

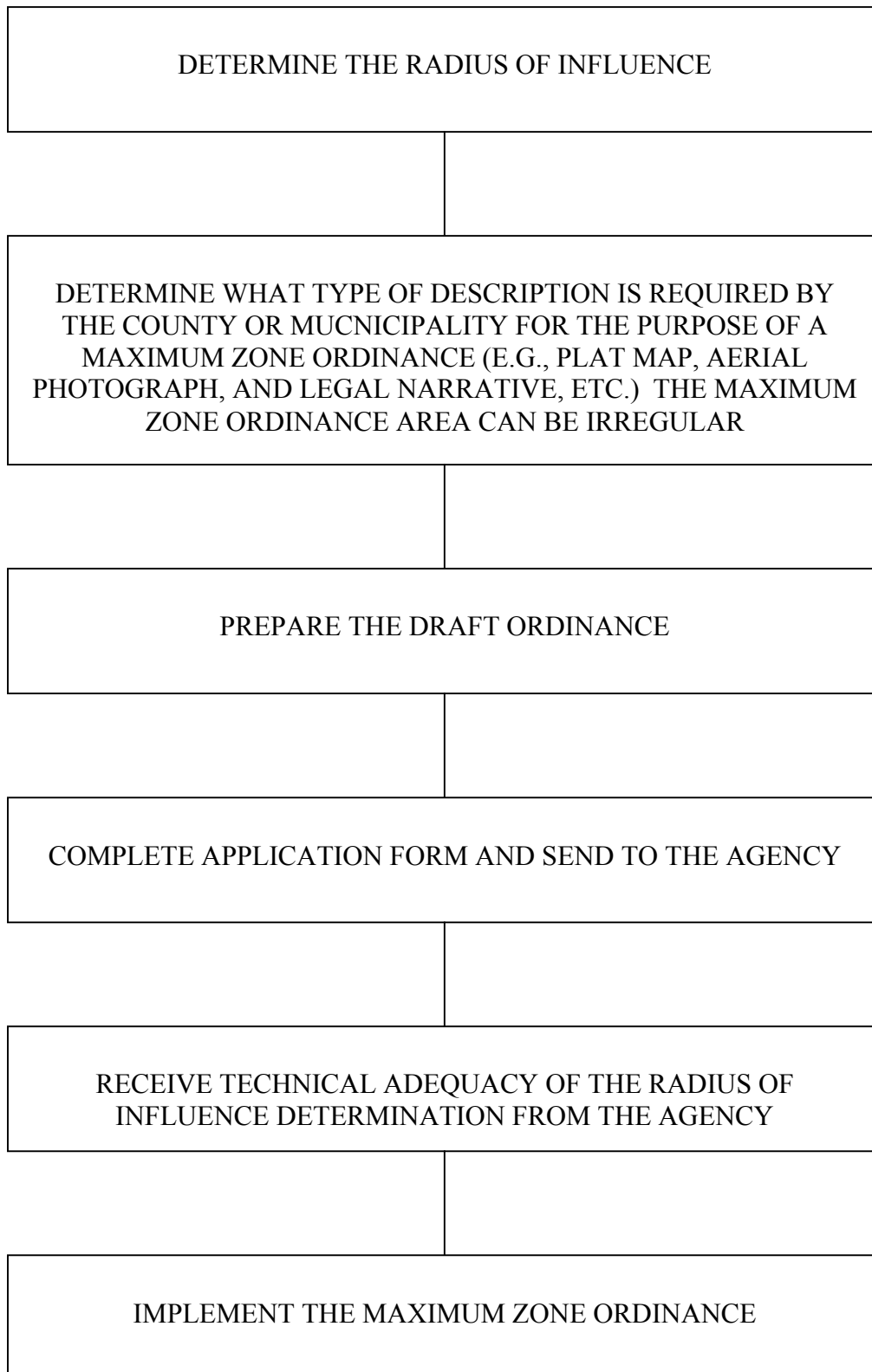
Maximum Setback Zone Workbook

Community Water Supply
Groundwater Quality Protection

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FLOW CHART OF THE MAXIMUM SETBACK ZONE PROCEDURE



HOW TO ESTABLISH A MAXIMUM SETBACK ZONE

INTRODUCTION

The Illinois Groundwater Protection Act (IGPA) was passed by the General Assembly and was signed by the Governor on September 24, 1987. The IGPA establishes a comprehensive program for the protection of groundwaters. Some parts of the program, such as minimum setback zones for wellhead protection, have already been implemented based directly upon detailed authority in the IGPA. The maximum setback zone, however, requires additional work before implementation and relies on a state and local partnership.

This workbook is intended to provide individuals with guidance on why maximum zones are need, how to apply for a maximum zone using the rules contained the “Part 671 Maximum Setback Zone For Community Water Supply Wells” and how to determine maximum zones. Section 14.3 of the Illinois Groundwater Protection Act (IGPA) provided counties and municipalities utilizing any community water supply well the authority to establish a maximum setback zone, up to 1,000 feet, around their well(s).

BENEFITS OF ESTABLISHING MAXIMUM SETBACK ZONES

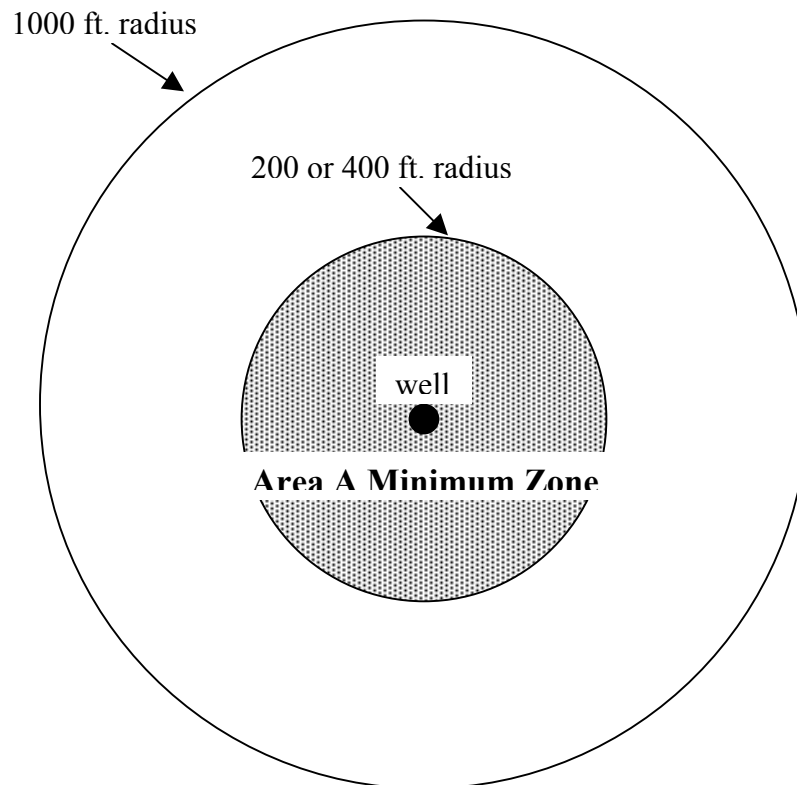
- Prevention of contamination by siting restrictions up to 1000’
- Regulatory control of new potential sources and of existing potential sources upon adoption of the groundwater standards and technology regulations
- Restriction of siting new potential primary sources
- Awareness of the sensitivity of the zone to contamination problems
- Exercise of local control and ordinances

Local groundwater protection programs can help prevent unexpected and costly water supply problems. A northern Illinois community has learned first hand the hardship and disruption caused by the loss of a water well. A leaking gasoline storage tank, operated by the city-owned garage, contaminated one well and threatens to contaminate the entire well field. To date, the community has expended more than \$300,000 in an attempt to replace the water supply. Economic hardship also impacts the individual by increasing the water bill to compensate for these additional costs.

WHAT IS PROHIBITED WITHIN SETBACK ZONES?

The minimum setback zone established by the IGPA prohibits the siting of new potential primary, potential secondary sources, and potential routes within the 200 or 400 foot radial area around a wellhead. The second level of protection made available by the IGPA to counties and municipalities served by a community water well is the maximum setback zone. The maximum zone prohibits the siting of new potential primary sources within the area outside the minimum setback zone up to 1,000 feet from the wellhead (see Figure 1). New potential secondary sources are not prohibited within this area outside the minimum zone. See page 3 for definitions of a potential route, potential primary source, potential secondary source, and setback zone.

If an active community water supply well is withdrawing water from an alluvial aquifer that is located within 1,000 feet of public waters (e.g., rivers and lakes) no new potential route shall be located up to 2,500 feet from the wellhead. The terms associated with these potential sources reflect real life differences in relative hazards (e.g., Landfills vs. salt pile storage, etc.). The term “public waters” means any body of water that is or was navigable and is open or dedicated to public use (Section 18 of “An Act in Relation to the Regulation of the Rivers, Lakes and Streams of the State of Illinois” approved June 10, 1911).



Area A – Within the minimum zone the following are prohibited:

- New Potential Primary Sources
- New Potential Secondary Sources
- New Potential Route

Area B – Within the maximum zone the following are prohibited:

- New Potential Primary Sources
- New Potential Routes up to 2,500 feet
(If the well is utilizing an alluvial aquifer and is 1,000 feet from public waters)

Figure 1. Setback Zones and What is Prohibited

“Potential route” means abandoned and improperly plugged wells of all kinds, drainage wells, all injection wells, including closed loop heat pump wells, and any excavation for the discovery, development or production of stone, sand or gravel.

A new potential route is:

1. a potential route which is not in existence or for which construction has not commence at its location as of January 1, 1988, or
2. a potential route which expands laterally beyond the currently permitted boundary or, if the potential route is not permitted, the boundary in existence as of January 1, 1988.

Construction shall be deemed commenced when all necessary federal, State and local approvals have been obtained, and work at the site has been initiated and proceeds in a reasonably continuous manner to completion.

“Potential primary source” means any unit at a facility or site not currently subject to a removal or remedial action which:

1. is utilized for the treatment, storage, or disposal of any hazardous or special waste not generated at the site; or
2. is utilized for the disposal of municipal waste not generated at the site, other than landscape waste and construction and demolition debris; or
3. is utilized for the landfilling, land treating, surface impounding or piling of any hazardous or special waste that is generated on the site or at other sites owned, controlled or operated by the same person; or
4. stores or accumulates at any time more than 75,000 pounds above ground, or more than 7,500 pounds below ground, of any hazardous substances.

A new potential primary source is:

- i. a potential primary source which is not in existence or for which construction has not commenced at its location as of January 1, 1988; or

- ii. a potential primary source which expands laterally beyond the currently permitted boundary, or if the primary source is not permitted, the boundary in existence as of January 1, 1988; or

- iii. a potential primary source which is part of a facility that undergoes major reconstruction. Such reconstruction shall be deemed to have taken place where the fixed capital cost of the new components constructed within a 2-year period exceed 50% of the fixed capital cost of a comparable entirely new facility.

Construction shall be deemed commenced when all necessary federal, State and local approvals have been obtained, and work at the site has been initiated and proceeds in a reasonably continuous manner to completion.

“Potential secondary source” means any unit at a facility or a site not currently subject to a removal or remedial action, other than a potential primary source which:

1. is utilized for the landfilling, land treating, or surface impounding of waste that is generated on the site or at other sites owned, controlled or operated by the same person, other than livestock and landscape waste, and construction and demolition debris; or
2. stores or accumulates at any time more than 25,000 but not more than 75,000 pounds above ground, or more than 2,500 but not more than 7,500 pounds below ground, of any hazardous substances; or
3. stores or accumulates at any time more than 25,000 gallons above ground, or more than 500 gallons below ground, of petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance; or
4. stores or accumulates pesticides, fertilizers, or road oils for purposes of commercial application or for distribution to retail sales outlets; or
5. stores or accumulates at any time more than 50,000 pounds of any de-icing agents; or

6. is utilized for handling livestock waste or for treating domestic wastewaters other than private sewage disposal systems as defined in the "Private Sewage Disposal Licensing Act".

A new potential secondary source is:

- i. a potential secondary source which is not in existence or for which construction has not commenced at its location as of July 1, 1988; or
- ii. a potential secondary source which expands laterally beyond the currently permitted boundary or, if the secondary source is not permitted, the boundary in existence as of July 1, 1988, other than an expansion for handling of livestock waste or for treating domestic wastewaters; or
- iii. a potential secondary source which is part of a facility that undergoes major reconstruction. Such reconstruction shall be deemed to have taken place where the fixed capital cost of the new components constructed within a 2-year period exceed 50% of the fixed capital cost of a comparable entirely new facility.

Construction shall be deemed commenced when all necessary federal, State and local approvals have been obtained, and work at the site has been initiated and proceeds in a reasonably continuous manner to completion.

"Setback zone" means a geographic area, designated pursuant to this Act, containing a potable water supply well or a potential source or potential route, having a continuous boundary, and within which certain prohibitions or regulations are applicable in order to protect groundwaters.

The description above provides the statutory definition of a new potential primary source, and the following provides some examples of potential primary sources:

- operations (e.g., solvent reprocessing, waste oil reprocessing, certain industrial process wastes, and hazardous waste landfills, etc.) which receive waste from other generators and treat, store, or dispose of it on-site;
- operations (e.g., power plant fly ash disposal, and chemical waste reprocessing, etc.) which landfill, land treat, surface impound, or pile their own hazardous or special waste on-site, or at another site owned, controlled or operated by the same operator;
- operations for the disposal of municipal waste (e.g., garbage and general household waste other than landscape waste and construction and demolition debris) in an off-site municipal landfill; and
- operations which store or accumulate at any time more than 75,000 pounds (lbs) above ground or more than 7,500 lbs below ground of any hazardous substances. For example:
 - a dry cleaner which stores 620 gallons (gal) or 7539 pounds (lbs) of trichloroethylene (TCE) in an underground tank; a common solvent having a density of 12.16 (lbs/gal), TCE, is also a hazardous substance;
 - a methanol production plant which produces methanol from grain and stores more than 7,500 lbs of methanol in a below-ground tank.

The examples described above provide several real-world examples of potential primary sources.

THREATS TO COMMUNITY WATER SUPPLY WELLS

The Agency is completing a well site survey report for all community water supplies. The well site survey report is intended to help communities become more aware of their groundwater supply and any potential threats to their wells. The report should also help provide a starting point for protecting groundwater supplies. The survey consists of an inventory and location of potential contamination sources, routes, and possible problem sites in relation to community water supply wells. These potential sources and routes (e.g., abandoned wells) are located and inventoried within a community well's minimum setback zone (200 or 400 feet), and up to a distance of 1,000 feet.

The well site survey report describes the character, number, and distance of potential sources of contamination adjacent to a community well. Preliminary well site survey report findings have clearly demonstrated the need for establishing maximum setback zones. Wells which have several potential sources in close proximity are generally the same wells contaminated with synthetic organic chemicals (e.g., solvents, degreasers, etc.).

WHO SHOULD BE INVOLVED

AND HOW TO APPLY FOR A MAXIMUM SETBACK ZONE

The Groundwater Protection Act relies on a state and local partnership. The Act contains numerous provisions by which local government can take the initiative to design a groundwater protection program meeting its specific needs. Behind any successful program is a powerful and dedicated constituency. Local participation is critical to assure success of groundwater protection programs. Interested parties can pursue a maximum setback zone by contacting the Agency and requesting the necessary rules and procedures. A community water supply owner, municipality or county served by a community water well can determine a well's area of influence. If an area of influence calculation indicates that it is greater than the minimum setback zone, then a county or municipality is qualified to submit a maximum zone application to the Agency for review. If the water supply is private or investor-owned, the county or municipality that the well serves will need to be contacted to make an application on behalf of the owner. The following information will be required to complete the application:

- description of the pump test procedure or the estimation technique selected to determine the lateral area of influence;
- area of influence or radius of influence distance;
- aquifer test data;
- geological logs and well construction details;
- draft ordinance;
- county or municipal; official signature on the application.

This information can be assembled by the water supply or by consulting a professional engineer or geologist and a legal professional. If the water supply owner does not have a copy of pump test data, copies can often be obtained from the drilling contractor or the Illinois State Water Survey. Boundaries determined by the pump test procedures are used to help shape the maximum setback zone.

Appendix C of this report has been provided to assist with the preparation of a draft ordinance. The legal narrative in Appendix C should be modified to relate to the specific well and area that a county or municipality is dealing with. In addition, the draft ordinance should also include a geographic illustration of the proposed minimum and maximum zone ordinance area.

The draft ordinances reviewed by the Agency to date have employed two contrasting approaches to this requirement. One approach used the aerial photograph provided to the community in their well site survey report to depict the proposed minimum and maximum zone ordinance area. Another approach was the perform a detailed land survey, and indicate specific parcels of property affected.

BACKGROUND, WHAT IS THE LATERAL AREA OF INFLUENCE?

When the pump in a well boring is initially activated, water is obtained from storage in the well casing and from aquifer storage in the immediate vicinity of the well. As pumping continues, water is derived from aquifer storage at greater and greater distances from the well bore. As water is drawn from the aquifer, the water level in the vicinity of the well is lowered. The reduction of the water level is greatest at the well boring and decreases with distance away from the well. The shape of the water surface around the well resembles a cone and is commonly referred to as the “cone of depression”. Each cone differs in size and shape depending on the pumping rate, the pumping duration, and aquifer characteristics.

This diagram illustrates the hydraulic behavior of a well in an unconfined aquifer. A vertical well is shown penetrating the ground, with a dashed line indicating the 'Water Table - Prior to pumping'. The 'Cone of Depression' is the region around the well where the water table has lowered due to pumping. The 'Lateral Area of Influence' is the horizontal area from which water is being drawn into the well, bounded by the 'Lateral Radius of Influence'. The diagram also shows the 'Unconfined Sand and Gravel Aquifer' above a 'Confining Layer' (bedrock). The 'Actual Water Surface While Pumping' is shown as a curve within the cone of depression. The 'Land Surface' and 'Subsoil' are also indicated.

Illustration of the Cone of Depression Showing the Lateral Area of Influence

It is extremely important to identify and protect the lateral area of influence. In general, the lateral area of influence in a confined aquifer is 4,000 times larger than the LAI in an unconfined aquifer. If a contaminant is introduced within the lateral area of influence, it will reach the well faster than other water replenishing the well. This is true because the slope of the water table steepens toward the well within the area of influence. Experience has even shown this to be a factor in protecting wells utilizing confined aquifers because of improper or failed well construction. Production wells have become contaminated by their radius of influence intercepting at some distance a well with failed well construction. In one example, a failed well was 1000 feet from the production well and was cased from the surface to the confining layer. The failed well was adjacent to a contamination source and the contaminant entered the confined aquifer via the failed casing.

