

An Assessment System for Potential Groundwater Contamination from Agricultural Pesticide Use in North Dakota

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A groundwater assessment system is proposed to help develop and implement best management practices (BMP) to protect groundwater from pesticide contamination. This system will help producers organize natural resource information into groundwater sensitivity categories. BMP recommendations will be adapted for each groundwater sensitivity category. To determine the groundwater sensitivity of a given area, a guided path, or stepwise algorithm, is used (Figure 1).

Figure 1. Stepwise algorithm for determination of ground water sensitivity to pesticides (first order of priority). (8KB b&w diagram)

Key factors that determine vulnerability or sensitivity will be assessed to assign each site to a specific category. The categories will emphasize similarities in factors, and will represent a rating system only in the broadest sense. Instead, the focus will be on placing sites in categories that allow logical development of an effective system of management practices that protect groundwater.

STEP 1. Aquifers versus groundwater

The first step requires the user to determine if an aquifer with a useable supply of water exists. Emphasis must be placed on protecting readily accessible groundwater or shallow aquifers with useable water. In North Dakota, aquifers located in glacially derived materials are of greatest value due to their generally good water quality, high yields, and shallow depths. The water must be of such quality that it is useable for human needs. The first order of priority is the determination of glacial or alluvial aquifers under the area of interest. All glacial and alluvial aquifers will be considered as worthy of protection, particularly those shallower than 50 feet.

Those aquifers that supply useable water to a significant number of people must also take on a higher level of importance than those that don't. Glacial or alluvial aquifers with useable water that are extensive enough to be used by significant numbers of people are identified in the groundwater studies report (North Dakota Geological Survey and State Water Commission) for each county in North Dakota.

In general, aquifers located in bedrock in North Dakota have poor quality water, are deep, and have variable yields. As a whole, these aquifers are not worthy of the same level of protection as glacial aquifers or alluvial aquifers. However, in some parts of the state, particularly the unglaciated southwest, bedrock aquifers are the only source of groundwater.

Within the county groundwater studies report, information about bedrock aquifers is quite general and difficult to apply to a specific area. This makes the sensitivity assessment more difficult, because important information about the aquifer is not as easily extracted from the report. Only in areas of southwestern North Dakota, where bedrock aquifers are the sole source of groundwater, should the assessment be extended to include these aquifers as second order of priority.

STEP 2. Pesticide use

Distribution of land use has been recognized as an important factor in groundwater protection from agricultural chemicals. Different types of land use will require different levels of agricultural inputs. Land use is a general indicator of the amount and type of pesticide applied above an aquifer. Pesticide use will be combined with land use in the following land use -- pesticide categories: 1) cropland with pesticides; 2) hayland, pastureland, forestland, and rangeland with pesticides; and 3) no pesticides.

STEP 3. Filtration potential

After the location of vulnerable aquifers and pesticide usage over them is assessed, the site properties that affect pesticide movement must be determined. In simple terms, the soil and geologic materials act as a filter to protect aquifers from contamination. That filtering process is often referred to as pesticide "**attenuation**" in scientific parlance. Attenuation can be defined as lessening the amount, force, or value of something. In this case, the amount of pesticide is lessened as it is filtered out on soil and geologic materials. An estimate of the potential for materials to attenuate or filter out pesticides will be presented as the "**filtration potential**" for this sensitivity assessment system.

Pesticide properties must also be accounted for when determining ground water sensitivity. Pesticide half-life ($T_{1/2}$) and organic carbon adsorption coefficient (K_{OC}) have been used to rate pesticide potential to leach. When the K_{OC} is divided by the $T_{1/2}$ and then multiplied by 10, the resulting number is called the Hornsby Index. A pesticide with a small Hornsby Index is more likely to leach to groundwater than a pesticide with a large Hornsby Index.

Pesticide Filtration Potential Factors

The assessment of filtration potential of materials overlaying an aquifer will include the following: 1) depth to the saturated aquifer combined with predominant waterflow direction; 2) soil and geologic strata permeability; 3) soil organic matter content; 4) pesticide K_{OC} and $T_{1/2}$.

