5th Bulletin of the Minnesota Agriculture Water Quality Certification Program and Assessment Tool

May 2015

What's in this bulletin?
-New N guidelines for irrigated sandy soil
-N crediting for irrigation water
-Update to the Technical Guide

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Preface

The information provided in these Bulletins is intended to be complementary to the handouts and Technical Guides. If major modifications are made to the Assessment Tool, a new Technical Guide will be published, which is completed in this Bulletin, and the previous version retired. Bulletins, however, are cumulative and can be used as references going forward. New participants and certifiers using the MAWQCP Assessment Tool are encouraged to consult the Bulletins and latest version of Technical Guides.

1 Technical Positions

New fertilizer recommendations for corn grown on irrigated sandy soils are released by University of Minnesota.

In spring of 2015, fertilizer recommendations for corn grown on irrigated sandy soils were published. Previously, irrigated corn was lumped together with dryland corn grown on highly productive soils, as insufficient data was available for the University of Minnesota to release recommendations. These new recommendations are based on extensive field studies conducted since 2007.

The most significant recommendations relate to nitrogen rate and time of application; other findings and more information can be found in Extension Bulletin AG-NM-1501. The new rate guidelines for corn on corn are found in Table 1. Nitrogen credits for previous crops are presented on Table 2. Like previously published recommendations, a rate range is presented to account for varying risk tolerance levels. Certifiers should note the changes on irrigated sandy soils and consult the new recommendations when scoring the N application rates.

Table 1. Guidelines for use of N fertilizer for corn after corn grown on irrigated sandy soils.

N price/Crop value ratio	MRTN	Acceptable range
------------- lb N/acre -------------		
0.05	233	214 – 252
0.10	209	192 – 225
0.15	191	177 – 206
0.20	177	164 - 190

Table 2. Nitrogen credits for different previous crops for first year corn.

Previous crop	1st year N credit *
lb N/acre	
Soybean	30
Harvested alfalfa	100
Group 1 crops **	75
Group 2 crops ***	0
Edible bean	20
Field pea	20

*Harvested alfalfa and red clover provide a 2nd year N credit to corn of 50 lbs N acre-1 and 35 lbs N acre-1, respectively.

**Group 1 crops include perennial grass/legume mixes.

***Group 2 crops include small grains, grass hay, corn, sunflower, vegetables, potatoes and sugarbeets.

The other significant update is relate to timing of application. Additional field studies have confirmed that pre-plant applications of nitrogen in these systems are not recommended due to the potential for loss to the environment and corresponding yield drag. Split applications, as listed below, are recommended and amenable to a wide-variety of management and equipment systems.

- N in starter plus side-dress N
- N in the starter plus split side-dress N
- N in the starter plus side-dress N plus N injected in the irrigation water
- N in the starter plus N injected in the irrigation water
- N in the starter plus pre-emergence herbicide applied with UAN plus side-dress N
- N in the starter plus pre-emergence herbicide applied with UAN plus N injected with the irrigation water.

Even with enhanced efficiency products, such as nitrapyrin and ESN formulations, pre-plant application underperformed when compared to split applications. It is unknown which classifications, if any, will change when the official ‘green book’ BMPs are updated, but for the purposes of this program and to align ourselves with new findings, any preplant application without the use of a nitrification inhibitor will be considered a ‘Not Recommended’ practice. This moves the currently-classified ‘Acceptable with Risk’ practice of single sidedress application of AA or urea in the spring without a nitrification inhibitor into a ‘ Not Recommended’ practice for purposed of scoring in the assessment tool.

Nitrogen crediting in irrigation water.