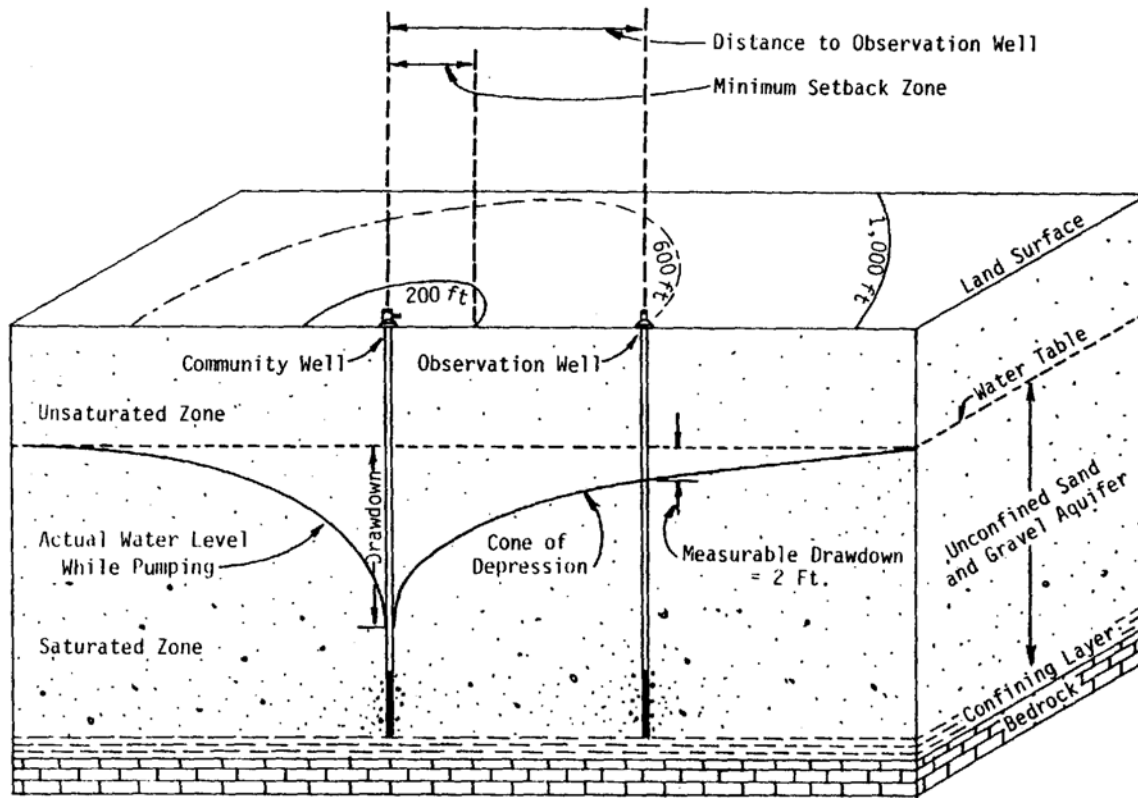
CASE STUDY EXAMPLES OF HOW TO DETERMINE

THE LATERAL RADIUS OF INFLUENCE

Determining the extent of the lateral radius of influence is a relatively straightforward procedure. The following case studies contain three types of determination methods. The direct measurement method involves measuring the drawdown in an observation well piezometer or a production well located outside the minimum setback zone of the production well. The direct measurement method determines if the well where the measurements are taken is within the area of influence. The second type of determination uses existing information, and the Theis equation or the volumetric flow equation. The Theis equation can be used to estimate the lateral radius of influence of a well if aquifer constants are available (e.g., storativity, transmissivity, and hydraulic conductivity) or can be determined. The Theis equation is especially helpful if the observation well was located within the minimum setback zone, i.e., the direct measurement method cannot be used. The volumetric flow equation is another method of estimating the radius of influence and is used for wells that pump continuously, and is a cost-effective alternative where aquifer constants are not available to use the Theis equation. The third method involves the interpretation of pump test data from observation wells within the minimum zone using a curve-matching technique and the Theis equation to determine the storativity and the transmissivity of the aquifer. Once these values have been determined, the Theis equation is utilized to determine the lateral radius of influence of the well. It should be noted that if the observation well or piezometer was outside the minimum zone that the determination could have been made by direct observation.

Case Study No. 1 Direct Water Level Measurement

The first case study example utilizes pump test data where an observation well was drilled beyond the minimum setback zone. Figure 3 illustrates that an observation well or drinking water well in the same formation at the same depth can be used to directly measure the



drawdown.

Figure 3. Illustration Representing a Direct Water Level Measurement by an Observation Well Drilled Beyond the Minimum Setback Zone

A steel tape was used to measure the water level in the observation well drilled 600 feet from the community well. The water level reading indicated that under normal operational conditions (e.g., one pumping period) there was 2.00 feet of drawdown compared to the original non-pumping water level. This well would be eligible for maximum zone protection.

Measurements taken with a steel tape are generally accurate down to a 1/100 of a foot. A county or municipality would qualify to apply for a maximum zone if the water level measurements indicate that the drawdown is greater than 1/100 of a foot, and the well is drilled beyond the minimum zone. Since the change in water level in the observation well in this example is a direct indication that the lateral radius of influence of the drinking water well is greater than the minimum setback (e.g., 400'), it will not be necessary to estimate the lateral radius of influence by using an "estimation technique"; therefore, calculation will not be necessary. If the county or municipality did not keep a record of the pump test data, often copies can be obtained from the drilling contractor or the Illinois State Water Survey.

Case Study No. 2 Direct Measurement

A pump test was completed at a community water supply well and the drawdown was measured in two existing water supply wells tapping the same aquifer. A block diagram illustrating this example is shown in Figure 4.

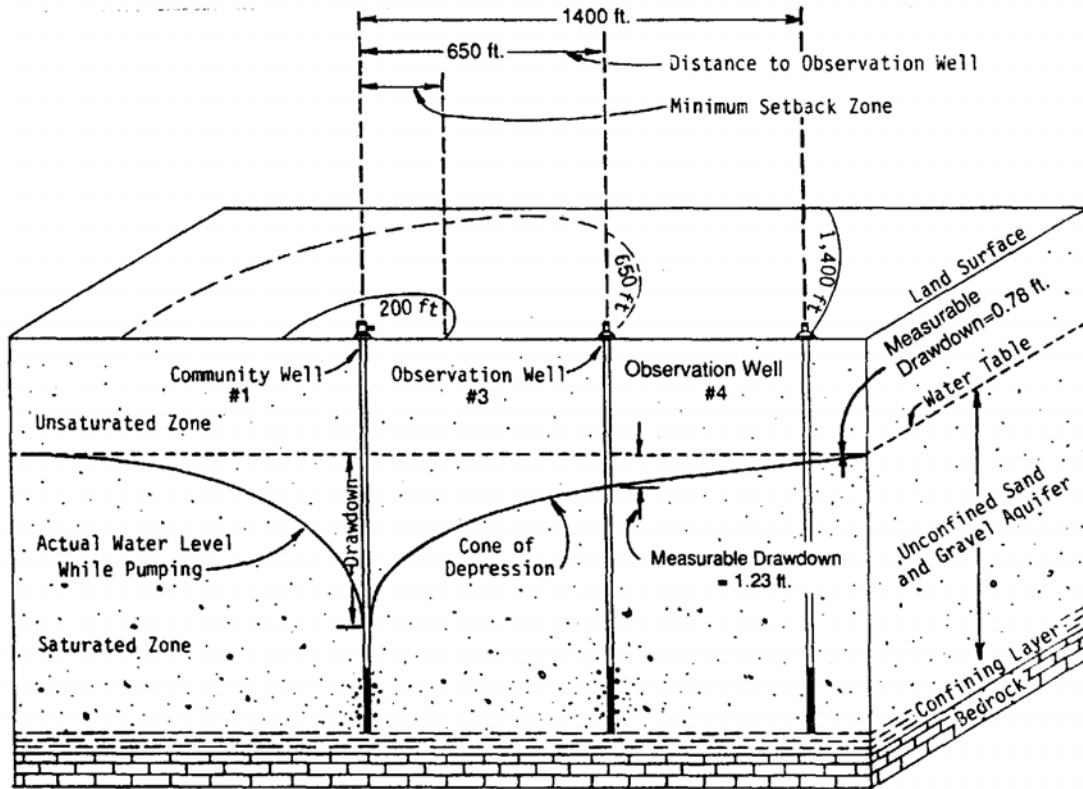


Figure 4. Block Diagram Showing the Pumping Well 1 and Observation Wells

Well 1 was pumped and water level measurements were taken in wells 3 and 4 located 650 and 1,400 feet respectively from well 1. The water level measurements were taken every 5 minutes for an hour in the two non-pumping wells to determine the non-pumping trend in these wells. These measurements indicated no change in water level during the one hour period. The production well was activated and pumped under normal operational conditions. Water level measurements were taken in 5-minute increments for the first hour and then every 20 minutes for the remainder of the test. After 4 hours of pumping the drawdown in wells 3 and 4 were 1.23 feet and 0.78 feet respectively. This well is eligible for maximum zone protection.

An application for Agency review of the two determinations described above would require the signature of a qualified geologist or engineer pursuant to Section 671.302 (c) or 671.303 (see Appendix A) on the application form.

Theis Equation Summary

Case Studies No. 3 and No. 4 use the Theis equation. The Theis equation can be used if pump test data is available for an unconfined/confined unconsolidated or non-fractured bedrock aquifer. Using the Theis equation, the lateral radius of influence can be calculated as follows:

$$r = \sqrt{\frac{uTt}{2,693S}}$$

Where

- r = radius of influence (feet)
- t = time the well is pumped under normal operational conditions (minutes)
- S = aquifer storativity or specific yield (dimensionless)
- T = aquifer transmissivity (gallons per day per foot)
- U = is a parameter related to the well function (dimensionless)

$$W(u) = \frac{T(h_o - h)}{114.6Q}$$

Where:

$W(u)$ = well function (dimensionless), the well function is calculated and u is obtained from Appendix A.

$h_o - h$ = drawdown in the piezometer or observation well (feet) assumed to be 0.01 feet.

Q = production well discharge rate under normal operational conditions (gallons per minute)

Theis Equation Case Study No. 3

An aquifer test was completed 3 miles north of Mossville in Peoria County. The generalized logs are illustrated in Figure 5. Water level measurements were taken in well 15 and 17 to determine the effects of pumping well 4. The drawdown data from well 15 which is located 22 feet from the pumping well was analyzed to determine the aquifer constants.

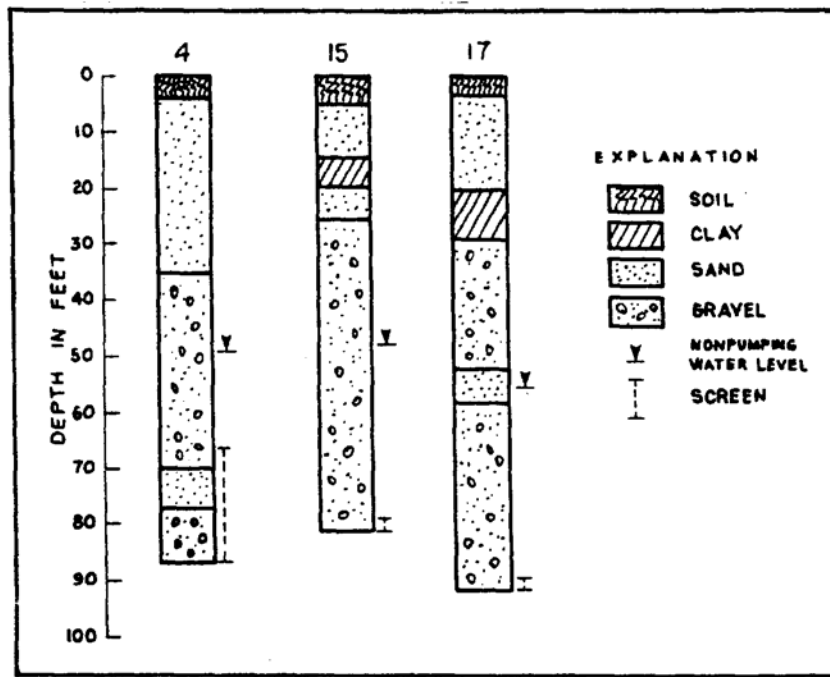


Figure 5: Generalized Graphic Logs of wells Used in a Pump Test Near Mossville (From: Bulletin 49 Illinois State Water Survey)

A) The aquifer test analysis from the Illinois State Water Survey provided the following aquifer data:

Transmissivity $(T) = 315,000$ gallons per day per foot
(gpd/ft) of drawdown.

Storativity $(S) = 0.08$ dimensionless (no units)

- B) The period of time the pump is operated under normal daily operating conditions was determined using information from the pumping records as follows:

The pumping rate under normal operating conditions (Q) = 1,100 gallons per minutes (gal/min)

Daily pumpage volume (V) = 726,000 gallons (gal)

Using: Time (t) = $\frac{V}{Q}$

$$(t) = \frac{726,000(gal)}{1,100(gal/min)}$$

$$(t) = 660 (min)$$

- C) The criteria used to represent a minimum level of drawdown was assumed to be:

$$\text{Drawdown } (h_o - h) = 0.01 (ft)$$

- D) The information determined above was used in the following equation:

$$W(u) = \frac{T(h_o - h)}{114.60}$$

$$W(u) = \frac{315,000 \times 0.01}{114.6 \times 1,100} \quad \frac{(gpd / ft) ft}{gpd}$$

$$W(u) = 0.025 \text{ (dimensionless)}$$

Appendix (A) was used as illustrated in Table 1, and the u value associated with a $W(u) = 0.025$ was determined to be:

$$U = 2.5 \text{ (dimensionless)}$$

Table 1. Example of How to Use Appendix A To Determine u From $W(u)$

10 Well Functions		
U	$W(u)$	I/U
1.0E+00	0.219	1.00E+00
1.1E+00	0.186	9.09E-01
1.2E+00	0.158	8.33E-01
1.3E+00	0.135	7.69E-01
1.4E+00	0.116	7.14E-01
1.5E+00	0.100	6.67E-01
1.6E+00	0.086	6.25E-01
1.7E+00	0.075	5.88E-01
1.8E+00	0.065	5.56E-01
1.9E+00	0.056	5.26E-01
2.0E+00	0.049	5.00E-01
2.1E+00	0.043	4.76E-01
2.2E+00	0.037	4.55E-01
2.3E+00	0.033	4.35E-01
2.4E+00	0.028	4.71E-01
2.5E+00	0.025	4.00E-01
2.6E+00	0.022	3.85E-01
2.7E+00	0.019	3.70E-01
2.8E+00	0.017	3.57E-01
2.9E+00	0.015	3.45E-01
3.0E+00	0.013	3.33E-01
3.1E+00	0.011	3.23E-01
3.2E+00	0.010	3.13E-01
3.3E+00	0.009	3.03E-01
3.4E+00	0.008	2.94E-01
3.5E+00	0.007	2.86E-01
3.6E+00	0.006	2.78E-01
3.7E+00	0.005	2.70E-01
3.8E+00	0.005	2.63E-01
3.9E+00	0.004	2.56E-01
4.0E+00	0.004	2.50E-01
4.1E+00	0.003	2.44E-01
4.2E+00	0.003	2.38E-01
4.3E+00	0.003	2.33E-01
4.4E+00	0.002	2.27E-01
4.5E+00	0.002	2.22E-01
4.6E+00	0.002	2.17E-01
4.7E+00	0.002	2.13E-01
4.8E+00	0.001	2.08E-01
4.9E+00	0.001	2.04E-01
5.0E+00	0.001	2.00E-01

E) The last step of the estimation procedure is to determine the lateral radius of influence as follow:

$$r = \sqrt{\frac{uTt}{2,693S}}$$

$$r = \sqrt{\frac{2.5 \times 340,000(\text{gal} / \text{day} / \text{ft}) \times 660(\text{min})}{2,693 \times (0.08)}}$$

$$r = 1,613 \text{ (ft)}$$

The results of the estimation procedure yielded that the lateral radius of influence (r) for well 3 was 1,613 feet. In other words, the level of drawdown was estimated to be equal to 0.01 feet at a distance of 1,613 ft. from the wellhead. Since the lateral radius of influence (r) for the well was greater than the minimum setback distance (400 ft) the well is eligible for a maximum setback zone and Agency review for technical adequacy.

Case Study No. 4 Theis Equation

An aquifer test was completed in Effingham County approximately 1 mile south of the corporate limits of the Village of Dieterich. Water level measurements were taken in observation wells 15, 16 and 19 to determine the effects of pumping well 18. The drawdown data from well 19 which is located approximately 100 feet from the pumping well was analyzed to determine the aquifer constants. A generalized graphic record of the materials encountered when the wells were drilled is shown in Figure 6. In addition, Figure 7 illustrates that the well is utilizing a confined aquifer because the water levels are above the water producing zone.

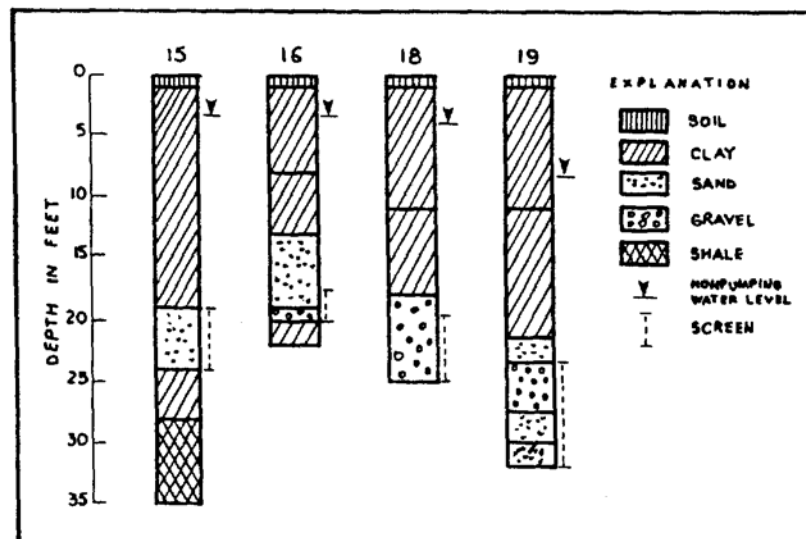


Figure 6. Graphic Record of Materials
Encountered During Drilling (From: Bulletin 49 Illinois State Water Survey)

- A) The aquifer test analysis from the Illinois State Water Survey provided the following aquifer data:

Transmissivity $(T) = 1,510$ gallons per day per foot of drawdown (gpd/ft)

Storativity $(S) = 0.0002$ dimensionless (no units)

- B) The period of time the pump is operated under normal operating conditions was determined using information from the pumping records. In this case the daily pumpage volume and the pumping rates were available from the pumping records. In some instances, time and pumping rate may be available in the records and this calculation would not be necessary.

The pumping rate under normal operating
Conditions $(Q) = 25$ gallons per minute (gal/min)

Daily pumpage volume $(V) = 15,000$ gallons (gal)

$$\text{Using Time } (t) = \frac{V}{Q}$$

$$(t) = \frac{15,000(\text{gal})}{25(\text{gal/min})}$$

$$(t) = 600 (\text{min})$$

- C) The criteria used to represent a minimum level of drawdown was assumed to be:

$$\text{Drawdown } (h_o - h) = 0.01 (\text{ft})$$

- D) The information determined above was used in the following equation:

$$W(u) = \frac{T(h_o - h)}{114.6Q}$$

$$W(u) = \frac{1,510 \times 0.01}{114.6 \times 25}$$

$$W(u) = 0.0053 (\text{dimensionless})$$

Appendix (A) was used as illustrated in Table 1 (page 13), and the u value associated with a $W(u) = 0.0053$ was determined to be:

$$u = 3.8 \text{ dimensionless}$$

- E) The last step of the estimation procedure is to determine the lateral radius of influence as follows:

$$r = \sqrt{\frac{uTt}{2.693S}}$$

$$r = \sqrt{\frac{3.8 \times 1,510 (\text{gal}/\text{min}/\text{ft}) 600 (\text{min})}{2.693 \times 0.0002}}$$

$$r = 2,528 \text{ (ft)}$$

The results of the estimation procedure yielded that the lateral radius of influence (r) for Well 18 was 2,528 feet. In other words, the level of drawdown was estimated to be equal to 0.01 feet at a distance of 2,528 feet from the wellhead. Since the lateral radius of influence (r) for the well was greater than the minimum setback distance (200 ft), the well is eligible for a maximum setback zone and Agency review for technical adequacy.