Aquifer depth -- water flow direction

Depth to the saturated aquifer can be determined from the county groundwater studies report. Depths less than 50 feet are considered to be shallow. Soils are an excellent indicator of long term water flow direction. Water flow through a soil to the groundwater can be categorized as **recharge** (downward through the soil to groundwater) and **discharge** (upward through the soil from the groundwater). **Flowthrough** is the term used to describe lateral movement of groundwater through the soil.

Depth to the saturated aquifer can be determined from a county groundwater studies report by the ND Geological Survey and ND State Water Commission.

The presence and depth of calcium carbonate (lime) will be used to assess the long-term water flow direction. In recharge areas the predominantly downward movement of water removes calcium carbonate from the upper levels of the soil. For this assessment system, soils of **recharge areas** lack calcium carbonate in the upper 30 inches of the soil profile. Depth to calcium carbonate can be determined from a county soil survey report (USDA, Soil Conservation Service). Presence of calcium carbonate in each soil horizon is indicated by effervescence when dilute hydrochloric acid is applied to the soil. This information is available in the soil series descriptions.

Irrigation increases the potential for groundwater recharge. Many factors such as timing of water application, tile drainage, soil texture, and pumping of wells influence groundwater recharge under irrigated fields. Despite these extenuating factors, the water flow for **irrigated soils** will be considered **recharge**.

A groundwater recharge area overlaying a shallow aquifer constitutes **low potential** for filtration of contaminants from percolating water. All other combinations of ground water flow and aquifer depth have **high filtration potential**.

Soil and geologic material permeability

Soil permeability is closely related to soil texture. Soils in the sandy and sandy-skeletal textural families that overlie sand and gravel geologic materials have **low potential** for filtration. Soils in the fine textural family that overlie geologic material finer than sand and gravel have **high potential** for filtration. All other textures or combination of textures will have **intermediate potential** for filtration. Family textural classification of soils can be determined from a county soil survey. Texture of geologic material overlaying the aquifer can be determined from a county groundwater studies report or sometimes from the county soil survey report.

Soil and geological material textures are important factors that control water infiltration and flow. [Illustration of infiltration and flow.](#) (57KB b&w illustration)

Organic matter content

Soil organic matter (o.m.) content has the largest influence on pesticide attenuation compared to the other soil factors. Organic matter content of less than 2 percent in the A horizon (very low to moderately low) will have **low potential** to filter pesticides from percolating water. As o.m. content increases, filtration potential also increases. Soils with more than 2 percent (moderate to very high) in the A horizon have a **high potential** to filter pesticides from percolating water. Soil organic matter classes are given in the map unit descriptions in most county soil survey reports (Table 1). If this information is not in the county soil survey report, the local SCS office should be contacted.

Soils are an excellent indicator of long term water flow direction and contain organic matter to which pesticides are absorbed.

Table 1. Soil organic matter content (percent) conversion from soil mapping unit description.

Organic Matter Descriptor	Organic Matter Content by Weight
	%
Very Low	< 0.5
Low	0.5 - 1.0
Moderately Low	1.0 - 2.0
Moderate	2.0 - 4.0
High	4.0 - 8.0
Very High	> 8.0

Pesticide chemistry

The tendency for a pesticide to move with water through soils is also influenced by its chemistry. This is referred to as leaching potential. It is just the opposite of filtration potential or a pesticide's tendency to be removed from the water and trapped or filtered by the soil. To remain consistent with the other pesticide filtration potential factors, the pesticide chemistry factor will be expressed in terms of filtration potential. The pesticide chemistry factors expressed as filtration potentials for pesticides used in North Dakota are listed in [Appendix 1](#).

The tendency for a pesticide to move with water through soils is strongly influenced by its chemistry.

Groundwater Sensitivity Categories

The proposed groundwater sensitivity categories are designed to guide management not dictate it. Groundwater sensitivity categories will reflect combinations of filtration factors that require similar management practices to protect groundwater. Groundwater sensitivity can be defined in four broad categories: 1) high; 2) high intermediate; and 3) low intermediate; and 4) low.

High sensitivity is defined as the worst case in which all four pesticide filtration factors are low.