Irrigation water itself can be a source of nitrate-nitrogen that requires crediting when scoring the nitrogen rate section of the assessment tool. The amount of N credits depends upon the annual acre-inches of irrigation applied and the nitrate concentration of the water. Table 3 provides a quick reference guide to determine the N credit from irrigation water. As an example, a well test of 20ppm nitrate-nitrogen is shown and cumulative irrigation of 6 acre-inches per growing season is applied. In this example, 27 lbs of N per acre should be credited. Some University of Minnesota publications suggest that irrigation water with nitrate-nitrogen concentrations below 10ppm combined with the actual acre-inches applied do not contribute a significant amount of nitrogen and therefore should be considered background N. It is recommended that certifiers do the math and consult the table to make that determination on a case-by-case basis.

Table 3. Nitrogen crediting from irrigation by well tests and acre-inches applied.

Irrigation Pivot Nitrate Results	**Annual Applied Irrigation Water (inches/acre)**					
(ppm)	**5**	**6**	**7**	**8**	**9**	**10**
	Nitrogen Credit (lbs/acre)					
5	6	7	8	9	10	11
10	11	14	16	18	20	23
15	17	20	24	27	31	34
20	26	27	32	36	41	45
25	28	34	40	45	51	57
30	34	41	48	55	61	68
35	40	48	56	64	72	80
40	45	55	64	73	82	91
45	51	61	72	82	92	102
50	57	68	80	91	102	114
Example: Based on your Irrigation water Nitrate Concentration (20 ppm) and annual irrigation water applied (6 inches), you are applying 27 lbs. N/acre.						

Update to the Technical Guide to the Minnesota Agricultural Water Quality Certification assessment tool.

The Technical Guide was first published in September 2013 to provide background information and details on the assessment tool. The calculations, including weighting and scoring, that underlay the assessment tool were also presented. Upon completion of a third-party analysis and technical review committee recommendations, several changes to the risk assessment tool were made. Attached is the updated Technical Guide that includes all changes discussed in the Bulletins to date as well as changes made following the evaluation. A hypothetical Martin County farm is presented to walk users through the calculations.

Technical Guide to the Minnesota Agricultural Water Quality Certification Program Assessment Tool

April 2015 update
Originally published September 2013

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Technical Guide to the Minnesota Agricultural Water Quality Certification Program assessment tool

The Minnesota Agricultural Water Quality Certification assessment tool and this technical guide were adapted by the Minnesota Department of Agriculture[1] *from the USDA/NRCS "Water Quality Index for Runoff Water from Agricultural Fields" written by Harbans Lal*[2] *and Shaun McKinney*[2]

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[1] Adaptions developed by the Minnesota Department of Agriculture Agricultural Water Quality Certification Program Staff in conjunction with RESPEC Consulting and Services, Kieser and Associates and Sense AI.

[2] Respectively Environmental Engineer and Team Leader of National Water Quality and Quantity Team of the Natural Resources Conservation Service of the US Department of Agriculture (NRCS/USDA) located at the West National Technology Support Center (WNTSC), Portland, OR

The authors thank Steve Campbell, Soil Scientist; Rich Fasching and Giulio Ferruzzi, Conservation Agronomists; Peter Robinson, Water Management Engineer; and Clare Prestwich, Irrigation Engineer of the WNTSC-NRCS/USDA, Portland, OR and all others who helped in developing different ranking factors and reviewing the manuscripts and making valuable suggestions

Preface

This technical guide was initially developed by United States Department of Agriculture's Natural Resource Conservation Service (USDA/NRCS) and describes an agricultural water quality index model (referred to as WQIag). This was developed to evaluate the quality of runoff water from agricultural fields and designed for use across the country.

The WQIag tool developed by USDA/NRCS was adapted by the Minnesota Department of Agriculture for use in the Minnesota Agricultural Water Quality Certification Program (MAWQCP). This is a voluntary program designed to accelerate adoption of on-farm conservation practices that protect Minnesota's lakes and rivers. Producers who implement and maintain approved farm management practices will be certified and in turn assured that their operation meets the state's water quality goals and standards for a period of 10 years.

