks on or below ground	400 ft.	200 ft.
Animal pasturage	50 ft.	50 ft.
Animal enclosure	200 ft.	100 ft.
Animal wastes - land application of solids	200 ft.	100 ft.
Animal wastes - land application of liquid/slurry	200 ft.	100 ft.
Animal wastes - storage tank	200 ft.	100 ft.
Animal wastes - solids stockpile	400 ft.	200 ft.
Animal wastes - storage basin or lagoon	1,000 ft.	400 ft.
Earthen silage trench or pit	200 ft.	100 ft.
Basements, pits, sumps	10 ft.	10 ft.
Flowing streams/other surface water bodies	50 ft.	50 ft.
Cisterns	100 ft.	50 ft.
Cemeteries	200 ft.	200 ft.
Private wells	400 ft.	200 ft.
Solid waste disposal site	1,000 ft.	1,000 ft.

Generalized hydrogeologic information can be used to improve upon the accuracy of an arbitrary fixed radius. This information can be used to approximate the cone of depression or time of travel distance for a specific well. A cone of depression is the depression of water level elevation around a pumping well caused by withdrawal of water, as shown in Figure 2B. The time of travel distance is the distance which water moves through the aquifer in a given amount of time, say five years. Because water typically moves slowly to a well, the area of influence of a well can be expressed in terms of time. Calculating this time of travel zone is often the basis for defining a WHPA. Extrapolated hydrogeologic data can be used to estimate the diameter of the cone of depression or the distance water will travel in a given amount of time. Either of these estimates can then be used to establish a somewhat more accurate fixed radius. This radius then would be applied to all wells in the area, without further consideration of site-specific conditions. This is termed the calculated fixed radius. Because hydrogeologic conditions may vary drastically over short distances (e.g., aquifer thickness, hydraulic conductivity, flow boundaries), this method also is not very accurate, though it is slightly better than an arbitrary fixed radius.

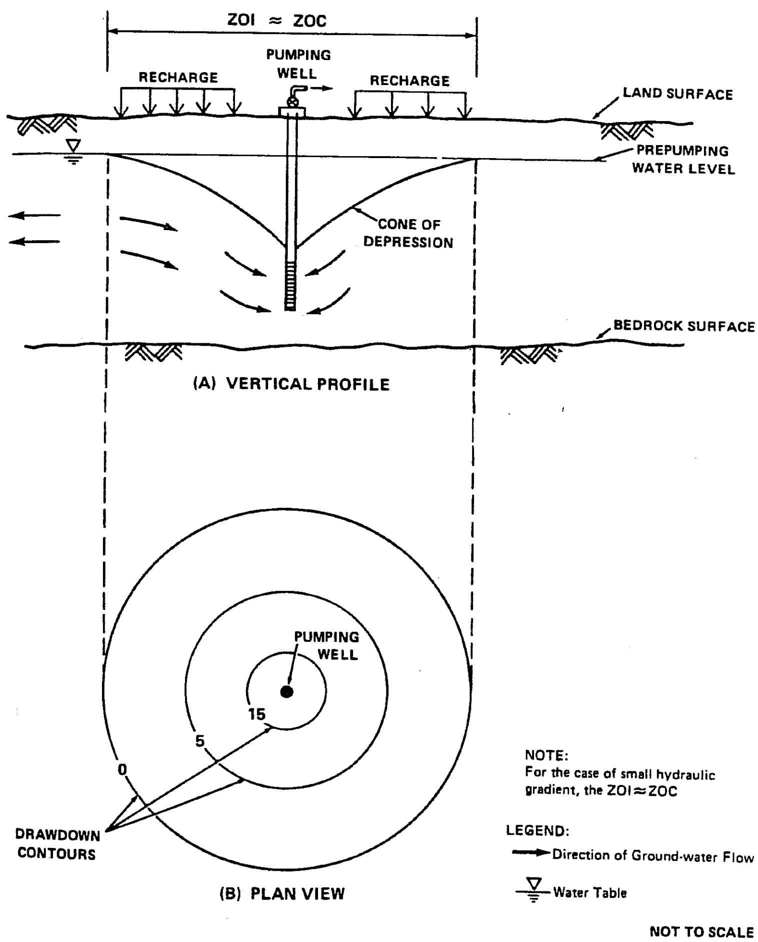


Figure 2B: Schematic of an Unconfined Aquifer Showing Drawdown (Cone of Depression) and an Evenly Distributed Recharge Area

The advantages of the fixed radius techniques are that they are relatively easy and inexpensive to apply. Fixed radius can be effective if large distances (say greater than two miles) are selected, thereby overcoming the lack of hydrogeologic precision. The primary disadvantages are that the methods may over- or under-protect recharge areas, and there is a high degree of uncertainty making fixed radius delineation difficult to defend.

Analytical Equations Method

Analytical equations are used to delineate groundwater flow patterns near a pumping well. Based on the flow patterns, an appropriate WHPA can be established. The size and shape of the WHPA is dependent upon the pumping rate, the location of aquifer boundaries, and the characteristics of the aquifer itself.

The equations are used to define the cone of depression around a specific pumping well. As noted above, a cone of depression occurs when water levels in the vicinity of the well are lowered, causing water to move toward the well. The drop in water level, relative to its original position, is called drawdown. The distance from the well at which no drawdown occurs is equal to the radius of the cone of depression and may be used as an approximate lateral boundary for the WHPA (Figure 2B). The upgradient extent of the WHPA can then be calculated based on an appropriate time of travel or local flow boundary condition. This method provides a conservative estimate of the WHPA boundary since it assumes that contaminants will move at the same rate as the groundwater, and thus does not account for natural processes that may reduce the concentration of the contaminant as it moves through the subsurface.

The advantages of this method are that it is easily understood by persons familiar with basic hydrogeology concepts and the equations take into account site-specific hydrogeologic and operating conditions. When combined with time of travel, distance, and flow boundary considerations, the analytical equations method is the most cost-efficient and accurate method available to address site-specific needs. It is also the most widely applied method in establishing WHPAs. The main disadvantage is that the equations are based on simplifying assumptions that may or may not adequately represent complex site-specific conditions.

Numerical Flow and Transport Models

Numerical models are used to simulate groundwater flow and contaminant transport or movement. The results are then used to establish the WHPA. The models can accurately simulate flow and contaminant transport in highly complex hydrogeologic conditions. One model commonly used is the EPA semi-analytical groundwater flow model, referred to as WHPA, which is designed to assist in the delineation process.

Groundwater flow models can be developed to simulate drawdown, flow boundaries, recharge areas, and time of travel using input data such as hydraulic conductivity, porosity, specific yield, aquifer thickness, recharge rates, aquifer geometry, and hydrologic boundary conditions. Once the flow model is developed and calibrated, a contaminant transport model using contaminant-specific characteristics can be developed.

The advantages of numerical models are that they can be used to represent complex site-specific hydrogeologic conditions. In addition to predicting groundwater flow and contaminant transport, they can also be used to predict recharge rates and the impact of additional pumping wells. The disadvantage is that the models are expensive to develop due to the large amount of site-specific data needed and the time-consuming field calibration which is required.

Other Methods

The fixed radius, analytical equations, and numerical models are the most frequently applied methods in determining WHPAs. There are several other methods which are less frequently applied, but still appropriate, for use in defining a WHPA. They include the hydrogeologic mapping method, water budget approach, and variable shapes method. Any one of these may be a suitable application at a given site and each offers advantages and disadvantages. Often, one of these methods may be combined with the fixed radius or analytical equations methods to provide a better definition of the WHPA.

