

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

(continued)

Extension Report No. 18, March 1994

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Factor Interactions

When multiple factors are used for sensitivity assessment, the system becomes complex. Many vulnerability or sensitivity assessment systems have attempted to assign a rating or score to each factor. Scores for individual factors are composited to determine an overall score or rating.

There are several problems with factor rating systems that have not been satisfactorily resolved. The first problem relates to the dominance or importance of one factor as compared to another. Statistical analyses have been used in some cases to help determine importance of factors. Importance of factors are often determined by assigned weights. Unfortunately, the actual assignment of weights is quite subjective (Dee et al., 1973). This type of system cannot take into account nonlinear or synergistic relationships between factors. If one factor overrides the effects of another factor, it cannot be discerned (Aller et al., 1985). In other words, a score of 10 for texture combined with a score of 10 for water table depth is not necessarily additive. The most appropriate combined contamination potential for those two factors may only be 15, 12, or 10, rather than 20. On the other hand, the effects of the two factors may be multiplicative, and the contribution to the overall score would be 100 rather than 20. Assessment of these types of relationships is complex; therefore, groundwater rating systems that attempt to account for relationships between multiple factors should be tested rigorously in the field.

Finally, categories based solely on a composite rating cannot convey which factors contribute significantly to each rating. Sites with the same composite score may require substantially different BMPs yet they will be placed in the same category. For example, how do you develop best management recommendations for a composite score of 20? The 20 may be from four factors with a score of 5 or just one factor with a score of 20 (the rest with scores of 0). Thus, category compatibility with BMPs becomes a source of confusion rather than a practical bridge to effective management.

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 factors would contribute only minimally to pesticide filtration. These conditions are defined as coarse textured soils in the sandy or sandy skeletal families with < 2% o.m., that overlie sand and gravel geologic materials in a groundwater recharge area that has a saturated aquifer < 50 feet from the surface where pesticides with a high leaching potential (low filtration potential) are used.

High Intermediate sensitivity is defined as a combination of factors in which one or more of the factors have low potential for filtration. An example would be a soil in the sandy or sandy skeletal family that overlies sand and gravel geologic materials, but all other factors do not meet the criteria for low filtration potential. 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. An example would be a fine textured soil with 3% o.m. overlaying sand and gravel geologic materials, with > 70 feet to the saturated aquifer in a hydrologically inactive area where a pesticide

with an intermediate leaching potential (intermediate filtration potential) is used.

Low sensitivity is defined as the best case in which all four factors would contribute substantially to pesticide filtration. These conditions are defined as a soil in the fine textural family with > 2 % o.m., in a groundwater discharge area that has a saturated aquifer > 50 feet from the surface where pesticides with low leaching potentials (high filtration potential) are used.

No attempt will be made to rate importance or interaction among the different factors that affect groundwater sensitivity. At the present time, the data to make those assessments or validate them are lacking. 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.**

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The system for groundwater sensitivity determination is designed for flexibility. Different users have need for different levels of information and have variable limitations regarding data access, entry, and interpretation. This system can be used to make both regional or farm field determinations of groundwater sensitivity with a minimal amount of information or with large amounts of site specific information depending on the user's needs.

Demonstration of a regional groundwater sensitivity assessment is presented for Ramsey County. In contrast to the regional assessment, a site specific aquifer assessment is presented for Sec. 29, T.155 N., R.65 W. in Ramsey county.

STEP 1.

The Ramsey County Groundwater Studies report (Hutchinson and Klausung, 1980) identifies three glacial aquifers in the county. They are the Spirit-wood, McVile, and Starkweather aquifers (Figure 2). In Sec. 29, the Spiritwood aquifer underlies approximately the western two-thirds. Nearly three-fourths of Ramsey county and one half of Sec. 29 can be eliminated from further consideration, because no glacial aquifer is present. After the aquifers of concern are geographically located, proceed to step 2 to determine agricultural activities over the aquifers.

Figure 2. Aquifer and ground water sensitivity map for Ramsey county. (13KB b&w image)

STEP 2.

At this stage, decisions about accuracy of information and subsequent interpretations must be made. Information about

agricultural activities over the aquifers of concern can be found in ASCS files, North Dakota Agricultural Statistics, Census of Agriculture, etc. For a regional analysis, detailed information on land use and pesticide use may be quite time consuming and difficult to get.