Through this program, certified producers receive:

- Regulatory certainty: certified producers will not be subject to new water quality regulations during the period of certification
- Priority for technical assistance and cost share dollars for practices that protect water quality
- Recognition for their efforts of managing water quality on their operations

Through this program, the public receives:

- Assurance that certified producers are employing Best Management Practices and conservation to protect Minnesota's lakes, rivers and streams

The program is the product of a state-federal partnership that includes the Minnesota Department of Agriculture, the Minnesota Pollution Control Agency (MPCA), the Minnesota Board of Water and Soil Resources (BWSR), the Minnesota Department of Natural Resources (DNR), and the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS).

A Memorandum of Understanding was signed on January 17, 2012, by Minnesota Governor Mark Dayton, U.S. Agriculture Secretary Tom Vilsack, and EPA Administrator Lisa Jackson. This document formalizes the state-federal partnership and confirms the joint commitment to developing and implementing the program.

1 Introduction

Water quality index (WQI) combines multiple water quality factors into a single dimensionless number by normalizing their values to subjective rating curves (Miller 1986). It is a simple, convenient way to express risk to water quality in easy to understand terms. Traditionally, it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes, etc. Factors included in a WQI vary depending upon the designated water uses of the waterbody and local preferences. Some of these factors include dissolved oxygen (DO), pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total coliform bacteria, temperature, and nutrients (nitrogen and phosphorus_. These parameters are measured in different ranges and expressed in different units. The WQI takes the complex scientific information of these variables and synthesizes them into a single number.

Several authors have worked on the WQI concept and presented examples with case scenarios

(Bolton et al. 1978; Bhargave, 1983; House 1989; Mitchell and Stapp, 1996; Pesce and Winderlin, 2000; Cude, 2001; Liou et al. 2004; Said et al. 2004; Nasiri et al., 2007, NSF, 2007). Lal (2011) reviewed these works; and summarized and compared different WQI models using an example dataset. The paper also recognized and recommended the need for a WQI model for qualifying the quality of surface water runoff from agricultural fields.

The USDA/NRCS provides technical assistance (TA) and financial assistance (FA) that encourage agricultural producers to be good stewards of the Nation's soil, water, and related natural resources on private and tribal lands. One of the key goals of implementing conservation practices is to safeguard and improve water quality of the watershed. The USDA/NRCS is always looking for approaches and techniques to evaluate the effects of its programs on the environment. For example, the CEAP Program (USDA/NRCS, 2011) is one such program that uses the APEX model for this purpose. The WQI may serve as a simple tool in the effort to evaluate the effects of the conservation practices on improving and/or sustaining the water quality in the watershed. However, the structure and components of conventional WQI models discussed by Lal, 2011 would need to be modified for it to be more appropriate for evaluating water quality from agricultural landscapes.

This technical note describes such a model (referred to as WQIag) developed to evaluate the quality of runoff water from agricultural fields. Besides different components and how they are integrated into a single dimensionless number (WQIag), the paper also presents an example of using the index on a hypothetical farm in Martin County, Minnesota.

In 2014, an analysis of the WQI was completed by a private-public consortium made up of the Stearns County Soil and Water Conservation District, Minnesota Department of Agriculture, Kieser and Associates and Sense AI. At the time of analysis the Assessment Tool had been field tested and data was available from over 600 assessments throughout Minnesota. With that data, a sensitivity analysis was performed to help guide tool authors in correctly scoring, weighting and aggregating parameters. Additionally, a literature review and comparison against actual edge of field monitoring results was completed. This analysis helped inform Technical Committee members in making updates to the assessment tool, which this update covers. The complete report can be found at : http://www.mda.state.mn.us/en/protecting/waterprotection/awqcprogram.aspx or by contacting the Minnesota Agricultural Water Quality Certification Program at the MDA.