Volumetric Flow Equation Summary

Case studies No. 5 and No. 6 use the volumetric flow equation. The volumetric flow equation is a cost-effective estimation alternative where aquifer constants are not available and the Theis equation cannot be used. The volumetric flow equation may be used for wells utilizing unconfined unconsolidated or unconfined nonfractured bedrock aquifers as follows:

$$r = \sqrt{\frac{Qt}{4,524nH}}$$

Where

r	=	radius of influence (feet)
Q	=	daily flow from the well under normal operational conditions (cubic feet per day)
t	=	time that the well is pumped under normal operational conditions (minutes)
H	=	open interval or length of well screen (feet)
N	=	aquifer porosity (dimensionless) (see Table 2) unless more site specific information is available

Table 2. Aquifer Porosity Values

Sand	0.21	Sandstone	0.06
Gravel	0.19	Limestones:	
Sand & Gravel	0.15	Primary dolomites,	0.18
		Secondary dolomites	0.18

Case Study No. 5 Volumetric Flow Equation

This equation is based on a very simple model of a pumping well in an unconfined aquifer. This equation should be utilized for wells that are pumped continuously and where aquifer constants are not available.

A generalized graphic well log, well construction details, and pump operating data were available for Dodge Street Well 1 from the Illinois American Water Company, Peoria. The well log in Figure 7 shows that the well was completed in a sand and gravel deposit which extends from 40-130 feet below the land surface. The static water level in the aquifer was 65 feet below the land surface. Because the static water level is below the top of the aquifer, this would be considered an unconfined aquifer.

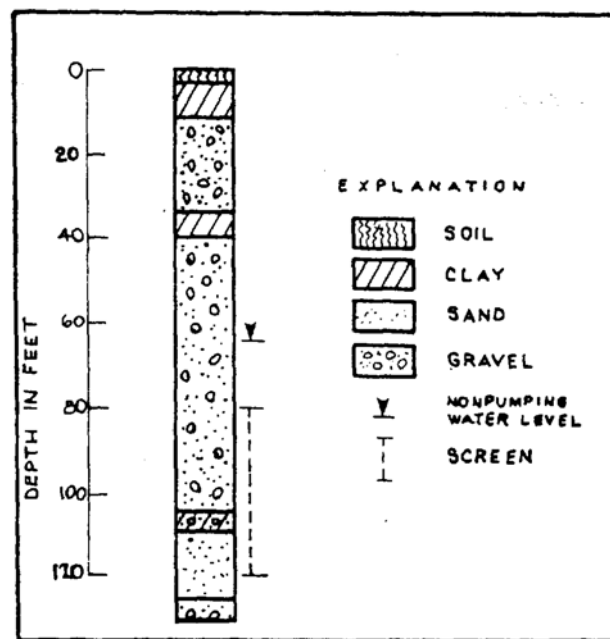


Figure 7. Graphic Well Logs for Dodge Street Well 1

-
- A) Well construction details indicate that the well screen length (H) is 44 feet (ft).
- B) Well operation records show that the pump is operated continuously for 30 days every other month. You may determine the number of minutes the well is pumped using the following equation:

$$\begin{aligned} \text{Time } (t) &= (?) \text{ (days)} \times 1,440 \text{ (min/day)} \\ (t) &= 30 \text{ (days)} \times 1,440 \text{ (min/day)} \\ (t) &= 43,200 \text{ (min)} \end{aligned}$$

- C) The pumping rate under normal operating conditions (Q) = 1,708 gallons per minute (gal/min)

The units used in the volumetric flow equation for pumping rate are cubic feet per day (ft^3/day). To convert gallons/minute (gal/min) to cubic feet per day (ft^3/day) use the following equation:

$$\begin{aligned} 192.51 \text{ X } (?) \text{ (gal/min)} &= (ft^3/day) \\ 192.51 \text{ X } (1,708) \text{ (gal/min)} &= 328.807 \text{ (ft}^3/day) \end{aligned}$$

$$Q = 328,807 \text{ (ft}^3/day)$$

- D) Table 2 repeated below was used to determine an approximate value for the porosity (n) = 0.15 of the sand and gravel deposit. If site specific data is available from sieve analyses or other methods it should be used instead of assuming a porosity value.

Table 2. Aquifer Porosity Values

Sand	0.21	Sandstone	0.06
Gravel	0.19	Limestones:	
Sand & Gravel	0.15	Primary dolomites,	0.18
		Secondary dolomites	0.18

- E) The final step of the procedure is to enter the above information into the following equation:

$$r = \sqrt{\frac{Qt}{4,524nH}}$$

$$r = \sqrt{\frac{328,807(ft^3/day) \times 43,200(min)}{4,524 \times 0.15 \times 44(ft)}}$$

$$r = 690 \text{ (ft)}$$

The results of the estimation procedure yielded that the lateral radius of influence (r) for Dodge Street Well 1 was 690 feet. Since the lateral radius of influence (r) for the well was greater than the minimum setback distance (400 ft), the well is eligible for a maximum setback zone and Agency review for technical adequacy.

A lateral radius of influence determination completed using an estimation technique (e.g., Theis equation, volumetric flow equation) does not require the signature of a geologist or engineer.

Type Curve Matching Case Study No. 6

An aquifer test was completed on an unconsolidated (e.g., sand and gravel) confined aquifer located in Gridley, Illinois. The effects of pumping well 3 were measured in wells 1 and 2. Well 1 is located 824 feet from well 3. The direct drawdown method could be used in this case due to the location of well 1 outside the minimum setback zone. This example was included to demonstrate type curve matching. The generalized graphic well logs are shown in Figure 8.

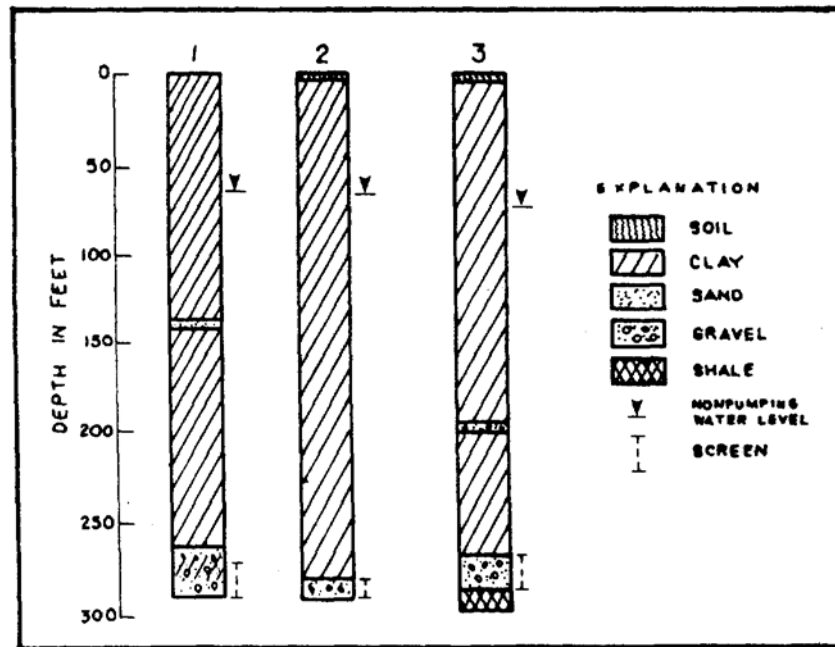


Figure 8. Generalized Graphic Logs Depicting Material Encountered in Well Borings 1, 2 and 3
(From: Bulletin 49 Illinois State Water Survey)

Time drawdown data from the pump test is shown in Table 3. This data is plotted on logarithmic paper as illustrated in Figure 9.

Table 3. Time-drawdown data for well 1 at Gridley

Time after pumping started (min)	Drawdown (ft)
3	0.3
5	0.7
8	1.3
12	2.1
20	3.2
24	3.6
30	4.1
38	4.7
47	5.1
50	5.3
60	5.7
70	6.1
80	6.3
90	6.7
100	7.0
130	7.5
160	8.3
200	8.5
260	9.2
320	9.7
380	10.2
500	10.9

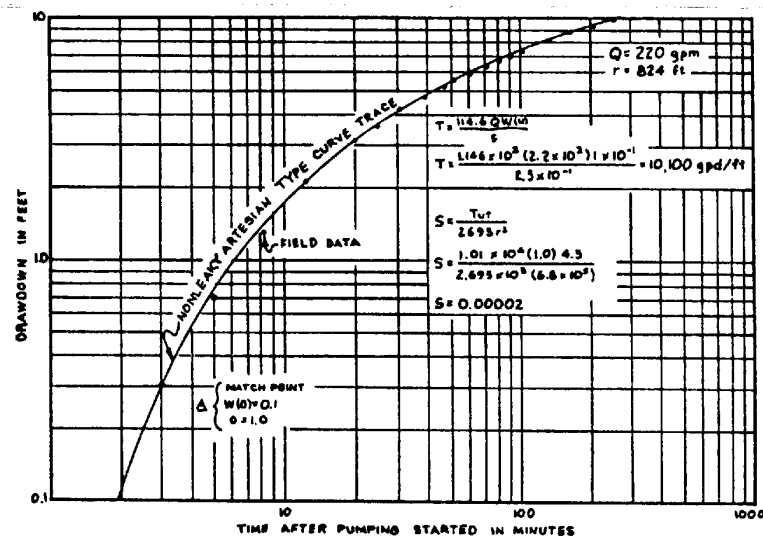


Figure 9. Time Drawdown Graph for Well 1 at Gridley
(From: Bulletin 49 Illinois State Water Survey)

The nonleaky artesian type curve was used to determine the match point illustrated in Figure 9. The following data was found from the match point.

$$W(u) = 0.1$$

$$U = 1.0 \text{ @ Time } (t) = 4.3 \text{ minutes}$$

$$\text{Drawdown } (h_o - h) = 0.25$$

$$\text{Pumping rate } (Q) = 220 \text{ gallons per minute}$$

In addition, the distance between pumping well and production well was $(r) = 824$ feet.

The variables above were then used to derive aquifer constants with the Theis equation as follows:

$$\begin{aligned} \text{A) Transmissivity } (T) &= \frac{114.6Q W(u)}{H_o - h} \\ &= \frac{114.6 \times 220 \times 0.1}{0.25} \\ &= 10,085 \text{ gpd/ft} \end{aligned}$$

$$\begin{aligned} \text{B) Storativity } (S) &= \frac{T u t}{2693 r^2} \\ &= \frac{10,085 \times 1.0 \times 4.3}{2693 (824)^2} \\ &= 0.00002 \text{ dimensionless} \end{aligned}$$

C) The period of time the pump is operated under normal operating conditions was determined using information from the pumping records as follows:

The pumping rate under normal operating conditions $(Q) = 220$ gallons per minute (*gal/min*)

The daily pumpage volume $(V) = 132,000$ gallons (*gal*)

$$\text{Using: Time } (t) = \frac{V}{Q}$$

$$(t) = \frac{132,000(\text{gal})}{220(\text{gal/min})}$$

$$(t) = 600 \text{ (min)}$$

D) The criteria used to represent a minimum level of drawdown was assumed to be:

$$\text{Drawdown } (h_o - h) = 0.01 \text{ (ft)}$$

E) The information determined above was entered into the following equation:

$$W(u) = \frac{T(h_o - h)}{114.6Q}$$

$$W(u) = \frac{10,085 \times 0.01}{114.6 \times 220}$$

$$W(u) = 0.004 \text{ dimensionless}$$

F) Appendix (A) was used as illustrated in Table 1 repeated below and the u value associated with a $W(u) = 0.004$ was determined to be:

$$\underline{u} = 4 \text{ dimensionless}$$

Table 1. Example of How to Use Appendix A to Determine U From $W(U)$

U	$W(u)$	I/U
1.0E+00	0.219	1.00E+00
1.1E+00	0.186	9.09E-01
1.2E+00	0.158	8.33E-01
1.3E+00	0.135	7.69E-01
1.4E+00	0.116	7.14E-01
1.5E+00	0.100	6.67E-01
1.6E+00	0.086	6.25E-01
1.7E+00	0.075	5.88E-01
1.8E+00	0.065	5.56E-01
1.9E+00	0.056	5.26E-01
2.0E+00	0.049	5.00E-01
2.1E+00	0.043	4.76E-01
2.2E+00	0.037	4.55E-01
2.3E+00	0.033	4.35E-01
2.4E+00	0.028	4.71E-01
2.5E+00	0.025	4.00E-01
2.6E+00	0.022	3.85E-01
2.7E+00	0.019	3.70E-01
2.8E+00	0.017	3.57E-01
2.9E+00	0.015	3.45E-01
3.0E+00	0.013	3.33E-01
3.1E+00	0.011	3.23E-01
3.2E+00	0.010	3.13E-01
3.3E+00	0.009	3.03E-01
3.4E+00	0.008	2.94E-01
3.5E+00	0.007	2.86E-01
3.6E+00	0.006	2.78E-01
3.7E+00	0.005	2.70E-01
3.8E+00	0.005	2.63E-01
3.9E+00	0.004	2.56E-01
4.0E+00	0.004	2.50E-01
4.1E+00	0.003	2.44E-01
4.2E+00	0.003	2.38E-01
4.3E+00	0.003	2.33E-01
4.4E+00	0.002	2.27E-01
4.5E+00	0.002	2.22E-01
4.6E+00	0.002	2.17E-01
4.7E+00	0.002	2.13E-01
4.8E+00	0.001	2.08E-01
4.9E+00	0.001	2.04E-01
5.0E+00	0.001	2.00E-01

- G) The last step of the estimation procedure is to determine the lateral radius of influence as follows:

$$r = \sqrt{\frac{uTt}{2.693S}}$$

$$r = \sqrt{\frac{4 \times 10,085 (\text{gal} / \text{day} / \text{ft}) \times 600 \text{min}}{2.693 \times (0.00002)}}$$

$$r = 22,199 \text{ (ft)}$$

The results of the estimation procedure yielded that the lateral radius of influence (r) for Gridley well 3 was 22,140 feet. In other words, the level of drawdown was estimated to be equal to 0.01 feet at a distance of 22,140 ft. from the wellhead. Since the lateral radius of influence (r) for the well was greater than the minimum setback distance (400 ft), the well is eligible for maximum setback zone and Agency review for technical adequacy. For additional information on interpreting aquifer test data, refer to the Illinois State Water Survey Bulletin 49.

SUMMARY AND CONCLUSIONS

Section 14.3 of the Illinois Groundwater Protection Act provides municipal and county officials served by a public or community water supply with the authority to establish a maximum setback zone. The following provides a summary of the major points associated with establishing a maximum setback zone:

- the lateral radius of influence is used to establish a maximum zone;
- in general, the information required to perform a radius of influence calculation is available in local water supply records or can be easily obtained;
- water supply owners or counties and municipalities served by a community water supply well can make a lateral radius of influence determination;
- if the radius of influence is greater than the minimum setback zone distance (200/400 feet) established by the IGPA, a county or municipality is qualified to apply for a maximum zone;
- the county or municipality must prepare a draft maximum zone ordinance prior to Agency review;
- after Agency confirmation of the technical adequacy of the maximum zone application, the county or municipality has the authority to adopt a maximum zone ordinance;
- the law requires the county or municipality to adopt an ordinance after Agency confirmation of the application to officially establish a maximum setback zone; and
- a maximum setback zone can have irregular boundaries (e.g., greater than the minimum zone but less than or equal to 1,000 feet) but cannot exceed 1,000 feet.

There are many benefits associated with establishing maximum setback zones including: prevention of contamination by siting restrictions up to 1,000 feet; regulation of certain existing and new potential sources by technology control and groundwater quality standards proposals after adoption by the Illinois Pollution Control Board; creation of an awareness of the sensitivity of the zone to contamination; and local control.

APPENDIX A

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

TITLE 35: ENVIRONMENTAL PROTECTION

SUBTITLE F: PUBLIC WATER SUPPLIES

CHAPTER II: ENVIRONMENTAL PROTECTION AGENCY

PART 671

MAXIMUM SETBACK ZONE FOR COMMUNITY WATER SUPPLY WELLS

SUBPART A: INTRODUCTION

Section

- 671.101 Purpose
- 671.102 Definitions
- 671.103 Severability
- 671.104 Agency Mailing Address

SUBPART B: PROCEDURES FOR DETERMINING THE LATERAL AREA
OF INFLUENCE OF WELLS UNDER NORMAL OPERATIONAL CONDITIONS

Section

- 671.201 Estimation Techniques and Pumping Test
- 671.202 Agency Approval of Alternate Estimation Techniques, Pump Tests, or Other Procedures

SUBPART C: REQUESTS FOR AGENCY REVIEW AND CONFIRMATION

Section

- 671.301 General
- 671.302 Contents of a Request
- 671.303 Agency Approval of Alternate Certification
- 671.304 Agency Review and Confirmation
- 671.305 Adoption of a Maximum Setback Zone Ordinance
- 671.306 Changing a Maximum Setback Zone

- Appendix A Volumetric Flow Equation
- Appendix B Theis Equation Using Available Data
- Appendix C Todd Uniform Flow Equation
- Appendix D Neuman Equations and Pump Test Procedures for Unconfined or Water Table Aquifers
- Appendix E Theis Equations and Pump Test Procedures for Confined Aquifers
- Appendix F Hydrogeologic Mapping
- Table A Well Functions for Confined Aquifers
- Table B Well Functions for Unconfined or Water Table Aquifers

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NOTICE OF ADOPTED RULES

AUTHORITY: Implementing and authorized by Section 14.3 of the Environmental Protection Act (Ill. Rev. Stat. 1987, ch. 111 1/2, par. 1014.3).

SOURCE: Adopted at _____ Ill. Reg. _____, effective _____

NOTE: CAPITALIZATION DENOTES STATUTORY LANGUAGE.

SUBPART A: INTRODUCTION

Section 671.101 Purpose

- a) Section 14.2 of the Act establishes a minimum setback zone for existing or permitted community water supply wells or other potable water supply wells.
- b) Section 14.3 of the Act authorizes a maximum setback zone to be established for community water supply wells.
- c) In order to establish a maximum setback zone, the lateral area of influence of the well under normal operational conditions must be determined.
- d) OWNERS OF COMMUNITY WATER SUPPLIES WHICH UTILIZE ANY WATER WELL, OR ANY COUNTY OR MUNICIPALITY SERVED BY ANY COMMUNITY WATER SUPPLY WELL, MAY DETERMINE THE LATERAL AREA OF INFLUENCE OF THE WELL UNDER NORMAL OPERATIONAL CONDITIONS. THE AGENCY SHALL ADOPT PROCEDURES BY WHICH SUCH DETERMINATIONS MAY BE MADE INCLUDING, WHERE APPROPRIATE, PUMPING TESTS AND ESTIMATION TECHNIQUES. (Section 14.3(a) of the Environmental Protection Act (Ill. Rev. Stat. 1987, ch. 111 1/2, par. 1014.3(a))).
- e) The rules set forth in this Part describe the procedures for establishing a maximum setback zone under Sections 14.3(a), 14.3(b), and 14.3(c) of the Act.
- f) The rules set forth in Subpart B describe the procedures to be used by owners of community water supplies, by counties, or by municipalities to determine the lateral area of influence of community water supply wells. The rules set forth in Subpart C describe the procedures to be used by counties or municipalities in requesting Agency review and confirmation of this determination.

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Section 671.102 Definitions

- a) Unless specified otherwise, all terms shall have the meanings set forth in the Act and the Illinois Groundwater Protection Act (Ill. Rev. Stat. 1987, ch. 111 1/2, pars. 7451 et seq.).
- b) For purposes of this Part, the following definitions apply:

"Act" means the Environmental Protection Act (Ill. Rev. Stat., 1987, ch. 111 1/2, pars. 1001 et seq., as amended).