Examples of Delineation

Two delineation examples are presented below, one for each unconfined and confined aquifers. Two examples are provided because of the significant differences between recharge of confined verses unconfined aquifers. These examples provide steps to guide you through the delineation process using the calculated fixed radius method in conjunction with the time of travel and flow boundary criteria mentioned at the beginning of this appendix. Certain steps are straightforward, requiring minimal to no expertise; while other steps are more technical, possibly requiring outside assistance or experience-based professional judgment.

The basis of the calculated fixed radius method, using the time of travel criterion, is to determine the direction in which groundwater is moving through the aquifer and the rate at which it is moving. With this information, the distance groundwater will travel in a specified period of time can be estimated. These time of travel (TOT) distances can then be used to approximate a WHPA.

Other than an arbitrary fixed radius, this is the least complex of the delineation methods. The end product of this method is an area that can be considered the minimum workable WHPA.

The first two steps are common to both Options. Complete Steps 1 and 2 and then proceed with the delineation process by selecting Option A if your aquifer is unconfined, or Option B if your aquifer is confined.

STEP 1: Base Map

The best way to show the important aspects from the data collection phase is to generate a base map showing pertinent information such as well locations, physical boundaries, and hydrogeologic boundaries. For the base map, use a city map showing streets and major features or some other small-scale map. You may also want to use a 7½-minute USGS quadrangle map as a regional base map.

STEP 2: Well Inventory and Screening

Note which aquifer supplies your well or well field and whether it is unconfined or confined. Examine the available well records for all wells in the area and determine which wells penetrate this aquifer. If you have wells in different aquifers, you will have to assess each aquifer independently.

Compile a data record for each well penetrating the aquifer(s). Include the exact location, water level information, well construction details, water quality information, a notation as to the quality of the drillers log, etc. This survey can be conducted by municipal workers, service clubs, senior citizens, etc.

Very likely, all of this data will not be readily available and a search will be required. The search should include municipal files, contacts with contractors, consultants, and local well drillers, as well as a phone call or visit to the IDNR-GSB at (319) 335-1575 or USGS at (319) 337-4191, both located in Iowa City.

On the small scale city map, plot and label all identified wells which penetrate the aquifer, including all municipal and industrial wells and, as many domestic wells as possible. If you are addressing two or more aquifers, make a base map for each. Also plot the locations of all test borings which were drilled into your aquifer prior to installation of the municipal wells. For convenience, use a variety of symbols to show the information for each well (e.g., circles around water levels, boxes around pumping rates, etc.).

Plot the major wells (municipal, high pumpage industrial, irrigation, or other public wells) on the 7½-minute quadrangle map. This will give you a regional perspective with respect to well locations and physical (topography) and hydrologic boundaries (rivers, lakes, etc.). It is important to recognize that high pumpage wells may alter flow paths of the water.

Proceed to Option A if your aquifer is unconfined, or Option B if the aquifer is confined.

OPTION A: UNCONFINED AQUIFER

The recharge area of an unconfined surficial or shallow bedrock aquifer is usually located relatively close to the well or well field. Unconfined aquifers are sensitive to surface contamination because there is no confining layer to protect the aquifer. In unconfined aquifers, surface water tends to move relatively freely down to the water table throughout the recharge area (see Figure 2B). The recharge area is often the surface watershed basin, or the area from which precipitation runs toward the well.

In the unconfined aquifer case, a good starting point is to identify the area which drains towards the well. This watershed basin will be a rough approximation of the local groundwater flow divides. The time of travel criterion can then be used to refine the WHPA, as appropriate.

STEP 3: Physical Boundaries

Sketch the surface watershed boundary, as shown in Figure 2C, on the quadrangle base map. Use the topographic information as your guide. These boundaries will tend to follow ridges and waterways.

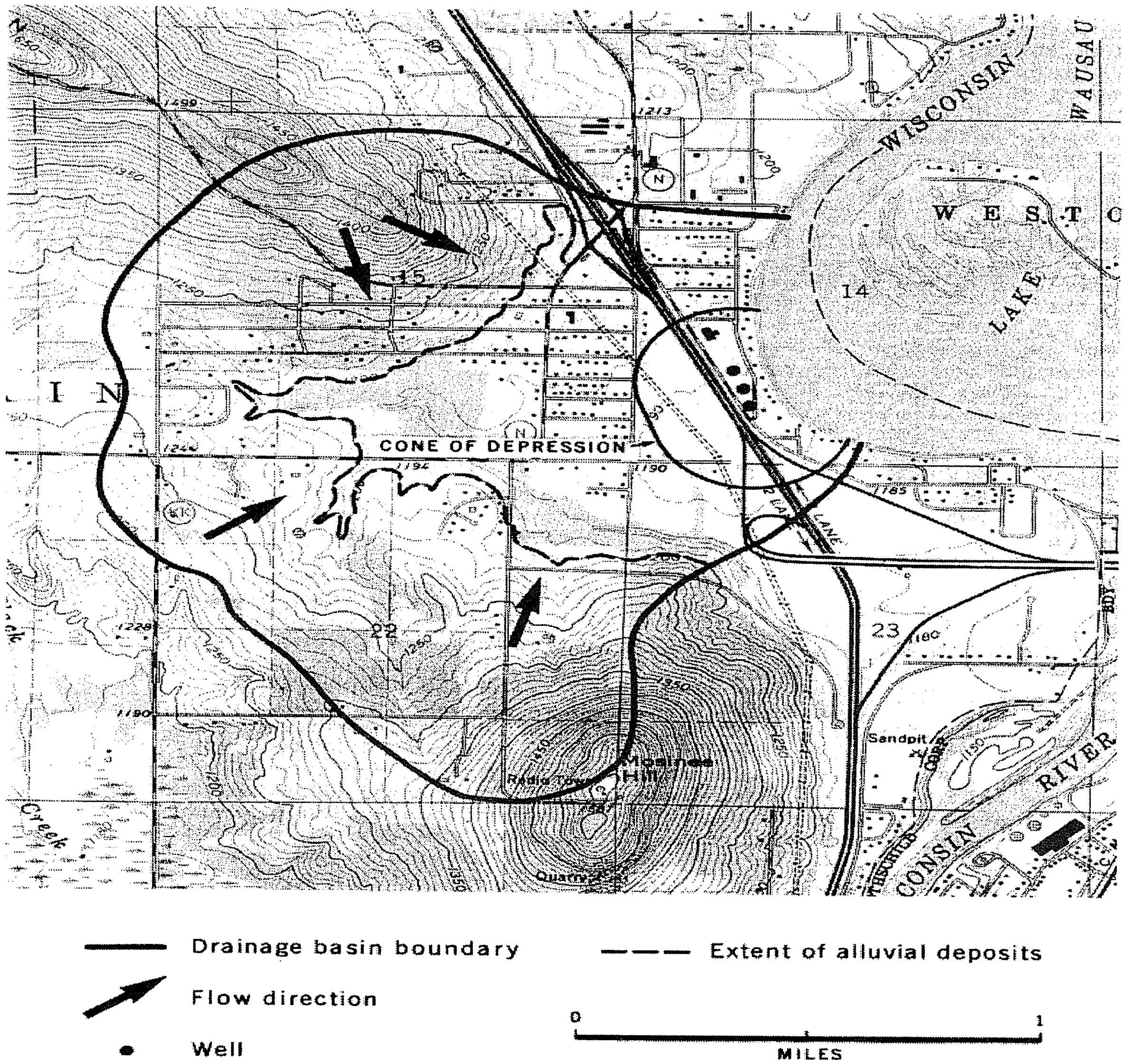


Figure 2C: Map illustrating drainage basin showing flow directions and cone of depression of a well field.

