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The Class V Underground Injection Control Study

Volume 2

Agricultural Drainage Wells

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AGRICULTURAL DRAINAGE WELLS

The U.S. Environmental Protection Agency (USEPA) conducted a study of Class V underground injection wells to develop background information the Agency can use to evaluate the risk that these wells pose to underground sources of drinking water (USDWs) and to determine whether additional federal regulation is warranted. The final report for this study, which is called the Class V Underground Injection Control (UIC) Study, consists of 23 volumes and five supporting appendices. Volume 1 provides an overview of the study methods, the USEPA UIC Program, and general findings. Volumes 2 through 23 present information summaries for each of the 23 categories of wells that were studied (Volume 21 covers 2 well categories). This volume, which is Volume 2, covers Class V agricultural drainage wells.

1. SUMMARY

Agricultural drainage wells (ADWs) are used in many places throughout the country to drain excess surface and subsurface water from agricultural fields, including irrigation tailwaters and natural drainage resulting from precipitation, snowmelt, floodwaters, etc. ADWs may also receive animal yard runoff, feedlot runoff, dairy runoff, or runoff from any other agricultural operation. In some cases, these fluids are released into ADWs in order to recharge aquifers that are used as sources of irrigation water.

The water that drains into ADWs may contain high levels of naturally occurring minerals or may be contaminated with fertilizers, pesticides, or bacteria and other microorganisms. Available sampling data show that the primary constituent in ADW injectate that is likely to exceed health-based standards is nitrate. The data also indicate that boron, sulfate, coliforms, and certain pesticides (cyanazine, atrazine, alachlor, aldicarb, carbofuran, 1,2-dichloropropane, and dibromochloropropane) in agricultural drainage have exceeded primary, or health-based, drinking water maximum contaminant levels (MCLs) or health advisory levels (HALs). Total dissolved solids (TDS) and chloride in some ADWs also have been measured above secondary MCLs, which are designed to protect against adverse aesthetic effects such as objectionable taste and odor.

Concerns about high concentrations of contaminants entering ADWs are compounded by the recognition that the point of injection for many ADWs is within a permeable coarse-grained unit, karst, or a fractured unit (some ADWs are in fact nothing more than improved sinkholes in areas with karst). Such hydrogeologic settings usually allow contaminants to migrate readily without significant attenuation.

A number of studies and incidents have shown that ADWs have in fact contributed to or caused ground water contamination. In particular, ten studies reviewed for this report document nitrate contamination of ground water in agricultural areas. Six of these studies clearly link the nitrate contamination to ADW use. For example, one study in north central Iowa between 1981 and 1983 found that areas with the highest density of ADWs also had the highest average concentrations of nitrate in ground water samples (37 percent of the farm wells sampled in an area with a relatively large number of ADWs had nitrate concentrations above the MCL). Four other studies, however, do not clearly distinguish nitrate contamination from ADWs versus more general sources of nonpoint source pollution associated with agriculture. In addition to these nitrate studies, there are two known contamination incidents in Iowa (in 1977 and 1997) involving direct discharges from septic tanks to ADWs. In one of these incidents, the ADW was also contaminated by runoff from the field application of hog manure. Other contamination incidents include ground water and drinking water contamination linked to 15 drainage wells in Minidoka County, Idaho in 1979, and a community supply well in Dane, Wisconsin being contaminated around 1988 by atrazine that likely drained into an improperly abandoned water well that had been illegally modified to receive surface runoff from an agricultural area.

A further concern associated with ADWs is the potential for some wells to be vulnerable to spills or illicit discharges. The close proximity of ADWs to large earthen lagoons for storing manure at large-scale confined animal feeding operations is a particular issue that has been recognized for some wells in Iowa; the growth of such operations nationwide may also make it an issue in other locations. The two cases cited above involving septic tank discharges to ADWs in Iowa may also illustrate a practice that is not uncommon in other states. Following one of those incidents, it was estimated that as many as 30 percent of the rural septic tanks in one Iowa township may be directly connected to ADWs. Separately, some ADWs may occasionally receive accidental releases of materials during farming operations, such as spills of motor oils used in equipment or bulk releases of pesticides during storage or handling. Moreover, if not carefully managed, the land application of manure in areas drained by ADWs can cause contamination, as illustrated by one of the incidents reported in Iowa.

According to the state and USEPA Regional survey conducted for this study, there are at least 1,069 documented ADWs and more than 2,842 ADWs estimated to exist in the U.S. Although believed to exist in at least 20 states, more than 95 percent of the documented wells are in just five states: Idaho (303), Iowa (290), Ohio (>200), Texas (135), and Minnesota (92). In truth, there may be thousands more ADWs than these results suggest, recognizing the significant uncertainties in the current inventory. For example, it is likely that more ADWs exist than have been counted because (1) there is often a lack of public records on such wells, (2) public officials are unable to document the locations of ADWs in remote areas on private land without the cooperation of the landowner, (3) some ADWs are hard to find or not even known to exist because they consist of tile drainage lines and cisterns entirely below ground, and (4) ADWs have been grouped with storm water drainage wells in some state inventories. Looking forward, the number of ADWs should decrease as the risk to USDWs becomes known and ADWs that cause or threaten contamination are discovered and closed. However, the known number of ADWs may actually increase as the existing wells are actively looked for and discovered.

States with the majority of known ADWs are developing and implementing regulatory programs to address these wells. Specifically:

- In Idaho, wells ≥18 feet deep are individually permitted, while shallower wells are permitted by rule.

- All ADW owners in Iowa are required to have applied for a permit by July 1, 1999. The only exception to this is ADW owners who can demonstrate that their ADW will be closed prior to December 31, 2001. New wells in Iowa are generally prohibited, although they may be permitted under very strict conditions (these conditions are so stringent that new ADWs in Iowa are unlikely to receive a permit).

- The regulations in Ohio authorize ADWs by rule as long as inventory information is submitted. All existing ADWs in the state are considered out of compliance (not rule authorized) because their owners or operators did not submit required inventory information by the applicable deadline. Any new ADWs would be examined individually by the state and subjected to conditions believed necessary to protect USDWs.

- All of the known ADWs in Texas received individual authorizations for construction of the wells. Owners or operators of any new wells would have to submit basic information to the state, which would either disapprove the well or authorize it subject to conditions deemed necessary to protect USDWs.

- Minnesota rules, which became effective on July 15, 1974, prohibit injection or disposal of any materials into a well. State staff, however, acknowledge that some ADWs continue to exist and require them to close when they are found. The prohibition relates to wells that reach ground water. Horizontal drain tiles are not included in the definition of a “well” in Minnesota.

The regulatory picture in other states with few or no ADWs in the current inventory is varied. In particular, Georgia, North Carolina, and North Dakota have banned new ADWs and require existing ADWs to close when they are found. Oregon, Washington, and Wisconsin also have a ban, but recognize that some ADWs continue to exist. Most other states authorize ADWs by rule, consistent with the existing federal UIC requirements.

These regulatory programs in the states are supplemented somewhat by non-regulatory programs and guidance at the federal level. Namely, under the authority of the Clean Water Act, the U.S. Department of Agriculture and USEPA released a draft *Unified National Strategy for Animal Feeding Operations* on September 11, 1998. Once finalized, the goal of this strategy will be for owners and operators of animal feeding operations to take actions to minimize surface and ground water pollution from confinement facilities and land application of manure. In addition, under the Coastal Zone Act Reauthorization Amendments, 29 coastal states are required to develop and implement Coastal Nonpoint Pollution Control Programs addressing nonpoint pollution from agriculture and other sources. Although these programs are aimed primarily toward surface water protection, they also will benefit ground water by emphasizing contaminant source reduction and conservation measures such as nutrient, integrated pest, and irrigation management. To support the development and implementation of these programs, USEPA issued *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. Much of this guidance is relevant to Class V ADWs because it presents techniques for minimizing seepage to ground water.

2. INTRODUCTION

Agricultural practices throughout the United States vary considerably by soil type, crops grown, cultural practices, climate, and historical precedent. There is one attribute, however, that is the same all over: crops need water to grow. Sometimes there is too much water and fields must be drained before the crops can be planted (or harvested). This situation, of course, is highly dependent upon the type of crop, some needing significantly more water (such as rice) and others needing less (such as corn). Sometimes natural precipitation is insufficient and water must be added through irrigation. This situation can vary from year to year and from region to region. When excess water is removed from a field it needs to go somewhere. Often the water is discharged to surface streams or rivers, but water can also be drained to the subsurface through the use of an ADW. An ADW helps to manage the water level in the soil so crops can be grown (USEPA, 1987 and 1997). In some areas, ADWs may be used to recharge an aquifer that provides irrigation water for crops. In other areas, ADWs are used for a combination of purposes. For example, in Idaho "[they] are used primarily for draining snow melt and storm water, ... with only minor irrigation tail water components" (Slifka, 1997).

According to the existing UIC regulations in 40 CFR 146.5(e)(4), "drainage wells used to drain surface fluid, primarily storm runoff, into a subsurface formation" are considered Class V injection wells. This type of well includes ADWs.

It is important to define exactly what is and what is not considered an ADW for the purpose of this study. ADWs are wells that receive fluids such as irrigation tailwaters or return flow, other field drainage (i.e., resulting from precipitation, snowmelt, floodwaters, etc.), animal yard runoff, feedlot runoff, or dairy runoff. As described in more detail in Section 4.2 below, ADWs are generally part of a system consisting of a buried collection basin or cistern, one or more tile drainage lines buried a few feet beneath the land surface to collect water and channel it to the cistern, and a drilled or dug well typically located near low-lying areas of fields. The cistern collects drainage water that is released into the well. Some ADWs are open at the land surface or have surface intakes, allowing surface runoff to enter the well directly, either by design or as a result of poor repair. Others collect only subsurface drainage (percolated water) by a network of tiles. Many ADW systems receive both surface runoff and subsurface drainage.

In order to qualify as an ADW, a system must have a "well." As currently defined in the UIC regulations (40 CFR 144.3), a "well means a bored, drilled or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension." Therefore, any hole that is deeper than it is wide qualifies as a well. This includes relatively sophisticated designs in which holes are drilled and cased with metal or plastic pipe. However, it also includes simple systems designed to drain fluids to the subsurface. For example, an improved sinkhole, defined as a surface depression altered to direct fluids into the opening (USEPA, 1987), qualifies as an injection well, as does an abandoned drinking water well that has been adapted to convey fluids to the subsurface. If improved sinkholes or abandoned drinking water wells accept surface and/or subsurface drainage from agricultural activities, they qualify as ADWs.

"Infiltration galleries" are also considered injection wells. These galleries consist of one or more vertical pipes leading to a horizontal, perforated pipe laid within a trench, often backfilled with gravel or some other permeable material. Such a design is commonly used to return treated ground water at aquifer remediation sites, but conceivably could be used to facilitate agricultural drainage at some sites. Each of the vertical pipes in such a system, individually or in a series, should be considered an injection well subject to UIC authorities (Elder and Lowrance, 1992).

Other kinds of systems with a drainfield type of design are also likely to be considered shallow injection wells, as long as they release fluids underground as opposed to a surface water body or the land surface. These may include french drains, tiles drains, infiltration sumps, and the like.

Injection wells, however, do not include surface impoundments or ditches that are wider than they are deep. Therefore, although such features are commonly used to direct or retain surface and/or subsurface drainage at farms, they do not qualify as wells themselves.

A number of wells on agricultural cropland in the Southwest and Central California pump ground water in order to lower the water table, and then release the water to surface outlets. These systems may be collector sumps, usually 10 to 20 feet deep, that are fed by a system of underground drainage tiles. Alternatively, unconfined aquifers may be pumped to lower the water table by creating a cone of depression, as occurs in Southern California and in Yuma and other locations in Arizona. In neither case, however, is the water injected back into the ground; to the contrary, water is removed from the ground by pumping to surface water outlets. Similar systems are found in other areas of the nation, although they may not be as prevalent as in the Southwest (Smith, 1998). When all of the water is discharged to the surface and there is no subsurface emplacement of fluids through a well, then there is no "well injection" under the UIC regulations (as defined in 40 CFR 144.3). Therefore, even though these systems are commonly used in the Southwest to drain agricultural fields, they do not qualify as ADWs for the purpose of this study and are not considered further. Similarly, the drains and wells used to pump ground water up for the purpose of dewatering a field are not injection wells and are not within the scope of this study.

Some ADWs receive other fluid that technically is not agricultural drainage. For example, as discussed in later sections, there are known instances in which septic tanks without leachfields discharge directly to tiles that drain to ADWs. This is a common practice in rural areas of Iowa where ADWs are used (Heathcote, 1998). In addition, many ADW systems located near roads have surface inlets for roadway and ditch drainage (USEPA, 1998). These systems, therefore, can receive both agricultural and more general storm water runoff. For the purpose of this volume, wells that receive multiple kinds of fluids are considered ADWs as long as some fraction of the injectate consists of agricultural drainage.

3. PREVALENCE OF WELLS

For this study, data on the number of Class V ADWs were collected through a survey of state and USEPA Regional UIC Programs. The survey methods are summarized in Section 4 of Volume 1 of the Class V Study. Table 1 lists the numbers of Class V ADWs in each state, as determined from this survey. The table includes the documented number and estimated number of wells in each state, along with the source and basis for any estimate, when noted by the survey respondents. If a state is not listed in Table 1, it means that the UIC Program responsible for that state indicated in its survey response that it did not have any Class V ADWs.

Many states and USEPA Regions administering the UIC program acknowledge that agricultural drainage wells probably exist in different areas, but they have not been able to determine exactly how many for a variety of reasons. Chief among these reasons is the fact that ADWs exist on rural private property, and often in a very remote area such as the middle of a field that cannot be located by public officials without the cooperation of the landowner. Moreover, some ADW designs are completely or almost completely below the ground, making them virtually invisible at the land surface. In cases where ADWs were constructed many years ago without any record, which is a common occurrence, it is not unusual for the current landowner to not even know that they exist. Another complication is that ADWs have been grouped together with storm water drainage wells in some state inventories. As a result, there is no way to tell based on current records which wells qualify under today's definition as ADWs versus storm water drainage wells or perhaps some other kind of injection well.

It is also a very difficult, if not impossible, task to develop a reasonable estimate of the number of ADWs nationwide based on the possible co-occurrence of ADWs with certain other known conditions, such as soil and geological characteristics and land use patterns. In a very general sense, current patterns suggest that ADWs are used in areas where crop land has inadequate natural drainage or poorly drained soils, and the crop land is coincident with underlying geologic formations that are capable of receiving and removing large volumes of excess drainage water. The areas where wells are likely to be located are characterized by poor internal soil drainage or a high water table, related to soil properties or an impermeable substrate, and/or flat topography or poorly integrated natural drainage through waterways. Suitable subsurface geologic formations often include areas with shallow, fractured bedrock formations, or limestone bedrock, particularly where affected by karst development that provides solution channels and sinkholes that allow rapid transmission of water.

For example, ADWs in Iowa discharge into limestone bedrock aquifers with karst features, including solution channels and sinkholes. In Idaho, ADWs discharge into basaltic lava flows that have many large fractures, pores, and tubes. These settings allow the intermittent and rapid transmission of large volumes of water over long periods of time (i.e., they do not plug up in the short term). These geologic formations also are usually located close to the surface, which eases and reduces the cost of drilling an ADW. They are also conducive to the formation of sinkholes that can be widened or otherwise "improved" to accept agricultural drainage.

Table 1. Inventory of Agricultural Drainage Wells in the U.S.