2 Components and Composition of WQIag

The factors influencing the runoff water quality from agricultural fields and captured within WQIag framework could be divided into following six (6) broad categories:

1) Field characteristics and soil physical/erosion factors,
2) Nutrient management factors,
3) Tillage management factors,
4) Pest management factors,
5) Irrigation and tile drainage management, and
6) Additional conservation practices

The precipitation (magnitude and its duration) falling on a field becomes a source of runoff. The field sensitivity/physical factors such as slope, soil texture, etc., control the rate and quantity of runoff. It carries sediments and other pollutants both dissolved constituents as well as entraining particles. This portion of the index addresses the inherent characteristics of the field which do not change significantly over time.

The management practices such as tillage, nutrient and pesticide management, and irrigation and tile drain system also affect the runoff water quality flowing out of a field. The primary objective of nutrient and pest management is to balance the application of nutrients (organic and/or inorganic fertilizers) and pesticides for obtaining sustainable crop yields while minimizing their off-site transport. Nutrient management is composed of four variables: the rate, timing, form, and method of fertilizer application. The Minnesota AgBMP Handbook Agricultural BMPs Nutrient Management (590) and Pest Management (595) respectively describe these practices in much greater details (Minnesota Department of Agriculture September 2012).

Just like WQIag, the revised Minnesota Agricultural Water Quality Certification Assessment Tool provides an index ranked from 1-10 where the value of 10 is assigned to the highest and ranking of 1 to the lowest water quality. It is attune with the conventional water quality index where highest water quality is assigned WQI of 100.

2.1 Field Characteristics and Soil Physical / Erosion Factors (WQI-fs)

Field characteristics, especially the field slope, play an important role in runoff generation and transport. The higher the slope, the more susceptible it is to generate runoff and soil erosion. In addition the field slope interacts with the rainfall and soil physical and erosion factors such as hydrologic soil group (HSG) and the K-factor in generating runoff and need to be accounted for the runoff water quality index.

Soils within a hydrologic group have similar runoff potential under similar storm and cover conditions. Soil map unit components are assigned a hydrologic group in the NASIS soil survey database (USDA/NRCS. 2009). Most soils are placed in hydrologic groups A, B, C, or D. Soils assigned to hydrologic group "A" have the lowest runoff potential followed by group "B","C" and "D." The soils in hydrologic group "D" have the highest runoff potential. Given a field with a 5 percent slope, if the dominant hydrologic group is "D", there would be a significantly higher runoff potential than if the dominant hydrologic group is "A". Soils with seasonal high water tables at depths less than 60 cm may be assigned to dual hydrologic groups A/D, B/D, or C/D. The first letter in the dual groups indicates a "drained" condition; the second letter indicates an "undrained" condition. The assessment tool map calculator default for dual designation is D. Users that are assessing a field with a dual designation and subsurface tile drainage should update the autopopulated value to the first letter of hydrologic group.

On the other hand, K-factor defines the susceptibility of a soil to sheet and rill erosion. It is one of the six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) that predict the average annual rate of soil loss (USDA/NRCS, undated). The K factor ranges from 0.02 to 0.69 and is based primarily on percentage of silt, sand and organic matter, the soil structure and the saturated hydraulic conductivity. Other factors being equal, the higher the K value, the more susceptible the soil is to sheet and rill erosion, thus leading to a decrease in the quality of runoff water. USDA/NRCS. 2004 defines two types of K factors: Kf and Kw. Kf is referred to as a rock free K-factor and Kw as the whole soil factor. For the WQIag, we use Kw as it accounts for the effect of surface rock fragments in reducing erodibility.

Organic matter is the plant and animal residue in the soil at various stages of decomposition. It is expressed as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. It has a positive effect on available water capacity, water infiltration, and soil organism activity.

The MAWQCP Assessment Tool interface is designed with the menu items such as " very low" to "very high" for soil erodibility for different Kw ranges; and soils with "low" to "high" runoff potential for different hydrologic groups (A, B, C, D, etc.) which are easy to understand by the user.