STEP 4: Hydrologic Boundaries

Make a note of the hydrologic boundaries on the base map. Hydrologic boundaries are features or conditions that form groundwater flow divides. In the same way that surface water flow does not cross a river or a topographic high point, groundwater flow does not cross a hydrologic boundary. Hydrologic boundaries often coincide with surface features such as rivers, major streams, lakes, or topographic ridges (since a groundwater divide will often be a subdued reflection of surface topography, the divide may generally correspond to the trend of an overlying topographic ridge). A hydrologic boundary may also be an area known to have lower than normal (or expected) production rates. This may be known through knowledge of a "poor" producing well.

STEP 5: Aquifer Vulnerability Map

The purpose of the vulnerability map is to assess how much natural protection an aquifer has, where it is or isn't protected, and its hydrologic properties. This map is generally useful when evaluating the unconfined surficial and shallow bedrock aquifers. Construct an aquifer sensitivity map. First, use the Iowa Groundwater Vulnerability Map (IDNR-GSB, 1991) as an overlay on the quadrangle map (or sketch it in since the two maps are different scales). This will provide a general idea of the hydrogeologic characteristics affecting the relative susceptibility of aquifers to contamination in your area. Note that the Iowa Groundwater Vulnerability Map is plotted at a scale suited for regional analysis and is not intended to address site-specific issues. However, it may be used as a general guide during site evaluations.

Site-specific detail can be added to the susceptibility map by incorporating information from the drillers' logs. This should be done with caution because the terminology used to describe drill cuttings are not always used in the same way by drillers. For example, a driller may use the term blue clay to describe glacial till. This implies the material has little water transmitting capability. In reality, the material may have significant sand content and transmit water readily. Another example is a driller may use the term "sandy clay," which in reality may be a fine sand with minor amounts of silt and clay. Again, the water transmitting capability is much greater than implied by "sandy clay."

STEP 6: Water Level Measurements

Measure the water levels in all the wells you have identified that are completed in your aquifer. Obtain the measurements, as depth to water from the ground surface, while the well is pumping, if possible. Convert the depth to elevation above mean sea level by subtracting the depth measurement from the ground elevation at the well. If the ground elevation is not available, estimate the elevation using the topographic contours on the quadrangle base map. Note the elevations on the small-scale base map near the well. Again, if you are dealing with two or more aquifers, collect readings from the wells that penetrate each aquifer and generate a map for each.

STEP 7: Water Level Surface Map

Using the elevations obtained in Step 6, draw lines of equal water level on the small-scale base map for each aquifer. To do this, pick an elevation which is even to the nearest 10 feet, say 660 feet. This contour line will pass outside points with a water elevation of less than 660 and inside all points with a water elevation of greater than 660. Draw additional contours for other elevations. Contours for lower elevations will lie inside contours for higher elevations in areas where there is a depression in the water surface. After the base map has been contoured, draw in some flow lines. These are drawn from relative high elevations toward lower elevations (i.e., point downgradient) and indicate the direction of groundwater flow (see Figure 2D). In the area of the pumping well, the flow lines will converge on the well. Flow lines always cross the water level contours at a right angle.

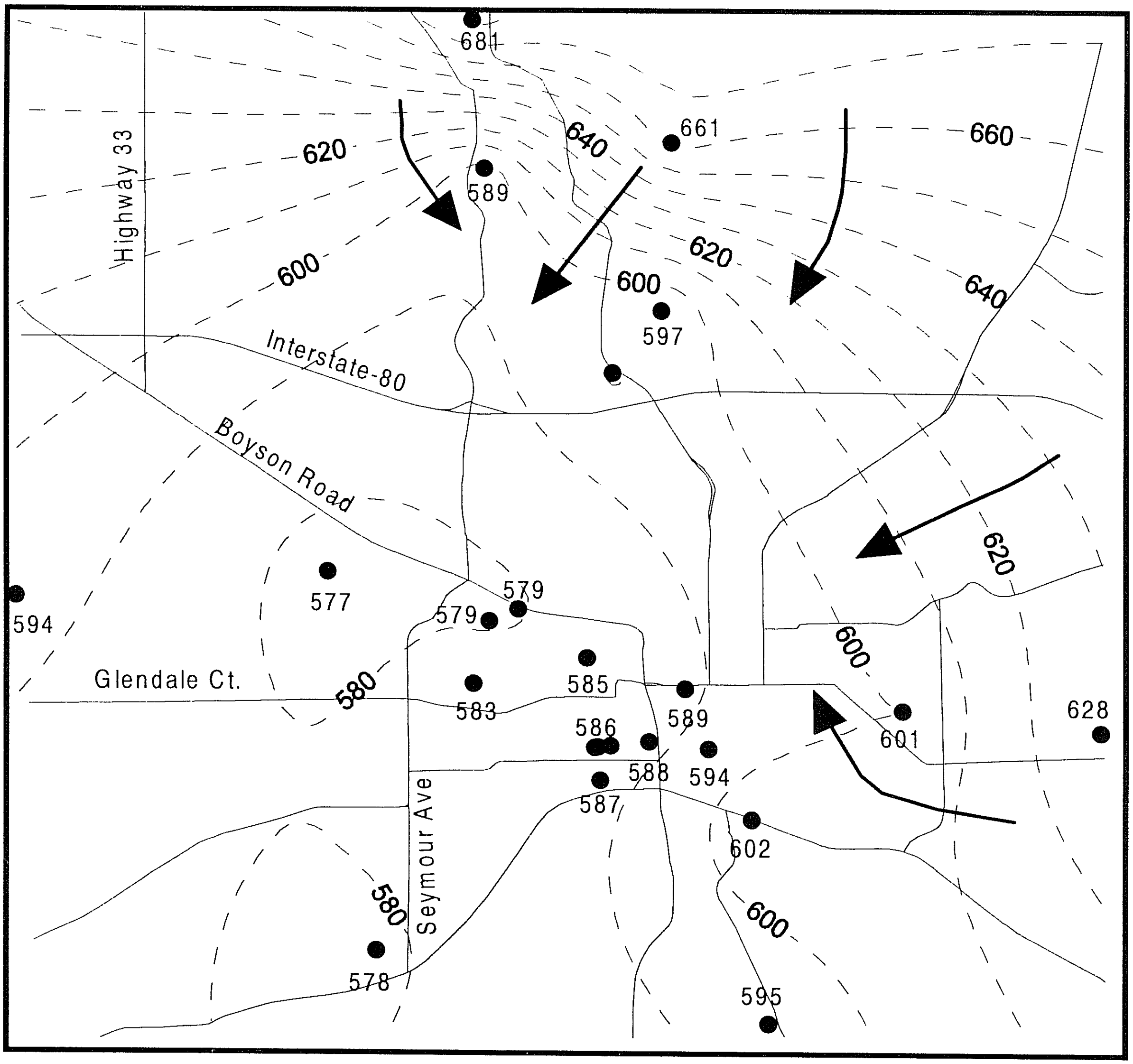


Figure 2D: Water Level Surface Map. Dashed lines follow points of equal water level elevation. The arrows represent groundwater flow paths which always cross the water level contours at a right angle.