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
USEPA Region 1 -- None			
USEPA Region 2			
NY	1	200	Discussions with farmers in state.
PR	NR	NR	N/A
USEPA Region 3			
DE	0	50	Best professional judgment.
PA	NR	NR	N/A
USEPA Region 4			
FL	Unknown	Unknown	N/A
KY	NR	NR	State officials indicated that agricultural drainage wells do exist in KY, but none are reported.
USEPA Region 5			
IL	6	NR	Best professional judgment. State officials suspect more than 6 wells exist. Local public health official used best professional judgment and personal observations to guess that maybe thousands of improved sinkholes may exist.
IN	6	NR	N/A
MI	14 or 15	NR	USEPA Region suspects more wells exist.
MN	92	>100	Several hundred wells may exist. Survey could not find basis for estimate but it might be an extrapolation of results from Quade (1990), using best professional judgment.
OH	>200 in Seneca County	1,000-1,500 (including improved sinkholes)	Best professional judgement. Ohio EPA derived the estimate from a combination of interviews with local officials, inspection, knowledge of north-central and northwestern Ohio's geology, and the results of the 319 grant study conducted in the Thompson Township of Seneca County.
WI	0	< 25	Best professional judgment. State officials assume 1 per county.
Tribal Program	NR	NR	N/A
USEPA Region 6			
OK	5	NR	N/A

Table 1. Inventory of Agricultural Drainage Wells in the U.S. (continued)

State	**Documented Number of Wells**	**Estimated Number of Wells**	
		Number	**Source of Estimate and Methodology**[1]
TX	135	>135	As documented in an existing UIC database, authorizations to construct have been issued for 135 ADWs. State officials, however, recognize that there may be many more unregistered wells located on private property.
USEPA Region 7			
IA	290	290	State registration and field inspections.
USEPA Region 8 -- None			
USEPA Region 9			
CA	1 (USEPA Region) 0 (Siskiyou Co.)	1 (USEPA Region) 3,000 (Siskiyou Co., see note to right)	Best professional judgment. The estimate for Siskiyou County is made up mostly of surface impoundments or basins that allow fluids to seep to the subsurface through their base, but probably not through a "well" (Barber, 1999). An initial survey response provided by the Division of Environmental Health in Yolo County estimated several thousand wells, but county staff have since stated that this estimate was based on a misunderstanding of what qualifies as an ADW, and a more accurate estimate is zero (Taniguchi, 1999).
USEPA Region 10			
ID	303	303	Based on original statewide screening by hydrogeologic basin to identify all ADWs at the time of initial permitting, plus regular field inspections allowing status updates and identification/investigation of unpermitted injection wells.
OR	7	100	Best professional judgment, based on discussion with the Oregon Department of Agriculture and Oregon State University Extension Service Staff. Confirmed by February 24, 1999 update from Calvin Terada of USEPA Region 10 (Terada, 1999).
WA	2	100	Calvin Terada of USEPA Region 10 (Terada, 1999).
Tribal Program	6	6	N/A
All USEPA Regions			
All States	>1,069	>2,842	Total estimated number counts the documented number when the estimate is NR. The total does not count the estimated 3,000 in Siskiyou County, California, which appear to be drainage impoundments or basins as opposed to "wells" within the scope of this study.

[1] Unless otherwise noted, the best professional judgment is that of the state or USEPA Regional staff completing the survey questionnaire.

N/A	Not available.
NR	Although USEPA Regional, state and/or territorial officials reported the presence of the well type, the number of wells was not reported, or the questionnaire was not returned.
Unknown	Questionnaire completed, but number of wells is unknown.

Despite this tendency for ADWs to be located in certain kinds of geologic settings, the number of ADWs nationwide cannot be estimated simply by assuming some density of ADWs in agricultural areas underlain by favorable soil and geological conditions, because there are many other factors involved. In particular, available inventory information indicates that historical farming and/or cultural practices strongly influence the occurrence of ADWs, with such wells being readily used by some farming families in a given area but not used at all by others in the same area. The water supply available to meet demands, which varies from place to place and often from season to season in the same place, also influences the occurrence and use of ADWs. For example, ADWs tend not to be used to drain water to the subsurface in arid areas where water is in short supply. This gives rise to the situation in the Southwest discussed above, where water is pumped from the ground to dewater a field and then released to surface outlets where the water can be used for other purposes. Alternatively, in locations where ground water is pumped and used for irrigation, the excess water may be drained back into ADWs for the purpose of recharging an aquifer. Because of these complicating factors, which are independent of geologic patterns and are very difficult to predict, USEPA has not attempted to develop a mathematical model for estimating the number of ADWs nationwide, as developed for storm water drainage wells and large-capacity septic systems (see Volumes 3 and 5, respectively, along with Appendix C). Such a model for ADWs is unwarranted based on the high level of effort that would be required relative to the likely accuracy that would be achieved.

Therefore, the current understanding of the prevalence of ADWs is based on data reported in the literature and on the results of the state and USEPA Regional survey, which many of the survey respondents acknowledge are based on incomplete knowledge. According to this information, there is now a total of at least 1,069 ADWs known to exist in the U.S. and more than 2,842 ADWs wells are estimated. The true number of ADWs in the nation, however, may be much larger. These wells appear to be concentrated primarily in Idaho, Iowa, Minnesota, Ohio, and Texas (a relatively large number are also estimated, but not documented, to exist in New York). ADWs are substantially less prevalent in other states where new and existing ADWs have been banned (e.g., Georgia, North Carolina, North Dakota) or where ADWs are not widely used as a matter of practice (e.g., California and Arizona). This information is discussed in more detail below for different states, based on the likely prevalence of ADWs and the certainty with which they are known to exist.

Looking forward, the number of ADWs should decrease as the risk to USDWs becomes known and ADWs that cause or threaten contamination are discovered and closed. However, the known number of ADWs may actually increase as the existing wells are actively looked for and discovered.

3.1 States Where Relatively Large Numbers of ADWs Are Known To Exist

Idaho now inventories 285 active ADWs in the state. This inventory is based on a concerted effort to locate ADWs using topography and land use maps and after several years of regular field inspections (Slifka, 1998). A total of 303 ADWs are currently registered in Idaho (Tallman and Slifka, 1998).

Current registration information for Iowa shows 290 active ADWs, mostly in north-central Iowa (Humboldt, Pocahontas, Floyd, and Wright Counties), according to the Class V UIC survey (Cadmus, 1999). These wells currently drain an estimated minimum of 40,000 acres. Construction of new ADWs has been prohibited in Iowa since 1957, but existing ADWs have been allowed to remain functional because of their important role in draining some of the most productive crop land in the world (Heathcote and Appelgate, 1998).

A study conducted in Thompson Township of Seneca County, Ohio indicates that there may be more than 200 ADWs in that county alone. Officials with the Ohio EPA estimate that, statewide, there are at least 1,000-1,500 ADWs, including improved sinkholes. The widespread occurrence of sinkholes make ADWs an attractive option for handling drainage in some areas of Ohio (Cadmus, 1999). In fact, in many areas in Ohio where improved sinkholes are used for drainage, the soil does not drain well and there are often no other drainage alternatives than the sinkholes if the fields are to be used for agriculture (Micham, 1999).

A total of 135 ADWs are currently in the Class V inventory in Texas, although officials with the Texas Natural Resource Conservation Commission recognize that there could be many more on private property. These wells are primarily located in the Pan Handle and the Lower Rio Grande Valley, where conditions of severely limited surface drainage, soil characteristics, and agricultural practices combine to create a need for ADWs. Of the 135 ADWs on record, 114 (84 percent) are in Hidalgo County. The rest are in Hudspeth County (11 wells), Runnels County (9 wells), and Oldham County (1 well).

Although Minnesota bans new ADWs and requires existing ADWs to close when found, it has 92 documented ADWs and estimates that greater than 100, possibly several hundred, wells may continue to exist. This estimate is based on a 1992 study by Quade of ADWs in three south-central Minnesota counties (Brown, Blue Earth, and Faribault Counties).

3.2 States Where No or Few ADWs Are Documented, But Where ADWs May Exist in Greater Numbers

Georgia, North Carolina, and North Dakota have banned new ADWs and require existing ADWs to close when they are found. Officials in these states, therefore, have reported that no ADWs currently exist within their borders. In contrast, Oregon, Washington, and Wisconsin also have a ban, but as described below, recognize that some wells continue to exist:

- Oregon has seven documented ADWs, but USEPA Region 10 and state staff estimate that there may be 100 ADWs in Oregon (Cadmus, 1999)

- Washington has two documented wells, but USEPA Region 10 officials, through discussion with state personnel, estimate that there may be 100 ADWs in the state.

- Wisconsin has no documented ADWs, but the state has closed 3 wells in the 10 years following the ban, indicating that wells exist regardless of the ban. Officials assumed that each county is likely to have one ADW, resulting in an estimate of less than 25 wells in the state.

A few states that do not officially ban ADWs have provided survey responses stating that none or very few are documented to exist within their borders. However, they estimate that many wells may exist, as outlined below:

- California has one documented well according to USEPA Region 9's survey response. Staff with the Bureau of Environmental Health in Siskiyou County are aware of roughly 3,000 seepage impoundments or ponds that are used to capture and remove excess water from agricultural fields, but it is unknown how many (if any) of these drain into a "well" (Barber, 1999). In addition, Braun and Hawkins (1991) described the existence of dry wells in and around citrus groves in Tulare County, and Holden (1986) reported that there were about 5,000 abandoned dry wells in the Central Valley. No information is available, however, on whether any of these wells can be counted as active ADWs in the current inventory.

- Delaware has no documented ADWs, but estimates that 50 may actually exist.

- According to USEPA Region 2 officials, New York has only one documented well, but discussions with farmers in the state have led to an estimate of possibly 200 ADWs in the state.

- Six ADWs are documented and in the inventory in Illinois, though it is unclear if any of these have been plugged or abandoned. State officials suspect more wells exist than are documented, with one local public health official speculating that there could be thousands of improved sinkholes accepting agricultural drainage.

The documented and estimated number of ADWs in Puerto Rico, Pennsylvania, Florida, Kentucky, and the USEPA Region 5 Tribal Program is either unknown or not reported. However, because ADWs are not banned in these locations, it is quite possible that some do exist there.

In all of the other states not mentioned above, ADWs are not banned but survey responses indicate that none or few ADWs are estimated to exist. For example, there are six ADWs in the 1997 UIC program inventory in Indiana, but there is a strong suspicion that this number is outdated (it is based on a 1988 study). There are also six documented ADWs existing on USEPA Region 10 Tribal Lands (encompassing the States of Alaska, Idaho, Oregon, and Washington). Michigan confirms that it has approximately 15 ADWs. The USEPA Region 5 UIC program, however, suspects that this documented inventory is lower than the true number. Although the exact location of all of these wells is unknown, some of the wells in Michigan are known to be in Monroe, Lenawee, and southern Washtenaw Counties. Survey responses suggest that the number of ADWs in all other states is zero.

4. WASTEWATER CHARACTERISTICS AND INJECTION PRACTICES

4.1 Injectate Characteristics

Water is the principal component of any injectate in an ADW, but the chemicals in that water may be a source of concern if they contaminate USDWs. Some chemicals are naturally occurring minerals, such as calcium, sodium, aluminum, and the like. Although naturally occurring, the levels of these minerals can often be altered (usually increased) by human activities. Other chemicals are the result of man-made practices, including general farming practices. These include pesticides, fertilizers (both natural and artificial), and biological contaminants (such as bacteria and other microorganisms).

The constituents that may be released into ADWs can be broadly categorized into inorganic constituents, biological contaminants, and organic chemical constituents. Sampling results from various studies that address the occurrence of these chemical groups in ADW injectate are summarized below. Some of these studies include subsurface drainage or ground water quality data that reflect aggregate agricultural practices, not just contaminant migration via ADWs. Additional studies that focus on nitrate and other chemicals measured in ground water around ADWs are discussed in Section 5.2.

4.1.1 Inorganic Constituents

The most common inorganic constituents in ADW injectate are nitrates, TDS, sediment, salts, and metals. Nitrogen compounds that are regularly applied to crop land for nutrients usually oxidize to nitrate, which is a highly mobile chemical in ground water.[1] As such, nitrate is a pervasive contaminant in both surface and subsurface flows entering ADWs. TDS is a collective term for solid salts, organometallic compounds, and other non-specific inorganic compounds that are dissolved in water. Dissolved solids do not function as a medium for transporting other materials in water. Sediment suspended in water, on the other hand, can transport other potential contaminants such as pesticides, bacteria, and metals. These contaminants are capable of sorbing onto the surfaces of suspended solids and eventually may desorb, contributing to the degradation of ground water quality. The addition of nutrients and soil conditioners often contribute to concentrations of major salt-forming ions, such as

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[1] Phosphorus compounds are also commonly applied to crops for nutrients. However, phosphorus is not toxic to humans or animals in the forms commonly found in water, so its presence does not appear to be a significant health concern with regard to ground water contamination by ADWs. The main concern associated with phosphorus-rich ground water is if it discharges to surface water, where it may induce eutrophication and other undesirable changes to aquatic ecosystems.

calcium, magnesium, sodium, potassium, chloride, and sulfate. These ions can become concentrated in ADW injectate through natural processes, including evaporation and transpiration, as well as through man-made processes such as recycling of irrigation waters.

Nitrate

Nutrients, essential for plant and crop growth, are commonly applied to agricultural land as chemical fertilizers, manure, or in some cases, sewage sludge. Nine studies summarized below illustrate the occurrence of nitrate in agricultural drainage, especially for ADWs in Iowa. These studies show a wide range of nitrate concentrations in ADW injectate that commonly exceed the primary MCL of 10 mg/l for nitrate measured as nitrogen (NO_3-N). Fertilization rates, crop rotation, soil characteristics, and stratigraphy contribute to these variations.

In Iowa, the concentration of nitrogen compounds (NO_3-N) found in subsurface drainage systems commonly exceeds the MCL of 10 mg/l. For example, Austin and Baker (1983) observed NO_3-N concentrations as high as 100 mg/l as fertilization rates and precipitation increased. In a statistical survey of private drinking water wells in Iowa, Kross et al. (1990) found that the average concentration of nitrate-N in drainage water was between 10 and 20 mg/l. In an Iowa Department of Natural Resources study of ground water quality in Floyd County, NO_3-N concentrations in tile water injectate ranged from 2 to 35 mg/l (Quade and Seigley, 1997).

Baker et al. (1985) monitored water draining into four ADWs in Humboldt County Iowa during periods of flow in 1981 and 1982. Results of this monitoring showed that during periods between runoff events when all the drainage to the ADWs was subsurface flow, NO_3-N concentrations were the highest, commonly in the range of 10-30 mg/l. When the ADWs received surface and subsurface drainage during periods of snowmelt or rainfall runoff, concentrations often dropped below 10 mg/l. Because nitrate is formed by oxidation in the soil, overland runoff typically has low concentrations compared to the subsurface drainage from cropland. Overall, Baker et al. (1985) found that nitrate-N concentrations ranged from 1.5 to 34.0 mg/l in the ADWs tested. Some 85 percent of the samples of drainage water analyzed exceeded the 10 mg/l MCL.

In Iowa’s Agricultural Drainage Well Project, NO_3-N concentrations in drainage water ranged from 4.0 mg/l to 29.0 mg/l over the course of the 4-year study (Iowa Dept. Of Agriculture and Stewardship, 1994). The study concluded that NO_3-N concentrations in subsurface drainage water are related to crop rotation, plus rate and timing of nitrogen fertilizer application. Citing research performed in Floyd County Iowa by Cherryholmes in 1986, USEPA Region 7 noted that nitrate-nitrite concentrations ranged from 0.2 to 31.0 mg/l for injectate water sampled from ADWs studied in Iowa (Langemeier and Marre, 1987).

In addition to the above Iowa studies, studies in Idaho and Texas provide data on the nitrate concentration of ADW injectate. In 1977, the U.S. Geological Survey (USGS) conducted a study in Idaho that found nitrate concentrations up to 9.8 mg/l in drainage water (Seitz, 1977). More recently, in 1995, the State of Idaho has found nitrate concentrations in ADW injectate ranging from 0.001 mg/l to 6.8 mg/l, with the majority of samples below 1 mg/l (Slifka, 1998). A 1983 study in Texas by Knape reported NO_3-N levels ranging from 15 to 45 mg/l in agricultural drainage water (Knape, 1983).

TDS and Sediment

Five available studies address TDS or sediment levels in ADW fluids. In the Texas study mentioned above in the nitrate section, Knape (1983) found that agricultural drainage waters in Texas contained 1,754 to 6,510 mg/l of TDS. The Idaho study by the USGS in 1977 found TDS levels between 1.0 and 4,575 mg/l (Seitz, 1977). In 1994, Skaggs et al. found that sediment loads in subsurface drainage were less than that of surface runoff for agricultural land, but admitted that sediment loading could be a problem (Skaggs et al., 1994). In an Iowa study, Austin and Baker (1983) found that after a snowmelt, TDS exceeded 1,000 mg/l in drainage water, suggesting that runoff was entering ADWs via surface intakes to tile drains or an uncapped or open drainage well. Finally, a study in the San Joaquin Valley in California found TDS concentrations as high as 11,600 mg/l in drainage water (Lee, 1993).

These results show that TDS levels in agricultural drainage are likely to greatly exceed the secondary MCL of 500 mg/l. This secondary MCL is not health-based, but rather was established to represent a goal that would prevent most adverse taste effects.

Salts and Metals

Other common inorganic constituents found in ADW injectate include salts and metals. Excess salt concentrations, including calcium, magnesium, sodium, potassium, chloride, sulfate, and carbonate are often found in agricultural drainage waters.

One study in the San Joaquin Valley in California found a maximum sodium level of 2,820 mg/l in drainage water. Measured concentrations of boron were as high as 18,000 mg/l (Lee, 1993). For comparison, the draft health advisory for boron is 0.6 mg/l (there is no health advisory for sodium).