High intermediate sensitivity is defined as a combination of pesticide filtration factors in which one or more of the factors are low. The high intermediate category name should always be accompanied by modifiers for land use and factors that have low potential to filter pesticides from percolating water.

Low intermediate sensitivity is defined as a combination of factors in which none of the factors have low filtration potential, but not all have high filtration potential.

Low sensitivity is defined as the best case in which all four pesticide filtration factors are high.

Groundwater sensitivity categories will be the basis for the best management practices (BMP) recommendations. Best management practices will be designed specifically to improve those factors that cause low filtration potential. All situations for low filtration potential occur within the high intermediate and high sensitivity categories.

Because BMPs will focus on specific factors, they will also be applicable to problems that may develop in the low intermediate and low sensitivity categories. There is always the possibility that a problem may develop even in the Low sensitivity category. Therefore, the system of BMPs must also be applicable to those situations. Relating BMPs to specific factors will make this possible, because the solution to problems associated with a specific factor will be similar regardless of the groundwater sensitivity category.

Groundwater sensitivity category names will include a modifier for the land use -- pesticide category discussed in step 2, if pesticides are used. Land use modifiers are the following: **1) cropland; 2) hayland; 3) pastureland, 4) rangeland; and 5) forestland.** The high intermediate category will also include a modifier for those factors that have low potential to filter pesticides from percolating water. This modifier will follow the land use -- pesticide modifier. High Intermediate modifiers are the following: **1) high permeability; 2) shallow recharge; 3) low o.m.; and 4) leachable pesticide.**

An Example of Groundwater Assessment for Pesticide Contamination

Sec. 29, T. 155 N., R. 65 W. - Ramsey County

STEP 1.

The Ramsey County Groundwater Studies Report identifies three glacial aquifers in the county. They are the Spiritwood,

Mcville, and Starkweather aquifers (Figure 2). In Sec. 29, the Spiritwood aquifer underlies approximately the western two-thirds. One-third of Sec. 29 can be eliminated from further consideration, because no glacial aquifer is present.

Figure 2. Glacial aquifers of Ramsey County. (7KB b&w map)

STEP 2.

For the sake of demonstration, it will be assumed that the S 1/2, Sec. 29 is cropland with regular pesticide applications. The N 1/2, Sec. 29 is assumed to be pastureland with no pesticide applications. Based on these assumptions, the majority of S 1/2, Sec. 29 overlies the Spiritwood Aquifer and will be placed in the **cropland-pesticide used** category.

STEP 3.

Groundwater sensitivity analysis of Sec. 29, T. 155 N, R. 65 W. is an example of the type of information that can be used to help make BMP recommendations for individual producers. The log from a well dug in the SW 1/4, Sec. 20 just to the north of Sec. 29 is assumed to be representative for the surrounding area including Sec. 29. In this area the Spiritwood Aquifer is overlain by less than 50 feet of clayey or silty materials.

For this hypothetical example, the N 1/2, Sec. 29 is pastureland where pesticides are not applied. The assessment of ground water sensitivity will be limited to cropland areas and only those that occur directly over the aquifer. The area of concern is slightly larger than the SW 1/4, Sec. 29. For this example, it is assumed that the area of cropland over the aquifer is in a wheat-sunflower-summer fallow rotation. The pesticides 2,4-D, trifluralin, and ethyl parathion are used for pest control on this farmland.

The county soil survey is the key to site-specific sensitivity analysis, because it can be used to determine variability in critical filtration factors at a scale appropriate for management decisions. There are 10 soil map units with 10 different soil series (Table 2) in the portion of the field that overlies the aquifer (Figure 3). When the filtration factors are assessed (Table 3), the categories of groundwater sensitivity can be located in the field (Figure 4) according to soil map unit.

Table 2. Soil mapping units overlaying the Spiritwood Aquifer on Sec. 29, T.155N., R. 65W., Ramsey County.