STEP 8: Estimate Aquifer Parameters

Aquifer parameters describe how the aquifer functions. Some pertinent parameters are hydraulic head, hydraulic gradient, effective porosity, hydraulic conductivity, and average groundwater flow velocity. Estimate each of these parameters at your most important or representative well. Each parameter is described briefly below.

Hydraulic head, h

The hydraulic head (h) is equal to the water level elevation collected in Step 6.

Hydraulic gradient, i

Hydraulic gradient (i) is the slope on the water surface. It is equal to the change in water level elevation between two points, divided by the distance (d) between the two points. Using the water level surface map, draw a line at right angles to the contours. Measure the distance between two points on the line, in feet. Calculate the difference in water level elevation between the two points. Calculate the slope at a number of points and use the steepest result as this will be most conservative and provide the greatest degree of protection. The slope will be greatest where the contours are closest together.

The equation for hydraulic gradient is: $i = (h1 - h2) / d$

Effective porosity, η

Effective porosity is a measure of how interconnected the pores in an aquifer are. Groundwater flows through pores that are interconnected, and thus, it is the effective porosity that is important. Effective porosity can be estimated from the values provided below based on the well log descriptions, or through personal communication with the IDNR-GSB, the USGS, or local consultant.

Representative values of effective porosity are as follows:

Soil	0.40
Clay	0.02
Sand	0.22
Gravel	0.19
Limestone	0.18
Dolomite	0.18
Sandstone	0.06

Hydraulic conductivity, K

Hydraulic conductivity is a measure of how fast water can move through an aquifer. Hydraulic conductivity can be estimated from the values provided below based on the well log descriptions, or through personal communication with the IDNR-GSB, the USGS, or local consultant.

Representative values of hydraulic conductivity in units of gallons per day per square foot (GPD/sq ft):

Coarse sand	1500
Medium sand	1000
Mixed sand	500
Silty sand, fine sand	15
Sandy gravel	2000
Clean gravel	4000
Limestone	2000
Dolomite	2000

Average Groundwater Flow Velocity, v

Groundwater flows at rates typically ranging from a few feet per year to several feet per day. The average groundwater flow velocity (v) is calculated as follows:

$v = Ki / 7.48\eta$

where: v = average groundwater flow velocity (ft/day)

K = hydraulic conductivity (GPD/sq ft)

i = hydraulic gradient (unitless)

η = effective porosity (decimal fraction, unitless)

STEP 9: Estimate Time of Travel

Once average groundwater velocity has been calculated you can estimate how far groundwater will move toward a pumping well in a given amount of time. Calculate the distance groundwater will travel in 2 years, 5 years, and 10 years by multiplying the velocity in feet per day times the number of years times 365 days per year. These distances are referred to as time of travel (TOT) threshold values. Assuming that contaminants in the groundwater will move at the same rate as the groundwater, these distances will represent the boundary along which it is estimated that groundwater (and thus contaminants) will take about 2, 5, and 10 years to reach the pumping well(s) or well field.

The TOT threshold values suggested above are chosen to allow remedial measures and contingency plans to be implemented if a contaminant is released into the aquifer within the protected area. The TOT threshold values usually vary between 2 to 20 years, with the 2- 5- and 10-year or 5-, 10-, and 20-year threshold values typically selected. Selection of an appropriate TOT threshold value(s) depends upon site-specific hydrogeologic conditions, monitoring frequency, and administrative response or policy implementation time needed to initiate remedial action or contingency plans.

STEP 10: Delineate the Wellhead Protection Area

The calculated fixed radius can now be defined in terms of TOT and, if applicable, groundwater flow boundaries. First, establish the upgradient direction from the well or well field. Upgradient is the direction from which the groundwater is flowing toward the well.

Next, establish initial WHPA boundaries by using the hydrologic and physical boundaries noted earlier, where possible. This may include the entire surface watershed basin, perhaps bounded by a river along one portion and uplands everywhere else. It is reasonable to assume these boundaries generally coincide with groundwater flow divides and, as such, may represent an approximate WHPA.

Draw circles (to scale) around each municipal well with radii equal to the 2-, 5-, and 10-year TOT distances (or be conservative and use 5-, 10-, and 20-year values).

Compare the TOT boundaries with the watershed boundary. If the watershed boundary approximation is smaller than the 5- or 10-year TOT boundary, use the watershed boundary as your WHPA. If the watershed boundary is much greater than the 10-year TOT boundary, or if it is too large to practically manage, establish the WHPA based on TOT alone. Perhaps a combination of the watershed boundary (along the downgradient and sidegradient portions) and TOT along the upgradient portion would form the best WHPA.

For example, create three management zones, where Zone 1 might be the 200-foot radius required by state regulation, or the 2-year TOT threshold boundary. Select whichever is the greater distance. This zone is typically subject to the highest contaminant threat, and therefore, the land use restrictions are the most severe. Zone 2 might be defined by the 5- or 10-year TOT threshold boundary. This zone would also be subject to strict, though slightly less restrictive, land use controls than Zone 1; and to a high degree of management effort (monitoring, potential source identification, etc.). Zone 3 might be defined as the 10- 15- or 20- year threshold boundary, or the remainder of the upgradient recharge (susceptible) portion of the watershed basin, as determined from the drillers' logs and guidance from the aquifer sensitivity map created in Step 5. This may provide the time required for the contaminant concentrations to be naturally reduced in the aquifer before reaching the well, thereby reducing remedial costs and the need for very rapid response. Land use control here would be the least restrictive, though monitoring and exercise of some control is definitely warranted.

Be accurate and conservative in your delineations. It is better to slightly overprotect the aquifer than invest in wellhead protection planning and find out there is a problem that was overlooked or underestimated.

STEP 11: Recognition of Limitations

Other than an arbitrary selection of distance, the calculated fixed radius method is the simplest method used to determine WHPA. This method, used in conjunction with the time of travel and/or flow boundary criteria, incorporates a very limited amount of site-specific data to determine a WHPA. The delineation is specific to a given well, though the results are typically then applied to all wells in the area, without further consideration of site-specific hydrogeologic or operating conditions. This method may leave the aquifer unprotected in vital recharge zones and must be applied with caution.

OPTION B: CONFINED AQUIFER

It may be that the recharge area of an confined buried channel or, in particular, deep bedrock aquifer is located some distance from the well or well field. In this case, surface features generally do not provide acceptable WHPA boundaries and the susceptibility of the aquifer to contamination cannot be assessed by using the Iowa Groundwater Vulnerability Map.

Confined aquifers are, by definition, overlain by low-permeability confining units. They are typically less likely to be impacted by surface contamination than are unconfined surficial or shallow bedrock aquifers. However, no confining unit is totally impervious and all are subject to eventual downward leakage of contaminants, either by slow leakage, rapid movement through fractures, or introduction along man-made pathways such as existing wells. This is another reason it is important to identify all wells that penetrate the confined aquifer, as they potentially represent a pathway for contaminant migration into the aquifer. Thus a slightly different concept is used in defining the WHPA for confined aquifers. For confined aquifers, only the time of travel approach is recommended.

STEP 3: Water Level Measurements

Measure the water levels in all the wells you have identified that are completed in your aquifer. Obtain the measurements, as depth to water from the ground surface, while the well is pumping, if possible. Convert the depth to elevation above mean sea level by subtracting the depth to water measurement from the ground elevation at the well. If the ground elevation is not available, estimate the elevation using the topographic contours on the quadrangle base map. Note the elevations on the small-scale base map near the well. Again, if you are dealing with two or more aquifers, collect readings from the wells that penetrate each aquifer and generate a map for each.