"Agency" means the Illinois Environmental Protection Agency.

"Certified professional geologist" means a person certified by the American Institute of Professional Geologists.

"Confined aquifer" means an aquifer bounded above and below by impermeable beds or by shale, clay, or siltstone.

"Drawdown" means the change in the water elevation of the static water level produced by a pumping well.

"Normal operational conditions" mean capability of a well at or under the safe yield rate.

"Professional judgment" means the use of those engineering principles and practices used by engineers when fulfilling their requirements and duties consistent with the specific requirements of this Part and as certified by a Professional Engineer licensed under the Illinois Professional Engineering Act (Ill. Rev. Stat. 1987, ch. 111, par. 5101 et seq.), or the use of those geologic principles and practices used by geologists when fulfilling their requirements and duties consistent with the specific requirements of this Part and as certified by a certified professional geologist who is a member of the American Institute of Professional Geologists (7828 Vance Drive, Suite 103, Arvada, Colorado 80003).

"Registered professional engineer" means a person registered under the provisions of the Illinois Professional Engineering Act (Ill. Rev. Stat. 1987, ch. 111, par. 5101 et seq.).

"Safe yield rate" means the rate (in gallons pumped per minute per foot of drawdown) at which water can be withdrawn from an aquifer without depleting the supply.

"Unconfined aquifer" means an aquifer other than a confined aquifer.

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Section 671.103 Severability

If any provisions of this Part or the application thereof to any person or in any circumstance is adjudged invalid, such adjudication shall not affect the validity of this Part as a whole or any provision thereof not adjudged invalid.

Section 671.104 Agency Mailing Address

Each request, report, notice, or other document submitted to the Agency under this Part shall be mailed to the following address:

Manager, Groundwater Section
Division of Public Water Supplies
Illinois Environmental Protection Agency
1021 North Grand Ave East
Post Office Box 19276
Springfield, Illinois 62794-9276

SUBPART B: PROCEDURES FOR DETERMINING THE LATERAL AREA OF
INFLUENCE OF WELLS UNDER NORMAL OPERATIONAL CONDITIONS

Section 671.201 Estimation Techniques and Pumping Test

Owners of community water supplies which utilize any water well, or any county or municipality served by any community water supply well, shall determine the lateral area of influence of the well under normal operational conditions in accordance with one or more of the following:

- a) The Volumetric Flow Equation set forth in Appendix A;
- b) The Theis Equation Using Available Data set forth in Appendix B;
- c) The Todd Uniform Flow Equation set forth in Appendix C;
- d) The Neuman Equations and Pump Test Procedures for Unconfined or Water Table Aquifers set forth in Appendix D;
- e) The Theis Equations and Pump Test Procedures for Confined Aquifers set forth in Appendix E;
- f) Hydrogeologic Mapping as set forth in Appendix F; or
- g) An alternate estimation technique, pump test, or other procedure approved by the Agency in accordance with Section 671.202.

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Section 671.202 Agency Approval of Alternate Estimation Techniques, Pump Tests, or Other Procedures

The Agency shall approve an estimation technique, pump test, or other procedure that, based upon the Agency's professional judgment, is equivalent to one or more of the methods described in Section 671.201(a) through (f).

SUBPART C: REQUESTS FOR AGENCY REVIEW AND CONFIRMATION

Section 671.301 General

WHERE THE RESULTS OF ANY DETERMINATION MADE PURSUANT TO SECTION 671.201 DISCLOSE THAT THE DISTANCE FROM THE WELL TO THE OUTERMOST BOUNDARY OF THE LATERAL AREA OF INFLUENCE OF THE WELL UNDER NORMAL OPERATIONAL CONDITIONS EXCEEDS THE RADIUS OF THE MINIMUM SETBACK ZONE ESTABLISHED FOR THAT WELL PURSUANT TO SECTION 14.2 of the Act, ANY COUNTY OR MUNICIPALITY SERVED BY SUCH WATER SUPPLY MAY IN WRITING REQUEST THE AGENCY TO REVIEW AND CONFIRM THE TECHNICAL ADEQUACY OF SUCH DETERMINATION. (Section 14.3(b) of the Act).

Section 671.302 Contents of a Request

Each county or municipality requesting Agency review and confirmation under Section 14.3(b) of the Act shall complete a request form prescribed by the Agency and shall:

- a) Submit proof that the determination made pursuant to Section 671.201 describes the outer boundary of drawdown of the affected groundwater by the well under normal operational conditions. Such proof shall include, but not be limited to, the following:
 - 1) Geologic logs and well construction details;
 - 2) Aquifer test data, if an estimation technique or pump test described in Section 671.201(a), (d), or (e) is used;
 - 3) Hydrogeologic information and the source of that information, if the estimation technique described in Section 671.201(c) is used; and
 - 4) Geologic maps and the source of those maps, if the procedure described in Section 671.201(f) is used.
- b) Submit the proposed ordinance to be adopted pursuant to Section 14.3(c) of the Act.
- c) If an estimation technique or pump test described in Section 671.201(c) through (f) is used, include the following certification by a registered professional engineer, certified professional geologist, or other person approved by the Agency under Section 671.303:

I hereby certify that I am familiar with the information contained in this application, and that to the best of my knowledge and belief such information is true, complete, and accurate.

ENVIRONMENTAL PROTECTION AGENCY

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Section 671.303 Agency Approval of Alternate Certification

The Agency shall approve the certification under Section 671.302(c) by a person other than a registered professional engineer or a certified professional geologist if the county or municipality proves that such person has a bachelor's degree or a graduate degree in science or engineering, and has work experience in Geology, Hydrogeology, or Earth Science. The proof shall include, but not necessarily be limited to, a resume for such person and the name, address, and telephone number of not fewer than three personal references who can verify the education and work experience of such person.

Section 671.304 Agency Review and Confirmation

- a) THE AGENCY SHALL, WITHIN 90 DAYS OF ANY WRITTEN REQUEST under Section 14.3(b) of the Act, NOTIFY THE COUNTY OR MUNICIPALITY WHETHER THE DETERMINATION IS TECHNICALLY ADEQUATE FOR DESCRIBING THE OUTER BOUNDARY OF DRAWDOWN OF THE AFFECTED GROUNDWATER BY THE WELL UNDER NORMAL OPERATIONAL CONDITIONS. (Section 14.3(b) of the Act)
The Agency will determine if the county or municipality has made a technically adequate determination by using the requirements of this Part.
- b) ANY ACTION BY THE AGENCY under this Section SHALL BE IN WRITING AND SHALL CONSTITUTE A FINAL DETERMINATION OF THE AGENCY. (Section 14.3(b) of the Act)

Section 671.305 Adoption of a Maximum Setback Zone Ordinance

- a) UPON RECEIPT OF AGENCY CONFIRMATION OF THE TECHNICAL ADEQUACY OF THE DETERMINATION under Section 14.3(b) of the Act, THE COUNTY OR MUNICIPALITY MAY, AFTER NOTICE AND OPPORTUNITY FOR COMMENT, ADOPT AN ORDINANCE SETTING FORTH THE LOCATION OF EACH AFFECTED WELL AND SPECIFYING THE BOUNDARIES OF A MAXIMUM SETBACK ZONE, WHICH BOUNDARIES MAY BE IRREGULAR. IN NO EVENT, HOWEVER, SHALL ANY PORTION OF SUCH A BOUNDARY BE IN EXCESS OF 1,000 FEET FROM THE WELLHEAD. (Section 14.3(c) of the Act).
- b) SUCH ORDINANCE SHALL INCLUDE THE AREA WITHIN THE APPLICABLE MINIMUM SETBACK ZONE AND SHALL INCORPORATE REQUIREMENTS WHICH ARE CONSISTENT WITH BUT NOT MORE STRINGENT THAN THE PROHIBITIONS OF the ACT AND THE REGULATIONS PROMULGATED BY THE BOARD UNDER SECTION 14.4 of the Act. (Section 14.3(c) of the Act).
- c) UPON ADOPTION, THE COUNTY OR MUNICIPALITY SHALL PROVIDE A COPY OF THE ORDINANCE TO THE AGENCY. (Section 14.3(c) of the Act).
- d) ANY COUNTY OR MUNICIPALITY WHICH FAILS TO ADOPT SUCH AN ORDINANCE WITHIN 2 YEARS OF RECEIPT OF AGENCY CONFIRMATION OF TECHNICAL ADEQUACY MAY NOT PROCEED UNDER THE AUTHORITY OF Section 14.3 of the Act WITHOUT OBTAINING A NEW CONFIRMATION OF THE TECHNICAL ADEQUACY PURSUANT TO Section 14.3(b) of the Act. (Section 14.3(c) of the Act).

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Section 671.306 Changing a Maximum Setback Zone

If a county or municipality has established a maximum setback zone by ordinance, the county or municipality shall, upon adoption, provide a copy to the Agency of each ordinance which in any way modifies the maximum setback zone.

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Section 671. Appendix A Volumetric Flow Equation

For unconfined unconsolidated, or unconfined non-fractured bedrock aquifers the lateral radius of influence can be calculated as follows:

$$r = \sqrt{\frac{Qt}{4524nH}}$$

Where:

- r = radius of influence (feet)
- Q = daily flow from the well under normal operational conditions (cubic feet per day)
- t = time that the well is pumped under normal operational conditions (minutes)
- H = open interval or length of well screen (feet)
- n = aquifer porosity (see Figure A-1) unless more site specific information is available

Sand	0.21	Sandstone	0.06
Gravel	0.19	Limestones:	
Sand & Gravel	0.15	Primary dolomites,	0.18
		Secondary dolomites	0.18

Figure A-1

Section 671. Appendix B Theis Equation Using Available Data

If pump test data is available for an unconfined/confined unconsolidated or non-fractured bedrock aquifer the lateral radius of influence can be calculated as follows:

$$r = \sqrt{\frac{uTt}{2693S}}$$

Where:

- r = radius of influence (feet)
- t = time well is pumped under normal operational conditions (minutes)
- S = aquifer storativity or specific yield (dimensionless)
- T = aquifer transmissivity (gallons per day per foot)
- u = is a dimensionless parameter related to the well function

$$W(u) = \frac{T(h_o - h)}{114.6Q}$$

Where:

- $W(u)$ = well function, the well function is calculated and u is obtained from Table A.
- $h_o - h$ = drawdown in the piezometer or observation well (feet)
- Q = production well discharge rate under normal operational conditions (gallons per minute)

ENVIRONMENTAL PROTECTION AGENCY

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Section 671. Appendix C Todd Uniform Flow Equation

If hydrogeologic information (e.g., transmissivity, porosity, hydraulic gradient, hydraulic conductivity, and saturated thickness of the aquifer) is available the lateral area of influence can be calculated for unconfined/confined unconsolidated or non-fractured bedrock aquifers as follows:

$$X = \frac{1.19 Q}{Ti}$$

$$Y = \frac{7.48 Q}{Ti}$$

Where:

Q = daily flow from the well under normal operational conditions (cubic feet per day)

i = hydraulic gradient of the water table or potentiometric surface

T = aquifer transmissivity (gallons per day per foot)

X = lateral area of influence or down gradient divide (feet)

Y = maximum width of the lateral area of influence or the maximum width of the influx zone (feet)

The distance to the upgradient divide is established as the distance to the upgradient regional groundwater divide.

Section 671. Appendix D Neuman Equations and Pump Test Procedures for Unconfined or Water Table Aquifers

If no data is available for unconsolidated or non-fractured bedrock aquifer constants, a pump test can be conducted to determine the lateral radius of influence as follows:

- A. At least one fully penetrating observation well is necessary.
- B. The pump test should be conducted for at least 48 hours.
- C. The flow equation for unconfined aquifers is given by:

$$T = \frac{114.6Q}{(h_o - h)} W(u_A, u_B, \alpha)$$

Where:

T = transmissivity (gallons per day per foot)

Q = production well discharge rate (gallons per minute)

$h_o - h$ = drawdown in the observation well (feet)

$W(u_A, u_B, \alpha)$ = well function for unconfined aquifers, the well function is calculated and (U_A, r) (U_B, r) is obtained from Table B

$$U_A = \frac{2693r^2 S}{Tt} \text{ (early phase drawn)}$$

$$r = \frac{r^2 K_V}{b^2 Kh}$$

$$U_B = \frac{2693r^2 S_Y}{Tt} \text{ (late phase draw down)}$$

$$T = Khxb$$

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Where:

- S = storativity (dimensionless)
 S_y = specific yield (dimensionless)
 t = time (minutes)
 b = aquifer saturated thickness (feet)
 K_v = aquifer vertical hydraulic conductivity (gallons per day per square feet)
 Kh = aquifer horizontal hydraulic conductivity (gallons per day per square feet)
 r = distance from the production well to observation well (feet)

The radius of influence can then be calculated using the following:

$$r = \sqrt{\frac{UbTt}{2693S_y}}$$

Where:

t = time pumped under normal operational conditions (minutes).

Two sets of type curves are used (Neuman, 1975). Type-A curves are used for early phase drawdown data, and Type-B curves are used for late phase drawdown. The type curves are used to evaluate field data for time and drawdown, which are plotted on logarithmic paper of the same scale. The following procedure can be used:

1. Overlay time drawdown data on Type-B curves. At any match point, the values of $W(U_B, r)$, U_B , t , and $h_o - h$ are determined. The value of r comes from the type curve. The value of T and S_y is calculated using these values and the following equations:

$$T = \frac{114.6Q}{(h_o - h)} \quad W(U_B, \vartheta) \quad S_y = \frac{Tt}{2693r^2}$$

2. Use the early phase drawdown Type-A curve to calculate $W(u_A, \vartheta)$, u_A , t , $h_o - h$ and S using the ϑ value previously determined for the Type-B curve and the following equation:

$$S = \frac{TtU_A}{2693r^2}$$

3. The value of horizontal hydraulic conductivity can be determined using:

$$Kh = \frac{T}{b}$$

4. The vertical hydraulic conductivity can be determined using the following:

$$K_v = \frac{rb^2 Kh}{r^2}$$

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5. The lateral radius of influence can then be calculated with the following:

$$r = \sqrt{\frac{uBTt}{2693Sy}}$$

Section 671. Appendix E Theis Equations and Pump Test Procedures for Confined Aquifers

If no data exists for confined unconsolidated or non-fractured bedrock aquifer constants, a pump test can be conducted to determine the lateral radius of influence as follows:

- A. At least one fully penetrating piezometer is necessary.
- B. The pump test should be conducted for at least 24 hours.
- C. The flow equations for confined aquifers are as follows:

$$T = \frac{114.6Q W(u)}{h_o - h}$$

$$u = \frac{2693r^2S}{Tt}$$

$$S = \frac{Ttu}{2693r^2}$$

PROCEDURE

The Theis type curve is used. The type curve is used to evaluate field data for time and drawdown, which are plotted on logarithmic paper of the same scale. The following procedure can be used:

1. Overlay time drawdown data on type curve. At any match point, the values of $W(u)$, u , and $h_o - h$ are determined (see Table B).
2. Transmissivity can be calculated using the values from the match point and the following equation:

$$T = \frac{114.6Q W(u)}{h_o - h}$$

3. From the value established above, k can be determined as follows:

$$k = \frac{T}{b}$$

4. From the values established above, S can be calculated as follows:

$$S = \frac{uTt}{2693r^2}$$

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5. From all of the above, the lateral radius of influence can be calculated as follows:

$$S = \frac{uTt}{2693S}$$

Where:

- r = radius of influence (feet)
- Q = production well discharge rate under normal operational conditions (gallons per minute)
- S = aquifer storativity (dimensionless)
- T = aquifer transmissivity (gallons per day per foot)
- u = is a dimensionless parameter related to well function
- $W(u)$ = well function, the well function is calculated and u is obtained from Table A
- $h_o - h$ = drawdown in the piezometer or observation well
- t = time the well is pumped under normal operational conditions (minutes)

Section 671. Appendix F Hydrogeologic Mapping

In many unconfined unconsolidated aquifers and unconfined bedrock aquifers, the fixed radius calculated with any of the previous methods can be supplemented with geologic mapping. A fixed radius could be modified to an irregular shape where impermeable barrier boundary is encountered within 1,000 feet and beyond the minimum setback.

Hydrogeologic mapping may also include mapping of groundwater levels in order to identify groundwater drainage divides.

Hydrogeologic mapping is unconfined karst or unconfined fractured bedrock areas may be the primary means of delineating the lateral radius of influence. It is extremely difficult to define the actual recharge area of a well in a fractured bedrock setting.

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Section 671.TABLE A Well Functions for Confined Aquifers

10 ⁻¹⁰ Well Functions					
U	W(U)	1/U	U	W(U)	1/U
1.0E-10	22.45	1.00E+10	5.3E-10	20.78	1.89E+09
1.1E-10	22.35	9.09E+09	5.4E-10	20.76	1.85E+09
1.2E-10	22.27	8.33E+09	5.5E-10	20.74	1.82E+09
1.3E-10	22.19	7.69E+09	5.6E-10	20.73	1.79E+09
1.4E-10	22.11	7.14E+09	5.7E-10	20.71	1.75E+09
1.5E-10	22.04	6.67E+09	5.8E-10	20.69	1.72E+09
1.6E-10	21.98	6.25E+09	5.9E-10	20.67	1.69E+09
1.7E-10	21.92	5.88E+09	6.0E-10	20.66	1.67E+09
1.8E-10	21.86	5.56E+09	6.1E-10	20.64	1.64E+09
1.9E-10	21.81	5.26E+09	6.2E-10	20.62	1.61E+09
2.0E-10	21.76	5.00E+09	6.3E-10	20.61	1.59E+09
2.1E-10	21.71	4.76E+09	6.4E-10	20.59	1.56E+09
2.2E-10	21.66	4.55E+09	6.5E-10	20.58	1.54E+09
2.3E-10	21.62	4.35E+09	6.6E-10	20.56	1.52E+09
2.4E-10	21.57	4.17E+09	6.7E-10	20.55	1.49E+09
2.5E-10	21.53	4.00E+09	6.8E-10	20.53	1.47E+09
2.6E-10	21.49	3.85E+09	6.9E-10	20.52	1.45E+09
2.7E-10	21.46	3.70E+09	7.0E-10	20.50	1.43E+09
2.8E-10	21.42	3.57E+09	7.1E-10	20.49	1.41E+09
2.9E-10	21.38	3.45E+09	7.2E-10	20.47	1.39E+09
3.0E-10	21.35	3.33E+09	7.3E-10	20.46	1.37E+09
3.1E-10	21.32	3.23E+09	7.4E-10	20.45	1.35E+09
3.2E-10	21.29	3.13E+09	7.5E-10	20.43	1.33E+09
3.3E-10	21.25	3.03E+09	7.6E-10	20.42	1.32E+09
3.4E-10	21.22	2.94E+09	7.7E-10	20.41	1.30E+09
3.5E-10	21.20	2.86E+09	7.8E-10	20.39	1.28E+09
3.6E-10	21.17	2.78E+09	7.9E-10	20.38	1.27E+09
3.7E-10	21.14	2.70E+09	8.0E-10	20.37	1.25E+09
3.8E-10	21.11	2.63E+09	8.1E-10	20.36	1.23E+09
3.9E-10	21.09	2.56E+09	8.2E-10	20.34	1.22E+09
4.0E-10	21.06	2.50E+09	8.3E-10	20.33	1.20E+09
4.1E-10	21.04	2.44E+09	8.4E-10	20.32	1.19E+09
4.2E-10	21.01	2.38E+09	8.5E-10	20.31	1.18E+09
4.3E-10	20.99	2.33E+09	8.6E-10	20.30	1.16E+09
4.4E-10	20.97	2.27E+09	8.7E-10	20.29	1.15E+09
4.5E-10	20.94	2.22E+09	8.8E-10	20.27	1.14E+09
4.6E-10	20.92	2.17E+09	8.9E-10	20.26	1.12E+09
4.7E-10	20.90	2.13E+09	9.0E-10	20.25	1.11E+09
4.8E-10	20.88	2.08E+09	9.1E-10	20.24	1.10E+09
4.9E-10	20.86	2.04E+09	9.2E-10	20.23	1.09E+09
5.0E-10	20.84	2.00E+09	9.3E-10	20.22	1.08E+09
5.1E-10	20.82	1.96E+09	9.4E-10	20.21	1.06E+09
5.2E-10	20.80	1.92E+09	9.5E-10	20.20	1.05E+09
			9.6E-10	20.19	1.04E+09
			9.7E-10	20.18	1.03E+09
			9.8E-10	20.17	1.02E+09
			9.9E-10	20.16	1.01E+09