About 75% of Ramsey County is cropland (North Dakota Agricultural Statistics Service Staff, 1992). In a given year pesticides are used on at least 70% of that land (U.S. Bureau of Census Staff, 1987). It is assumed that pesticide usage for other land use in Ramsey County such as rangeland and pastureland will be minimal. Approximately 2% of pastureland in North Dakota is treated with a pesticide (McMullen et al., 1989). For this assessment, it is assumed that cropland is the major land use over the three aquifers and pesticides are used regularly. 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 the foregoing assumptions, the majority of the area overlaying the three aquifers in Ramsey County will be placed in the **cropland-pesticide used** category as will the area of section 29 overlaying the Spiritwood aquifer. For the regional assessment of Ramsey County, the small areas of **hayland, pastureland, forestland, and rangeland** will not be determined. Also small areas over the aquifers where pesticides are not used will not be determined. These areas would be difficult to locate without considerable investigation, which will not be done for this example.

After agricultural activities have been determined over the aquifers of concern proceed to step 3. Some of the information gathered in step 2 will also be used in step 3 and for subsequent BMP recommendations.

STEP 3.

Regional Groundwater Sensitivity

As in step 2, the user must decide on the level of accuracy and resolution of the groundwater sensitivity information. As the requirement for accuracy increases, the amount of data needed also increases. Given limited finances and manpower, the data requirements for a highly accurate regional analysis of groundwater sensitivity may be unattainable. However, if a lower level of accuracy and resolution is acceptable, regional determinations can be made utilizing generalized data that is easily accessed. Accuracy and resolution are most important at the farm or field level where specific BMPs are to be recommended to individual operators. At this level, data requirements for accurate information are not unmanageable, because the user is working with a comparatively small parcel of land.

Information from the Ramsey County Groundwater Studies report (Hutchinson and Klausing, 1980) indicate that in most places the Spiritwood and Starkweather aquifers have > 50 feet of clayey or silty material overlaying them. The McVile aquifer, however, has sandy material overlaying a water table of < 50 feet. According to the general soil map from the Ramsey County Soil Survey (Bigler and Liudahl, 1986) the soil associations of greatest extent overlaying the Spiritwood, Starkweather, and McVile aquifers, respectively, were Svea-Hamerly-Barnes, Hamerly-Cresbard-Svea, and Barnes-Buse-Svea (Figure 3).

Figure 3. General soil map of Ramsey county with glacial aquifers superimposed. (After Bigler and Liudahl, 1986; and Hutchinson and Klausing, 1980) (27KB b&w image)

The major crops in Ramsey County were wheat, barley, and sunflower. According to McMullen et al. (1989), 2,4-D was the most commonly used pesticide on wheat and barley acres in North Dakota for the period 1984–89. MCPA, dicamba, trifluralin, and sulfonyleurea were also regularly used on wheat and barley in North Dakota. Trifluralin and ethyl parathion were the most commonly used pesticides on sunflower acres in North Dakota. Other commonly used pesticides were ethalfluralin, methyl parathion, and fenvalerate. It is assumed that these pesticides are used in cropland areas over the three aquifers in Ramsey County.

The most commonly used pesticides in the region are 2,4-D, trifluralin, and ethyl parathion with leaching potentials of high, intermediate, and low, respectively.

An accurate regional analysis, as mentioned before, depends on how much time and money can be spent gathering and entering site specific data. For this example, information that is an indicator of the most prevalent or dominant conditions that affect groundwater contamination by pesticides will be used. For many purposes this type of analysis is adequate. As generalized information, however, it is not appropriate for site specific recommendations or decisions.

The generalized information about Ramsey County aquifers, geology, soils, land use, and pesticide use is used to place

each aquifer in a groundwater sensitivity category (Table 3). Because more than one pesticide receives major usage above these aquifers, the overall filtration category will be based on the pesticide that is most likely to leach to groundwater. In this case, that pesticide would be 2,4-D. All three aquifers would be placed in the **high intermediate - cropland - leachable pesticide** sensitivity category (Figure 2).

Table 3. Groundwater sensitivity categories for Ramsey Co. aquifers based on major soil series and related filtration potential.