STEP 4: Water Level Surface Map

Using the elevations obtained in Step 3, draw lines of equal water level on the small scale base map for each aquifer. After the base map has been contoured draw in some flow lines. These are drawn from relative high elevations toward lower elevations (i.e., point downgradient) and indicate the direction of groundwater flow. The flow lines will converge on the pumping wells. Flow lines always cross the water level contours at a right angle. (See figure 2D on page 109.)

STEP 5: Estimate Aquifer Parameters

Aquifer parameters describe how the aquifer functions. Some pertinent parameters are hydraulic head, hydraulic gradient, effective porosity, hydraulic conductivity, and average groundwater flow velocity. Estimate each of these parameters at your most important or representative well. Each parameter is described briefly below.

Hydraulic head, h

The hydraulic head (h) is equal to the water level elevation collected in Step 6.

Hydraulic gradient, i

Hydraulic gradient (i) is the slope on the water surface. It is equal to the change in water level elevation between two points, divided by the distance (d) between the two points. Using the water level surface map, draw a line at right angles to the contours. Measure the distance between two points on the line, in feet. Calculate the difference in water level elevation between the two points. Calculate the slope at a number of points and use the steepest result as this will be most conservative and provide the greatest degree of protection. The slope will be greatest where the contours are closest together.

The equation for hydraulic gradient is: $i = (h1 - h2) / d$

Effective porosity, η

Effective porosity is a measure of how interconnected the pores in an aquifer are. Groundwater flows through pores that are interconnected, and thus, it is the effective porosity that is important. Effective porosity can be estimated from the values provided below based on the well log tant. Effective porosity can be estimated from the values provided below based on the well log descriptions, or through personal communication with the IDNR-GSB, the USGS, or local consultant.

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Hydraulic conductivity is a measure of how fast water can move through an aquifer. Hydraulic conductivity can be estimated from the values provided below based on the well log descriptions, or through personal communication with the IDNR-GSB, the USGS, or local consultant.

Representative values of hydraulic conductivity in units of gallons per day per square foot (GPD/sq ft):

Coarse sand	1500
Medium sand	1000
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Silty sand, fine sand	15
Sandy gravel	2000
Clean gravel	4000
Limestone	2000
Dolomite	2000

Average Groundwater Flow Velocity, v

Groundwater flows at rates typically ranging from a few feet per year to several feet per day. The average groundwater flow velocity (v) is calculated as follows:

$$v = Ki / 7.48\eta$$

where: v = average groundwater flow velocity (ft/day)
K = hydraulic conductivity (GPD/sq ft)
i = hydraulic gradient (unitless)
η = effective porosity (decimal fraction, unitless)

STEP 6: Estimate Time of Travel

Once average groundwater velocity has been calculated you can estimate how far groundwater will move toward a pumping well in a given amount of time. Calculate the distance groundwater will travel in 2 years, 5 years, and 10 years by multiplying the velocity in feet per day times the number of years times 365 days per year. These distances are referred to as time of travel (TOT) threshold values. Assuming that contaminants in the groundwater will move at the same rate as the groundwater, these distances will represent the boundary along which it is estimated that groundwater (and thus contaminants) will take about 2, 5, and 10 years to reach the pumping well(s) or well field.

The TOT threshold values suggested above are chosen to allow remedial measures and contingency plans to be implemented if a contaminant is released into the aquifer within the protected area. The TOT threshold values usually vary between 2 to 20 years, with the 2- 5- and 10-year or 5-, 10-, and 20-year threshold values typically selected. Selection of an appropriate TOT threshold value(s) depends upon site-specific hydrogeologic conditions, monitoring frequency, and administrative response or policy implementation time needed to initiate remedial action or contingency plans.

STEP 7: Delineate the Wellhead Protection Area

The calculated fixed radius can now be defined in terms of TOT. Draw circles (to scale) around each municipal well with radii equal to the 2-, 5-, and 10-year TOT distances (or be conservative and use the 5-, 10-, and 20-year values).

Create three management zones, where Zone 1 might be the 200 foot radius required by state regulation, or the 2-year TOT boundary. Select whichever is the greater distance. This zone is typically subject to the highest contaminant threat, and therefore, the land use restrictions are the most severe. Zone 2 might be a 5-year TOT threshold. This zone would also be subject to strict, though slightly less restrictive, land use controls than Zone 1; and to a high degree of management effort (monitoring, potential source identification, etc.). Zone 3 might be defined as the 10- 15- or 20- year threshold limits. This may provide the time required for the contaminants to decay or disperse in the aquifer before reaching the well, thereby reducing remedial costs and the need for very rapid response. Land use control here would be the least restrictive, though monitoring and exercise of some control is definitely warranted.

For confined aquifers where there is an impermeable layer greater than 50 feet thick, a Zone 1-type delineation may provide adequate wellhead protection. However, this is only true if a complete inventory of nearby wells served by the same aquifer has been conducted, and the wells are found to be in sound operating condition. Additionally, the Zone 1 delineation would be adequate only with assurance that all inactive wells were properly abandoned.

Again, be accurate and conservative in your delineations. It is better to slightly overprotect the aquifer than invest in wellhead protection planning and find out there is a problem that was overlooked or underestimated.

STEP 8: Recognition of Limitations

Other than an arbitrary selection of distance, the calculated fixed radius method is the simplest method used to determine WHPA. This method, used in conjunction with the time of travel criterion, incorporates a very limited amount of site-specific data to determine a WHPA. The delineation is specific to a given well, though the results are typically then applied to all wells in the area, without further consideration of site-specific hydrogeologic or operating conditions. This method may leave the aquifer unprotected in vital recharge zones and must be applied with caution.

The delineation of a WHPA is a crucial step in providing substantial protection to one of your greatest resources - groundwater. In concept, it is not difficult to understand that the preservation of chemical quality of an aquifer is related to land use practices within the recharge area for that aquifer. Practically though, it can be difficult to visualize or determine exactly where and how the aquifer is being recharged, making it difficult to inventory and manage potential contamination sources.

Thus, a systematic and science-based evaluation of site-specific hydrogeologic and operating conditions is essential to completing an accurate and defensible delineation. The steps outlined above (fixed radius delineation using time of travel/flow boundary criteria) provide guidance for conducting the initial step in meeting this goal. They represent the minimum recommended delineation approach. It is important to recognize that the successful completion of the steps will likely not result in an entirely effective wellhead protection area, but rather provide a minimum approximation of something that resembles a wellhead protection area.

To establish a wellhead protection area with greater certainty and completeness, it is recommended that the analytical equations method be used in combination with several delineation criteria (distance, drawdown, time of travel, hydrogeologic boundaries) at each well, and then integrated to accurately delineate a comprehensive wellhead protection area. In particular, the recognition of the site-specific hydrogeologic conditions for each well is critical to selecting the appropriate delineation criteria, as they likely vary from one well to the next. For more complex conditions, numerical modeling may be an economical alternative to the analytical equations method. Whatever the circumstance, when applying the analytical equations or numerical modeling methods, outside guidance or assistance from experienced personnel specializing in hydrogeology and planning is recommended.

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YAGGY COLBY ASSOCIATES, INC.
Timothy Moreau, P.E., Vice President
215 N. Adams
Mason City, IA 50401
(515) 424-6344

WARNER ENGINEERING ASSOCIATES, INC.
James I. Warner, P.E., President
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Fairfield, IA 52556
(515) 472-5581

WILBUR SMITH ASSOCIATES, INC.
Joel A. Dermid, Jr., P.E.
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Des Moines, IA 50309
(515) 280-5310

Appendix Four

Instructions for Completing the *Contaminant Inventory Site-Specific Evaluation Table*

In the ***No.*** section, write the appropriate number of this inventory. Your inventories should be chronologically numbered using any system you deem satisfactory.