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 10^{-9} Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-09	20.15	1.00E+09	5.1E-09	18.52	1.96E+08
1.1E-09	20.05	9.09E+08	5.2E-09	18.50	1.92E+08
1.2E-09	19.96	8.33E+08	5.3E-09	18.48	1.89E+08
1.3E-09	19.88	7.69E+08	5.4E-09	18.46	1.85E+08
1.4E-09	19.81	7.14E+08	5.5E-09	18.44	1.82E+08
1.5E-09	19.74	6.67E+08	5.6E-09	18.42	1.79E+08
1.6E-09	19.68	6.25E+08	5.7E-09	18.41	1.75E+08
1.7E-09	19.62	5.88E+08	5.8E-09	18.39	1.72E+08
1.8E-09	19.56	5.56E+08	5.9E-09	18.37	1.69E+08
1.9E-09	19.50	5.26E+08	6.0E-09	18.35	1.67E+08
2.0E-09	19.45	5.00E+08	6.1E-09	18.34	1.64E+08
2.1E-09	19.40	4.76E+08	6.2E-09	18.32	1.61E+08
2.2E-09	19.36	4.55E+08	6.3E-09	18.31	1.59E+08
2.3E-09	19.31	4.35E+08	6.4E-09	18.29	1.56E+08
2.4E-09	19.27	4.17E+08	6.5E-09	18.27	1.54E+08
2.5E-09	19.23	4.00E+08	6.6E-09	18.26	1.52E+08
2.6E-09	19.19	3.85E+08	6.7E-09	18.24	1.49E+08
2.7E-09	19.15	3.70E+08	6.8E-09	18.23	1.47E+08
2.8E-09	19.12	3.57E+08	6.9E-09	18.21	1.45E+08
2.9E-09	19.08	3.45E+08	7.0E-09	18.20	1.43E+08
3.0E-09	19.05	3.33E+08	7.1E-09	18.19	1.41E+08
3.1E-09	19.01	3.23E+08	7.2E-09	18.17	1.39E+08
3.2E-09	18.98	3.13E+08	7.3E-09	18.16	1.37E+08
3.3E-09	18.95	3.03E+08	7.4E-09	18.14	1.35E+08
3.4E-09	18.92	2.94E+08	7.5E-09	18.13	1.33E+08
3.5E-09	18.89	2.86E+08	7.6E-09	18.12	1.32E+08
3.6E-09	18.87	2.78E+08	7.7E-09	18.10	1.30E+08
3.7E-09	18.84	2.70E+08	7.8E-09	18.09	1.28E+08
3.8E-09	18.81	2.63E+08	7.9E-09	18.08	1.27E+08
3.9E-09	18.79	2.56E+08	8.0E-09	18.07	1.25E+08
4.0E-09	18.76	2.50E+08	8.1E-09	18.05	1.23E+08
4.1E-09	18.74	2.44E+08	8.2E-09	18.04	1.22E+08
4.2E-09	18.71	2.38E+08	8.3E-09	18.03	1.20E+08
4.3E-09	18.69	2.33E+08	8.4E-09	18.02	1.19E+08
4.4E-09	18.66	2.27E+08	8.5E-09	18.01	1.18E+08
4.5E-09	18.64	2.22E+08	8.6E-09	17.99	1.16E+08
4.6E-09	18.62	2.17E+08	8.7E-09	17.98	1.15E+08
4.7E-09	18.60	2.13E+08	8.8E-09	17.97	1.14E+08
4.8E-09	18.58	2.08E+08	8.9E-09	17.96	1.12E+08
4.9E-09	18.56	2.04E+08	9.0E-09	17.95	1.11E+08
5.0E-09	18.54	2.00E+08	9.1E-09	17.94	1.10E+08
			9.2E-09	17.93	1.09E+08
			9.3E-09	17.92	1.08E+08
			9.4E-09	17.91	1.06E+08
			9.5E-09	17.89	1.05E+08
			9.6E-09	17.88	1.04E+08
			9.7E-09	17.87	1.03E+08
			9.8E-09	17.86	1.02E+08
			9.9E-09	17.85	1.01E+08

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 10^{-8} Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-08	17.84	1.00E+08	5.1E-08	16.21	1.96E+07
1.1E-08	17.75	9.09E+07	5.2E-08	16.19	1.92E+07
1.2E-08	17.66	8.33E+07	5.3E-08	16.18	1.89E+07
1.3E-08	17.58	7.69E+07	5.4E-08	16.16	1.85E+07
1.4E-08	17.51	7.14E+07	5.5E-08	16.14	1.82E+07
1.5E-08	17.44	6.67E+07	5.6E-08	16.12	1.79E+07
1.6E-08	17.37	6.25E+07	5.7E-08	16.10	1.75E+07
1.7E-08	17.31	5.88E+07	5.8E-08	16.09	1.72E+07
1.8E-08	17.26	5.56E+07	5.9E-08	16.07	1.69E+07
1.9E-08	17.20	5.26E+07	6.0E-08	16.05	1.67E+07
2.0E-08	17.15	5.00E+07	6.1E-08	16.04	1.64E+07
2.1E-08	17.10	4.76E+07	6.2E-08	16.02	1.61E+07
2.2E-08	17.06	4.55E+07	6.3E-08	16.00	1.59E+07
2.3E-08	17.01	4.35E+07	6.4E-08	15.99	1.56E+07
2.4E-08	16.97	4.17E+07	6.5E-08	15.97	1.54E+07
2.5E-08	16.93	4.00E+07	6.6E-08	15.96	1.52E+07
2.6E-08	16.89	3.85E+07	6.7E-08	15.94	1.49E+07
2.7E-08	16.85	3.70E+07	6.8E-08	15.93	1.47E+07
2.8E-08	16.81	3.57E+07	6.9E-08	15.91	1.45E+07
2.9E-08	16.78	3.45E+07	7.0E-08	15.90	1.43E+07
3.0E-08	16.74	3.33E+07	7.1E-08	15.88	1.41E+07
3.1E-08	16.71	3.23E+07	7.2E-08	15.87	1.39E+07
3.2E-08	16.68	3.13E+07	7.3E-08	15.86	1.37E+07
3.3E-08	16.65	3.03E+07	7.4E-08	15.84	1.35E+07
3.4E-08	16.62	2.94E+07	7.5E-08	15.83	1.33E+07
3.5E-08	16.59	2.86E+07	7.6E-08	15.82	1.32E+07
3.6E-08	16.56	2.78E+07	7.7E-08	15.80	1.30E+07
3.7E-08	16.54	2.70E+07	7.8E-08	15.79	1.28E+07
3.8E-08	16.51	2.63E+07	7.9E-08	15.78	1.27E+07
3.9E-08	16.48	2.56E+07	8.0E-08	15.76	1.25E+07
4.0E-08	16.46	2.50E+07	8.1E-08	15.75	1.23E+07
4.1E-08	16.43	2.44E+07	8.2E-08	15.74	1.22E+07
4.2E-08	16.41	2.38E+07	8.3E-08	15.73	1.20E+07
4.3E-08	16.38	2.33E+07	8.4E-08	15.72	1.19E+07
4.4E-08	16.36	2.27E+07	8.5E-08	15.70	1.18E+07
4.5E-08	16.34	2.22E+07	8.6E-08	15.69	1.16E+07
4.6E-08	16.32	2.17E+07	8.7E-08	15.68	1.15E+07
4.7E-08	16.30	2.13E+07	8.8E-08	15.67	1.14E+07
4.8E-08	16.27	2.08E+07	8.9E-08	15.66	1.12E+07
4.9E-08	16.25	2.04E+07	9.0E-08	15.65	1.11E+07
5.0E-08	16.23	2.00E+07	9.1E-08	15.64	1.10E+07
			9.2E-08	15.62	1.09E+07
			9.3E-08	15.61	1.08E+07
			9.4E-08	15.60	1.06E+07
			9.5E-08	15.59	1.05E+07
			9.6E-08	15.58	1.04E+07
			9.7E-08	15.57	1.03E+07
			9.8E-08	15.56	1.02E+07
			9.9E-08	15.55	1.01E+07

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 10^{-7} Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-07	15.54	1.00E+07	5.1E-07	13.91	1.96E+06
1.1E-07	15.45	9.09E+06	5.2E-07	13.89	1.92E+06
1.2E-07	15.36	8.33E+06	5.3E-07	13.87	1.89E+06
1.3E-07	15.28	7.69E+06	5.4E-07	13.85	1.85E+06
1.4E-07	15.20	7.14E+06	5.5E-07	13.84	1.82E+06
1.5E-07	15.14	6.67E+06	5.6E-07	13.82	1.79E+06
1.6E-07	15.07	6.25E+06	5.7E-07	13.80	1.75E+06
1.7E-07	15.01	5.88E+06	5.8E-07	13.78	1.72E+06
1.8E-07	14.95	5.56E+06	5.9E-07	13.77	1.69E+06
1.9E-07	14.90	5.26E+06	6.0E-07	13.75	1.67E+06
2.0E-07	14.85	5.00E+06	6.1E-07	13.73	1.64E+06
2.1E-07	14.80	4.76E+06	6.2E-07	13.72	1.61E+06
2.2E-07	14.75	4.55E+06	6.3E-07	13.70	1.59E+06
2.3E-07	14.71	4.35E+06	6.4E-07	13.68	1.56E+06
2.4E-07	14.67	4.17E+06	6.5E-07	13.67	1.54E+06
2.5E-07	14.62	4.00E+06	6.6E-07	13.65	1.52E+06
2.6E-07	14.59	3.85E+06	6.7E-07	13.64	1.49E+06
2.7E-07	14.55	3.70E+06	6.8E-07	13.62	1.47E+06
2.8E-07	14.51	3.57E+06	6.9E-07	13.61	1.45E+06
2.9E-07	14.48	3.45E+06	7.0E-07	13.59	1.43E+06
3.0E-07	14.44	3.33E+06	7.1E-07	13.58	1.41E+06
3.1E-07	14.41	3.23E+06	7.2E-07	13.57	1.39E+06
3.2E-07	14.38	3.13E+06	7.3E-07	13.55	1.37E+06
3.3E-07	14.35	3.03E+06	7.4E-07	13.54	1.35E+06
3.4E-07	14.32	2.94E+06	7.5E-07	13.53	1.33E+06
3.5E-07	14.29	2.86E+06	7.6E-07	13.51	1.32E+06
3.6E-07	14.26	2.78E+06	7.7E-07	13.50	1.30E+06
3.7E-07	14.23	2.70E+06	7.8E-07	13.49	1.28E+06
3.8E-07	14.21	2.63E+06	7.9E-07	13.47	1.27E+06
3.9E-07	14.18	2.56E+06	8.0E-07	13.46	1.25E+06
4.0E-07	14.15	2.50E+06	8.1E-07	13.45	1.23E+06
4.1E-07	14.13	2.44E+06	8.2E-07	13.44	1.22E+06
4.2E-07	14.11	2.38E+06	8.3E-07	13.42	1.20E+06
4.3E-07	14.08	2.33E+06	8.4E-07	13.41	1.19E+06
4.4E-07	14.06	2.27E+06	8.5E-07	13.40	1.18E+06
4.5E-07	14.04	2.22E+06	8.6E-07	13.39	1.16E+06
4.6E-07	14.01	2.17E+06	8.7E-07	13.38	1.15E+06
4.7E-07	13.99	2.13E+06	8.8E-07	13.37	1.14E+06
4.8E-07	13.97	2.08E+06	8.9E-07	13.35	1.12E+06
4.9E-07	13.95	2.04E+06	9.0E-07	13.34	1.11E+06
5.0E-07	13.93	2.00E+06	9.1E-07	13.33	1.10E+06
			9.2E-07	13.32	1.09E+06
			9.3E-07	13.31	1.08E+06
			9.4E-07	13.30	1.06E+06
			9.5E-07	13.29	1.05E+06
			9.6E-07	13.28	1.04E+06
			9.7E-07	13.27	1.03E+06
			9.8E-07	13.26	1.02E+06
			9.9E-07	13.25	1.01E+06

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NOTICE OF ADOPTED RULES

10⁻⁶ Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-06	13.24	1.00E+06	5.1E-06	11.61	1.96E+05
1.1E-06	13.14	9.09E+05	5.2E-06	11.59	1.92E+05
1.2E-06	13.06	8.33E+05	5.3E-06	11.57	1.89E+05
1.3E-06	12.98	7.69E+05	5.4E-06	11.55	1.85E+05
1.4E-06	12.90	7.14E+05	5.5E-06	11.53	1.82E+05
1.5E-06	12.83	6.67E+05	5.6E-06	11.52	1.79E+05
1.6E-06	12.77	6.25E+05	5.7E-06	11.50	1.75E+05
1.7E-06	12.71	5.88E+05	5.8E-06	11.48	1.72E+05
1.8E-06	12.65	5.56E+05	5.9E-06	11.46	1.69E+05
1.9E-06	12.60	5.26E+05	6.0E-06	11.45	1.67E+05
2.0E-06	12.55	5.00E+05	6.1E-06	11.43	1.64E+05
2.1E-06	12.50	4.76E+05	6.2E-06	11.41	1.61E+05
2.2E-06	12.45	4.55E+05	6.3E-06	11.40	1.59E+05
2.3E-06	12.41	4.35E+05	6.4E-06	11.38	1.56E+05
2.4E-06	12.36	4.17E+05	6.5E-06	11.37	1.54E+05
2.5E-06	12.32	4.00E+05	6.6E-06	11.35	1.52E+05
2.6E-06	12.28	3.85E+05	6.7E-06	11.34	1.49E+05
2.7E-06	12.25	3.70E+05	6.8E-06	11.32	1.47E+05
2.8E-06	12.21	3.57E+05	6.9E-06	11.31	1.45E+05
2.9E-06	12.17	3.45E+05	7.0E-06	11.29	1.43E+05
3.0E-06	12.14	3.33E+05	7.1E-06	11.28	1.41E+05
3.1E-06	12.11	3.23E+05	7.2E-06	11.26	1.39E+05
3.2E-06	12.08	3.13E+05	7.3E-06	11.25	1.37E+05
3.3E-06	12.04	3.03E+05	7.4E-06	11.24	1.35E+05
3.4E-06	12.01	2.94E+05	7.5E-06	11.22	1.33E+05
3.5E-06	11.99	2.86E+05	7.6E-06	11.21	1.32E+05
3.6E-06	11.96	2.78E+05	7.7E-06	11.20	1.30E+05
3.7E-06	11.93	2.70E+05	7.8E-06	11.18	1.28E+05
3.8E-06	11.90	2.63E+05	7.9E-06	11.17	1.27E+05
3.9E-06	11.88	2.56E+05	8.0E-06	11.16	1.25E+05
4.0E-06	11.85	2.50E+05	8.1E-06	11.15	1.23E+05
4.1E-06	11.83	2.44E+05	8.2E-06	11.13	1.22E+05
4.2E-06	11.80	2.38E+05	8.3E-06	11.12	1.20E+05
4.3E-06	11.78	2.33E+05	8.4E-06	11.11	1.19E+05
4.4E-06	11.76	2.27E+05	8.5E-06	11.10	1.18E+05
4.5E-06	11.73	2.22E+05	8.6E-06	11.09	1.16E+05
4.6E-06	11.71	2.17E+05	8.7E-06	11.07	1.15E+05
4.7E-06	11.69	2.13E+05	8.8E-06	11.06	1.14E+05
4.8E-06	11.67	2.08E+05	8.9E-06	11.05	1.12E+05
4.9E-06	11.65	2.04E+05	9.0E-06	11.04	1.11E+05
5.0E-06	11.63	2.00E+05	9.1E-06	11.03	1.10E+05
			9.2E-06	11.02	1.09E+05
			9.3E-06	11.01	1.08E+05
			9.4E-06	11.00	1.06E+05
			9.5E-06	10.99	1.05E+05
			9.6E-06	10.98	1.04E+05
			9.7E-06	10.97	1.03E+05
			9.8E-06	10.96	1.02E+05
			9.9E-06	10.95	1.01E+05

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

10⁻⁵ Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-05	10.94	1.00E+05	5.1E-05	9.31	1.96E+04
1.1E-05	10.84	9.09E+04	5.2E-05	9.29	1.92E+04
1.2E-05	10.75	8.33E+04	5.3E-05	9.27	1.89E+04
1.3E-05	10.67	7.69E+04	5.4E-05	9.25	1.85E+04
1.4E-05	10.60	7.14E+04	5.5E-05	9.23	1.82E+04
1.5E-05	10.53	6.67E+04	5.6E-05	9.21	1.79E+04
1.6E-05	10.47	6.25E+04	5.7E-05	9.20	1.75E+04
1.7E-05	10.41	5.88E+04	5.8E-05	9.18	1.72E+04
1.8E-05	10.35	5.56E+04	5.9E-05	9.16	1.69E+04
1.9E-05	10.29	5.26E+04	6.0E-05	9.14	1.67E+04
2.0E-05	10.24	5.00E+04	6.1E-05	9.13	1.64E+04
2.1E-05	10.19	4.76E+04	6.2E-05	9.11	1.61E+04
2.2E-05	10.15	4.55E+04	6.3E-05	9.10	1.59E+04
2.3E-05	10.10	4.35E+04	6.4E-05	9.08	1.56E+04
2.4E-05	10.06	4.17E+04	6.5E-05	9.06	1.54E+04
2.5E-05	10.02	4.00E+04	6.6E-05	9.05	1.52E+04
2.6E-05	9.98	3.85E+04	6.7E-05	9.03	1.49E+04
2.7E-05	9.94	3.70E+04	6.8E-05	9.02	1.47E+04
2.8E-05	9.91	3.57E+04	6.9E-05	9.00	1.45E+04
2.9E-05	9.87	3.45E+04	7.0E-05	8.99	1.43E+04
3.0E-05	9.84	3.33E+04	7.1E-05	8.98	1.41E+04
3.1E-05	9.80	3.23E+04	7.2E-05	8.96	1.39E+04
3.2E-05	9.77	3.13E+04	7.3E-05	8.95	1.37E+04
3.3E-05	9.74	3.03E+04	7.4E-05	8.93	1.35E+04
3.4E-05	9.71	2.94E+04	7.5E-05	8.92	1.33E+04
3.5E-05	9.68	2.86E+04	7.6E-05	8.91	1.32E+04
3.6E-05	9.65	2.78E+04	7.7E-05	8.89	1.30E+04
3.7E-05	9.63	2.70E+04	7.8E-05	8.88	1.28E+04
3.8E-05	9.60	2.63E+04	7.9E-05	8.87	1.27E+04
3.9E-05	9.57	2.56E+04	8.0E-05	8.86	1.25E+04
4.0E-05	9.55	2.50E+04	8.1E-05	8.84	1.23E+04
4.1E-05	9.52	2.44E+04	8.2E-05	8.83	1.22E+04
4.2E-05	9.50	2.38E+04	8.3E-05	8.82	1.20E+04
4.3E-05	9.48	2.33E+04	8.4E-05	8.81	1.19E+04
4.4E-05	9.45	2.27E+04	8.5E-05	8.80	1.18E+04
4.5E-05	9.43	2.22E+04	8.6E-05	8.78	1.16E+04
4.6E-05	9.41	2.17E+04	8.7E-05	8.77	1.15E+04
4.7E-05	9.39	2.13E+04	8.8E-05	8.76	1.14E+04
4.8E-05	9.37	2.08E+04	8.9E-05	8.75	1.12E+04
4.9E-05	9.35	2.04E+04	9.0E-05	8.74	1.11E+04
5.0E-05	9.33	2.00E+04	9.1E-05	8.73	1.10E+04
			9.2E-05	8.72	1.09E+04
			9.3E-05	8.71	1.08E+04
			9.4E-05	8.70	1.06E+04
			9.5E-05	8.68	1.05E+04
			9.6E-05	8.67	1.04E+04
			9.7E-05	8.66	1.03E+04
			9.8E-05	8.65	1.02E+04
			9.9E-05	8.64	1.01E+04