Spiritwood Aquifer					
Soil Series	Aquifer Depth-Water Flow	Material Texture	O.M. Content	Hornsby Index	Ground water Sensitivity Category
Svea	Deep-inactive (high *F.P.)	fine-loamy/clay and silt (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Hamerly	Deep-discharge (high *F.P.)	fine-loamy/clay and silt (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Barnes	Deep-inactive (high *F.P.)	fine-loamy/clay and silt (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Starkweather Aquifer					
Hamerly	Deep-discharge (high *F.P.)	fine-loamy/clay and silt (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Cresbard	Deep-discharge (high *F.P.)	fine-loamy/clay and silt (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Svea	Deep-discharge (high *F.P.)	fine-loamy/clay and silt (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
McVile Aquifer					
Barnes	Shallow-inactive (high *F.P.)	fine-loamy/sand (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Buse	Shallow-inactive (high *F.P.)	fine-loamy/sand (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Svea	Shallow-inactive (high *F.P.)	fine-loamy/sand (intermediate *F.P.)	>2% (high *F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide

*F.P. - filtration potential

Granted, information from the regional analysis is generalized and cannot be used for making recommendations regarding individual farming operations. The regional analysis does, however, identify groundwater resources of greatest importance to the region and those farms that may affect them. It helps to identify where specific site analyses for groundwater sensitivity should be done if problems are detected. It also helps to focus attention on the main factors that have the greatest potential to cause aquifer contamination in the region. It is useful to know that the behavior of 2,4-D on cropland is the primary threat to aquifer integrity as opposed to other possible factors.

Site Specific Groundwater Sensitivity

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 of Sec. 20 just to the north of Sec. 29 is assumed to be representative for the surrounding area including Sec. 29. The aquifer is overlain by <50 feet of clayey or silty materials (Hutchinson, 1977). The gray color of the aquifer sands indicate they are saturated with

water.

In this hypothetical example, the N 1/2 of Sec. 29 is pastureland where pesticides are not applied. The assessment of groundwater 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 of 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 used for pest control on this farmland are 2,4-D, trifluralin and ethyl parathion.

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 4) in the portion of the field that overlies the aquifer (Figure 4). When the filtration factors are assessed (Table 5), the categories of groundwater sensitivity can be located in the field (Figure 5) according to soil map unit.

Table 4. Soil mapping units overlaying the Spiritwood Aquifer on Sec. 29, T.155 N., R.65 W.

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

Figure 4. Detailed soil map for Sec. 29, T.155 N., R.65 W. with Spiritwood aquifer superimposed (After Bigler and Liudahl, 1986; and Hutchinson and Klausung, 1980) (23KB b&w image)

Table 5. Groundwater sensitivity categories for Sec. 29, T.155 N., R.65 W. based on major soil series and filtration potential.

Soil Series	Aquifer Depth-Water Flow	Material Texture	O.M. Content	Hornsby Index	Ground water Sensitivity Category
Aberdeen	Shallow-discharge (high *F.P.)	fine/clay and silt (high *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Barnes	Shallow-discharge (high *F.P.)	fine-loamy/ clay and silt (interm. *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Colvin	Shallow-discharge (high *F.P.)	fine-silty/ clay and silt (interm. *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Cresbard	Shallow-discharge (high *F.P.)	fine/clay and silt (high *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Fargo	Shallow-inactive (high *F.P.)	fine/clay and silt (high *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Hamerly	Shallow-discharge (high *F.P.)	fine-loamy/ clay and silt (high *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Hegne	Shallow-discharge (high *F.P.)	fine/clay and silt (high *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide

Overly	Shallow-inactive (high *F.P.)	fine-silty/ clay and silt (interm. *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Svea	Shallow-inactive (high *F.P.)	fine-loamy/ clay and silt (interm. *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Leachable pesticide
Tonka	Shallow-recharge (low *F.P.)	fine/clay and silt (high *F.P.)	>2% (high*F.P.)	20 (2,4-D) (low *F.P.)	High intermediate-Cropland-Shallow recharge, Leachable pesticide

Figure 5. Ground water sensitivity map for Sec. 29, T.155N., R.65 W. (37KB b&w image)

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. The other factors (Table 5) should also be considered for BMP recommendations but with less emphasis than those factors with low filtration potential.

A NOTE OF CAUTION

Application of this assessment system depends on information extracted from a number of different sources. It is 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 that 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" (Seelig, 1993) 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.

The differences in contamination potential among the different categories are relatively certain. The real effect of different contamination potentials on water quality in an aquifer remains relatively uncertain and untested. Changes in the producer's management for groundwater protection should only be recommended when the extent of groundwater and/or vadose zone 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.

Regional groundwater assessments based on generalized information should under no circumstances be used to recommend or dictate site specific management practices. Regional groundwater sensitivity determinations are useful when attempting to utilize limited funding and manpower efficiently. Efforts to identify and monitor water quality

problems can be maximized by focussing on areas that have the greatest potential for contamination due to low filtration of pesticides.

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 due 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.

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