In addition, there is information on salt-forming metals and ion complexes from the 1977 USGS Idaho study, Knape's Texas study, and Baker et al.'s work in Iowa. These data are summarized in Table 2, along with available standards for the purpose of comparison (NA means no standard is available). As shown, the concentrations of sulfate, chloride, and boron in Texas exceeded the standards, and the maximum iron concentration in Iowa exceeded the standard. None of the observed concentrations in Idaho exceeded the available standards.

4.1.2 Biological Constituents

Pathogens such as bacteria, viruses, and parasites may be transported by surface runoff and can be found in drainage water and ground water near animal feedlots, or improperly constructed, leaking manure tanks or earthen material storage basins (USEPA, 1997). Three Idaho studies, summarized below, address biological constituents in agricultural drainage water.

Table 2. Inorganic Contaminant Concentrations from Selected ADW Studies

Contaminant	Standard (mg/l)	Range of Concentrations (mg/l)		
		Idaho*	Iowa**	Texas***
Ca	NA	35 - 76	13 - 150	206 - 430
Mg	NA	9.2 - 30.0		38 - 130
Na	NA	9.1 - 53.0		354 - 1659
K	NA	2.9 - 15.0		4 - 10
HCO_3	NA	138 - 278		294 - 366
SO_4	500 (proposed primary MCL)	7.2 - 110.0		571 - 1361
Cl	250 (secondary MCL)	2 - 86	1 - 120	371 - 1999
F	4 (primary MCL under review)	0.4 - 0.9		0.9 - 2.2
Fe	0.3 (secondary MCL)		0.01 - 2.6	
B	0.6 (draft health advisory)			2.7 - 15.0
SiO_2	NA	0.4 - 35.0		41 - 61
P	NA	0.06 - >4.6	0.01 - 1.99	

Sources:* Seitz et al., 1977.
****Baker et al., 1985.**
*****Knape, 1983.**

In 1979 in Minidoka County, Idaho, domestic drinking water wells and ADW drainage water were tested for coliform bacteria. Turbidity and fecal coliform bacteria in the sampled drainage water exceeded acceptable limits. Coliform levels in 31 percent of domestic wells exceeded drinking water standards during the irrigation season. Turbidity levels in sampled drainage water from both the study and control area were known to exceed drinking water standards regularly throughout the year. Coliform concentrations in the study area were significantly higher than in control areas throughout the year (Graham, 1979).

The USGS conducted a study of irrigation drainage wells in the western Snake River- Plain Aquifer area of Idaho (Seitz et al., 1977). The study area is underlain by basalt flows and interbedded pyroclastic and sedimentary rocks. The volcanic members are extensively fractured and vesicular, providing conduits for movement of water to the subsurface. The quality of the irrigation waste water is highly variable, depending upon the original source of the irrigation water, amount of nutrient added to crops, dilution by precipitation, and numerous other factors. Researchers found that nearly all the irrigation waste water entering drainage wells contained significantly higher concentrations of indicator bacteria than either surface or ground water. Specifically, the research showed that injectate contained 30 to >200,000 colonies/100 ml of total coliform, 4 to 20,000 colonies/100 ml of fecal coliform, and >160 to 80,000 colonies/100 ml of fecal streptococci.[2]

More recent investigations of injectate quality in Idaho generally found biological contaminants in the lower range of the above concentrations. These recent investigations show very few cases of high concentrations of bacterial contaminants (Slifka, 1997).

In addition to these Idaho studies, two contamination incidents in Iowa provide information on the levels of microbiological contamination that may enter ADWs in mismanagement scenarios. In once incident, hog manure runoff draining into an ADW resulted in fecal coliform levels as high as 4,000 colonies per 100 ml in water in tile lines draining into an ADW collection cistern (USEPA Region 7, 1997a). In the other incident, an ADW that received discharge directly from septic systems contained water with 830,000 colonies of fecal coliforms per 100 ml (Stone, 1979). These two contamination incidents are discussed further in Section 5.2.2.

4.1.3 Organic Chemical Constituents

Pesticides in agricultural drainage water may also pose a threat to ground water quality and human health. Pesticides that may be found in drainage water, drainage wells, and ground water include bactericides, fungicides, insecticides, nematocides, rodenticides, and herbicides. Other incidental organic contaminants may also be a problem if hazardous materials, such as fuel or solvents used for cleaning, are accidentally or intentionally allowed to enter ADWs. The likelihood of such events increases when ADWs are located near roads, equipment preparation or maintenance areas, or other trafficked areas.

Seven studies are summarized below addressing organic constituents in agricultural drainage water or ground water associated with ADWs. Tables presenting concentration information are also included.

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[2] For comparison, the primary MCL that community water systems have to meet for total coliforms (including fecal coliform and *E. Coli*) states that no more than 5.0% of samples can test positive for total coliform in a month. For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive. Every sample that has total coliforms must be analyzed for fecal coliforms. There cannot be any fecal coliforms.

Baker et al. (1985) monitored water draining from row-cropped areas into four drainage wells in Iowa during periods of flow in 1981 and 1982. The researchers detected several different pesticides in the water draining to the wells, but usually at levels below 0.001 mg/l. Pesticide levels were highest in samples taken soon after rainfall of at least 20 mm, when surface runoff or ponding would be expected. The following concentrations of pesticides were found: alachlor, 0 - 0.055 mg/l; atrazine, 0 - 0.0005 mg/l; carbofuran, 0 - 0.0006 mg/l; chlordane, 0 - 0.0018 mg/l; cyanazine, 0 - 0.08 mg/l; 2,4-D, 0 - 0.0004 mg/l; dicamba, 0 - 0.012 mg/l; dieldrin, 0 - 0.000028 mg/l; and metribuzin, 0 - 0.00041 mg/l. For the pesticides with standards set, alachlor and cyanazine exceeded the MCL.

USEPA Region 8 compiled research for a 1987 symposium on Class V Injection Well Technology (Langemeier and Marre, 1987). Citing a 1986 Cherryholmes publication, the authors showed maximum concentrations of several pesticides found in eight ADWs in Floyd County, Iowa between June and September 1986. These include atrazine, 0.0052 mg/l; cyanazine, 0.0028 mg/l; metolachlor, 0.0059 mg/l; alachlor, 0.00029 mg/l; metribuzin, 0.00073 mg/l; and carbofuran, 0.0002 mg/l. Concentrations of atrazine and cyanazine exceeded MCLs. Also, The Floyd County Iowa Soil and Water Conservation District sampled private drinking water wells from 1990 to 1996 as part of its Groundwater Protection Project (Moore, 1997). Investigators monitored for atrazine at 12 different locations throughout the county. Concentrations ranged from less than method detection level (<MDL) to 0.0035 mg/l. The report shows higher atrazine concentrations in areas with shallow bedrock-aquifer conditions. However, the authors noted that this may not be directly attributable to ADWs.

Knape (1983) studied ADWs in the Lower Rio Grande Valley, Texas. ADWs were installed in this area to help alleviate the problem of poor soil drainage resulting from perched (shallow) water tables in agricultural areas. Knape tested for 23 different pesticides. Pesticides that were detected include bromacil, < MDL - 0.016 mg/l, and simazine, < MDL - 0.016 mg/l. Pesticides and other synthetic organic chemicals tested for, but absent or below detection levels, were: aldrin, chlordane, DDD, DDE, DDT, diazinon, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, methyl parathion, parathion, toxaphene, PCB, malathion, diethylhexyl phthlate, dibutyl phthlate, ethion, and guthion.

The Iowa Agricultural Drainage Well Research and Demonstration Project examined the concentrations of several pesticides in drainage water from 1990 to 1993 (Iowa Dept. of Agriculture and Land Stewardship, 1994). The samples were collected from subsurface drainage water leaving controlled test plots, not actual farms, in underground tiles. Table 3 summarizes the annual maximum values reported. These concentrations are expected to be lower than those in surface runoff, because pesticides are generally much lower in subsurface drainage due to filtration through the soil profile. No surface runoff, however, was collected from the test plots for analysis.

Additionally, the USGS lists pesticide concentration data from the Snake River-Plain Aquifer Study in Idaho's ADW area (Seitz et al., 1977). Table 4 lists the pesticides analyzed and the concentrations observed in ADW injectate.

Table 3. Iowa Herbicide Concentrations in Subsurface Drainage Water, 1990-1993

Herbicide	Range of Maximum Concentration (mg/l)
atrazine	0.00029 - 0.0012
cyanazine	0.00046 - 0.005 [i]
metolachlor	0.00016 - 0.0019
dicamba	< MDL[a] - 0.00056
pendimethalin	< MDL
butylate	< MDL
2,4-D	< MDL
bentazon	0.00053 - 0.0064
chloramben	< MDL - 0.0082
metribuzin	0.00016 - 0.0022
acifluorfen	< MDL - 0.00033
clomazone	< MDL
fluazifop-butyl	<MDL
alachlor	<MDL
trifluralin	<MDL

[a] Less than method detection level

[i] Exceeds the draft HAL of 0.001 mg/l (see Appendix D).

Source: Iowa Department of Agriculture and Land Stewardship, 1994.

Table 4. Pesticides in Snake River-Plain Aquifer Irrigation Waste Water (Idaho)

Pesticide	Range of Concentrations (mg/l)
aldrin	< MDL[a]
chlordane	< MDL - 0.00016
DDD	< MDL - 0.00003
DDE	<MDL
DDT	< MDL - 0.00002
diazinon	< MDL - 0.00006
dieldrin	< MDL - 0.00018
dyfonate	0.00003
endrin	< MDL
heptachlor	< MDL
heptachlor-epoxide	< MDL
lindane	< MDL
malathion	< MDL
methylparathion	< MDL
parathion	< MDL
PCB	< MDL
2,4-D	< MDL - 0.00092
2,4,5-T	< MDL
Silvex	< MDL

[a] Less than method detection level

Source: Seitz et al., 1977.

Table 5 lists pesticides reported in past USEPA reviews that are often found in drainage water and ground water (USEPA, 1990). This list is not comprehensive and is intended to provide a general overview of the various types of pesticides that have been commonly reported in drainage water and ground water. The concentrations of the chemicals that have been found in the literature are presented as ranges or the highest detected level. The proposed or actual MCL is also presented, where available. Except for the pesticide EDB, Table 5 shows that sampled ground and drain water do not exceed MCLs for pesticides that have established MCLs. However, the same results show that pesticide concentrations exceed the proposed standards for the following: alachlor, aldicarb, carbofuran, cyanazine, 1,2-DCP, and DBCP.

Table 5. Pesticide Concentrations in Drainage Water or Ground Water [a]

Pesticide (source)	Concentration Ranges (mg/l)	Proposed (P) or Actual (A) MCL (mg/l)	Found in Drainage Water (DRAIN) or Ground Water (GW)
alachlor (USEPA, 1990)	0.0001-0.01	0.002 (A)	GW
aldicarb (USEPA, 1990)	0.001-0.05	0.007 (P)	GW
aldrin (Knape, 1983)	< 0.00002		DRAIN & GW
atrazine (USEPA, 1990)	0.0003-0.003	0.003 (A)	GW
bromacil (USEPA, 1990)	0.3		GW
carbofuran (USEPA, 1990)	0.001-0.05	0.04 (A)	GW
cyanazine (Libra et al., 1994; USEPA, 1990)	0.001-0.0028	0.001 (DHAL)[b]	GW
1,2-DCP (USEPA, 1990)	0.001-0.05	0.005 (P)	GW
DCPA (USEPA, 1990)	0.05-0.7		GW
DBCP (USEPA, 1990)	0.0002-0.02	0.0002 (P)	GW
diazinon (Knape, 1983)	< 0.0003		DRAIN & GW
dinoseb (USEPA, 1990)	0.001-0.005	0.007 (A)	GW
dyfonate (USEPA, 1990)	0.0001		GW
EDB (USEPA, 1990)	0.00005-0.02	0.00005 (A)	GW
endrin (Knape, 1983)	< 0.0002	0.002 (A)	DRAIN & GW
heptachlor epoxide (Knape, 1983)	< 0.00006	0.0002 (A)	DRAIN & GW
metolachlor (USEPA, 1990)	0.0001-0.0004		GW
metribuzin (USEPA, 1990)	0.001.0-0.004		GW
oxamyl (USEPA, 1990)	0.005-0.065	0.2 (A)	GW
simazine (USEPA, 1990)	0.0002-0.003	0.004 (A)	GW
1,2,3-trichloropropane (USEPA, 1990)	0.0001-0.005		GW

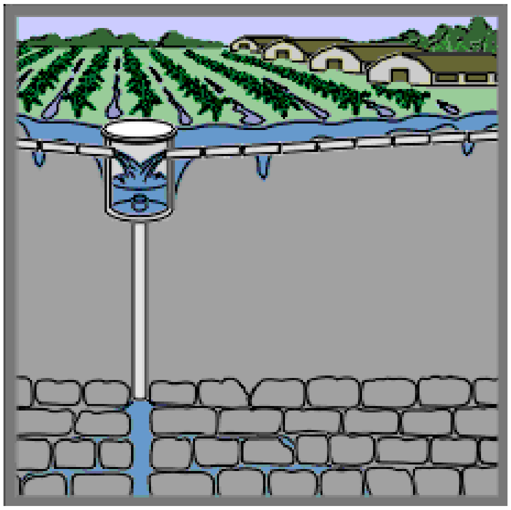
[a] Please note that the original table provided in a prior USEPA review (USEPA, 1990) cited pesticide concentrations in mg/l (parts per million) when the values should have been cited as : g/L (parts per billion). All values taken from this USEPA report have been converted to mg/l.

[b] DHAL stands for draft health advisory level (see Appendix D).

4.2 Well Characteristics

ADWs often consist of a buried cistern or collection basin that is fed by fluids from subsurface drainage lines (“tile lines”), as illustrated in Figure 1. The cisterns may also collect surface water. The cistern or collection basin sits atop a cased, drilled, or dug well that releases fluid into the subsurface.

Figure 1. Schematic Diagram of an ADW Designed to Accept Tile Drainage Water



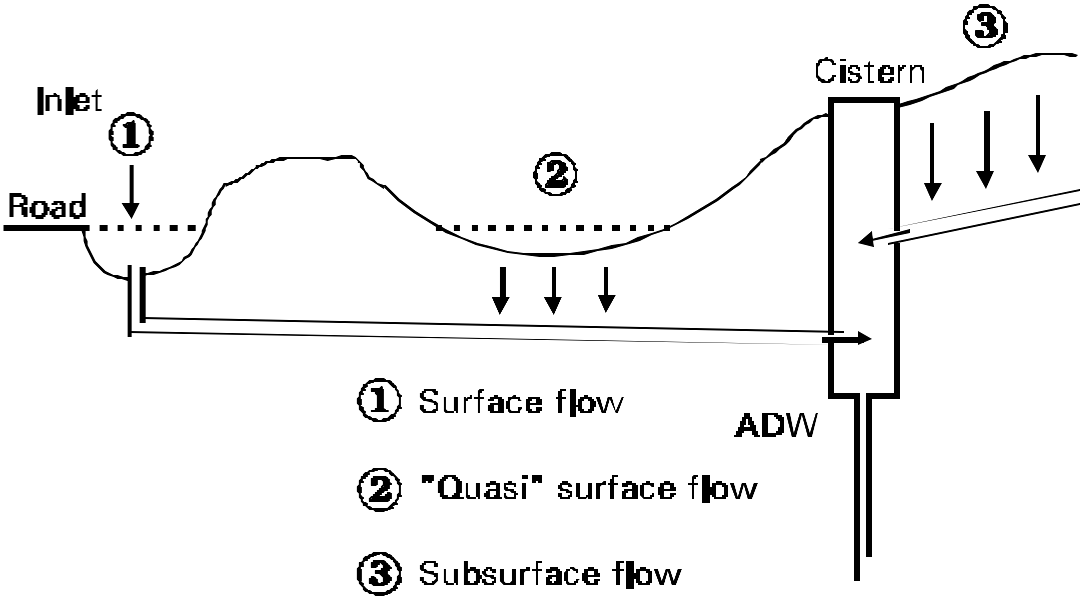
Source: Pat Lohmann, Iowa DNR

Drain tile lines are typically just a few feet below the surface and are used to draw down excess soil water and move it laterally to an outlet. The outlet may discharge directly to an ADW, or it may discharge to a surface depression or waterway that leads to an ADW. Most drain lines are constructed of plastic, concrete, or clay, and may be perforated and gravel-packed to encourage percolation (Knape, 1983). In addition to accepting subsurface drainage, many tile line systems use surface intakes to provide more rapid drainage from low areas.

ADWs range in diameter from 3 to 36 inches and may be constructed in various ways related to their age. Some use steel casing, while others may use brick or concrete pipe. They may range in depth from 20 to hundreds of feet, typically injecting drainage water into the shallowest permeable zone (USEPA, 1990). Although the majority of ADWs in Iowa are less than 100 feet deep, many are deeper, with the deepest ADW in Iowa reported to be 400 feet deep (Heathcote, 1999).