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

10⁻⁴ Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-04	8.63	1.00E+04	5.1E-04	7.00	1.96E+03
1.1E-04	8.54	9.09E+03	5.2E-04	6.98	1.92E+03
1.2E-04	8.45	8.33E+03	5.3E-04	6.97	1.89E+03
1.3E-04	8.37	7.69E+03	5.4E-04	6.95	1.85E+03
1.4E-04	8.30	7.14E+03	5.5E-04	6.93	1.82E+03
1.5E-04	8.23	6.67E+03	5.6E-04	6.91	1.79E+03
1.6E-04	8.16	6.25E+03	5.7E-04	6.89	1.75E+03
1.7E-04	8.10	5.88E+03	5.8E-04	6.88	1.72E+03
1.8E-04	8.05	5.56E+03	5.9E-04	6.86	1.69E+03
1.9E-04	7.99	5.26E+03	6.0E-04	6.84	1.67E+03
2.0E-04	7.94	5.00E+03	6.1E-04	6.83	1.64E+03
2.1E-04	7.89	4.76E+03	6.2E-04	6.81	1.61E+03
2.2E-04	7.84	4.55E+03	6.3E-04	6.79	1.59E+03
2.3E-04	7.80	4.35E+03	6.4E-04	6.78	1.56E+03
2.4E-04	7.76	4.17E+03	6.5E-04	6.76	1.54E+03
2.5E-04	7.72	4.00E+03	6.6E-04	6.75	1.52E+03
2.6E-04	7.68	3.85E+03	6.7E-04	6.73	1.49E+03
2.7E-04	7.64	3.70E+03	6.8E-04	6.72	1.47E+03
2.8E-04	7.60	3.57E+03	6.9E-04	6.70	1.45E+03
2.9E-04	7.57	3.45E+03	7.0E-04	6.69	1.43E+03
3.0E-04	7.53	3.33E+03	7.1E-04	6.67	1.41E+03
3.1E-04	7.50	3.23E+03	7.2E-04	6.66	1.39E+03
3.2E-04	7.47	3.13E+03	7.3E-04	6.65	1.37E+03
3.3E-04	7.44	3.03E+03	7.4E-04	6.63	1.35E+03
3.4E-04	7.41	2.94E+03	7.5E-04	6.62	1.33E+03
3.5E-04	7.38	2.86E+03	7.6E-04	6.61	1.32E+03
3.6E-04	7.35	2.78E+03	7.7E-04	6.59	1.30E+03
3.7E-04	7.33	2.70E+03	7.8E-04	6.58	1.28E+03
3.8E-04	7.30	2.63E+03	7.9E-04	6.57	1.27E+03
3.9E-04	7.27	2.56E+03	8.0E-04	6.55	1.25E+03
4.0E-04	7.25	2.50E+03	8.1E-04	6.54	1.23E+03
4.1E-04	7.22	2.44E+03	8.2E-04	6.53	1.22E+03
4.2E-04	7.20	2.38E+03	8.3E-04	6.52	1.20E+03
4.3E-04	7.17	2.33E+03	8.4E-04	6.51	1.19E+03
4.4E-04	7.15	2.27E+03	8.5E-04	6.49	1.18E+03
4.5E-04	7.13	2.22E+03	8.6E-04	6.48	1.16E+03
4.6E-04	7.11	2.17E+03	8.7E-04	6.47	1.15E+03
4.7E-04	7.09	2.13E+03	8.8E-04	6.46	1.14E+03
4.8E-04	7.06	2.08E+03	8.9E-04	6.45	1.12E+03
4.9E-04	7.04	2.04E+03	9.0E-04	6.44	1.11E+03
5.0E-04	7.02	2.00E+03	9.1E-04	6.43	1.10E+03
			9.2E-04	6.41	1.09E+03
			9.3E-04	6.40	1.08E+03
			9.4E-04	6.39	1.06E+03
			9.5E-04	6.38	1.05E+03
			9.6E-04	6.37	1.04E+03
			9.7E-04	6.36	1.03E+03
			9.8E-04	6.35	1.02E+03
			9.9E-04	6.34	1.01E+03

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

 10^{-3} Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-03	6.33	1.00E+03	5.1E-03	4.71	1.96E+02
1.1E-03	6.24	9.09E+02	5.2E-03	4.69	1.92E+02
1.2E-03	6.15	8.33E+02	5.3E-03	4.67	1.89E+02
1.3E-03	6.07	7.69E+02	5.4E-03	4.65	1.85E+02
1.4E-03	6.00	7.14E+02	5.5E-03	4.63	1.82E+02
1.5E-03	5.93	6.67E+02	5.6E-03	4.61	1.79E+02
1.6E-03	5.86	6.25E+02	5.7E-03	4.60	1.75E+02
1.7E-03	5.80	5.88E+02	5.8E-03	4.58	1.72E+02
1.8E-03	5.74	5.56E+02	5.9E-03	4.56	1.69E+02
1.9E-03	5.69	5.26E+02	6.0E-03	4.54	1.67E+02
2.0E-03	5.64	5.00E+02	6.1E-03	4.53	1.64E+02
2.1E-03	5.59	4.76E+02	6.2E-03	4.51	1.61E+02
2.2E-03	5.54	4.55E+02	6.3E-03	4.50	1.59E+02
2.3E-03	5.50	4.35E+02	6.4E-03	4.48	1.56E+02
2.4E-03	5.46	4.17E+02	6.5E-03	4.47	1.54E+02
2.5E-03	5.42	4.00E+02	6.6E-03	4.45	1.52E+02
2.6E-03	5.38	3.85E+02	6.7E-03	4.44	1.49E+02
2.7E-03	5.34	3.70E+02	6.8E-03	4.42	1.47E+02
2.8E-03	5.30	3.57E+02	6.9E-03	4.41	1.45E+02
2.9E-03	5.27	3.45E+02	7.0E-03	4.39	1.43E+02
3.0E-03	5.23	3.33E+02	7.1E-03	4.38	1.41E+02
3.1E-03	5.20	3.23E+02	7.2E-03	4.36	1.39E+02
3.2E-03	5.17	3.13E+02	7.3E-03	4.35	1.37E+02
3.3E-03	5.14	3.03E+02	7.4E-03	4.34	1.35E+02
3.4E-03	5.11	2.94E+02	7.5E-03	4.32	1.33E+02
3.5E-03	5.08	2.86E+02	7.6E-03	4.31	1.32E+02
3.6E-03	5.05	2.78E+02	7.7E-03	4.30	1.30E+02
3.7E-03	5.03	2.70E+02	7.8E-03	4.28	1.28E+02
3.8E-03	5.00	2.63E+02	7.9E-03	4.27	1.27E+02
3.9E-03	4.97	2.56E+02	8.0E-03	4.26	1.25E+02
4.0E-03	4.95	2.50E+02	8.1E-03	4.25	1.23E+02
4.1E-03	4.92	2.44E+02	8.2E-03	4.23	1.22E+02
4.2E-03	4.90	2.38E+02	8.3E-03	4.22	1.20E+02
4.3E-03	4.88	2.33E+02	8.4E-03	4.21	1.19E+02
4.4E-03	4.85	2.27E+02	8.5E-03	4.20	1.18E+02
4.5E-03	4.83	2.22E+02	8.6E-03	4.19	1.16E+02
4.6E-03	4.81	2.17E+02	8.7E-03	4.18	1.15E+02
4.7E-03	4.79	2.13E+02	8.8E-03	4.16	1.14E+02
4.8E-03	4.77	2.08E+02	8.9E-03	4.15	1.12E+02
4.9E-03	4.75	2.04E+02	9.0E-03	4.14	1.11E+02
5.0E-03	4.73	2.00E+02	9.1E-03	4.13	1.10E+02
			9.2E-03	4.12	1.09E+02
			9.3E-03	4.11	1.08E+02
			9.4E-03	4.10	1.06E+02
			9.5E-03	4.09	1.05E+02
			9.6E-03	4.08	1.04E+02
			9.7E-03	4.07	1.03E+02
			9.8E-03	4.06	1.02E+02
			9.9E-03	4.05	1.01E+02

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

10⁻² Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-02	4.04	1.00E+02	5.1E-02	2.45	1.96E+01
1.1E-02	3.94	9.09E+01	5.2E-02	2.43	1.92E+01
1.2E-02	3.86	8.33E+01	5.3E-02	2.41	1.89E+01
1.3E-02	3.78	7.69E+01	5.4E-02	2.39	1.85E+01
1.4E-02	3.71	7.14E+01	5.5E-02	2.38	1.82E+01
1.5E-02	3.64	6.67E+01	5.6E-02	2.36	1.79E+01
1.6E-02	3.57	6.25E+01	5.7E-02	2.34	1.75E+01
1.7E-02	3.51	5.88E+01	5.8E-02	2.33	1.72E+01
1.8E-02	3.46	5.56E+01	5.9E-02	2.31	1.69E+01
1.9E-02	3.41	5.26E+01	6.0E-02	2.30	1.67E+01
2.0E-02	3.35	5.00E+01	6.1E-02	2.28	1.64E+01
2.1E-02	3.31	4.76E+01	6.2E-02	2.26	1.61E+01
2.2E-02	3.26	4.55E+01	6.3E-02	2.25	1.59E+01
2.3E-02	3.22	4.35E+01	6.4E-02	2.23	1.56E+01
2.4E-02	3.18	4.17E+01	6.5E-02	2.22	1.54E+01
2.5E-02	3.14	4.00E+01	6.6E-02	2.21	1.52E+01
2.6E-02	3.10	3.85E+01	6.7E-02	2.19	1.49E+01
2.7E-02	3.06	3.70E+01	6.8E-02	2.18	1.47E+01
2.8E-02	3.03	3.57E+01	6.9E-02	2.16	1.45E+01
2.9E-02	2.99	3.45E+01	7.0E-02	2.15	1.43E+01
3.0E-02	2.96	3.33E+01	7.1E-02	2.14	1.41E+01
3.1E-02	2.93	3.23E+01	7.2E-02	2.12	1.39E+01
3.2E-02	2.90	3.13E+01	7.3E-02	2.11	1.37E+01
3.3E-02	2.87	3.03E+01	7.4E-02	2.10	1.35E+01
3.4E-02	2.84	2.94E+01	7.5E-02	2.09	1.33E+01
3.5E-02	2.81	2.86E+01	7.6E-02	2.07	1.32E+01
3.6E-02	2.78	2.78E+01	7.7E-02	2.06	1.30E+01
3.7E-02	2.76	2.70E+01	7.8E-02	2.05	1.28E+01
3.8E-02	2.73	2.63E+01	7.9E-02	2.04	1.27E+01
3.9E-02	2.71	2.56E+01	8.0E-02	2.03	1.25E+01
4.0E-02	2.68	2.50E+01	8.1E-02	2.02	1.23E+01
4.1E-02	2.66	2.44E+01	8.2E-02	2.00	1.22E+01
4.2E-02	2.63	2.38E+01	8.3E-02	1.993	1.20E+01
4.3E-02	2.61	2.33E+01	8.4E-02	1.982	1.19E+01
4.4E-02	2.59	2.27E+01	8.5E-02	1.971	1.18E+01
4.5E-02	2.57	2.22E+01	8.6E-02	1.960	1.16E+01
4.6E-02	2.55	2.17E+01	8.7E-02	1.950	1.15E+01
4.7E-02	2.53	2.13E+01	8.8E-02	1.939	1.14E+01
4.8E-02	2.51	2.08E+01	8.9E-02	1.929	1.12E+01
4.9E-02	2.49	2.04E+01	9.0E-02	1.919	1.11E+01
5.0E-02	2.47	2.00E+01	9.1E-02	1.909	1.10E+01
			9.2E-02	1.899	1.09E+01
			9.3E-02	1.889	1.08E+01
			9.4E-02	1.879	1.06E+01
			9.5E-02	1.869	1.05E+01
			9.6E-02	1.860	1.04E+01
			9.7E-02	1.851	1.03E+01
			9.8E-02	1.841	1.02E+01
			9.9E-02	1.832	1.01E+01

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

10⁻¹ Well Functions

U	W(U)	1/U	U	W(U)	1/U
1.0E-01	1.823	1.00E+01	5.1E-01	0.548	1.96E+00
1.1E-01	1.737	9.09E+00	5.2E-01	0.536	1.92E+00
1.2E-01	1.660	8.33E+00	5.3E-01	0.525	1.89E+00
1.3E-01	1.589	7.69E+00	5.4E-01	0.514	1.85E+00
1.4E-01	1.524	7.14E+00	5.5E-01	0.503	1.82E+00
1.5E-01	1.464	6.67E+00	5.6E-01	0.493	1.79E+00
1.6E-01	1.409	6.25E+00	5.7E-01	0.483	1.75E+00
1.7E-01	1.358	5.88E+00	5.8E-01	0.473	1.72E+00
1.8E-01	1.310	5.56E+00	5.9E-01	0.464	1.69E+00
1.9E-01	1.265	5.26E+00	6.0E-01	0.454	1.67E+00
2.0E-01	1.223	5.00E+00	6.1E-01	0.445	1.64E+00
2.1E-01	1.183	4.76E+00	6.2E-01	0.437	1.61E+00
2.2E-01	1.145	4.55E+00	6.3E-01	0.428	1.59E+00
2.3E-01	1.110	4.35E+00	6.4E-01	0.420	1.56E+00
2.4E-01	1.076	4.17E+00	6.5E-01	0.412	1.54E+00
2.5E-01	1.044	4.00E+00	6.6E-01	0.404	1.52E+00
2.6E-01	1.014	3.85E+00	6.7E-01	0.396	1.49E+00
2.7E-01	0.985	3.70E+00	6.8E-01	0.388	1.47E+00
2.8E-01	0.957	3.57E+00	6.9E-01	0.381	1.45E+00
2.9E-01	0.931	3.45E+00	7.0E-01	0.374	1.43E+00
3.0E-01	0.906	3.33E+00	7.1E-01	0.367	1.41E+00
3.1E-01	0.882	3.23E+00	7.2E-01	0.360	1.39E+00
3.2E-01	0.858	3.13E+00	7.3E-01	0.353	1.37E+00
3.3E-01	0.836	3.03E+00	7.4E-01	0.347	1.35E+00
3.4E-01	0.815	2.94E+00	7.5E-01	0.340	1.33E+00
3.5E-01	0.794	2.86E+00	7.6E-01	0.334	1.32E+00
3.6E-01	0.774	2.78E+00	7.7E-01	0.328	1.30E+00
3.7E-01	0.755	2.70E+00	7.8E-01	0.322	1.28E+00
3.8E-01	0.737	2.63E+00	7.9E-01	0.316	1.27E+00
3.9E-01	0.719	2.56E+00	8.0E-01	0.311	1.25E+00
4.0E-01	0.702	2.50E+00	8.1E-01	0.305	1.23E+00
4.1E-01	0.686	2.44E+00	8.2E-01	0.300	1.22E+00
4.2E-01	0.670	2.38E+00	8.3E-01	0.294	1.20E+00
4.3E-01	0.655	2.33E+00	8.4E-01	0.289	1.19E+00
4.4E-01	0.640	2.27E+00	8.5E-01	0.284	1.18E+00
4.5E-01	0.625	2.22E+00	8.6E-01	0.279	1.16E+00
4.6E-01	0.611	2.17E+00	8.7E-01	0.274	1.15E+00
4.7E-01	0.598	2.13E+00	8.8E-01	0.269	1.14E+00
4.8E-01	0.585	2.08E+00	8.9E-01	0.265	1.12E+00
4.9E-01	0.572	2.04E+00	9.0E-01	0.260	1.11E+00
5.0E-01	0.560	2.00E+00	9.1E-01	0.256	1.10E+00
			9.2E-01	0.251	1.09E+00
			9.3E-01	0.247	1.08E+00
			9.4E-01	0.243	1.06E+00
			9.5E-01	0.239	1.05E+00
			9.6E-01	0.235	1.04E+00
			9.7E-01	0.231	1.03E+00
			9.8E-01	0.227	1.02E+00
			9.9E-01	0.223	1.01E+00

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

10 Well Functions

U	W(U)	1/U
1.0E+00	0.219	1.00E+00
1.1E+00	0.186	9.09E-01
1.2E+00	0.158	8.33E-01
1.3E+00	0.135	7.69E-01
1.4E+00	0.116	7.14E-01
1.5E+00	0.100	6.67E-01
1.6E+00	0.086	6.25E-01
1.7E+00	0.075	5.88E-01
1.8E+00	0.065	5.56E-01
1.9E+00	0.056	5.26E-01
2.0E+00	0.049	5.00E-01
2.1E+00	0.043	4.76E-01
2.2E+00	0.037	4.55E-01
2.3E+00	0.033	4.35E-01
2.4E+00	0.028	4.17E-01
2.5E+00	0.025	4.00E-01
2.6E+00	0.022	3.85E-01
2.7E+00	0.019	3.70E-01
2.8E+00	0.017	3.57E-01
2.9E+00	0.015	3.45E-01
3.0E+00	0.013	3.33E-01
3.1E+00	0.011	3.23E-01
3.2E+00	0.010	3.13E-01
3.3E+00	0.009	3.03E-01
3.4E+00	0.008	2.94E-01
3.5E+00	0.007	2.86E-01
3.6E+00	0.006	2.78E-01
3.7E+00	0.005	2.70E-01
3.8E+00	0.005	2.63E-01
3.9E+00	0.004	2.56E-01
4.0E+00	0.004	2.50E-01
4.1E+00	0.003	2.44E-01
4.2E+00	0.003	2.38E-01
4.3E+00	0.003	2.33E-01
4.4E+00	0.002	2.27E-01
4.5E+00	0.002	2.22E-01
4.6E+00	0.002	2.17E-01
4.7E+00	0.002	2.13E-01
4.8E+00	0.001	2.08E-01
4.9E+00	0.001	2.04E-01
5.0E+00	0.001	2.00E-01