2.1.1 Hydrologic Soil Group (WQI-fhg)

The field slope can range from a relatively flat land (no slope) to significantly high slope up to 40%. However, for the sake of simplicity for the WQIag calculation we grouped field slope gradients into five broad categories:

less than 2%, 2-5%, 5-10%, 10-15% and more than 15%. **Table 1** presents the ranking of WQI-fhg for different soil groups under different slope ranges. For example, the relatively flat lands (slope < 2%) and the Hydrologic Soil group A of low runoff potential gets the highest WQI-fhg value of 10. It is mainly because this condition will generate much less amount of runoff compared to a field with the slope of more than 15% and Hydrologic soil group D with high runoff potential which is assigned the WQI-fhg of 1.

Table 1: WQI-fhg values for different hydrologic soil groups under different field slopes (**Hydrologic Soil Group (HSG) - Slope Interaction)**

Hydrologic Soil Group	**Slope Gradients**				
	< 2%	**2-5%**	**5-10%**	**10-15%**	**>15%**
A:Low runoff potential	10	9	7	5	4
B: Moderately low runoff potential	10	8	6	4	3
C :moderately high runoff potential	9	7	5	3	2
D, high runoff potential	8	6	4	2	1

2.1.2 K-Factor (WQI-fkw)

The soil K-factor referred to as soil erodibility factor also interact with the slope. **Table 2** gives the values of WQI-fkw for different combinations of the Kw and field slope ranges. The low gradient field (< 2%) and the very low erodibility (Kw <= 0.10) gets the highest WQI-fkw as it would produce much less amount of soil erosion compared to soils with very high erodibility (Kw between 0.44 to 0.64) on steeper fields with slope more than 15% which is assigned the WQI-fkw of 1.

Table 2: WQI-fkw values for different Kw ranges under different field slopes (**Kw Factor - Slope Interaction)**

Kw factor - surface mineral layer	**Slope Gradients**				
	< 2%	**2 - 5%**	**5 - 10%**	**10 - 15%**	**>15%**
<=0.10 very low erodibility	10	10	10	9	7
0.11 - 0.20 low erodibility	10	10	9	7	5
0.21 - 0.32 moderate erodibility	9	8	7	5	4
0.33 - 0.43 high erodibility	8	7	5	3	2
0.44 - 0.64 very high erodibility	8	6	4	2	1

2.1.3 Organic Matter (OM) content (WQI-fom)

Organic matter content of the soil can significantly influence the quality of water running off from a field. Soil organic matter can hold 10 to 1000 times more water and nutrients than the same amount of soil. The presence of OM in soils reduces sediment and nutrient load in the runoff and improves the water quality. Thus, **Table 3** assigns the highest WQI-fom value of 10 to the soil with the OM content of more than 8 percent and then is reduced correspondingly for the soils with smaller percentages of OM content.

Table 3: Percentage Organic Matter (OM) and associated WQI-fom

% OM Range	**WQI-om**
>8%	10
6-8%	9
4-6%	7
2-4%	6
0.5-2%	4
<.5%	2

2.1.4 Rainfall/ Vegetation Factor (WQI-fvr)

Rainfall falling on a field is the catalyst for runoff and soil erosion. However, vegetative cover (live and/or dead) present on the soil surface during the rainfall can significantly reduce runoff generation. Thus, this section evaluates the combined effect of these two factors on the water quality index.

Vegetative cover (live or dead) and rainfall are classified into three categories (low, medium and high). The following categories are used to reflect vegetative cover (Live or dead):

Less than or equalt to 30% vegetative cover = Low Vegetation (Vl)
31 to 80% vegetative cover = Medium Vegetation (Vm)
More than 80% vegetative cover = High Vegetation (Vh)

Appendix A1 provides a USDA/NRCS brochure that discusses farming with crop residues and details how different tillage operations and decomposition impact expected residue on a field.