Figure 2 shows a schematic of a typical ADW in Iowa where a buried basin or cistern collects drainage from surface and subsurface inlets (Iowa Dept. of Agriculture and Land Stewardship, 1994). In this type of system, the cistern does not have a silt storage area where particles will settle and remain outside the drainage well; as a result, any silt contained within the drainage is washed down the well. Subsurface outlets may be located in the cistern, or adjacent to the cistern, depending on the system design. In many cases, the top of the cistern has been left open to receive surface runoff in addition to subsurface agricultural drainage. The drain lines often run parallel to each other at varying intervals from 75 to 225 feet. Many tile line systems also have surface inlets as shown in Figure 2. A law passed in Iowa in 1997, however, requires that surface intakes be removed and repairs made to prevent surface water from entering ADWs by December 31, 2001.

Figure 2. ADW Typically Used in Iowa



Source: Iowa Department of Agriculture and Land Stewardship, 1994.

Figures 3 and 4 are photographs of the top of the cisterns of two ADWs in Iowa. The well in Figure 3 is located in Weaver Township (Section 1), Humboldt County, Iowa. The hole and missing bricks shown at the bottom, which reflect the common state of repair of ADWs in the state, provide a ready opening for surface runoff to drain directly into the well. The well in Figure 4 is located in Corinth Township (Section 6), also in Humboldt County. The cistern for this well is covered simply by a board with a rock on top of it.

Figure 3. ADW in Weaver Township, Humboldt County, Iowa

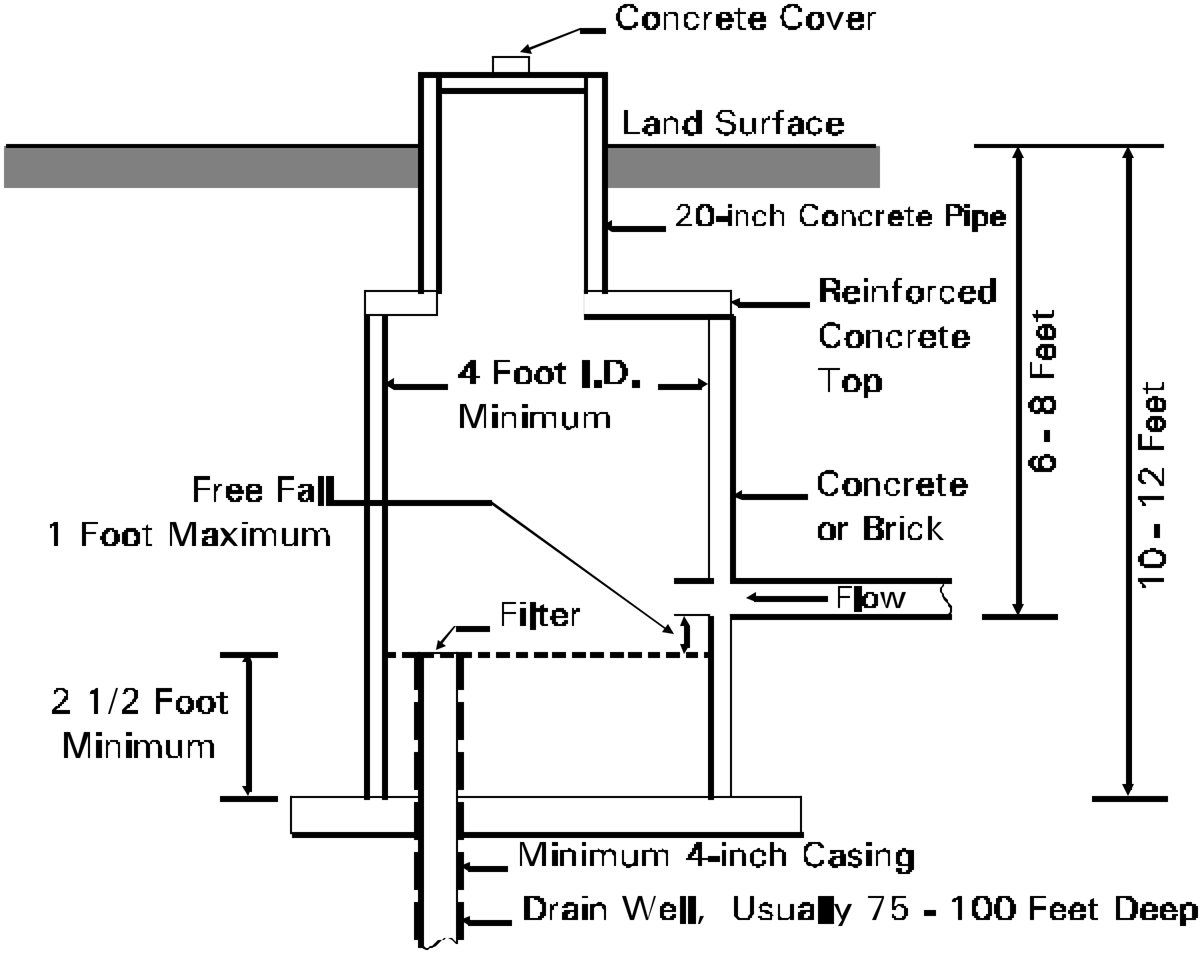
Source: Iowa Environmental Council

Figure 4. ADW in Humboldt County

Corinth Township, Iowa

Source: Iowa Environmental Council

Figure 5. ADW Typically Used in Texas

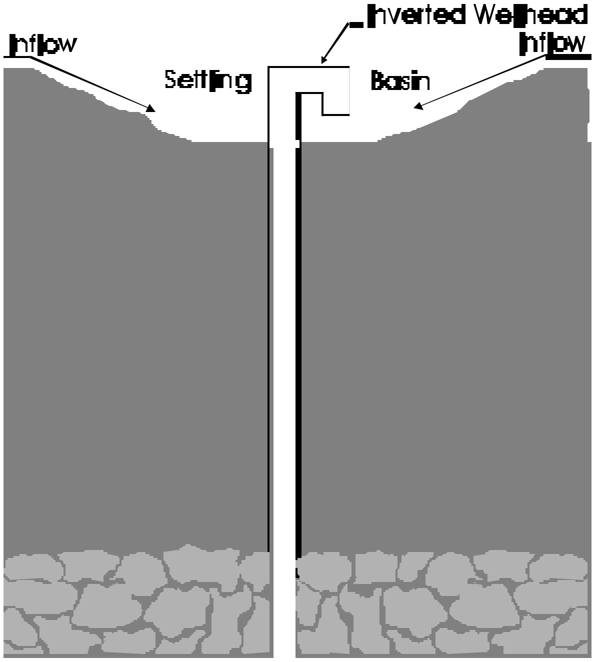


Source: Texas Department of Water Resources, 1984.

Figure 5 shows an ADW design commonly used in Texas. ADW systems in Texas use drain lines that flow into a cistern before entering the drainage well, as in Iowa. The drainage lines are placed in a field approximately six feet below the ground surface and have a nylon filter fabric that covers the perforations so that coarse particles do not enter the drainage well (Knape, 1983). In Texas, three types of drain tile designs are used to collect agricultural drainage. In the oldest ADW design, the drainage well is placed inside the cistern. The top of the drainage well is approximately 2 feet higher than the base of the cistern so that a silt storage area is created at the bottom of the cistern. To further prevent the entry of foreign matter into the drainage well, a screen filter is placed on the top of the drainage well (Knape, 1983). In the second design, the drainage well is located adjacent to the cistern where gravity flow transfers fluid from the cistern to the drainage well through a plastic pipe. The third design uses a centrifuge pump to transfer drainage fluids from the cistern to the ADW. The pump is placed at the top of the cistern and is activated when the water in the cistern rises to a certain level. A float that hangs from a switch on the pump rises with the water level, activating the pump. Fluids are transferred from the cistern via a plastic pump and subsequently injected under pressure into the drainage well. This design is more costly than the older designs, and is rarely used (Knape, 1983).

In Idaho, most injection wells are steel cased wells drilled into subsurface porous formations (see Figure 6). Many wells have uncased rock (lava) holes in the lower sections. The top of the cistern, or the actual well, is left open to receive surface runoff in addition to subsurface agricultural drainage (USEPA, 1997). In these systems, the well head has a screen and/or syphon attached to the casing to keep larger debris from entering the well. Catchment basins are constructed near the well inlets to reduce sediment in the injectate (Slifka, 1998).

Figure 6. ADW Typically used in Idaho



Source: *State of Idaho, Department of Water Resources*.

As noted in Section 2, some abandoned drinking water wells are used for ADWs. Abandoned drinking water wells may be constructed with a variety of materials and design specifications, depending on the age of the well and the hydrogeological conditions at the site. There are three types of drinking water wells: hand dug or bored, driven, and drilled wells. Hand dug or bored wells are usually less than 100 feet deep and range in diameter from 1 to 6 feet, although some wells are reported to be greater than 10 feet in diameter (Alabama Cooperative Extension Service, 1995; Black et al., 1989; Brichford and Matzat, 1995; Derickson, 1996; Eversoll et al., no date; Glanville, 1995; Zahniser and Gaber, 1993). They are typically cased with brick, rock, concrete (Black et al., 1989; Brichford and Matzat, 1995), stone tile, or other curbing material to hold the soil back from the well (Alabama Cooperative

Extension Service, 1995; Zahniser and Gaber, 1993). Driven wells usually range from 1 to 6 inches in diameter and are 10 to 50 feet deep (Alabama Cooperative Extension Service, 1995; Black et al., 1989; Brichford and Matzat, 1995; Eversoll et al., no date; Glanville, 1995; Zahniser and Gaber, 1993). They are driven down into an aquifer and made from steel piping, typically with a short, pointed sandpoint and well screen on the leading end. Drilled wells are the most common type of water well in use today (Brichford and Matzat, 1995). Most domestic water supply wells range from two to eight inches in diameter (Black et al., 1989, Glanville, 1995) and are drilled to various depths, depending on the depth to the aquifer. Wells have been drilled from 30 to more than 1,000 feet deep (Alabama Cooperative Extension Service, 1995).

Finally, some ADWs are simply improved sinkholes, where a surface depression has been altered to direct fluids into the opening. In order to qualify as an injection well, an improved sinkhole has to be deeper than it is wide. This type of ADW is often found near roadways and culverts to drain not only excess irrigation water, but also storm water runoff. Figure 7 provides a photograph of an improved sinkhole north of Madison, Wisconsin.

Figure 7. Improved Sinkhole North of Madison, Wisconsin

Source: USEPA Region 5

4.3 Operational Practices

The operational practices for ADWs can be quite varied, depending on the well location (both the state and the location within the state), the type of ADW, the age and economic situation of the landowner, and the proximity to potential sources of contamination, among other factors. Each of these factors is briefly discussed below.

4.3.1 Location

As discussed in Section 7 below, there is a range of different state and local programs designed to address ADWs. There is a heightened awareness of the importance of this issue in certain states, such as Iowa, Idaho, and several others that have specific regulatory programs to address ADWs. In other instances, there may be little or no data available on ADWs within a state, especially if the wells are not officially recognized and counted as an ADW in the state. For example, though improved sinkholes and abandoned irrigation and drinking water wells are considered ADWs if they receive agricultural drainage, they may not be identified as such by the state UIC program and their locations are most likely unknown.

As previously discussed, cultural practices of the various landowners may significantly affect the operational practices associated with ADWs. In one region of a state, ADWs may all be constructed according to a single type (having been constructed during roughly the same points in time), while other regions may not have ADWs or have ADWs of a different type and using different operational parameters.

4.3.2 Type of ADW

For ADWs constructed to drain land of natural water that occurs either through a high water table or precipitation, the operational characteristics are often quite similar. That is, they are fed through surface flow, subsurface flow, or a combination of the two and the farmer often has little or no activity to perform (other than cleaning any screens that exist).

In contrast, ADWs used to drain irrigation water may have different operational characteristics. If the landowner is aware of the ADW (which is not always the case, especially with abandoned wells), then he or she will endeavor to maintain the ADW to continue to operate. Irrigation is a principal source of injectate water in some states.

4.3.3 Economic Condition of the Landowner

This factor can often play the most significant role in the operation and control of ADWs. A study in Iowa (Huber, 1988) found that many owners of ADWs have little financial incentive for mitigating problems associated with their ADWs. Also a number of complicating factors, such as debt outstanding, availability of Conservation Reserve Program easements (which make income tax credits available for land taken out of cultivation), and inheritance tax obligations, affect the likelihood of activities being undertaken. Changing the use of the land from crops to forage (for livestock) can be a sound way of avoiding drainage problems, but such a change may not be made by the landowner for a variety of reasons. Obviously, changing the way people operate their land and businesses is difficult for an outsider to force.

4.3.4 Proximity to Potential Sources of Contamination

It is not always easy to identify the origin of a chemical detected in an ADW or receiving ground water. The data shown in Section 4.1 above indicate a wide variety of contaminants may enter ADWs. The logical source of these contaminants is the land that the ADW is designed to drain, but that is not always the case. Direct discharges from human septic tanks, subsurface plumes from septic systems, nearby feedlot and manure storage operations, accidental releases of materials during farming operations (e.g., spills of motor oils used in equipment or bulk releases of pesticides during storage or handling), and other sources can contaminate an ADW with a variety of the same contaminants, such as nitrate. Moreover, simply identifying nitrate or pesticides in a well does not tell you which field it came from, particularly when the tile lines (subsurface drain lines) cross over property lines. If farmer A uses pesticide X, while farmer B uses pesticides X, Y, and Z, and both their properties drain into an ADW, then whose pesticide X is being detected in the well? Likewise, for ADWs that receive storm water runoff from roads or suburban areas, metals, hydrocarbons, and household pesticides could contaminate the ADW, even if the ADW is in a rural area. Short of accurately identifying each source of contaminant, its individual mobility characteristics and modeling each well, there is no simple means of identifying where a particular contaminant originated.

The close proximity of ADWs to large-scale confined animal feeding operations (CAFOs) is a particular concern, as illustrated by recent developments in Iowa. In the mid-1990s, large-scale CAFOs began expanding in Iowa and with them came multi-million gallon earthen manure storage structures. Many of the largest facilities are located in the area of north-central Iowa where ADWs are concentrated. For example, in Wright County there are 46 large-scale permitted livestock facilities and 38 active ADWs. In Lincoln Township, just southeast of the town of Clarion, there are 12 permitted hog confinements and 28 ADWs. Including the area surrounding Lincoln Township, there are 27 ADWs within one mile of a permitted hog confinement facility. In some cases, the ADWs are very close (hundreds of meters) to the facilities and their manure storage structures. A recent paper by the Iowa Environmental Council presents photographs of wells in close proximity to a large earthen lagoon of a hog confinement facility, a facility that houses 950,000 chickens and 24,000 finishing hogs, and a swine nursery facility (Heathcote and Appelgate, 1998).

Although similar data are not available for other states, it appears likely that some ADWs in other locations are also in close proximity to animal feeding operations (AFOs). It is estimated that there are 450,000 AFOs in the United States. An AFO is a “lot or facility” in which livestock “have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation, forage, growth or post harvest residues are not sustained in normal growing season over any portion of the lot or facility” (U.S. Dept. of Agriculture, 1998).

The close proximity of large livestock confinement facilities to ADWs presents at least two concerns: (1) possible impact to aquifers from runoff after land application of manure, and (2) risk of a catastrophic spill from a manure storage basin or lagoon entering an ADW. These risks have been particularly evident in Wright County Iowa, where the Mississippian aquifer into which ADWs near feedlots drain is the main water supply for public and private waters supplies for much of north-central Iowa (Heathcote and Appelgate, 1998).

5. POTENTIAL AND DOCUMENTED DAMAGE TO USDWs

5.1 Injectate Constituent Properties

The primary constituent properties of concern when assessing the potential for Class V ADWs to adversely affect USDWs are toxicity, persistence, and mobility. The toxicity of a constituent is the potential of that contaminant to cause adverse health effects if consumed by humans. Appendix D of the Class V Study provides information on the health effects associated with contaminants found above drinking water MCLs or HALs in the injectate of ADWs and other Class V wells. As discussed in Section 4.1, the contaminants that have been observed above primary (health-based) drinking water standards or health advisory levels in ADW injectate are nitrate, boron, sulfate, coliforms, and certain pesticides (cyanazine, atrazine, alachlor, aldicarb, carbofuran, 1,2-dichloropropane (DCP), and dibromochloropropane (DBCP)). TDS and chloride have been measured above secondary MCLs in some ADWs, but these standards are designed to minimize aesthetic (taste) effects not adverse health effects (health-based standards do not exist for these parameters).