ILLINOIS REGISTER

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF ADOPTED RULES

Section 671. Table B Well Functions For Unconfined or Water Table Aquifers

$1/u_a$	$\Gamma = 0.001$	$\Gamma = 0.01$	$\Gamma = 0.06$	$\Gamma = 0.2$	$\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 2.0$	$\Gamma = 4.0$	$\Gamma = 6.0$
4.0×10^{-1}	2.48×10^{-2}	2.41×10^{-2}	2.30×10^{-2}	2.14×10^{-2}	1.88×10^{-2}	1.70×10^{-2}	1.38×10^{-2}	9.33×10^{-3}	6.39×10^{-3}
8.0×10^{-1}	1.45×10^{-1}	1.40×10^{-1}	1.31×10^{-1}	1.19×10^{-1}	9.88×10^{-2}	8.49×10^{-2}	6.03×10^{-2}	3.17×10^{-2}	1.74×10^{-2}
1.4×10^0	3.58×10^{-1}	3.45×10^{-1}	3.18×10^{-1}	2.79×10^{-1}	2.17×10^{-1}	1.75×10^{-1}	1.07×10^{-1}	4.45×10^{-2}	2.10×10^{-2}
2.4×10^0	6.62×10^{-1}	6.33×10^{-1}	5.70×10^{-1}	4.83×10^{-1}	3.43×10^{-1}	2.56×10^{-1}	1.33×10^{-1}	4.76×10^{-2}	2.14×10^{-2}
4.0×10^0	1.02×10^0	9.63×10^{-1}	8.49×10^{-1}	6.88×10^{-1}	4.38×10^{-1}	3.00×10^{-1}	1.40×10^{-1}	4.78×10^{-2}	2.15×10^{-2}
8.0×10^0	1.57×10^0	1.46×10^0	1.23×10^0	9.18×10^{-1}	4.97×10^{-1}	3.17×10^{-1}	1.41×10^{-1}		
1.4×10^1	2.05×10^0	1.88×10^0	1.51×10^0	1.03×10^0	5.07×10^{-1}				
2.4×10^1	2.52×10^0	2.27×10^0	1.73×10^0	1.07×10^0					
4.0×10^1	2.97×10^0	2.61×10^0	1.85×10^0	1.08×10^0					
8.0×10^1	3.56×10^0	3.00×10^0	1.92×10^0						
1.4×10^2	4.01×10^0	3.23×10^0	1.93×10^0						
2.4×10^2	4.42×10^0	3.37×10^0	1.94×10^0						
4.0×10^2	4.77×10^0	3.43×10^0							
8.0×10^2	5.16×10^0	3.45×10^0							
1.4×10^3	5.40×10^0	3.46×10^0							
2.4×10^3	5.54×10^0								
4.0×10^3	5.59×10^0								
8.0×10^3	5.62×10^0								
1.4×10^4	5.62×10^0	3.46×10^0	1.94×10^0	1.08×10^0	5.07×10^{-1}	3.17×10^{-1}	1.41×10^{-1}	4.78×10^{-2}	2.15×10^{-2}

$1/u_b$	$\Gamma = 0.001$	$\Gamma = 0.01$	$\Gamma = 0.06$	$\Gamma = 0.2$	$\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 2.0$	$\Gamma = 4.0$	$\Gamma = 6.0$
4.0×10^{-4}	5.62×10^0	3.46×10^0	1.94×10^0	1.09×10^0	5.08×10^{-1}	3.18×10^{-1}	1.42×10^{-1}	4.79×10^{-2}	2.15×10^{-2}
8.0×10^{-4}								4.80×10^{-2}	2.16×10^{-2}
1.4×10^{-3}								4.81×10^{-2}	2.17×10^{-2}
2.4×10^{-3}								4.84×10^{-2}	2.19×10^{-2}
4.0×10^{-3}					5.08×10^{-1}	3.18×10^{-1}	1.42×10^{-1}	4.78×10^{-2}	2.21×10^{-2}
8.0×10^{-3}					5.09×10^{-1}	3.19×10^{-1}	1.43×10^{-1}	4.96×10^{-2}	2.28×10^{-2}
1.4×10^{-2}					5.10×10^{-1}	3.21×10^{-1}	1.45×10^{-1}	5.09×10^{-2}	2.39×10^{-2}
2.4×10^{-2}					5.12×10^{-1}	3.23×10^{-1}	1.47×10^{-1}	5.32×10^{-2}	2.57×10^{-2}
4.0×10^{-2}					5.16×10^{-1}	3.27×10^{-1}	1.52×10^{-1}	5.68×10^{-2}	2.86×10^{-2}
8.0×10^{-2}				1.09×10^0	5.24×10^{-1}	3.37×10^{-1}	1.62×10^{-1}	6.61×10^{-2}	3.62×10^{-2}
1.4×10^{-1}			1.94×10^0	1.10×10^0	5.37×10^{-1}	3.50×10^{-1}	1.78×10^{-1}	8.06×10^{-2}	4.86×10^{-2}
2.4×10^{-1}			1.95×10^0	1.11×10^0	5.57×10^{-1}	3.74×10^{-1}	2.05×10^{-1}	1.06×10^{-1}	7.14×10^{-2}
4.0×10^{-1}			1.96×10^0	1.13×10^0	5.89×10^{-1}	4.12×10^{-1}	2.48×10^{-1}	1.49×10^{-1}	1.13×10^{-1}
8.0×10^{-1}	5.62×10^0	3.46×10^0	1.98×10^0	1.18×10^0	6.67×10^{-1}	5.06×10^{-1}	3.57×10^{-1}	2.66×10^{-1}	2.31×10^{-1}
1.4×10^0	5.63×10^0	3.47×10^0	2.01×10^0	1.24×10^0	7.80×10^{-1}	6.42×10^{-1}	5.17×10^{-1}	4.45×10^{-1}	4.19×10^{-1}
2.4×10^0	5.63×10^0	3.49×10^0	2.06×10^0	1.35×10^0	9.54×10^{-1}	8.50×10^{-1}	7.63×10^{-1}	7.18×10^{-1}	7.03×10^{-1}
4.0×10^0	5.63×10^0	3.51×10^0	2.13×10^0	1.50×10^0	1.20×10^0	1.13×10^0	1.08×10^0	1.06×10^0	1.05×10^0
8.0×10^0	5.64×10^0	3.56×10^0	2.31×10^0	1.85×10^0	1.68×10^0	1.65×10^0	1.63×10^0	1.63×10^0	1.63×10^0
1.4×10^1	5.65×10^0	3.63×10^0	2.55×10^0	2.23×10^0	2.15×10^0	2.14×10^0	2.14×10^0	2.14×10^0	2.14×10^0
2.4×10^1	5.67×10^0	3.74×10^0	2.86×10^0	2.68×10^0	2.65×10^0	2.65×10^0	2.64×10^0	2.64×10^0	2.64×10^0
4.0×10^1	5.70×10^0	3.90×10^0	3.24×10^0	3.15×10^0	3.14×10^0	3.14×10^0	3.14×10^0	3.14×10^0	3.14×10^0
8.0×10^1	5.76×10^0	4.22×10^0	3.85×10^0	3.82×10^0	3.82×10^0	3.82×10^0	3.82×10^0	3.82×10^0	3.82×10^0
1.4×10^2	5.85×10^0	4.58×10^0	4.38×10^0	4.37×10^0	4.37×10^0	4.37×10^0	4.37×10^0	4.37×10^0	4.37×10^0
2.4×10^2	5.99×10^0	5.00×10^0	4.91×10^0	4.91×10^0	4.91×10^0	4.91×10^0	4.91×10^0	4.91×10^0	4.91×10^0
4.0×10^2	6.16×10^0	5.46×10^0	5.42×10^0	5.42×10^0	5.42×10^0	5.42×10^0	5.42×10^0	5.42×10^0	5.42×10^0
8.0×10^2	6.47×10^0	6.11×10^0	6.11×10^0	6.11×10^0	6.11×10^0	6.11×10^0	6.11×10^0	6.11×10^0	6.11×10^0
1.4×10^3	6.67×10^0	6.67×10^0	6.67×10^0	6.67×10^0	6.67×10^0	6.67×10^0	6.67×10^0	6.67×10^0	6.67×10^0
2.4×10^3	7.21×10^0	7.21×10^0	7.21×10^0	7.21×10^0	7.21×10^0	7.21×10^0	7.21×10^0	7.21×10^0	7.21×10^0
4.0×10^3	7.72×10^0	7.72×10^0	7.72×10^0	7.72×10^0	7.72×10^0	7.72×10^0	7.72×10^0	7.72×10^0	7.72×10^0
8.0×10^3	8.41×10^0	8.41×10^0	8.41×10^0	8.41×10^0	8.41×10^0	8.41×10^0	8.41×10^0	8.41×10^0	8.41×10^0
1.4×10^4	8.97×10^0	8.97×10^0	8.97×10^0	8.97×10^0	8.97×10^0	8.97×10^0	8.97×10^0	8.97×10^0	8.97×10^0
2.4×10^4	9.51×10^0	9.51×10^0	9.51×10^0	9.51×10^0	9.51×10^0	9.51×10^0	9.51×10^0	9.51×10^0	9.51×10^0
4.0×10^4	1.94×10^1	1.94×10^1	1.94×10^1	1.94×10^1	1.94×10^1	1.94×10^1	1.94×10^1	1.94×10^1	1.94×10^1

SOURCE: Adapted from S. P. Neuman, *Water Resources Research*, 11(1975): 329-42.

APPENDIX B – EXAMPLE MAXIMUM ZONE APPLICATION

FOR IEPA USE: SUSPENSE DATE ____/____/____

LOG NUMBER M _____ APPROVAL NUMBER AND DATE M _____ - ____/____/____

DATE RECEIVED BY IEPA ____/____/____

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
DIVISION OF PUBLIC WATER SUPPLIES
GROUNDWATER SECTION
SPRINGFIELD, ILLINOIS 62794-9276

APPLICATION FOR AGENCY REVIEW OF LATERAL AREA OF INFLUENCE DETERMINATION

1. Public Water Supply Facility Name and Number Illinois PWS 1110000
2. Well Name, Number, Description, and agency 5-Digit Well I.D. Illinois Well 2, corner of Main Street, IEPA Well 50001
3. Municipality or Township Lincoln County Sangamon
4. Name of Public Water Supply Owner Jane Doe
Address 112 2nd Street, Land of Lincoln, Illinois 62704
5. Indicate entity which determined the lateral radius of influence.
A = Owner, B = Municipality, C = County (circle one or more.)
Name Jane Doe Title Superintendent
Address Illinois PWS, Main Street, Land of Lincoln, Illinois 62704
- 6.0 REQUEST FOR AGENCY REVIEW
Section 671.301. Where the results of any determination made pursuant to Section 671.201 (Estimation Techniques and Pumping Tests) disclose that the distance from the well to the outermost boundary of the lateral area of influence under normal operational conditions exceeds the radius of the minimum setback established for that well pursuant to Section 14.2 of the Act, any County or Municipality served by such water supply may in writing request the Agency to review and confirm the technical adequacy of such determination.
- 6.1 Indicate entity filing petition for Agency review.
A = County, B = Municipality (circle one or more.)

APPLICATION FOR AGENCY REVIEW OF LATERAL AREA OF INFLUENCE DETERMINATION

Page 2

6.2 Certificate by Applicant

I hereby certify that I have read and thoroughly understand the conditions and requirements of this submittal.

Name of Applicant Filing Petition for Agency Review Land of Lincoln City Hall #1 Main Street, Land of Lincoln, Illinois 62704

Signature John Doe (Print Name) Date: 10/16/89

6.3 List any other counties or municipalities served by the public water supply other than the county or municipality in which the public water supply is located.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
Entity	Address(s)

7. List documents being submitted and indicate appendix procedure used:

- | | | |
|--|---|----------|
| 1) <u>Radius of influence calculations</u> | Appendix A. Volumetric Flow Equation | _____ |
| 2) <u>Pump Test Information</u> | Appendix B. Theis Nonequilibrium Equation | <u>x</u> |
| 3) <u>Geologic Logs/Well Construction Details</u> | Appendix C. Todd Uniform Flow Equation | _____ |
| | Appendix D. Neuman Equations | _____ |
| 4) <u>Draft Ordinance, including a map of the ordinance area</u> | Appendix E. Pump Test confined Aquifer | _____ |
| | Appendix F. Hydrogeologic Mapping | _____ |
| | Appendix G. Alternate Procedure | _____ |
| | (description _____) | |

8. Indicate the shape of the lateral radius of influence

1 = Irregular, 2 = Circular (circle one)

and the maximum lateral radius of influence distance in feet 500.

9.0 INFRINGEMENT ON EXISTING PUBLIC WATER SUPPLIES

9.1 Is any part of the maximum lateral radius of influence located within the boundaries of an area served by another public water supply? _____ Yes x No

APPLICATION FOR AGENCY REVIEW OF LATERAL AREA OF INFLUENCE DETERMINATION

Page 3

9.2 If yes, name that water supply facility and indicate the facility number.

Name _____ # _____

10.0 CERTIFICATION

Section 671.201 (Estimation Techniques and Pumping Tests) please indicate the Appendix used by circling one of the following: A, B, C, D, E, F, G. Section 671.302 (Contents of a Request) Appendix A or B may be used by a person other than a geologist or engineer. Appendix C-G must be performed by a registered engineer or geologist; or may also be performed by a non-registered engineer or geologist through Section 671.303 (Agency Approval of Alternate Certification).

10.1 Certificate by a person other than an engineer or geologist Section 671.302 if calculated using Section 671.201 Appendix A or B.

I hereby certify that I am familiar with the information contained in this application and that to the best of my knowledge and belief such information is true, complete and accurate.

_____	_____
Name	Title
_____	_____
Address	Phone Number
_____	_____
Signature	Date

10.2 Certificate by engineer or geologist Section 671.302 if calculated using Section 671.201 Appendix A, B, C, D, E, F, or G.

I hereby certify that I am familiar with the information contained in this application, and that to the best of my knowledge and belief such information is true, complete and accurate.

Engineer	<u>Joe Doe</u>	<u>IL 00499</u>
	Name	Registration Number
Geologist	_____	_____
	Name	Registration Number
Alternate*	_____	_____
	Name	Registration Number

*Please attach proof pursuant to Section 671.303

_____	_____
Name	Phone Number
_____	_____
Address	
_____	_____
Signature	Date

APPENDIX C – DRAFT MINIMUM AND MAXIMUM SETBACK ORDINANCE

[NOTE: THIS DRAFT DESCRIBES SUGGESTED BASIC PROVISIONS TO BE INCLUDED IN A MINIMUM AND MAXIMUM SETBACK ZONE ORDINANCE. THIS DRAFT IS INTENDED FOR INFORMATION PURPOSES ONLY. THESE PROVISIONS RELATE SOLELY TO MINIMUM AND MAXIMUM SETBACK ZONES. OTHER LEGAL REQUIREMENTS MAY APPLY, AND OTHER PROVISIONS MAY NEED TO BE INCLUDED IN A COUNTY OR MUNICIPAL ORDINANCE IN ORDER FOR SUCH AN ORDINANCE TO BE VALID AND ENFORCEABLE.]

DRAFT

MINIMUM AND MAXIMUM SETBACK ZONE ORDINANCE PROVISIONS

Section 1.	Purpose
Section 2.	Definitions
Section 3.	Prohibitions
Section 4.	Waivers, Exceptions, and Certifications of Minimal Hazard
Section 5.	Exclusion
Appendix A	Minimum and Maximum Setback Zone Map and Description

Section 1. Purpose

Pursuant to the authority conferred by ILCS 5/11-125-4 (2000) [cite only if municipality is adopting ordinance]; 55 ILCS 5/5-15016 (2000) [cite only if county board is adopting ordinance]; 415 ILCS 5/14.2, and 5/14.3 (2000); and in the interest of securing the public health, safety, and welfare; to preserve the quality and quantity of groundwater resources in order to assure a safe and adequate water supply for present and future generations; and to preserve groundwater resources currently in use and those aquifers having a potential for future use as a public water supply, the provisions of this ordinance shall apply to all properties located within the minimum setback zone established under Section 14.2 of the Environmental Protection Act. (“Act”) (415 ILCS 5/14.2 (2000)) and this ordinance, and the maximum setback zone established under Section 14.3 of the Act (415 ILCS 5/14.3 (2000)) and this ordinance.

Section 2. Definitions

Except as stated in this ordinance, and unless a different meaning of a word or term is clear from the context, the definition of words or terms in this ordinance shall be the same as those used in the Act and the Illinois Groundwater Protection Act (415 ILCS 55/1 (2000)):

“Act” means the Environmental Protection Act (415 ILCS 5/1 (2000)):

“Agency” means the Illinois Environmental Protection Agency.

“Board” means the Illinois Pollution Control Board.

“Maximum setback zone” means the area around a community water supply well established under Section 14.3 of the Act and this ordinance, and described in Appendix A.

“Minimum setback zone” means the area around a community water supply well established under Section 14.2 of the Act and this ordinance, and described in Appendix A.

Section 3. Prohibitions

- a) Except as provided in Sections 4 or 5, no person shall place a new potential source, new potential secondary source, or new potential route within the minimum setback zone.
- b) Except as provided otherwise in Section 4, no person shall place a new potential primary source within the maximum setback zone.

Section 4. Waivers, Exceptions, and Certifications of Minimal Hazard

- a) If, pursuant to Section 14.2(b) of the Act, the owner of a new potential primary source, new potential secondary source, or new potential route is granted a waiver by the Agency, such owner shall be deemed to have a waiver to the same extent from Section 3(a) of this ordinance.
- b) If, pursuant to Section 14.2(c) of the Act, the owner of a new potential primary source (other than land filling or land treating), new potential secondary source, or new potential route is granted an exception by the Board, such owner shall be deemed to have an exception to the same extent from Section 3(a) of this ordinance.
- c) If, pursuant to Section 14.2(c) of the Act, the owner of a new potential primary source (other than land filling or land treating), is granted an exception by the Board, such owner shall be deemed to have an exception to the same extent from Section 3(b) of this ordinance.
- d) If, pursuant to Section 14.5 of the Act, the owner of a new potential primary source, new potential secondary source, or new potential route is issued a certificate of minimal hazard by the Agency, such owner shall not be subject to Section 3(a) of this ordinance to the same extent that such owner is not subject to Section 14.2(d) of the Act.

Section 5. Exclusion

Section 3(a) of this ordinance shall not apply to new common sources of sanitary pollution as specified pursuant to Section 17 of the Act and the regulations adopted there under by the Agency; however, no such common sources may be located within the applicable minimum distance from a community water supply well specified by such regulations.

APPENDIS D – GROUNDWATER GLOSSARY FUNDAMENTALS/FACTS

“Aquifer” – means saturated (with groundwater) soils and geologic materials which are sufficiently permeable to readily yield economically useful quantities of water to wells, springs, or streams under normal hydraulic gradients (Section 3(b) of IGPA).

“Aquitard” – means a rock or clay layer that is not permeable enough to yield usable quantities of water to a well or springs under ordinary hydraulic gradients.

“Confined aquifer” – means an aquifer bounded above by impermeable beds or by shale, clay or siltstone (Section 671.102 (b) of 35 Ill. Adm. Code 671).

“Drawdown” – means the change in the elevation of the static water level produced by a pumping well (Section 671.102(b) of 35 Ill. Adm. Code 671).

“Dolomite” – means a mineral composed of calcium magnesium carbonate. A term applied to rocks which approximate the mineral dolomite.

“Groundwater” – means underground water which occurs within the saturated zone and geologic materials where the fluid pressure in the pore space is equal to or greater than atmospheric pressure (Section 3(g) of the IGPA).

“Municipality” – means any city, village or incorporated town.

“Non-community water system” – means a public water system which is not a community water system, and has at least 15 Service connections used by non-residents, or regularly serves 25 or more nonresident individuals daily for at least 60 days per year (Section 9(a) (4) Of the IGPA).