To account for the field slope interaction with the rainfall potential to generate runoff, we categorized the monthly rainfall into three categories (low, medium and high). The precipitation data is from the thirty-year (1984-2014) monthly averages compiled by the Minnesota State Climatology Office network of trained weather observers. Isometric maps were created to determine estimatesof precipitation at locations between weather stations. A weighted average calculation is used in situations where field boundaries cross isolines. **Table 4** presents these ranges for different slope intervals. At higher slopes (> 15%) even a small amount of rainfall can produce runoff while on the flatter lands it would require significantly higher amount to produce similar magnitude of runoff. Thus, for a flatter land with slope less than 2% a monthly rainfall of 7.0 inch or more is classified a high rainfall. On the other hand, on the steeper land with the slope more than 15% this amount reduced to 3.0 inch.

With three levels of vegetative covers: low (Vl), medium (Vm), and High (Vh); and the three levels of rainfall categories: low (Rl), medium (Rm), and high (Rh), a 3 by 3 matrix was developed to generate WQI-fvr as depicted in **Table 5a and 5b**. In this matrix, the combination of high vegetation (Vh) and low rainfall (Rl) gets the highest WQI-fvr rating of 9 as it would generate minimum amount of runoff. On the other extreme the combination of the low vegetation (Vl) and high rainfall (Rh) gets the lowest WQI-fvr rating of 1 as it would generate high runoff and erosion.

Multiple year and location information from the Discovery Farms shows that, on average, runoff starts in March with snowmelt and continues until frozen ground conditions in November. To coincide with these findings, the Rainfall/Vegetation scores takes into consideration March-November scores only. However, to aid in planning and education purposes the entire year is presented.

Table 4: Categorization of average monthly rainfall (low, medium and high) for different field slope ranges (**Rainfall - Slope Interaction)**

Rainfall Category	**Slope Gradients**				
	< 2%	**2-5%**	**5-10%**	**10-15%**	**>15 %**
Low	< 2.50 in	< 2.00 in	< 1.75 in	< 1.50 in	< 1.00 in
Medium	2.51 to 7.0 in	2.01 to 6.0 in	1.76 to 5.0 in	1.51 to 4.0 in	2.0 to 3.0 in
High	> 7.0 in	> 6.0 in	> 5.0 in	> 4.0 in	> 3.0 in

Table 5a: Decision Matrix for Rainfall/Vegetative (Includes crop, residue, cover crop) cover

Vegetative cover	**Rainfall**		
	Vh*Rl (9)	Vh*Rm (8)	Vh*Rh (7)
	Vm*Rl (6)	Vm*Rm (5)	Vm*Rh (4)
	Vl*Rl (3)	Vl*Rm (2)	Vl*Rh (1)

Vegetative Cover Range: low (Vl), medium (Vm), high (Vh)

Rainfall Range: low (Rl), medium (Rm), high (Rh)

Table 5b: Combination of rainfall and vegetative and associated WQI-fvr

VegCover*Rainfall	WQI-fvr
Vl*Rh	1
Vl*Rm	2
Vl*Rl	3
Vm*Rh	4
Vm*Rm	5
Vm*Rl	6
Vh*Rh	7
Vh*Rm	8
Vh*Rl	9

Table 5c presents an example for estimating the WQI-fvr for a field in Martin County, Minnesota. It shows the average monthly precipitation ranging from 0.71 inch in January to 4.06 inches in August. A rainfall ranking factor is assigned for each month using the following characterization system based for field slope between 2-5%.

Rainfall less than or equal to 2 in = Low Rainfall (Rl)
Rainfall between 2.0 to 6.0 in = Medium Rainfall (Rm)
Rainfall more than > = 6.0 in = High Rainfall (Rh)

The table 5c also shows monthly vegetation ranking for the test case scenario. The months of July to September, primarily the growing season in Minnesota, are assigned high (Vh) vegetative cover followed by October getting the medium vegetative cover (Vm), and December to April getting the low vegetative cover (Vl) with May and June again having medium cover (Vm). This assignment is arbitrarily taking into account the cropping season of the region. It could vary in real condition based upon the land use and land cover type.