Persistence is the ability of a chemical to remain unchanged in composition, chemical state, and physical state over time. Appendix E of the Class V Study presents published half-lives of common constituents in fluids released in ADWs and other Class V wells. All of the values reported in Appendix E are for ground water. Caution is advised in interpreting these values because ambient conditions have a significant impact on the persistence of both inorganic and organic compounds. The primary inorganics of concern in ADW injectate are, in general, highly persistent in ground water. As for the organic constituents of concern, atrazine, aldicarb, carbofuran, and 1,2-dichloropropane are highly persistent in ground water.[3] A wide range of values for bacterial die-off rates are reported in the literature, as presented in Appendix E.

Appendix E also provides a discussion of mobility of certain constituents found in the injectate of ADWs and other Class V wells. Because the point of injection for ADWs is within a permeable coarse-grained unit, karst, or a fractured unit in many areas (because substantial void space is needed to accept large quantities of drainage), conditions are often present that would allow constituents in ADW injectate to be highly mobile.

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[3] Published half-lives are not available for the other organics in ADW injectate observed above MCLs, including cyanazine, alachlor, and dibromochloropropane.

5.2 Observed Impacts

This section summarizes known contamination incidents involving ADWs and other studies on ground water impacts associated with agricultural drainage. The discussion is organized into three main sections, first dealing with nitrate in ground water, then contamination incidents involving the direct discharge of septic tank contents to ADWs, and then finally other contamination incidents and studies.

5.2.1 Nitrate in Ground Water

Nitrate is a widespread contaminant of ground water, and high concentrations of nitrate in ground water are often linked to agricultural practices, including, but not limited to, the use of ADWs (Hallberg and Keeney, 1993). Large amounts of nitrogen are added to the soil in many agricultural systems providing the opportunity for large leaching losses of nitrate into ground water (Hallberg and Keeney, 1993), but not necessarily a correlation to injection wells. Much research shows background nitrate-N concentrations are low, often less than 2.0 mg/l, in ground water moving from forested, pasture, or grassland areas to agricultural areas (Hallberg, 1989).

There are numerous factors that affect the fate and transport of nitrate in ground water, including hydrogeologic factors, agricultural land use and practices, local features, and water chemistry. Among the most important of these controlling factors are the amount of nitrogen source available, the amount of infiltrating or percolating water, the hydraulic conductivity of the subsurface, depth to the water table, and the potential for nitrate-reduction and/or denitrification (Hallberg, 1989). Several studies, discussed below, illustrate the interplay of these various controlling factors with respect to ADW use and nitrate contamination of ground water.

A compilation of data from the Big Spring Basin in northeastern Iowa provides qualitative evidence of the link between the amount of nitrogen source available and increased concentrations of nitrate in ground water. The data indicate that in the 1930s, nitrate-N concentrations in an aquifer were less than 1 mg/l. In the 1950s and 1960s, the nitrate-N concentration in the aquifer averaged about 3 mg/l and by 1983, the average concentration was 10.1 mg/l. The increases in nitrate concentrations were reported to directly parallel increases in the amount of nitrogen fertilizer applied (Hallberg, 1986). Thus, these data suggest that nitrogen source availability directly influences nitrate contamination of ground water.

Similarly, a study in Idaho conducted by the Idaho Department of Water Resources based on nitrate data collected by the U.S. Bureau of Reclamation showed nitrate levels in ground water increasing from 1980 to 1995. The largest increases were in areas of gravity or flood irrigation. The highest level of nitrate in ground water was measured at 8.0 mg/l in 1995. At this same time, the highest level of nitrate contamination in the fluids entering ADWs in the area was measured at 6.8 mg/l. Much of the irrigation water in the area is pumped from ground water and is the source of much of the injectate placed back into the aquifer. Many agricultural areas along the Snake River Plain that show high levels of nitrates in ground water have few ADWs (Slifka, 1998).

Scientists made stronger connections between ADW use and nitrate in ground water from a study in north central Iowa between 1981 and 1983 (Baker et al., 1985; Baker and Austin, 1984). Investigation of farm water supply wells in three study areas showed nitrate ground water contamination of the local carbonate aquifer studied. The results showed that areas with the highest density of ADWs had the highest average concentrations of nitrate in ground water samples. Further, the percent of drinking water wells in the study areas whose average concentration exceeded the MCL of 10 mg/l was highest in the areas with the greatest concentration of ADWs.[4] Baker et al. (1985) also related nitrate concentrations in farm drinking water wells to their distance from an ADW, and found that drinking water wells within 0.3 to 1.2 miles of an ADW showed the highest nitrate concentrations. Finally, the study showed that farm wells in areas with greater than 50 feet or more of overlying earth material (overburden) had significantly higher nitrate concentrations than areas with less overburden. This suggests that nitrate in the recharge to drainage wells, rather than the nitrate in normal infiltration, had increased nitrate concentrations in the aquifer. The authors pointed to prior research that shows that areas with 50 feet or more of overburden are more confined, and typically show low nitrate levels. In these settings recharge from the surface, carrying nitrate, typically has not penetrated the protective confinement and affected this deeper ground water.

The Baker et al. (1985) results highlight several key factors affecting nitrate in ground water. In particular, the results indicate the importance of hydrogeological factors on nitrate contamination. The type of terrain and the amount of overburden influenced nitrate concentrations in ground water. The study also suggests that areas with a confined bedrock aquifer may have higher nitrate concentrations than normal with ADW use. The ADWs allow nitrate easy access into these aquifers. Additionally, in areas with high densities of ADWs, drinking water wells may show increased nitrate contamination from ADW use.

Further illustrations of the factors influencing nitrate contamination of ground water are found in a 1994 review of hydrologic and water quality impacts of agricultural drainage (Skaggs et al., 1994). Researchers reviewed evidence that showed nitrate contamination of ground water from areas with improved subsurface drainage in California, Georgia, Illinois, Indiana, Iowa, Michigan, Minnesota, North Carolina, Ohio, and Vermont. In general, the research reviewed showed that intensive subsurface drainage will increase outflows of mobile constituents, such as nitrate-nitrogen and certain salts, but decrease overland runoff and the loss of sediment, phosphorous, organic nitrogen, and other pollutants that are typically contained in runoff water. Most of the studies reviewed attributed increased nitrate levels to increases in nitrification with decreases in denitrification caused by deeper water table depths with subsurface drainage. Nitrification is the microbial oxidation of ammonium to nitrate; it is the

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[4] Specifically, samples take from one area, with the most ADWs, averaged the highest NO_3-N concentration at 10.9 mg/l with 37 percent of the farm wells having an average greater than or equal to the MCL of 10 mg/l; samples taken from a second area, with less ADWs than the first area, averaged slightly less at 8.7 mg/l with 30 percent of the wells greater than or equal to 10 mg/l; and samples taken from a third area, with no ADWs, averaged much less than the first two areas at 3.0 mg/l with only 9 percent of the wells greater than or equal to 10 mg/l (Baker and Austin, 1984).

principal natural source of nitrate to the biosphere. Denitrification refers to the removal of nitrate through microbial respiratory processes in anaerobic, reducing environments, such as those found in wetlands, saturated soils, and some confined and/or deeper aquifers. ADWs that accept subsurface drainage water may increase nitrate levels by deepening the water table, thus eliminating the denitrifying environment, and in turn allowing nitrification processes to act on water filtering through the subsurface. The review found that nitrate losses from similarly cropped soils varied from 3 lbs/acre/year for low intensity subsurface drainage to 14 lbs/acre/year for medium intensity subsurface drainage to 29 lbs/acre/year for high intensity drainage. This review illustrates the importance of nitrification/denitrification, and the relationship of soil drainage water on nitrate contamination.

Noting that tile-drainage water is shallow ground water, Hallberg reports that leaching losses of nitrate to subsurface drainage water are directly proportional to the nitrogen fertilizer applied for agricultural purposes (Hallberg, 1986). The author presents additional evidence of the impact that nitrogen source availability has on nitrate contamination. In doing so, he notes many studies showing a linear relationship between nitrate losses with subsurface drainage (increased nitrate levels in injectate) to nitrogen application rates exceeding 45 pounds per acre. The author presents evidence from several studies that show this same general trend, including studies of an Iowa carbonate aquifer system and an Iowa alluvial aquifer. The report notes that a considerable amount of applied nitrogen is left in the soil and lost through leaching into tile effluents. According to the report, nearly half of the applied fertilizer nitrogen may be discharged with tile drainage water at rates commonly applied to corn. Large leaching losses can be expected to continue as farmers continue to rely on increased fertilizer use.

Another study, conducted by the Iowa Department of Natural Resources (DNR) in 1994, examined the effects of ADWs on water quality in Floyd and Mitchell Counties, Iowa (Libra et al., 1994). Among other issues, scientists studied the effects of ADW effluent on ground water and related the results to the hydrogeologic setting in the two counties. Results of the study showed that the study area strata form a three-part aquifer system in these counties, and that ADWs did deliver agricultural contaminants, most notably nitrate, to ground water. Results were mixed; monitoring at a well nest located 500 feet from a 300 foot-deep ADW showed significant ADW contamination at some depths, and negligible contamination at other depths. For instance, samples from the middle and lower aquifer piezometers were generally below 1 mg/l, although occasional samples showed up to 7 mg/l NO_3-N. Similarly, large increases in nitrate-N concentration (some as high as 22 mg/l) were observed in some deep bedrock aquifer areas during wet periods, yet other deep bedrock sampling areas with similar potentiometric response to the wet conditions did not show this same result. The researchers could not explain all the variations, but differences in the sampling results were attributed to different depths of ADWs and bedrock saturation conditions. Additionally, some private wells located within one to two miles of clusters of ADWs were affected by the drainage wells, while others were not. Factors affecting these results are the interplay between private well depth and construction, ADW depth, and stratigraphy. Overall, the study found that clearly discernable effects of ADWs on ground water are limited to areas that have a low natural susceptibility to agricultural contamination, including deep bedrock areas overlain by more than 50 feet of low-permeability glacial deposits and/or shales. These results further illustrate the importance of aquifer depth and hydraulic conductivity. In areas with less confinement, the effects of ADWs cannot be clearly discerned from the general level of nonpoint source contamination that is affecting the bedrock aquifers in the area.

Iowa DNR researchers studied the effects of ADW closure on ground water quality in Floyd County, Iowa (Quade and Seigley, 1997). The project, beginning in 1994, sought to monitor the effects of ADW closure on the water quality of the carbonate aquifer system in Floyd County. Results showed an increase in nitrate concentration in the shallow water table (29 feet). None of the closed ADWs injected into this shallow zone, so researchers did not expect to see improvement. However, they also did not expect to see an increase in nitrate concentration; they attributed the increase to various factors, including climate, farming practices, and fertilization rates. Mean nitrate-N concentration in the shallowest bedrock well (103 ft.) showed a decrease from 19 to 12 mg/l. Similarly, post closure mean nitrate concentrations declined to "negligible" values for bedrock wells at 207 ft., 297 ft., and 360 ft. The decrease in mean nitrate concentration at these three wells was statistically significant, suggesting that ADW closure had a causal impact on improved ground water quality at these sites.

Kross et al. (1990) found nitrate levels in ground water in Floyd, Wright, Humboldt, and Pocahontas counties in Iowa (counties with ADWs) to range between 0.5 to 7.0 mg/l, below the MCL. From the statewide survey they could not discern a water-quality impact attributable to ADWs, but the survey was not designed to detect such localized effects in relation to the wider-scale nonpoint source problems in adjacent karst and shallow bedrock aquifer regions. These results suggest that nitrate contamination of ground water from ADW use may be localized in areas adjacent to the wells, and that over an entire region, contamination effects may be hard to distinguish from other sources.

Finally, the Floyd County Iowa Soil and Water Conservation District found nitrate-N levels in private drinking water wells that ranged from <0.1 to 26 mg/l in their ADW test program from 1991 to 1995 (Moore, 1997).

Results from these studies suggest that nitrate ground water contamination from ADWs is influenced strongly by nitrogen source availability, amount of percolating water, depth to water table or zone of injection, and nitrate reduction/denitrification. Increased ground water nitrate concentrations can be expected in areas with densely spaced ADWs and is most evident in settings where the local aquifer would not otherwise exhibit high nitrate levels.

5.2.2 Septic Tank Contamination

There are at least two known incidents involving septic tank contamination of an ADW. Both of these cases are reported in Wright County, Iowa.

In the first case, an investigation conducted in 1977 made it apparent that raw sewage was entering a drainage well in the Lake Cornelia area. It was further evident that this waste originated from at least seven homes located in the area that were discharging their waste to a drain tile system leading to an ADW associated with some cropland (Choquette, 1977a).

The other incident was associated with the field application of wastewater from a hog manure lagoon in Lincoln Township. Between April 2, 1997 and April 18, 1997, approximately 1,556,376 gallons of manure were applied to 72 acres of land surrounding an ADW. The addition of manure to the croplands already saturated with excess water from snow melt caused rapid infiltration of the liquid manure. The liquid manure then leached into tile lines leading to the ADW. All fluids received by the well discharged into the Mississippian Aquifer that is used as an underground source of drinking water for public and private water supplies.

Upon investigation of the incident by USEPA and the Iowa DNR, it was determined that fluids containing fecal coliform entered the ADW as a result of not only the manure runoff and infiltration, but also direct discharges from a septic tank hooked to a tile line leading to the ADW. On May 18, 1998, USEPA Region 7 issued a consent agreement and consent order requiring the farm that applied manure to pay $7,000 in civil penalties and to locate and eliminate all surface openings in tiles located on land to which manure is applied (USEPA Region 7, 1998).

In this latter incident, contamination from the septic tank was small compared to the large volume of the manure application. However, when examined on a regional basis, contamination from septic tanks can be a significant source of aquifer contamination. Direct discharges from septic tanks to ADWs in the area may create an equal or greater impact on ground water than manure application. It was estimated that about 30% of the individual rural septic tanks in Lincoln Township were directly connected to agricultural drainage tiles/wells. If this is true, an estimated one million gallons per year of sewage from septic tanks may be entering drainage tiles and ADWs (Choquette, 1997b).

5.2.3 Other Contamination Incidents and Studies

In 1979, the Idaho Department of Water Quality conducted a study to assess evidence of ground water contamination from ADWs. In 3 areas of Minidoka County, Idaho, 15 drainage wells were monitored for 1 year. Turbidity levels exceeded MCLs almost 78 percent of the time, while other contaminants found in drainage water seasonally exceeded MCLs or safe levels. Coliform bacteria were found in unusually high concentrations in 31 percent of domestic drinking water wells, while levels of nitrate-nitrogen, chloride, and specific conductance were much higher in the test areas than the control areas during the agricultural season. This suggests that contamination resulted from ADW use (Graham, 1979).

Around 1988 (approximately 10 or 11 years ago), a water supply well for the Village of Dane, in Dane County, Wisconsin, was discovered to be contaminated by atrazine. A survey of the area found that the source of this contamination was likely to be an improperly abandoned drinking water well that had been illegally modified to receive surface runoff from an agricultural area. The drainage well was subsequently sealed in accordance with applicable requirements, and the atrazine contamination in the water supply well disappeared (Roth, 1999).

A 1987 survey by the California Department of Food and Agriculture (Troiana and Segawa, 1987) revealed that 49 percent of 122 ground water wells sampled in Tulare County, California were contaminated with detectable levels of one or more herbicides, including simazine, diuron, atrazine, bromacil, and prometon. A followup study in 1991 (Braun and Hawkins, 1991) detected bromacil, diuron, and simazine in surface runoff water from agricultural fields (citrus groves) and non-crop sites following a rain or irrigation event. Samples of rain runoff collected within orange groves and near suspected dry wells contained high concentrations of diuron and simazine, but significantly lower concentrations of bromacil. Water was observed running into suspected dry wells at the time of the sampling, but Braun and Hawkins (1991) concluded that the extent to which this runoff was contributing to ground water contamination was unknown and needed to be investigated further.

Other cases involving the cross-contamination of aquifers by abandoned water wells are documented in a fact sheet published by Nork (1992). Cross-contamination occurs when two aquifers are penetrated by one abandoned well without a seal placed between the zones that would prevent the water from mixing. This allows contaminated water in one aquifer to mix with and contaminate water in another aquifer. The fact sheet, however, provides no specific information on these cases and whether they were caused by ADWs.

6. BEST MANAGEMENT PRACTICES

Only a few physical alterations to ADWs themselves will avoid or reduce their potential to contaminate ground water. Therefore, aside from closing ADWs and getting rid of excess water by other means, the only way to reduce the potential for contamination from agricultural drainage while minimizing adverse economic impact is to follow best management practices (BMPs).

The following discussion relies on developing and existing USEPA guidance to protect ground water and surface water from risks posed by contaminants from agricultural sources. In particular, it draws primarily from draft *Agricultural Drainage Wells Interim Guidance* (USEPA, 1999). This draft interim guidance relied heavily on Chapter 2 of USEPA's *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, issued under the authority of section 6217(g) of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990. The CZARA guidance document also presents techniques for minimizing seepage to ground water and describes in great detail the nutrient and pesticide management measures summarized below.