“Permeable” – means a material through which liquids can readily pass.

“Permeability” – means a measure of a substance’s ability to transmit liquids.

“Porosity” – means a measure of the amount of void or open space in a unit volume of material expressed mathematically.

“Saturated zone” – means the area underground in which all available spaces are filled with water.

“Solution channel” – means an underground opening or passage formed by the dissolving action of water on rocks such as limestone or dolomite.

“Unconsolidated deposits” – means loose earth materials or sediments.

“Unsaturated zone” – means the area underground in which the soil pores (spaces) are only partially filled with water.

“Water table” – means the upper boundary of the saturated zone.

“Water-table aquifer, or unconfined aquifer” – means an aquifer whose upper boundary is the water table.

GROUNDWATER FUNDAMENTALS/FACTS

The Hydrologic Cycle – is the continual movement of water above, on, and below the earth's surface. Figure D-1 illustrates this cycle. Movement is the key element in the concept of the hydrologic cycle. The water you use today may have evaporated from the ocean, traveled through the atmosphere, fallen back to the earth's surface, gone underground and from there moved to streams leading back to the ocean.

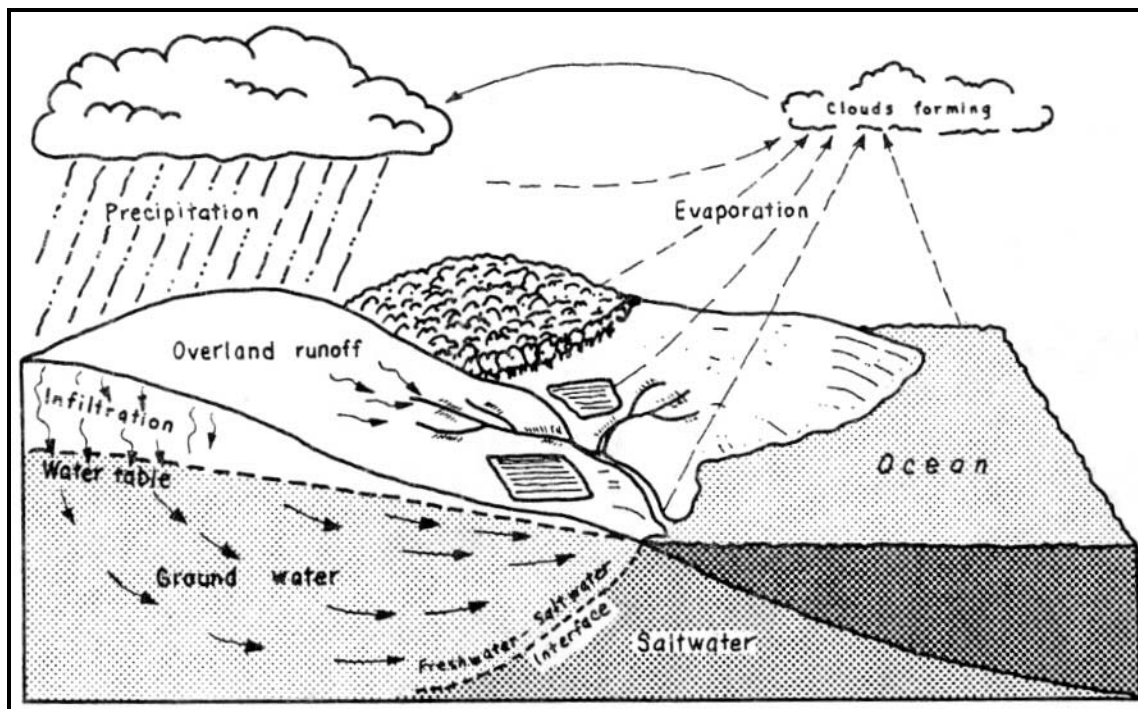


Figure D-1 The Hydrologic cycle (USEPA Seminar Publication)

When water falls to the earth as rain or snow, a portion of it seeps into the ground. The first zone which the water encounters is the unsaturated zone where soil pores are filled partially with air and partially with water. Ground water flows through the unsaturated zone into the saturated zone where all the pore space is filled with water. The upper boundary of the saturated zone is referred to as the water table. As water enters the saturated zone, the water table rises; when water is pumped from the saturated zone, the water table drops.

Recharge Zone – The process by which water from rainfall, snowmelt and other sources enters an aquifer is known as recharge. The land surface through which a particular aquifer is recharged is known as the recharge area.

Aquifers – Occurrence and movement of groundwater are governed by geologic deposits. Groundwater occurs in many types of rock formations and deposits; those that yield usable quantities of groundwater to wells are known as aquifers. Aquifer literally means, "waterbearer".

Unconsolidated Deposits – The common misconception is that groundwater occurs in the form of underground lakes or rivers just as fresh water lakes occur at the earth's surface. Actually groundwater occurs in the numerous pores (open spaces) between unconsolidated or loose particles of sand, gravel and soil. One way this can be described is by thinking of a fish bowl which is filled halfway with water, what you have is a replica of an unconsolidated water table aquifer as illustrated in Figure D-2. The upper portion of the gravel which contains no water would be considered the unsaturated zone. The water surface is the water table and the lower portion of the bowl which is filled with gravel and water is the saturated zone.

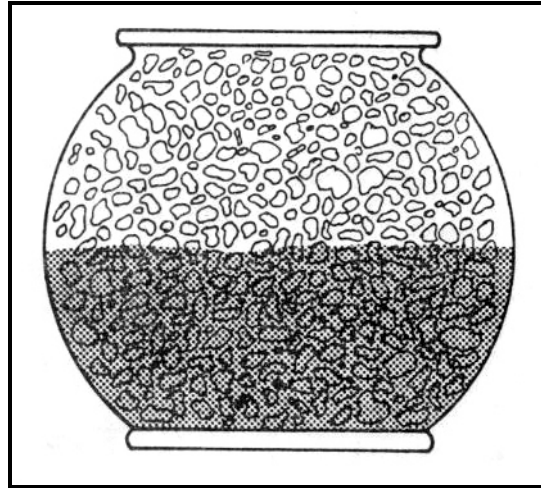


Figure D-2 Groundwater In An Unconsolidated Deposit Represented By A Half-Filled Fishbowl, Occupies All The Space Between Gravel Particles

Consolidated Deposits – In addition to occurring in the pores of sand, gravel and soil, groundwater can also be found in consolidated rock deposits. Consolidated deposits consist of solid rock rather than loose individual particles. Groundwater occurs in pores, cracks, fissures and in solution channels found in bedrock (e.g., sandstone, limestone, and dolomite). Solution channels start as cracks or joints which occur naturally due to the movements and shifts within the rock masses. Over time, water flows through the cracks and joints and they become enlarged due to the dissolving action of the water on limestone and dolomite rock types. Well developed solution channels act more as pipes or conduits than as water-bearing material.

Porosity-Permeability – Porosity is defined as a volume of voids divided by the unit volume of the solid. Porosity is usually given as a percentage and it is an indication of how much void or air space there is in a unit volume of material. This pore space is the area which will become saturated when this material is saturated with water. Permeability is the ability of a unit permeability is that in order for material to be permeable the pores or open spaces in the material must be interconnected. These interconnected passageways allow the material to transmit water.

Aquitards – Aquitards are formations which transmit very small amounts of water. The permeability of these aquitards is so low that wells finished in them cannot produce usable amounts of water.

Confined and Unconfined Aquifers – There are two types of aquifers, confined and unconfined. The upper boundary of an unconfined aquifer is the water table. Unconfined aquifers are commonly referred to as water table aquifers. A confined aquifer is a water-bearing material which is bound above by an aquitard. When the water level in a well tapping the confined aquifer stands at some height above the top of the aquifer, the aquifer is under artesian pressure. If the water level in an artesian well rises above the land surface, the well is a flowing artesian well. The water level in cased wells open to a confined aquifer stands at the level of the potentiometric surface. Figure D-3 displays examples of unconfined and water table aquifers.

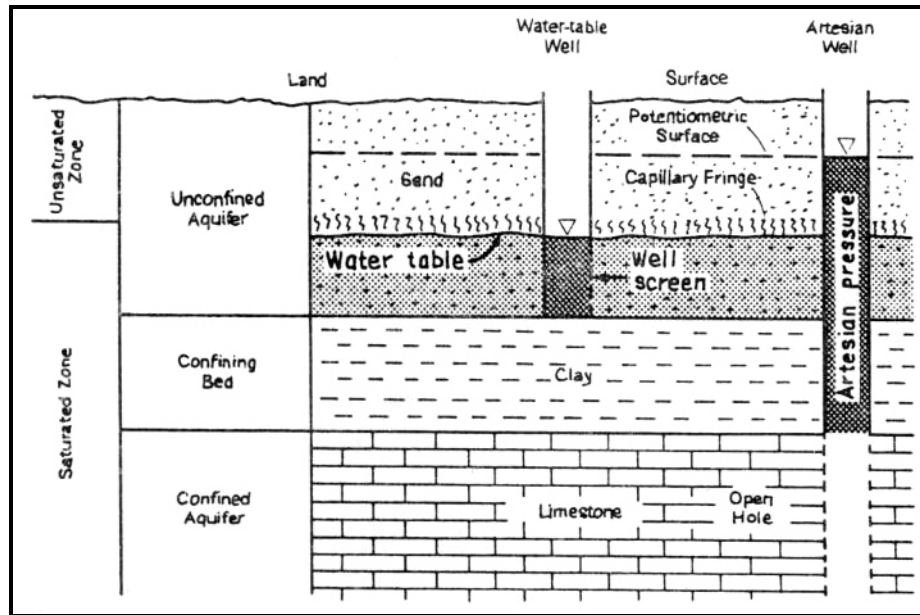


Figure D-3 Unconfined and Water Table Aquifer (USEPA Seminar Publication)

Transmissivity – Transmissivity (T) is defined as the rate at which water flows through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness of the aquifer under a hydrologic gradient of one vertical foot per one horizontal foot. Transmissivity has units of gallons per day per foot (GPD/FT). See Figure D-4 for an illustration of transmissivity.

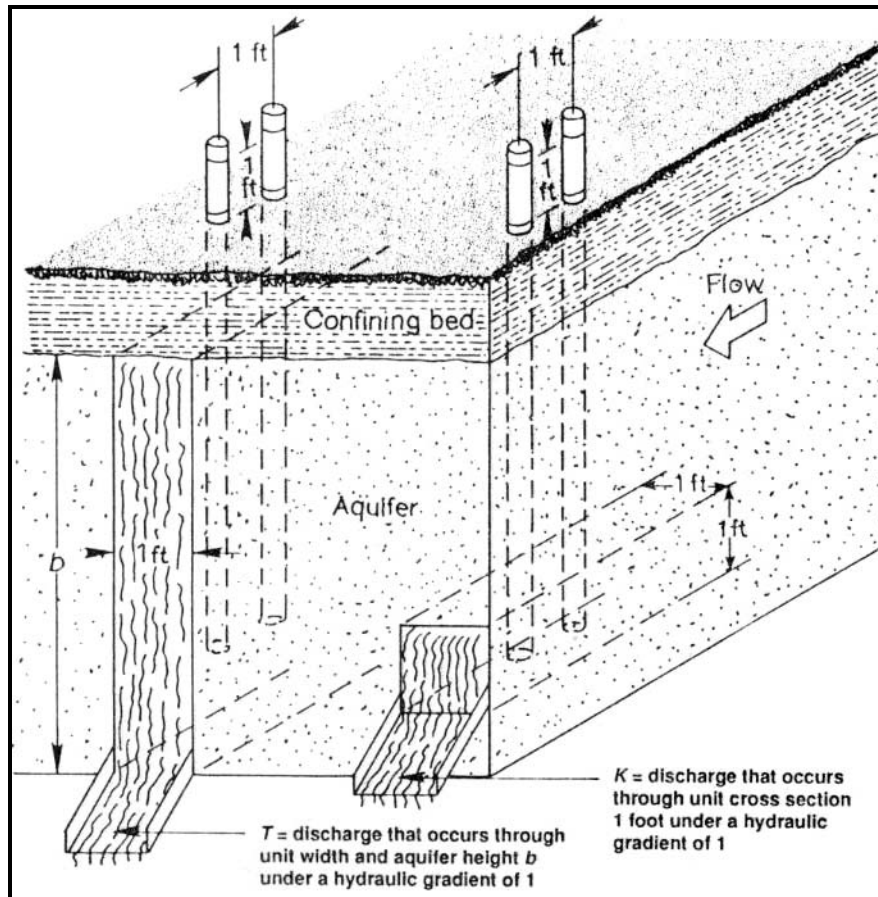


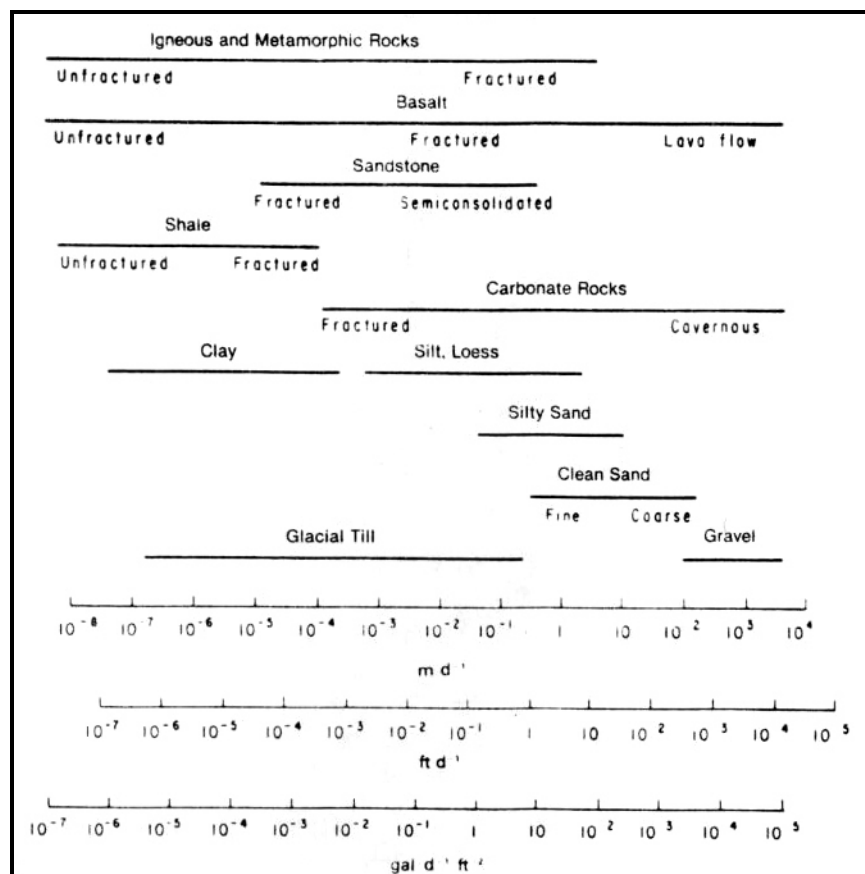
Figure D-4 Illustration of the Coefficients of Hydraulic Conductivity (K) and Transmissivity (T). Hydraulic Conductivity Multiplied by the Aquifer Thickness Equals Coefficient of Transmissivity. (Groundwater and Wells 2nd edition)

Hydraulic Conductivity - Hydraulic conductivity represents the discharge that occurs through a unit cross section one foot square under a hydraulic gradient of one vertical foot per one horizontal foot. See Figure D-4 for an illustration of hydraulic conductivity. Hydraulic conductivity has units of gallons per day per foot squared (GPD/FT²). The hydraulic conductivity (K) multiplied by the thickness of the aquifer equals the transmissivity.

$$T = K \times b$$

Hydraulic conductivity values for consolidated and unconsolidated aquifers are shown in Table D-1.

Table D1 Range of Values and Hydraulic Conductivity and Permeability (USEPA Seminar Publication)



Storativity – Storativity can be defined as the volume of water that an aquifer releases from storage per unit surface area per decline in water level or potentiometric surface. Figure D-5 illustrates the differences in storativity values for unconfined and confined aquifers. Confined aquifer storativity values range from 0.005 to 0.00005. Storativity for unconfined aquifers has a usual range of 0.01 to 0.30. There are no units associated with storativity which is commonly referred to as being dimensionless.

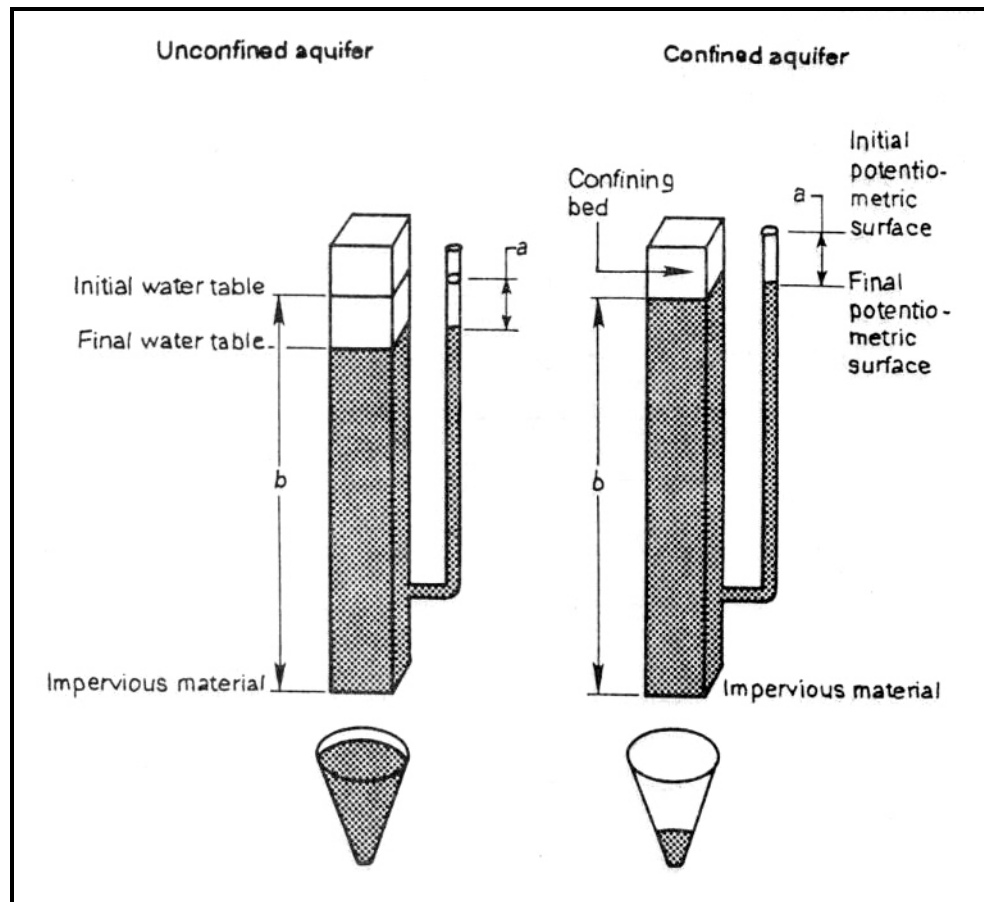


Figure D-5 Unit Prisms of Unconfined and Confined Aquifers Illustrating Differences in Storage Coefficients. For Equal Declines in Head, the Yield From an Unconfined Aquifer is Much Greater Than that From a Confined Aquifer. (Groundwater and Wells 2nd Edition)

Water Levels – The non-pumping water level in a well is called the static water level. The pumping water level in a well is the location of the water surface while the pump is in operation. The drawdown is the difference in the non-pumping and pumping water level.