Symbol	Soil Mapping Unit
1	Tonka silt loam
11	Svea-Barnes loams, 1 to 3 percent slopes
12B	Barnes-Svea loams, 3 to 6 percent slopes
23	Hamerly-Cresbard loams, 1 to 3 percent slopes
24	Svea-Cresbard loams, 1 to 3 percent slopes
35	Overly silty clay loam, 0 to 3 percent slopes
39	Colvin silty clay loam
42	Fargo-Hegne silty clays
45	Hegne silty clay
46	Aberdeen-Fargo silty clay loams

Table 3. Groundwater sensitivity categories for the Spiritwood Aquifer in Section 29, T. 155N., R. 65W., based on major soil series and pesticide filtration factor potentials.

Soil Series	Aquifer Depth- Water Flow	Material Texture	O.M. Content	Pesticide Chemistry	Groundwater Sensitivity Category
Aberdeen	high	high	high	low	(2,4-D) High intermediate-

					cropland-leachable pesticide
Barnes	high	intermediate	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Colvin	high	intermediate	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Cresbard	high	high	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Fargo	high	high	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Hamerly	high	high	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Hegne	high	high	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Overly	high	intermediate	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Svea	high	intermediate	high	low	(2,4-D) High intermediate-cropland-leachable pesticide
Tonka	low (shallow-recharge)	high	high	low	(2,4-D) High intermediate-cropland-shallow recharge, leachable pesticide

Figure 3. Detailed soil map for Sec. 29, T.155 N., R.65 W. superimposed over the Spiritwood Aquifer.
(14KB b&w map)

Figure 4. Groundwater sensitivity map for Sec. 29, T.1 55N., R.65 W. (20KB b&w map)

BMPs can be tailored according to the producer's needs and field distribution of the following two categories: 1) High intermediate - cropland - shallow recharge, leachable pesticide; and 2) High intermediate - cropland - leachable pesticide. The factors that have low filtration potential will be the basis for BMP recommendations. They are identified as modifiers to the **High intermediate** category, leachable pesticide and shallow recharge.

A Note of Caution

Application of this assessment system depends on information extracted from a number of different sources. It's important that the limits of accuracy of that information are kept in mind. In order to gather and compile data over large areas, it's necessary to group and organize that information so it is manageable. County soil survey reports, water resources reports, and agricultural statistics are examples of this process. Average or grouped data lose some of their accuracy as the focus of study is narrowed to smaller and smaller areas.

County soil survey information is critical to this assessment system and its limitations should be understood. NDSU Extension Bulletin No. 60, "Soil Survey: The Foundation for Productive Natural Resource Management," explains how to use this information within the framework of its limitations.

Briefly, soil properties are organized into groups at several different levels. Each group represents a range of soil properties. Also, soil mapping units, which are shown on soil maps, are not pure units. They contain small percentages of completely different soils that could not be separated out because the scale of the map did not permit it. Therefore, an element of error exists in using this information.

Under most circumstances that error is probably quite acceptable for management of large areas and farm fields. It is when the focus of study is narrowed to just a few acres that the error becomes unacceptable and site specific information will be more appropriate.

This system of groundwater assessment is primarily dedicated to categorizing pertinent information, so that best management practices can be applied if necessary. It is not intended to be used to impose management practices on land that may fall in one category or another. Because an area is placed in the High sensitivity category does not mean that the aquifer is contaminated, nor does it mean that contamination is imminent. It does mean, however, the potential for contamination is greater than for other areas. On the other hand, an area that is placed in the Low sensitivity category may contribute to contamination, but it is not as likely.

Voluntary adjustment of management practices that help protect North Dakota's groundwater resources is always desirable. However, in the case where management changes for groundwater protection cause significant disruption of the producers operation, these changes should only be recommended when the extent of ground water contamination has been convincingly demonstrated by standard monitoring and analytical techniques. When this occurs, BMP recommendations should be based on the groundwater sensitivity analysis of the site.

It should also be noted that this system excludes many small aquifers, because they do not receive extensive use. Groundwater sensitivity can be determined in these cases. However, critical information about the aquifer will not be found in the county groundwater studies report and must be determined from other sources.

Finally, this system does not assess the sensitivity of groundwater to contamination from accidents or inappropriate handling and disposal of pesticides. The method of determining groundwater sensitivity outlined above assumes that pesticides are applied as recommended on the pesticide container label.

[[Appendix 1](#) - Trade and Common Names of Pesticides and their Filtration Potential]

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