6.1 Closure and Alternatives to Agricultural Drainage Wells

Often, closing ADWs is the best solution to the problems associated with such wells when feasible alternatives exist. States like Iowa are taking steps in that direction. In 1997, Iowa passed a law requiring all ADWs in the drainage area of a large permitted earthen manure lagoon to be closed. As a result, ADWs identified as located in the most critical areas will be closed first (over the next 2 years). The Iowa law also requires permits for all remaining ADWs in operation. To qualify for a continued use permit, all of a well's surface intakes must be removed and cisterns must be water tight and have raised sidewalls to prevent surface water from flowing directly into the wells. All cisterns must have locked covers to prevent unauthorized access. Also, all septic tank connections must be removed from the ADW system. Rules for the continued use provisions of the 1997 Legislation were approved in December 1997 and became effective in June 1998 (Heathcote and Appelgate, 1998). Other ADWs in Iowa are being closed voluntarily, with financial assistance from the state for closure costs and the construction of alternative drainage outlets. Separately, U.S. Department of Agriculture (USDA) Natural Resources Conservation Service cost-share money from the Environmental Quality Incentives Program (EQIP) can be used for ADW repairs and removal of surface intakes.

Wells must always be closed in compliance with state and federal requirements related to well closure and plugging and in compliance with other regulations (e.g., wetland protection). Some states offer both technical and financial assistance to address well closure and drainage alternatives.

Temporarily and permanently abandoned agricultural drainage wells have to be properly managed to prevent accidents or misuse, which could pose a hazard to farmers, farm equipment, and vulnerable aquifers. Proper management activities include installing locked covers on drainage well cisterns to prevent contamination from unauthorized disposal and to prevent accidental entry by children or small animals, closing (i.e., plugging or filling) permanently abandoned wells in accordance with state and federal regulations, marking abandoned wells or wells hidden beneath the soil surface, and keeping inventories of well locations and records of their past use.

There are three possible alternatives to letting agricultural drainage flow down ADWs:

- Provide other drainage outlets where appropriate, such as open ditches or tile mains, to route the drainage water to the closest natural outlet.

- Construct seepage ponds or storage reservoirs for temporary water retention or reuse in irrigation.

- Allow part or all of the land to return to its natural drainage state (e.g., conversion of some or part of the land to wetland).

6.1.1 Alternative Drainage Outlets

Maintaining land in production after ADWs are closed may require the construction of alternate drainage outlets. The typical alternate outlet is a surface water body connected to agricultural land by a network of open ditches or tile mains. Using alternate outlets is often complex, mainly because ADWs are typically outside of existing drainage districts and constructing drainage routes to the outlets involves contending with adverse geological and terrain conditions, other engineering difficulties, and socioeconomic and legal constraints. The use of alternate outlets also may lead to pollution problems in areas formerly not directly affected by ADWs (e.g., surface water bodies such as lakes and rivers). It is appropriate to use drainage outlets only if monitoring indicates that drainage waters will not adversely affect surface water and associated ecosystems.

6.1.2 Temporary Storage

Excess irrigation water may be collected in ponds for temporary storage, then reused through a sprinkler system on other land. Sand and gravel-filled seepage ponds allow water to both evaporate and seep into the ground. This alternative to ADWs generally allows nonpersistent contaminants, such as bacteria, to degrade at the surface or to be filtered out as the water percolates downward. For these reasons, storage and seepage ponds are generally considered preferable to the alternative of diverting agricultural water to natural outlets. However, it is important to adequately demonstrate that the design of a pond will prevent contaminants from migrating to ground water. Bottom liners may be necessary to prevent seepage and ground water monitoring may be necessary to provide early detection of any seepage that does occur.

6.1.3 Return to Natural Drainage State

Eliminating drainage systems from cropland without providing alternative and efficient water outlets could interfere with routine farming activities. The effects of closing ADWs depend on site characteristics including climate, soils, land use and cover, and topography. In general, closure of ADWs could lead to ponding in low-lying areas and on poorly drained soils, creating wetlands that are unsuitable for crop production. In addition, crop yields in dry areas may be affected due to isolation of better drained soils, variable wetness conditions, small or irregular field patterns, short row length, and less efficient use of large equipment. Reverting drained agricultural land to wetland requires careful land-use planning to prevent economic and environmental damage (such as flooding and decreased ground water recharge).

6.2 Erosion and Sediment Control

Erosion controls can reduce the threat of ground water contamination by improving the quality of surface runoff flowing into ADWs. In general, erosion control practices are intended to minimize the impact of precipitation on the soil surface by reducing the velocity of surface runoff and the channelization it causes. These practices are especially useful during periods when vegetation cover is sparse and the potential for erosive rainfalls is high. USEPA and the U.S. Department of Agriculture have evaluated numerous erosion control practices that address the problem agricultural erosion poses for ground water quality in the joint USEPA-USDA publication, *Control of Water Pollution from Cropland, Volume 1: A Manual for Guideline Development* (USEPA/USDA, 1975).

BMPs for erosion control are designed to allow suspended solids and associated pollutants to settle out of runoff. The most desirable BMP strategy involves implementing farming practices that prevent erosion and transport of sediment from the field, including conservation tillage, contour strip cropping, terraces, and critical area planting. Another BMP strategy involves routing runoff from fields through structures that remove sediment, such as filter strips, field borders, grade stabilization structures, sediment retention ponds, water and sediment control basins, and terraces. Site conditions will dictate the appropriate combination of practices for any given situation (USEPA, 1993).

USEPA recognizes the possibility that implementing some of these measures may increase the potential for movement of water and soluble pollutants through the soil profile to ground water. It is not, however, USEPA's intent for these BMPs to avoid surface water problems at the expense of ground water or vice versa. It is necessary to design erosion and sediment control systems to protect against the contamination of both ground water and surface water.

6.2.1 Conservation Tillage

Conservation tillage is any tillage or planting system that leaves at least 30 percent of the soil surface covered with residue after planting; or, where soil erosion by wind is the primary concern, maintains at least 1,000 pounds of flat, small-grain residue equivalent on the surface during the critical erosion period. Ordinarily, water tends to remain in the upper soil profile, promoting surface runoff and, consequently, soil erosion. Studies have shown, however, that conservation-tillage practices channel soil moisture downward through undisturbed soil macro pores, thus reducing erosion. By slowing the flow of surface runoff, conservation tillage reduces the material-carrying capacity of runoff water. It also shields soil from the impact of rainfall, thus protecting the soil surface from detachment and erosion during highly vulnerable crop-establishment periods. This, in turn, may reduce the potential for USDW contamination by ADWs that receive surface flows.

A potential drawback of conservation tillage is that residue left on farm fields can intercept pesticides before they reach the soil, making greater, or more frequent, pesticide applications necessary. This problem can be compounded by the greater infiltration capacity (from cracks, root channels, worm holes, and decreased runoff velocities) in conservation- or reduced-tillage soils; this greater infiltration capacity promotes the leaching of agrichemicals. (That is why nutrient and pest management plans must be part of a complete system of BMPs -- to reduce the nutrient and pesticide loads on ground water and surface water.) At times, some reduced-till systems must also rely heavily on herbicides to control weeds that conventional tillage normally buries (USEPA, 1993).

The overall positive effect of conservation tillage on surface water quality is well documented but its effect on ground water quality is still being studied and evaluated by agricultural scientists. Currently, there is a difference of opinion on the usefulness and effectiveness of this BMP. It is recommended that conservation tillage practices be implemented only after consulting with tillage experts who understand the impact of such site conditions as climate, soil properties, depth to ground water, and the physical characteristics of the aquifer. In circumstances where any tillage method can be employed, conservation tillage is usually chosen because it conserves soil, saves fuel, and reduces labor and material costs, all of which are important concerns to farmers (NRC, 1989; USEPA, 1993).

6.2.2 Filter Strips

Filter strips are bands of planted or indigenous vegetation situated downslope of cropland or animal production facilities to provide localized erosion protection and to filter nutrients, sediment, and other pollutants from agricultural runoff. Due to their low installation and maintenance costs and effectiveness in removing a variety of pollutants, many conservation and regulatory agencies encourage the use of vegetated filter strips (Dillaha et al., 1989).

Filter strips are often coupled with practices that reduce nutrient inputs, minimize soil erosion, or collect runoff. Filter strips can also enhance wildlife habitat by providing wildlife nesting and feeding sites, in addition to serving as a pollution control measure. Some filter strips need maintenance such as mowing of grass or removal of accumulated sediment. Filter strips may be effective for controlling particulate and soluble pollutants, where sedimentation is not excessive. Thus, in many cases, filter strips are used as pretreatment or supplemental treatment for other practices within a management system, rather than as an entire solution to a sedimentation problem (USEPA, 1993). In general, filter strip effectiveness is dependent on factors such as incoming sediment and nutrient load, flow velocity and depth, vegetation height and density, and the slope and width of the filter strip (Dillaha et al., 1989).

6.2.3 Water and Sediment Control Basins

Water and sediment control basins may be constructed at the lower end of a field to impound runoff and retain sediment. Retention ponds or sediment basins help reduce the volume of direct runoff that causes surface erosion. This, in turn, may help improve the quality of surface water entering drainage wells. Control basins also allow sediment and adsorbed agricultural chemicals time to settle and degrade prior to entering an ADW. Consequently, control basins afford the ground water below them some protection against contamination. Waste treatment lagoons can also be used to retain agricultural runoff. There is debate, however, about inadequate seals in lagoons, causing seepage through the lagoon sidewalls and bottom. Usually the long-term seepage rate is low enough that the concentration of contaminants transported into the ground water does not reach an unacceptable level (USEPA, 1993).

6.2.4 Crop Rotation

Crop rotation is the successive planting of different crops in the same field. It can break pest cycles and disrupt weed life cycles, reducing the need for agrichemicals and, thus, helping protect ground water from contamination. Crop rotation can also increase harvests and provide other benefits. By improving tillage, it may disrupt disease, insect, and weed reproduction cycles, and, therefore, increase grain yields beyond those achieved with continuous cropping under similar conditions. The practice also promotes crop diversification, which provides an economic buffer against price fluctuations associated with crops and production inputs, pest infestations, and damaging weather (NRC, 1989). Planting legumes as part of a crop rotation plan can also provide nitrogen for subsequent crops, thus aiding nutrient management.

6.3 Fertility Management and Nutrient Management

Fertility management and nutrient management are interchangeable terms. Proper fertilizer application and management can reduce the quantity of nutrients used in agricultural production. Fertility management helps protect ground water from contamination by reducing the excess nutrients that may be lost to surface runoff and leachate. A fertility management plan helps farmers (1) apply nutrients at rates necessary to achieve realistic crop yield goals, (2) improve the timing of nutrient application, and (3) use agronomic crop production technology to increase nutrient use efficiency.

Fertility management involves testing soil, manure, and plant tissue; using manure and composted agricultural wastes where possible; properly timing nutrient applications; applying nutrients to obtain realistic yields; and calibrating application equipment. The application of nutrients during periods conducive to surface water runoff and soil leaching is discouraged.

It is necessary to consider realistic crop needs when determining the amount of nutrients to be applied and the timing of nutrient applications. Testing is needed at a point in the growing cycle when the farmer is able to predict nutrient need (keeping in mind proper crop yield goals), while allowing enough time for application and for crops to respond to the application. Premature application can result in greater loss of fertilizer to the environment. Accounting for all sources of nitrogen in soil (newly applied sources, residual nitrate in the soil, nitrate mineralized from soil organic matter, and nitrate in precipitation and irrigation water) will provide a safeguard against excess fertilizer application. Furthermore, slow-release fertilizers and nitrification inhibitors may enhance fertilizer effectiveness. Proper calibration and operation of equipment is needed to ensure accurate application rates.

6.4 Integrated Pest Management

Integrated pest management (IPM) is a mixture of chemical and other, nonpesticide, methods to control pests. Pesticides protect food and fiber crops from losses caused by weeds, diseases, insects, and other pests. However, the potential for pesticides to contaminate surface water and ground water has caused farmers and the public to re-evaluate pesticide use. Keeping a crop free of pests is usually not possible, and attempting to do so can be prohibitively expensive -- not only in monetary terms, but in terms of environmental quality.

IPM combines chemical, cultural, and biological control practices into a single program to manage pest populations, while minimizing the potential to contaminate surface water and ground water. Its goal is to keep pest numbers and crop losses from pests below economically damaging levels. IPM emphasizes preventive and remedial practices that make crops less attractive, more competitive, or more resistant to pests. IPM practices also reduce opportunities for pests to survive near a crop. They include timely planting, crop rotation, use of resistant cultivars, and fertility/nutrient management, all of which contribute to long-term control of pest populations.

IPM practices help attain the goal of preventing ground water contamination from ADWs. This is accomplished primarily through the reduced use of pesticides, which can contaminate agricultural drainage water. Significant reductions in pesticide use on some crops can be achieved in IPM programs while providing maximum protection to humans and the environment, with minimal disruption of food and fiber production (CAST, 1982). In addition, farmers may select pesticides that are less persistent, bioaccumulative, or toxic. Predicting pest intensities and calculating crop losses and economic injury associated with various pest intensities can provide information useful for improving application rates and timing.

6.5 Irrigation Management

Irrigated cropland accounts for approximately 15 percent of the harvested U.S. cropland and approximately 38 percent of the total value of crops produced (Rajinder et al., 1992). The potential impact of irrigation on ground water quality varies depending on the method of irrigation. ADWs are sometimes used to return excess irrigation water to an aquifer; this practice can directly inject contaminants into a USDW. Excessive application or uneven distribution of irrigation water may cause runoff or deep percolation of water contaminated with agrichemicals and other dissolved matter, which may eventually reach and contaminate ground water.

Irrigation management involves managing water, soil, and plant resources to optimize precipitation use and applied irrigation water according to plant water needs. This includes:

- Measuring water needs of soil.
- Applying the correct amount of water at the proper time (irrigation scheduling) without significant soil erosion and translocation of applied water.
- Applying the predetermined amount of water (includes measurement).
- Adjusting irrigation system operations to maximize irrigation application uniformity.
- Performing necessary irrigation system maintenance.

Chemigation operations, which add chemicals to irrigation water, need additional management measures, including:

- Use of backflow preventers for wells.
- Minimizing the harmful amounts of contaminated water that discharge from the edge of the field.
- Controlling deep percolation.
- Using a tailwater management system for furrow irrigation.

6.6 Livestock Waste Management

Livestock waste includes fecal and urinary wastes; process water (such as that from a milking parlor); and the feed, bedding, litter, and soil with which they become intermixed.

Contaminants from livestock production can be transported to ADWs both through-surface runoff and leaching into subsurface drainage and ground water. An objective of livestock waste management is to minimize the amount of solid material transported by surface runoff and reduce the amount of dissolved substances that contaminate surface runoff and ground water. The BMPs outlined in the box below can be used to control potential contamination of surface and ground water by animal wastes. These BMPs can be used in an approved livestock waste management plan.

Livestock Waste Management BMPs

- Annual soil testing to determine nutrient content and evaluation of efficiency of nutrient use in the production system.
- Nutrient analysis of the waste prior to application to match with crop requirements.
- Determination of application rates based on crop needs and soil hydraulic conditions.
- Timing of application to match maximum crop uptake such as spring or summer.
- Incorporation into soil to avoid volatilization or loss in runoff.
- Installation of vegetative filter strips to control sediment and nutrient losses in feedlot and dairy runoff.
- Livestock access restrictions to streams, lakes, and other impoundments, and rotational grazing to maintain sufficient vegetative cover on pasture land.
- Neutralization of waste streams, or waste strength reduction.
- Erosion and runoff control methods and buffer zones.
- Burial or disposal of animal carcasses away from drainage wells and conduits to ground water and surface water.

Source: North Carolina State University, 1982.

As discussed in Section 4.3.4, there is a risk of contamination when subsurface tile lines and ADWs are located downhill or downgradient from earthen lagoons used to store manure. Contamination could result from overland spills due to overtopping or a breach of surrounding surface berms, from seepage leaving the bottom of the lagoon, and from a subsurface breach that can allow fluids from a lagoon to directly enter a tile line and flow to an ADW (like pulling a plug out of a full bath tub). There have been several subsurface “spills” of this latter kind in Iowa where lagoons emptied through a breach to a tile line and traveled through the tile to a surface outlet. In these instances, no spill was evident at the surface but it was discovered either through the observation of a sudden drop in the liquid level or through the report of a large volume spill in a nearby river or stream. To date, there has not been a documented case in which a subsurface spill of this magnitude has entered tiles connected to an ADW, but the potential continues to exist (Heathcote, 1999).