In the ***Date of this inventory*** *section*, write the date on which this inventory occurs. If more than one day is needed to complete the survey, write down every date applicable.

In the ***Date of last inventory*** section, note the date on which any previous inventory was taken. This will help you gauge the time between inventories, and decide how often surveys need to be taken.

In the ***Name of person taking inventory*** section, write down the name of the Wellhead Protection Team member of volunteer who is conducting the survey.

In the ***Name of person being interviewed*** section, record the name of the person who is answering the questions on the survey. If more than one person participates, write down every name applicable.

In the ***Proper name of facility*** section, recordthe name of the business situated on this land.

In the ***Landowner's name*** section, record the name of the property owner. Often businesses are owned by one person, but the land on which the business is situated is owned by another. If contaminations are discovered, it is necessary to determine who is liable for the clean-up costs.

In the ***Operator's name*** section, write down the name of the manager of the business who is likely to be there on a daily basis.

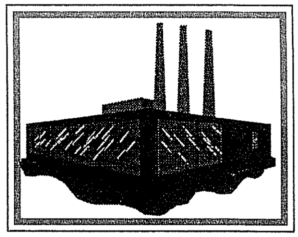
In the ***Property address*** section, record the business address of the facility.

In the ***Diagram of hazard locations*** section, draw a sketch of the physical property situated on the land, then indicate the location of each hazard identified.

In the ***Nature of Property*** section, place a check mark in the box that most closely relfects what type of activity or business is situated on this property.

In the ***Potential Sources of Contamination*** section, place a check mark beside each hazard that already is, or poses a potential contamination threat to this particular well. In the space provided to the right of each hazard, in the ***Quantity*** section, record the quantity of each hazard found. In the ***Notes*** section, write information such as if there is more than one site at this location where this hazard can be found, and any other pertinent information.

Contaminant Inventory Site-Specific Evaluation Table



No. ________________

Date of this inventory		Date of last inventory	
Name of person taking inventory		Name of person being interviewed	
Proper name of facility			
Landowner's name		Operator's name (if different)	
Property address			
City	Zip code	Phone number	County

Diagram of hazard locations

Scale = ____________

Nature of Property

Residential	❑	Commercial	❑	Agricultural	❑	Industrial	❑
City Gov't Site	❑	State Gov't Site	❑	Rental	❑	Other	❑

Potential Sources of Contamination

Place a check mark beside each potential hazard listed below you have identified might have an impact on your well.

✓	Potential Source	Quantity	✓	Potential Source	Quantity
	Above-ground storage tanks			Landfills	
	Airports (operating/abandoned)			Laundromats	
	Animal burial sites			Machine/metalworking shops	
	Animal feedlots, stables, kennels			Manure spreading sites/pits	
	Artificial recharge			Medical institutions	
	Asphalt plants			Mining and mine drainage	
	Auto repair, service, salvage sites			Municipal incinerators	
	Boatyards			Municipal landfills	
	Car washes			Municipal sewer lines	
	Cemeteries			Oil/Gas wells	
	Cesspools			Open burning sites	
	Chemical manufacture/storage sites			Paint manufacture/storage sites	
				Petroleum production/storage sites	

				Photography/printing establishments	
				Pesticide use/storage sites	
				Pipelines	
	Construction sites			Quarries	
	Drainage wells/ditches/tiles			Railroad tracks and yards	
	Dry cleaners			Recycling/reduction sites	
	Dumps			Research laboratories	
	Electronics manufacture			Road deicing operations	
	Electroplaters			Road maintenance depots	
	Fertilizer use/storage sites			Scrap and junkyards	
				Septage lagoons and sludge	
	Foundries/metal fabricators			Septage overflows	
	Fuel oil use/storage sites			Septic systems	
	Furniture stripping/refinishing			Service station disposal wells	
	Gas stations			Sewer lines	
	Golf courses			Storage tanks	
	Grain storage bins			Storm water drains/basins	
	Hazardous waste landfills			Storm sewers	
	Herbicide use/storage sites			Streams (lakes, rivers, creeks)	
				Swimming pools	
				Toxic and hazardous spill sites	
	Highways			Transfer stations	
	Holding ponds/lagoons			Underground storage tanks	
	Household hazardous products			Wells (operating/abandoned)	
	Household lawns			* Residential	
	Injection wells			* Municipal	
	Irrigation sites			* Production	
	Irrigation wells				
	Wood preserving facilities				
	Jewelry/metal plating establishments			Other	

Notes:

Appendix Five - Toxicity and Mobility Index

TOXICITY AND MOBILITY SCORES BY CONTAMINANT/MIXTURE AND SOURCE CATEGORY			
SOURCE CATEGORY: AGRICHEMICAL APPLICATION	**CONTAMINANT**	**TOXICITY SCORE**	**MOBILITY SCORE**
Corn Crop - Pesticides, Fertilizers	Composite - dicamba, other pesticides, nitrate-nitrogen	2	3
Soybean Crop - Pesticides, Fertilizers	Composite - trifluralin, other pesticides, nitrate-nitrogen	2	3
Cotton Crop - Pesticides, Fertilizers	Composite - aldicarb, nitrate-nitrogen	2	3
Wheat Crop - Pesticides, Fertilizers	Composite - aldicarb, nitrate-nitrogen	2	3
Other Crops - Pesticides	Composite - aldicarb, nitrate-nitrogen	2	3
SOURCE CATEGORY: LANDFILLS	**CONTAMINANT**	**TOXICITY SCORE**	**MOBILITY SCORE**
Hazardous Waste ("Subtitle C" Sites) and Municipal Waste ("Subtitle D" Sites) pre-1976	Composite - arsenic, benzene, chromium	3	3
Municipal Waste ("Subtitle D" Sites) post-1976	Composite - arsenic, organics mix[1], iron	3	3
NOTE: [1] vinyl chloride and dichloromethane			
SOURCE CATEGORY: PIPELINES	**CONTAMINANT**	**TOXICITY SCORE**	**MOBILITY SCORE**
Sewer	Composite - chloroform, benzene, bis(2 ethylhexyl) phthalate, chromium	2	3
Other (Includes Petroleum)	benzene	3	2
SOURCE CATEGORY: SEPTIC TANK SYSTEMS	**CONTAMINANT**	**TOXICITY SCORE**	**MOBILITY SCORE**
Septic Tank Systems	nitrates	2	3
SOURCE CATEGORY: SURFACE IMPOUNDMENTS	**CONTAMINANT**	**TOXICITY SCORE**	**MOBILITY SCORE**
Hazardous Waste ("Subtitle C")	Composite - arsenic, benzene, chromium, metals mix[1]	3	3
Industrial Waste ("Subtitle D")	Composite - chloroform, organics mix[2], nitrobenzene	3	3
Municipal Waste Treatment Ponds("Subtitle D")	Composite - chloroform, benzene, chromium	3	2
Urban Stormwater Retention Ponds	Composite - arsesnic, chromium, metals mix[4]	3	3
ANIMAL FEEDLOTS Dirt Lot Runoff and Paved Lot Runoff	nitrate	2	3
MINE TAILING PONDS Copper Sector	Composite - arsenic, manganese, metals mix[3]	3	3
Lead Sector	Composite - arsenic, metals mix[3]	3	3
Zinc/Zinc Oxide	Composite - arsenic, metals mix[3]	3	3
Aluminum Sector	arsenic	3	3
NOTES: [1] cyanide, cadmium and lead; [2] benzene, and 2,4,6 trichlorophenol; [3] cadmium and lead; [4] zinc, lead, cadmium and nickel			