Therefore, it is important to never locate earthen manure storage lagoons where a surface or subsurface breach could cause wastes to reach an ADW. Precisely because of the risk of spills entering tiles and traveling through the tile system to an ADW possibly a mile or more away, Iowa has a new law that prohibits earthen lagoons in the drainage basin of an ADW. However, if earthen manure storage lagoons are located in the vicinity of an ADW in other states, strict precautions are necessary to prevent releases. For example, it would be necessary to line such lagoons with compacted clay (at least three-feet thick) and/or synthetic materials. The sides and bottom of livestock waste treatment lagoons have been found to seal somewhat, but this layer by itself only reduces seepage and does not prevent fluid movement altogether.

In addition to the above concerns associated with earthen manure storage lagoons, ground water may become contaminated by leachate from feedlots, runoff holding ponds, manure stockpiles, and silos. ADWs may be a direct conduit for such leachate to reach ground water. To minimize the potential threat posed by removal of manure from feedlot surfaces, it is necessary to exercise caution to preserve the integrity of the “surface-seal layer.” Formed on active feedlots, this layer is normally 2 to 4 inches thick and may reduce water movement downward (US Congress, 1990).

On some farms, an applicable BMP involves applying liquid manure to agricultural land in an environmentally acceptable manner while maintaining or improving soil resources. This includes carefully managing the land application of manure in areas that drain to ADWs. In particular, nutrient loading needs to be carefully managed to prevent subsurface leaching and hydraulic loading needs to be controlled to prevent overloading and rapid soil infiltration that can drain directly into an ADW. Such overloading was the primary cause of one of the contamination incidents in Iowa described in Section 5.2.2. Moreover, in the vicinity of ADWs, land application of manure needs to be prohibited on frozen or snow-covered ground and spray application needs to be either prohibited altogether or allowed only under closely managed circumstances that ensure incorporation into the soil and avoid loss in runoff.

In conjunction with livestock waste management BMPs, grazing management practices can maintain enough live vegetation and litter cover to protect the soil from erosion and help prevent ground water contamination. Appropriate systems adjust grazing intensity and duration to reflect the availability of forage and feed designated for livestock uses and control animal movements through the operating unit of range or pasture. Practices that accomplish this are:

- Deferred grazing: Postponing grazing or resting grazing land for prescribed periods.

- Planned grazing system: A practice in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years, and rest periods may be throughout the year or during the growing season of key plants.

- Proper grazing use: Grazing at an intensity that will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation.

C Proper woodland grazing: Grazing wooded areas at an intensity that will maintain adequate cover for soil protection and maintain or improve the quantity or quality of trees and forage vegetation.

C Pasture and hay land management: Proper treatment and use of pasture or hay land.

6.7 Improvement of Surface Drainage

Both surface drainage (runoff) and subsurface drainage deliver water and contaminants to ADWs. Subsurface drainage systems consist of buried drainage tiles or corrugated plastic piping systems installed to lower the water table and drain soil with poor natural drainage. Studies have shown that nitrate and pesticides may be found in waters of subsurface drainage systems (Ritter et al., 1995). As discussed, however, surface waters carry most of the suspended solids (sediments), microbes, animal wastes, and the highest concentrations of most pesticides to ADWs. Hence, improvements in the design and management of drainage waters reaching an ADW can help to reduce the threat to ground water.

Examples of such improvements include the elimination of surface water inlets on a drainage well or within the tile system connected to such a well to prevent direct entry of surface water runoff. This might include making the cisterns water tight, raising the inlets (sidewalls) above maximum ponding levels, and marking drainage well locations so they are not damaged by plows or other farm equipment. Similarly, some subsurface drainage systems have surface water inlets upslope from ADWs. It is important to also close these inlets to ensure no surface water entry. The removal of direct surface water runoff from ADW systems will significantly reduce most contaminants including pesticides and bacteria, but this is not the case for nitrate. Research in Iowa has shown that concentrations of nitrate will increase in drainage water when surface water intakes are removed because all drainage is forced to infiltrate through the soil profile where additional nitrate is leached from the soil. Current Iowa research shows that other innovative approaches such as processing drainage water through wetland areas holds some promise in helping remove nitrate prior to injection of drainage water in ADWs (Heathcote, 1999).

7. CURRENT REGULATORY REQUIREMENTS

As discussed below, several federal, state, and local programs exist that either directly manage or regulate ADWs, or impact them indirectly through broad based water pollution prevention initiatives.

7.1 Federal Programs

On the federal level, management and regulation of agricultural drainage falls primarily under the UIC program authorized by the Safe Drinking Water Act (SDWA). Some states and localities have used these authorities, as well as their own authorities, to extend the controls in their areas to address endemic concerns associated with ADWs. Other federal programs that address ADWs indirectly are implemented under the Clean Water Act (CWA), the Coastal Zone Management Act (CZMA), and the Coastal Zone Reauthorization Amendments of 1990 (CZARA).

7.1.1 SDWA

Class V wells are regulated under the authority of Part C of SDWA. Congress enacted the SDWA to ensure protection of the quality of drinking water in the United States, and Part C specifically mandates the regulation of underground injection of fluids through wells. USEPA has promulgated a series of UIC regulations under this authority. USEPA directly implements these regulations for Class V wells in 19 states or territories (Alaska, American Samoa, Arizona, California, Colorado, Hawaii, Indiana, Iowa, Kentucky, Michigan, Minnesota, Montana, New York, Pennsylvania, South Dakota, Tennessee, Virginia, Virgin Islands, and Washington, DC). USEPA also directly implements all Class V UIC programs on Tribal lands. In all other states, which are called Primacy States, state agencies implement the Class V UIC program, with primary enforcement responsibility.

ADWs currently are not subject to any specific regulations tailored just for them, but rather are subject to the UIC regulations that exist for all Class V wells. Under 40 CFR 144.12(a), owners or operators of all injection wells, including ADWs, are prohibited from engaging in any injection activity that allows the movement of fluids containing any contaminant into USDWs, “if the presence of that contaminant may cause a violation of any primary drinking water regulation . . . or may otherwise adversely affect the health of persons.”

Owners or operators of Class V wells are required to submit basic inventory information under 40 CFR 144.26. When the owner or operator submits inventory information and is operating the well such that a USDW is not endangered, the operation of the Class V well is authorized by rule. Moreover, under section 144.27, USEPA may require owners or operators of any Class V well, in USEPA-administered programs, to submit additional information deemed necessary to protect USDWs. Owners or operators who fail to submit the information required under sections 144.26 and 144.27 are prohibited from using their wells.

Sections 144.12(c) and (d) prescribe mandatory and discretionary actions to be taken by the UIC Program Director if a Class V well is not in compliance with section 144.12(a). Specifically, the Director must choose between requiring the injector to apply for an individual permit, ordering such action as closure of the well to prevent endangerment, or taking an enforcement action. Because ADWs (like other kinds of Class V wells) are authorized by rule, they do not have to obtain a permit unless required to do so by the UIC Program Director under 40 CFR 144.25. Authorization by rule terminates upon the effective date of a permit issued or upon proper closure of the well.

Separate from the UIC program, the SDWA Amendments of 1996 establish a requirement for source water assessments. USEPA published guidance describing how the states should carry out a source water assessment program within the state’s boundaries. The final guidance, entitled *Source Water Assessment and Programs Guidance* (EPA 816-R-97-009), was released in August 1997.

States must conduct source water assessments which are comprised of three steps. First, a state must delineate the boundaries of the assessment areas in the state from which one or more public drinking water systems receive supplies of drinking water. In delineating these areas, states must use "all reasonably available hydrogeologic information on the sources of the supply of drinking water in the state and the water flow, recharge, and discharge and any other reliable information as the state deems necessary to adequately determine such areas." Second, the state must identify contaminants of concern, and for those contaminants, the state must inventory significant potential sources of contamination in delineated source water protection areas. Class V wells, including ADWs, should be considered as part of this source inventory, if present in a given area. Third, the state must "determine the susceptibility of the public water systems in the delineated area to such contaminants." States should complete all of these steps by May 2003 according to the final guidance.[5]

7.1.2 CWA

In February 1998, President Clinton released the Clean Water Action Plan (CWAP), which provides a blueprint for restoring and protecting water quality across the nation. The CWAP describes over 100 specific actions to expand and strengthen existing efforts to protect water quality. As part of these efforts, the CWAP calls for the development of a USDA and USEPA unified strategy to minimize the water quality and public health impacts of animal feeding operations (AFOs). For the purpose of this strategy, AFOs are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures or fields.

The USDA and USEPA released a draft Unified National Strategy for Animal Feeding Operations on September 11, 1998 (http://www.nhq.nrcs.usda.gov/cleanwater/afo/index.html). USDA and USEPA's goal is for AFO owners and operators to take actions to minimize surface and ground water pollution from confinement facilities and land application of manure. To accomplish this goal, the draft unified strategy establishes a national performance expectation that all AFOs should develop and implement technically sound and economically feasible Comprehensive Nutrient Management Plans (CNMPs) to minimize impacts on water quality and public health.

In general terms, a CNMP identifies actions or priorities that will be followed to meet clearly defined nutrient management goals at an agricultural operation. CNMPs should address, at a minimum, feed management, manure handling and storage, land application of manure, land management, record keeping, and management of other utilization options (e.g., sale of manure to other farmers, composting and sale of compost to home owners, and using manure for power generation). The draft Unified Strategy provides guidance on each of these components of a CNMP and discusses opportunities for technical and financial assistance for the development of CNMPs.

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[5] May 2003 is the deadline including an 18-month extension.

The draft Unified Strategy also outlines a two-pronged approach for providing AFO owners and operators and the animal agricultural industry with necessary assistance and ensuring protection of water quality and public health. That approach consists of: (1) voluntary programs for most AFOs; and (2) regulatory programs for some AFOs.

For the vast majority of AFOs, voluntary efforts will be the principal approach to assist owners and operators in developing and implementing CNMPs and in reducing water pollution and public health risks associated with AFOs. While CNMPs are not required for AFOs participating in voluntary programs, they are strongly encouraged as the best possible means of managing potential water quality and public health impacts from these operations. The draft Unified Strategy proposes incentives to further the voluntary development and implementation of CNMPs through locally led conservation, environmental education, and technical and financial assistance programs.

The primary means for regulating AFOs is through National Pollutant Discharge Elimination System (NPDES) permits, which have been written to limit discharges to surface waters from certain AFOs. Such permits have been reserved for relatively large operations defined as "concentrated animal feeding operations" (CAFOs), where more than 1,000 "animal units" are confined at the facility. CAFOs that may be subject to NPDES permit requirements also include operations where more than 300 animal units are confined at the facility and: (1) pollutants are discharged into navigable waters through a manmade ditch, flushing system, or other similar manmade device; or (2) pollutants are discharged directly into waters that originate outside of and pass over, across, or through the facility or come into direct contact with the confined animals. In addition, the NPDES permitting agency may, after conducting an on-site inspection, designate an animal feeding operation of any size as a CAFO based on a finding that the facility "is a significant contributor of pollution to the waters of the United States." This may include facilities with 300 animal units or less in certain situations.

While the addition of pollutants from a discrete conveyance (e.g., natural channel or gullies) to surface waters is regulated under the NPDES program as a "point source" discharge, the CWA exempts "agricultural stormwater discharges" from the definition of a point source. USEPA has in the past, and will in the future, assume that discharges from the vast majority of agricultural operations are exempted from the NPDES program by this provision. The agricultural storm water exemption, however, does not apply in a small number of circumstances that meet the following criteria:

- The discharge is associated with the land disposal of animal wastes (e.g., manure or other animal waste) originating from a CAFO (which is defined as a point source within the CWA and is regulated as a point source); and

- The discharge is not the result of proper agricultural practices (i.e., in general, the disposal occurred without a CNMP developed by a public official or a certified private party or on a manner inconsistent with the CNMP).

Finally, the draft Unified Strategy describes the desired outcomes and specific actions that will be undertaken in coming months and years with respect to seven major strategic issues. These issues are: (1) building capacity for CNMP development and implementation; (2) accelerating voluntary, incentive-based programs; (3) implementing and improving the existing regulatory program; (4) coordinated research, technical innovation, compliance assistance, and technology transfer; (5) encouraging industry leadership; (6) data coordination; and (7) performance measures and accountability. Actions planned under Strategic Issue #3 (implementing and improving the existing regulatory program) include USEPA coordination with the states to establish a two-phase approach to issuing NPDES permits to CAFOs, development of NPDES permitting guidance and model permits, development of state-specific CAFO permitting strategies, review and revision of effluent limitations guidelines for feedlots, revision of the NPDES permit regulations regarding CAFOs, and improved implementation of the existing CWA compliance and enforcement program.

7.1.3 CZMA and CZARA

The 1990 CZARA included a new requirement (found in § 6217 of CZARA) that coastal states with coastal zone management programs under § 306 of the CZMA develop and implement Coastal Nonpoint Pollution Control Programs. Twenty-nine states were required to submit plans to USEPA and the National Oceanic and Atmospheric Administration (NOAA) by July 1995, and to implement the management measures by January 1999. The plans are required to establish specific management measures to control nonpoint pollution from several different types of sources, including urban runoff, hydromodification, marinas, silviculture, and agriculture. States may apply the management measures in their § 6217 CZARA plans to both point and nonpoint sources in the management area, as long as NPDES requirements also are met for point sources subject to CWA NPDES permitting requirements.

The coastal nonpoint program must be based on the impact of land and water uses on coastal waters. Identification and mitigation of such impacts is a five-step process. First, each state must identify its impaired and threatened coastal waters. Second, states must identify the land uses that individually or cumulatively cause or contribute to coastal water quality impairments. Third, the critical coastal areas that need additional measures to protect against current and anticipated nonpoint pollution problems must be identified and established. A state, for example, could specify a land area along a shoreline and extending inland a specified distance. Fourth, once the land uses and critical coastal areas have been identified, states must describe the management measures applicable to those areas and land uses to address the sources of nonpoint pollution. Finally, the state selects the additional management measures to be implemented.

In practice, the critical coastal area in which the management measures called for by the program are implemented is usually the coastal watershed, although NOAA reviews the state's §6217 management area, and when necessary will recommend that the management area extend inland of the coastal watershed (NOAA/USEPA, 1993).

The statute defines management measures as the following:

> "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, siting criteria, operating methods, or other alternatives."

Guidance prepared by USEPA in 1993 specifies management measures for sources of nonpoint pollution from agricultural sources, as well as management measures for other types of sources (USEPA, 1993). The management measures are grouped into six major categories: (1) Erosion and sediment control management measures; (2) Management measures for facility wastewater and runoff from confined animal facility management; (3) Nutrient management measures; (4) Pesticide management measures; (5) Grazing management measures; and (6) Irrigation water management measures. Most of these measures are summarized in Section 6 above.

7.2 State and Local Programs

As discussed in Section 3 above, more than 95% of the documented ADWs in the nation exist in five states: Idaho, Iowa, Ohio, Texas, and Minnesota. Idaho, Ohio, and Texas are UIC Primacy States for Class V wells. Attachment A to this volume describes how each of these states currently regulate ADWs. In brief:

- In Idaho, wells ≥18 feet deep are individually permitted, while shallower wells are permitted by rule.

- In Iowa, all ADWs that existed before February 18, 1998 must close or get a permit by December 31, 2001. New wells in Iowa are generally prohibited, although they may be permitted under strict conditions.

- The regulations in Ohio authorize ADWs by rule as long as inventory information is submitted. All existing ADWs in the state are considered out of compliance (not rule authorized) because their owners or operators did not submit required inventory information by the applicable deadline. Any new ADWs would be examined individually by the state and subjected to conditions believed necessary to protect USDWs.

- All of the known ADWs in Texas received individual authorizations for construction of the wells. Owners or operators of any new wells would have to submit basic information to the state, which would either disapprove the well or authorize it subject to conditions deemed necessary to protect USDWs.

- Minnesota bans new ADWs and requires existing ADWs to close when found, but acknowledges that some continue to exist.

The regulatory picture in other states with few or no ADWs in the current inventory is varied. In particular, Georgia, North Carolina, and North Dakota have banned new ADWs and require existing ADWs to close when they are found. Oregon, Washington, and Wisconsin also have a ban, but recognize that some ADWs continue to exist. Most other states authorize ADWs by rule, consistent with the existing federal UIC requirements.

ATTACHMENT A
STATE AND LOCAL PROGRAM DESCRIPTIONS

This attachment does not describe every state's program; instead it focuses on the five states where relatively large numbers of ADWs are known to exist: Idaho, Iowa, Minnesota, Ohio, and Texas. Altogether, these five states have a total of 1,020 documented ADWs, which is slightly more than 95% of the documented well inventory for the nation.

Idaho

Idaho is a UIC Primacy State for Class V wells and has promulgated regulations for the UIC program in the Idaho Administrative Code (IDAPA), Title 3, Chapter 3. Deep injection wells are defined as more than 18 feet in vertical depth below the land surface (37.03.03.010.11 IDAPA). Wells are further classified, with Class V Subclass 5F1 defined as agricultural runoff waste wells (37.03.03.01.e.j IDAPA).

Authorization

Construction and use of shallow injection wells is authorized by rule, provided that inventory information is provided and use of the well does not result in unreasonable contamination of a drinking water source or cause a violation of water quality standards that would affect a beneficial use (37.03.03.03.d. IDAPA). Construction and use of Class V deep injection wells may be authorized by permit (37.03.03.03 c IDAPA). The regulations outline detailed specifications for the information that must be supplied in a permit application (37.03.03.035 IDAPA).

Operating Requirements

Standards for the quality of injected fluids and criteria for location and use are established for rule-authorized wells, as well as for wells requiring permits. The rules are based on the premise that if the injected fluids meet MCLs for drinking water for physical, chemical, and radiological contaminants at the wellhead, and if ground water produced from adjacent points of diversion for beneficial use meets the water quality standards found in Idaho's "Water Quality Standards and Wastewater Treatment Requirements" (16.01.02 IDAPA), then the aquifer will be protected from unreasonable contamination. The state may, when it is deemed necessary, require specific injection wells to be constructed and operated in compliance with additional requirements (37.03.03.050.01 IDAPA (Rule 50)). Rule-authorized wells "shall conform to the drinking water standards at the point of injection and not cause any water quality standards to be violated at the point of beneficial use" (37.03.03.050.04.d. IDAPA).

Monitoring, record keeping, and reporting may be required if the state finds that the well may adversely affect a drinking water source or is injecting a contaminant that could have an unacceptable effect upon the quality of the ground waters of the state (37.03.03.055 IDAPA (Rule 55)).

Plugging and Abandonment

The Idaho Department of Water Resources (IDWR) has prepared “General Guidelines for Abandonment of Injection Wells,” which are not included in the regulatory requirements. IDWR expects to approve the final abandonment procedure for each well. The General Guidelines recommend the following:

- Pull casing, if possible. If casing is not pulled, cut casing a minimum of two feet below land surface. The total depth of the well should be measured.

- If the casing is left in place, it should be perforated and neat cement with up to 5% bentonite can be pressure-grouted to fill the hole. As an alternative, when the casing is not pulled, owners/operators may use course bentonite chips or pellets. If the well extends into the aquifer, the chips or pellets must be run over a screen to prevent any dust from entering the hole. No dust is allowed to enter the bore hole because of the potential for bridging. Perforation of casing is not required under this alternative.

- If a well extends into the aquifer, a clean pit-run gravel or road mix may be used to fill bore up to ten feet below top of saturated zone or ten feet below the bottom of casing, whichever is deeper, and cement grout or bentonite clay used to surface. The use of gravel may not be allowed if the lithology is undetermined or unsuitable. A cement cap should be placed at top of casing if not pulled, with a minimum of two feet of soil overlying filled hole/cap.

- Abandonment of well must be witnessed by IDWR representative.

Financial Responsibility

No financial responsibility requirement exists for rule-authorized ADWs. Permitted wells are required by the permit to demonstrate financial responsibility through a performance bond or other appropriate means to abandon the injection well according to the conditions of the permit. (37.03.03.35.03.e IDAPA).

Iowa

Iowa is a Direct Implementation State. However, the State Department of Natural Resources (DNR) has promulgated regulations for ADWs in 567 Iowa Administrative Code (IAC) Chapters 50 and 51. In 1997, ADWs in designated drainage areas (areas where there are anaerobic lagoons or earthen manure storage structures that require permits under 567-65 IAC) were required to be closed and BMPs were required for all other ADWs (Senate File 473).

Authorization

All owners of ADWs that existed prior to February 18, 1998 are required to have applied for a permit by July 1, 1999 or close their well by December 31, 2001 (567-50.4(1) IAC). In particular, a permit is required for diversion of water or any other material from the surface directly into any aquifer, including diversion by means of an ADW. Diversion by tile or ditch into a sinkhole or quarry excavated in carbonate rock is presumed to be a diversion from the surface directly into an aquifer in the absence of convincing evidence to the contrary (567-51.3 IAC). Water in drain tile lines is considered surface water (567-51.4 IAC). Any person who proposes to pump or divert by gravity more than 25,000 gallons of water during a period of 24 hours or less from any source of ground water or surface water, including streams bordering the state, impound surface water, divert surface runoff into a well, sinkhole, or excavation, or inject water or any material into a well is required to clarify with DNR if a permit is required under 567-51 (567-50.1 IAC). If the ADW is located in a legally organized drainage district, the drainage district is a joint applicant for the permit (567-50.4(1) IAC).

All supporting information necessary to allow the DNR to investigate the permit application must be supplied, including certain specified information:

- Location of the ADW to at least the nearest quarter-quarter section, township, and range;
- Diameter and depth of the ADW, if known;
- Description and ownership of the lands that are drained by the ADW and associated drainage system;
- Location of tiles that drain to the ADW, if known, and the existence of any existing surface water intakes;
- The location and description of any earthen storage structures, confinement feeding operations, or open feedlots within the agricultural drainage area;
- Information regarding any known connections between the ADW or its drainage system and wastewater disposal or storage systems such as septic tanks and the location of such connections;
- The nature and extent of any agreements between the well owner and adjacent landowners who have lands that are drained by the ADW and associated tile drainage system; and
- Any available information regarding the economic and physical feasibility of closing the ADW (567-50.6 and 50.6(7) IAC).

The Iowa rules specify criteria for issuance of permits. A permit may not be issued if (1) the ADW is located within a designated drainage area (i.e., within the drainage basin of a permitted anaerobic lagoon or earthen manure storage structure); or (2) if the ADW would be constructed after February 18, 1998. A permit may be issued if there is reasonable assurance that the applicant(s) can minimize the contamination potential to the aquifer through closure of surface water intakes, elimination of any septic system connections, and other appropriate management practices including nutrient and pesticide management as required under 567-52.21(2) IAC. In addition, there must be no economically and physically viable alternatives to the use of the ADW. The DNR will consult with the Division of Soil Conservation, Department of Agriculture, and other parties with drainage expertise as necessary. In determining if a viable drainage alternative exists, the DNR will consider the impact that closure of the ADW would have on lands drained by the ADW if an alternative drainage system is not provided; the cost and feasibility of providing an alternative outlet, including systems constructed by the Division of Soil Conservation; the availability of public assistance for constructing an alternative outlet or for compensation for loss of productivity on lands drained by the ADW; and the results of engineering studies under 567-52.21(2) IAC.

New wells in Iowa are generally prohibited, although they may be permitted under the same set of strict conditions outlined above. In general, these conditions are so stringent that it is unlikely that new ADWs in Iowa will receive a permit.

Operating Requirements

A permitted ADW may be subject to restrictions related to its potential effects on ground water or surface water. These restrictions are specified in 567-52.2 IAC. These provisions are unlikely to be pertinent to many ADWs.

The following permit conditions are also specified for ADWs in 567-39.7 and -39.8 IAC:

- All surface water intakes must be removed by December 31, 2001. Additional tile lines may be added to compensate for removal of surface water intakes provided that the additional tiles do not increase the size of the ADW area. Replacement tiles must conform to specified standards.

- Cisterns must be sealed or otherwise modified as necessary by December 31, 2001 to prevent direct entry of surface water. Compliance with state-specified wellhead protection Interim Standard 981 is considered compliance.

- The ADW or cistern must be provided with a locked cover to prevent unauthorized access. Ventilation must not allow surface water to enter the ADW.

- Repair and maintenance must be conducted as necessary. The ADW and associated tile drainage system must be maintained in a condition so as to prevent surface water which has not filtered through the soil profile from entering the drainage well.

- DNR approval is required for modification of the ADW. Construction of new surface water intakes is not allowed. The drainage system may be modified without DNR approval if the modifications do not enlarge the ADW area.

- If use of the ADW is discontinued, DNR must be notified and closure made in accordance with 567-Chapter 39 IAC or by an alternative method approved by DNR.

- DNR may modify or cancel permits, or require other actions to protect the public health and safety, protect the public interest in lands and waters, or prevent any substantial harm to persons or property.

- Effluent from wastewater treatment or storage systems, including septic systems, may not be allowed to go directly into the ADW or associated drainage system. Runoff controls may be required for feedlots that discharge across lands drained by an ADW.

- Nitrogen application on lands within an ADW drainage area is limited to the levels necessary to obtain optimum crop yields.

- Liquid animal wastes to lands drained by an ADW may not result in a discharge of waste to the ADW or associated drainage system.

- Pesticide application within the ADW drainage area must conform to state standards in Iowa Code Chapter 206.

- Prior to issuance of a permit, the applicant must conduct an engineering study of the physical and economic feasibility of alternatives to the continued use of the ADW.

Plugging and Abandonment

Closure is required to satisfy the requirements of 567-Chapter 39 IAC on plugging of abandoned wells or alternative means approved by DNR. Cisterns must be filled in or removed and any tile lines must be removed for a distance of 10 feet around the wellhead or be replaced with non-perforated pipe. Under Chapter 39, approved sealing materials are bentonite products and cement. Filling materials also are specified. The plugging procedures specified vary according to the depth and diameter of the well (567-39.7 and -39.8 IAC).

Minnesota

Minnesota is a Direct Implementation State. It currently has no separate Class V rules for ADWs. The 1989 Minnesota Ground Water Protection Act (Minn. Laws ch. 326), however, establishes that it is the goal of the state that ground water be maintained in its natural condition, free from any degradation by human activities. The state's regulations implementing the Act also specify that "for the conservation of underground water supplies for present and future generations and prevention of possible health hazards, it is necessary and proper that the Minnesota Pollution Control Agency (MPCA) employ a nondegradation policy to prevent pollution of the underground waters of the state" (7060.0200 Minnesota Rules (MR) and 7060.0500 MR).

Consequently, the state prohibits discharge into both the saturated and the unsaturated zones by means of injection wells or other devices (7060.0600 Subparts 1 and 2, MR). No sewage, industrial waste, or other wastes shall be discharged directly into the zone of saturation; no sewage, industrial waste, other waste, or other pollutants shall be allowed to be discharged to the unsaturated zone or deposited in such place, manner, or quantity that the effluent or residue therefrom, upon reaching the water table, may actually or potentially preclude or limit the use of the underground waters as a potable water supply; and no discharge or deposit shall be allowed that may pollute the underground waters.

In addition, the Department of Health has promulgated regulations pertaining to wells and borings that provide that a well or boring must not be used for disposal of surface water, ground water, or any other liquid, gas or chemical (4725.2050 MR). Wells are defined as drilled, dug, or bored excavations that end below the water table (4725.0100 Subpart 51 MR and 1031.005 Subdivision 21 Minnesota Statutes). This prohibition therefore does not address injection into the unsaturated zone.

Although ADWs may exist that predate the ban, the rules in 7060.0600 and 4725.2050 MR are considered by the MPCA to ban all new ADWs in the state, including wells that do not inject directly into a USDW.

Ohio

Ohio is a UIC Primacy State for Class V wells. Regulations establishing the UIC program are found in Chapter 3745-34 of the Ohio Administrative Code (OAC).

Authorization

Any underground injection, except as authorized by permit or rule, is prohibited. Injection into Class V wells is authorized by rule (3745-34-13 OAC). The permit-by-rule provision requires owners or operators of Class V wells to supply information on the facility name and location, legal contact, ownership of the facility, nature and type of well, and operating status.

According to an official with the Ohio EPA, owners or operators of existing ADWs in the state did not submit required inventory information within the applicable deadline, and thus are technically out of compliance, as opposed to currently rule authorized. However, given the current priorities and limited funding of the state UIC program, these wells are not being called in for a permit and are not being subject to any enforcement action. If a new ADW were identified, the state would investigate its particular circumstances and impose conditions to ensure that it did not endanger USDWs (Orr, 1999).

Operating Requirements

ADWs are not considered to be subject to the conditions applicable to all permits in 3745-34-26 OAC. An ADW, however, could be subject to the requirements for corrective action, monitoring and reporting, or operation, if required for the protection of USDWs (3745-34-14 OAC).

Texas

Texas is a UIC Primacy State for Class V wells. The Injection Well Act (Chapter 27 of the Texas Water Code) and Title 3 of the Natural Resources Code provide statutory authority for the UIC program. Implementing regulations are found in Title 30, Chapter 331 of the Texas Administrative Code (TAC).

Authorization

Underground injection is prohibited unless authorized by permit or rule (331.7 TAC). In general, injection into a Class V well is authorized by rule, although the Texas Natural Resource Conservation Commission (TNRCC) may require the owner or operator of a well authorized by rule to apply for and obtain an individual permit (331.9 TAC). No permit or authorization by rule is allowed where an injection well causes or allows the movement of fluid that would result in the pollution of a USDW. A permit or authorization by rule must include terms and conditions reasonably necessary to protect fresh water from pollution (331.5 TAC).

All of the 135 ADWs presently on record with the TNRCC are authorized by rule. All of these wells were constructed several years ago, when it was only necessary to receive authorization to construct a well. Today, a well owner or operator would need both authorization to construct and operate the well. Although TNRCC has not received an application for a new ADW in at least three years, the process would start with the proposed well owner or operator submitting a form to get the state's approval. If approved, the state would then grant authorization in the form of a letter that would include any conditions believed necessary to protect USDWs. This process and the resulting conditions would be simpler than those associated with an individual permit (Eyster, 1999).

Siting and Construction

All Class V wells are required to be completed in accordance with explicit specifications in the rules, unless otherwise authorized by the TNRCC. These specifications are:

- A form provided either by the Water Well Drillers Board or the TNRCC must be completed.
- The annular space between the borehole and the casing must be filled from ground level to a depth of not less than 10 feet below the land surface or well head with cement slurry. Special requirements are imposed in areas of shallow unconfined ground water aquifers and in areas of confined ground water aquifers with artesian head.

- In all wells where plastic casing is used, a concrete slab or sealing block must be placed above the cement slurry around the well at the ground surface; the rules include additional specifications concerning the slab.

- In wells where steel casing is used, a slab or block will be required above the cement slurry, except when a pitless adaptor is used, and the rules contain additional requirements concerning the adaptor.

- All wells must be completed so that aquifers or zones containing waters that differ significantly in chemical quality are not allowed to commingle through the borehole-casing annulus or the gravel pack and cause degradation of any aquifer zone.

- The well casing must be capped or completed in a manner that will prevent pollutants from entering the well.

- When undesirable water is encountered in a Class V well, the undesirable water must be sealed off and confined to the zone(s) of origin (331.132 TAC).

Operating Requirements

None specified. Chapter 331, Subpart H, " Standards for Class V Wells" addresses only construction and closure standards (331.131 to 331.133 TAC).

Mechanical Integrity Testing

Injection may be prohibited for Class V wells that lack mechanical integrity, although this requirement would be unlikely to be applied to ADWs (because they do not have mechanical integrity like Class I or II wells). The TNRCC may require a demonstration of mechanical integrity at any time if there is reason to believe mechanical integrity is lacking. The TNRCC may allow plugging of the well or require the permittee to perform additional construction, operation, monitoring, reporting, and corrective actions that are necessary to prevent the movement of fluid into or between USDWs caused by the lack of mechanical integrity. Injection may resume on written notification from the TNRCC that mechanical integrity has been demonstrated (331.4 TAC).

Plugging and Abandonment

Plugging and abandonment of a well authorized by rule is required to be accomplished in accordance with §331.46 TAC (331.9 TAC). In addition, closure standards specific to Class V wells provide that closure is to be accomplished by removing all of the removable casing and filling the entire well with cement to land surface. Alternatively, if use of the well is to be permanently discontinued, and if the well does not contain undesirable water, the well may be filled with fine sand, clay, or heavy mud followed by a cement plug extending from the land surface to a depth of not less than 10 feet. If the use of a well that does contain undesirable water is to be permanently discontinued, either the zone(s) containing undesirable water or the fresh water zone(s) must be isolated with cement plugs and the remainder of the wellbore filled with sand, clay, or heavy mud to form a base for a cement plug extending from the land surface to a depth of not less than 10 feet (331.133 TAC).

Financial Responsibility

Chapter 27 of the Texas Water Code, "Injection Wells," enacts financial responsibility requirements for persons to whom an injection well permit is issued. A performance bond or other form of financial security may be required to ensure that an abandoned well is properly plugged (§ 27.073). Detailed financial responsibility requirements also are contained in the state's UIC regulations (331.141 to 331.144 TAC). A permittee is required to secure and maintain a performance bond or other equivalent form of financial assurance or guarantee to ensure the closing, plugging, abandonment, and post-closure care of the injection operation. However, the requirement, unless incorporated into a permit, applies specifically only to Class I and Class III wells and is unlikely to be applied to ADWs (331.142 TAC).

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