TOXICITY AND MOBILITY SCORES BY CONTAMINANT/MIXTURE AND SOURCE CATEGORY

SOURCE CATEGORY: CONTAINER STORAGE AND MATERIAL TRANSFER AND TRANSPORT	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
HAZARDOUS WASTE/ACCUMULATION			
D001: Ignitable Wastes	Composite - benzene, methanol, organics mix[1]	3	2
D002: Corrosive Wastes	Composite - methanol, toluene	2	2
F001: Spent, Halogenated Solvents Used for Degreasing	Composite - chloroform, carbon tetrachloride, organics mix[2]	3	2
F003: Spent, Non-Halogenated Solvents	Composite - benzene, methyl ethyl ketone	3	2
RCRA PERMITTED STORAGE			
D001: Ignitable Wastes	Composite - benzene, methanol organics mix[1]	3	2
F003: Spent, Non-Halogenated Solvents	Composite - benzene, methyl ethyl ketone	3	2
X500: Ignitable Waste Mixtures	Composite - benzene, organics mix[1]	3	2
X501: Corrosive Waste Mixtures	Composite - chromium mix [3], lead	2	2
X504: Toxic Waste Mixtures	Composite - chloroform, carbon tetrachloride, organics mix[4]	3	2
HAZARDOUS MATERIAL/PRODUCTS			
Petroleum (gasoline, diesel)	benzene	3	2
Chemical/Cleaning Liquids (corrosive)	acetic acid	1	3
Sulfuric Acid	sulfuric acid	1	3
Paint Dryer (flammable)	Composite - benzene, organics mix 1[5], organics mix 2[6]	3	2

NOTES:
[1] acetone and methylethyl ketone
[2] 1,2-dichlorobenzene
[3] chromium and methanol
[4] 1, 1, 1-trichloroethane
[5] methyl ethyl ketone, cresol and acetone
[6] xylene, napthalene, toluene and 1,1,1-trichloroethane

SOURCE CATEGORY: INJECTION WELLS/DEEP WELLS (Classes I, II, and III)	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
Class I: Wastewater Disposal	Composite - benzene, chromium mix [1], cyanide	3	2
Class II: Oil and Gas Activity	Composite - arsenic, benzene, boron	3	3
Class III: Mineral Extraction - Metals Mining	Composite - arsenic, metals mix 1[2], metals mix 2[3]	3	3

NOTES:
[1] chromium and sulfuric acid
[2] chromium, manganese and barium
[3] nickel, vanadium, mercury, iron, cadmium, zinc, berylium, silver and lead

SOURCE CATEGORY: INJECTION WELLS/SHALLOW WELLS (Class V)	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
AGRICULTURAL DRAINAGE WELLS			
Corn Crop	Composite - dicamba, other pesticides, nitrate-nitrogen	2	3
Soybean Crop	Composite - trifluralin, other pesticides, nitrate-nitrogen	2	3
Other Crops	Composite - aldicarb, nitrate-nitrogen	2	3
AUTOMOBILE SERVICE STATION DISPOSAL WELLS			
Service and Repair	Composite - arsenic, chromium, metals mix[1]	3	3
Body Shops	Composite - chromium, metals mix[1]	2	3
Car Washing	Composite - arsenic, chromium, metals mix[1]	3	3

TOXICITY AND MOBILITY SCORES
BY CONTAMINANT/MIXTURE AND SOURCE CATEGORY

SOURCE CATEGORY: INJECTION WELLS/SHALLOW WELLS (Class V) (continued)	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
INDUSTRIAL PROCESS WATER DISPOSAL WELLS			
Low Throughput (less than 2.6 million gallons/year)	Composite - methanol, cyanide mix[2], metals mix[3]	2	2
Medium Throughput (between 2.6 and 31.2 million gallons/year) Inorganic Chemical Manufacture	Composite - chromium, cyanide, metals mix[4]	2	3
Laundry and Cleaning Services	tetrachloroethylene	2	2
High Throughput (more than 31.2 million gallons/year) Electroplating	Composite - chromium, cyanide, metals mix[5]	2	3
Cooling waters	chromium	2	3

NOTES:
[1] cadmium and lead
[2] cyanide, phenol and acetone
[3] iron, boron and silver
[4] nickel, mercury, zinc and lead
[5] nickel, zinc, iron, silver, cadmium and lead

SOURCE CATEGORY: LAND TREATMENT	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
Petroleum Refining	Composite - arsenic, benzene, metals mix 1[1], metals mix 2[2]	3	3
Inorganic Chemicals	Composite - chromium (total), metals mix [3]	2	3
Organic Chemicals	Composite - chromium (total), metals mix [4]	2	3

NOTES: [1] chromium and barium
[2] lead, vanadium, nickel and zinc
[3] chromium, zinc and nickel
[4] lead, zinc and cadmium

SOURCE CATEGORY: STORAGE PILES	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
HEAP LEACHING PILES	Composite - arsenic, metals mix 1[1], metals mix 2[2]	3	3
NON-HEAP LEACHING PILES/ HAZARDOUS WASTE PILES			
D002 & D006: Corrosive Materials Waste & Cadmium	Composite - arsenic, sulfuric acid, metals mix [3]	3	3
D008: Lead Waste	lead	2	2
F001: Spent Halogenated Solvents Used in Degreasing	Composite - dichloroethane, 1,1,1-trichloroethane	3	3
F006: Wastewater Treatment Sludges from Electroplating, Except Aluminum, Tin or Zinc	Composite - metals mix 1[4], cyanide, metals mix 2[5]	2	3
F019: Waste fromthe Chemical Conversion Coating of Aluminum	Composite - metals mix 1[4], cyanide, metals mix 2[5]	2	3
K048, K049, K050, K051: Sludges from the Petroleum Refining Industry	Composite - arsenic, benzene, metals mix 1[4], metals mix 2[7]	3	3
K061: Emission Control Dust/Sludges from Steel Production	Composite - arsenic, chrominum (VI), metals mix [5]	3	3
NONHAZARDOUS WASTE PILES	Composite - chromium, metals mix [8]	2	3
MATERIAL STOCK PILES	Composite - arsenic, metals mix 1[9], metals mix 2[10]	3	3
MINE WASTE PILES Copper Sector	Composite - arsenic, metals mix[11]	3	3
Lead Sector	Composite - arsesnic, metals mix[11]	3	3
Zinc/Zinc Oxide	Composite - arsenic, manganese, metals mix[11]	3	3
Aluminum Sector	arsenic	2	2

NOTES:
[1] chromium, manganese and barium
[2] nickel, vanadium, mercury, iron, cadmium, zinc, berylium, silver and lead
[3] tin and lead
[4] chromium and barium
[5] nickel, lead, zinc and cadmium
[6] nickel and zinc
[7] cyanide, vanadium, lead and zinc
[8] chromium, nickel, cadmium, zinc and lead
[9] chromium and manganese
[10] lead, nickel, berylium, cadmium, iron and mercury
[11] cadmium and lead

TOXICITY AND MOBILITY SCORES BY CONTAMINANT/MIXTURE AND SOURCE CATEGORY			
SOURCE CATEGORY: TANKS	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
HAZARDOUS WASTE TREATMENT/ DISTILLATION			
D001: Ignitable Wastes	Composite - benzene, methanol, organics mix[1]	3	2
F003: Spent, Halogenated Solvents	Composite - benzene, methyl ethyl ketone, organics mix[2]	3	2
X907: Chlorinated Pesticide Production Wastes	Composite - chloroform, hexachlorobenzene, hexachloro-cyclopentadiene	3	2
OXIDATION/REDUCTION PRECIPITATION			
D007: Chromium Waste	chromium	2	3
F006: Wastewater Treatment Sludges from Electroplating	chromium	2	3
K048: Dissolved Air Flotation Waste From the Petroleum Refining Industry	Composite - metals mix[3], chromium, lead	2	3
HAZARDOUS WASTE STORAGE/ ACCUMULATION			
D001: Ignitable Wastes	Composite - benzene, methanol, organics mix[1]	3	2
D002: Corrosive Wastes	Composite - methanol, toluene	2	2
F001: Spent, Halogenated Solvents Used for Degreasing	Composite - chloroform, carbon tetrachloride, organics mix[4]	3	2
F003: Spent, Non-Halogenated Solvents:	Composite - benzene, methyl ethyl ketone	3	2
RCRA PERMITTED STORAGE			
D001: Ignitable Wastes	Composite - benzene, methanol, organics mix[1]	3	2
F003: Spent, Non-Halogenated Solvents	Composite - benzene, methyyl ethyl ketone	3	2
X500: Ignitable Waste Mixtures	Composite - benzene, organics mix[1]	3	2
X501: Corrosive Waste Mixtures	Composite - chromium mix[6], lead	2	2
X504: Toxic Waste Mixtures	Composite - chloroform, carbon tetrachloride, organics mix[6]	3	2
SMALL QUANTITY GENERATORS - ABOVE GROUND TANKS			
Stream 1: Halogenated Spent Solvents and Ignitable Wastes	Composite - chloroform, carbon tetrachloride, 1,1,1-trichloroethane	3	2
Stream 2: Non-Halogenated Spent Solvents and Ignitable Wastes	Composite - benzene, organics mix[1]	3	2
Stream 3: Strong Acid or Alkaline Waste	lead	2	2
SMALL QUANTITY GENERATORS - BELOW GROUND TANKS			
Stream 1: Halogenated Spent Solvents and Ignitable Wastes	Composite - chloroform, carbon tetrachloride, 1,1,1-trichloroethane	3	2
Stream 2: Non-Halogenated Spent Solvents and Ignitable Wastes	Composite - benzene, organics mix[1]	3	2
Stream 3: Strong Acid or Alkaline Waste	lead	2	2

TOXICITY AND MOBILITY SCORES BY CONTAMINANT/MIXTURE AND SOURCE CATEGORY			
SOURCE CATEGORY: TANKS (continued)	CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
PRODUCT STORAGE Petroleum (gasoline, diesel)	benzene	3	2
Chemical/Cleaning Liquids (corrosive)	acetic acid	1	3
Sulfuric Acid	sulfuric acid	1	3
Paint Dryer (flammable)	Composite - benzene, organics mix 1[7], organics mix 2[8]	3	2
MUNICIPAL ("SUBTITLE D") WASTEWATERS	Composite - chloroform, benzene, bis(2-ethylhexyl)phtalate, chromium	3	2

NOTES:
[1] acetone and methyl ethyl ketone
[2] xylene and toluene
[3] cadmium, lead and nickel
[4] 1,2-dichlorobenzene
[5] chromium and methanol
[6] 1,1,1-trichloroethane
[7] methyl ethyl ketone, cresol and acetone
[8] xylene, napthalene, toluene and 1,1,1-trichloroethane

TOXICITY AND MOBILITY SCORES BY CONTAMINANT		
CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
1,1,1-Trichloroethane	1	2
1,1,2,2-Tetrachloroethane	3	2
1,2-Dichlorobenzene	1	2
1,2-Trans-Dichloroethylene	2	3
2,4, 5-TP Silvex	3	2
2,4,6-Trichlorophenol	3	2
2,4-D	2	2
Acetic Acid	1	3
Acetone	1	3
Alachlor	2	2
Aldicarb	2	3
Antimony	3	1
Arsenic	3	3
Atrazine	2	2
Barium	1	3
Bentazon	2	2
Benzene	3	2
Beryllium	2	2
Bis(2-ethylhexyl)phthalate	2	1
Boron	1	2
Butylate	1	2
Cadmium	2	2
Carbon Tetrachloride	3	2
Chloride	1	3
Chloroform	2	3
Chromium	2	3
Cresol	2	1
Cyanazine	2	2
Cyanide	2	3
Dicamba	2	2
Dichloroethane	3	3
Dichloromethane	2	3
Dinitro-butyl phthalate	1	2
Endrin	3	1
EPTC+	2	2
Ethylbenzene	2	2
Hexachlorobenzene	3	2
Hexachlorobutadiene	3	1
Hexachlorocyclopentadiene	2	2
Iron	1	2
Lead	2	2
Lindane	3	2

TOXICITY AND MOBILITY SCORES BY CONTAMINANT		
CONTAMINANT	TOXICITY SCORE	MOBILITY SCORE
Manganese	1	3
Mercury	3	2
Methanol	1	3
Methyl ethylketone	2	3
Methoxychlor	3	1
Metolachor	2	2
Metribuzin	2	2
M-xylene	1	2
Naphthalene	1	2
Nickel	2	2
Nitrate-Nitrogen	2	3
Nitrobenzene	3	3
Phenol	1	3
Selenium	2	3
Silver	2	2
Sulfuric Acid	1	3
Tetrachloroethylene	2	2
Trichlorethylene	2	2
Tin	1	2
Toluene	2	2
Trifluralin	2	1
Vandium	2	2
Vinyl chloride	3	3
Xylene	2	2
Zinc	1	2

Appendix Six - Technical Assistance

Iowa Department of Natural Resources

Region	Address & Phone	Name
Field Office 1	817 W. Fayette St. Manchester, IA 52057 (319) 927-2640	Shelli Grapp Mike Wade
Field Office 2	2300 15th St., S.W. P.O. Box 1443 Mason City, IA 50401 (515) 424-4073	Jeff Vansteenburg
Field Office 3	1900 N. Grand Ave. Spencer, IA 51301 (712) 262-4177	Bryon Whiting Gregory Olson Julie Sievers
Field Office 4	706 Sunnyside Atlantic, IA 50022 (712) 243-1934	Mike Spetman Shellie Ferguson Jerry Jordison
Field Office 5	607 E. Second St. River Hills Business Park Des Moines, IA 50309 (515)281-9069	Jim Stricker Randy Lane Janet Gastineau Steve Grgurich Bob Schuelzky
Field Office 6	1004 W. Madison Washington, IA 52353 (319) 653-2135	Dan Stipe
Central Office	900 E. Grand Ave. Des Moines, IA 50319	
	(515) 281-8998	Dennis Alt
	(515) 281-6599	Mike Anderson
	(515) 281-8945	Roy Ney
	(515) 281-7814	Brent Parker
	(515) 281-3989	Mike Wiemann
	(515) 281-5130	Jennifer Simmons
	(515) 281-6853	Brian Haugstad
	(515) 281-6845	Hal Frank
	(515) 281-8863	Diane Moles
	(515) 281-3998	Anne Lynam
	(515) 281-8743	Joe Zerfas
	(515) 281-8914	Charlotte Henderson
Geological Survey Bureau	109 Trowbridge Hall Iowa City, IA 52242-1319 (319) 335-1575	

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