Based upon the rainfall and vegetation ranking, a value of WQI-fvr is assigned for each month from the decision matrix tables 5a and 5b. The months of July to September get the highest ranking of 8 because of high vegetative cover (Vh) and medium rainfall combinations. **Table 5c** provides WQI-fvr value for each month and the overall mean for the entire year. The WQI-fvr values could be aggregated for a season such as the corn growing season or winter wheat growing season to calculate WQIag for that period. We could also use them individually for estimating WQIag for each month.

Table 5c: An Example of estimating WQI-fvr based upon the monthly rainfall and expected vegetative cover for a field in Martin County,Minnesota

	Rain (in)	Rain Factor	Veg. Factor	Veg* Rain	Veg*Rain Ranking
Jan	0.71	Rl	Vl	Vl*Rl	
Feb	0.78	Rl	Vl	Vl*Rl	
Mar	1.84	Rl	Vl	Vl*Rl	3
Apr	2.96	Rm	Vl	Vl*Rm	2
May	3.5	Rm	Vm	Vm*Rm	5
June	4.0	Rm	Vm	Vm*Rm	5
July	4.02	Rm	Vh	Vh*Rm	8
Aug	4.06	Rm	Vh	Vh*Rm	8
Sept	3.08	Rm	Vh	Vh*Rm	8
Oct	2.25	Rm	Vm	Vm*Rm	5
Nov	1.51	Rl	Vl	Vl*Rl	3
Dec	1.08	Rl	Vl	Vl*Rl	
Mean					**5.22**

2.1.5 Integrating Field Characteristics and Soil Physical / Erosion Factors into a single value (WQI-fs)

The rankings of field characteristics and soil physical / erosion factors (K-factor, Hydrologic Soil group, organic matter content, and rainfall/vegetation factor) are combined into a single WQI-fs value for the entire year using a simple arithmetic mean with a weighing factor assigned to each value. This technique permits adjusting the contribution of each component in the overall WQI-fs based upon the local preferences as demonstrated in **Table 6**. This table presents an example scenario for the Martin County, Minnesota with slope range of 2 to 5%.

Table 6: Integrating Soil Sensitivity/Physical factors

into a single WQI-fs value for a slope of 2-5%

Soil Sensitivity Component	Soil Sensitivity Option	WQI Ranking (WR)	Weighing Factor (WF)[1]	WR *WF
Hydrologic Soil Group	**Group B** moderately low runoff potential	8	0.1	0.8
K-Factor	**0.30** 0.21-0.32 moderate erodibility	8	0.1	0.8
OM Content	**5%** 4-6% range	7	0.4	2.8
Rainfall/ Vegetation	Annual Mean Average for the example case	5.22	0.4	2.09
Mean WQI-fs (Total of all four rows)			**1.00**	**6.49**

[1] The sum total of rows should equal 1

2.2 Nutrient Management (WQI-nm)

2.2.1 Nutrient Application Rate (WQI-nar)

Nutrient management components that affect runoff water quality from a field include: rate, form, timing and method of application of fertilizers. Higher fertilizer application rates lead to increasing water quality concerns. Farmers generally apply fertilizers using the State Land Grant University (LGU) recommendations. Minnesota provides separate recommendations for nitrogen and phosphorus application rates to optimize the balance between agronomic and environmental concerns. Thus as depicted in **Table 7a and 7b** the recommended Minnesota fertilizer rate applications are scored near the top of the range for the water quality and are awarded a rating of 10 on the scale of 1-10 with anything greater than the recommended application rate receiving fewer points in the WQI-nar ranking.

Table 7a: Nitrogen application rate and associated WQI-nar

Application Rate	WQI-nar
Legumes/No Fertilizer Applied	10
MN BMP recommendations	10
</=10% over the BMP recommendations	7
>10-20% over the BMP recommendations	5
>20-30% over the BMP recommendations	2
>300% over the BMP recommendations	1

Table 7b: Phosphorus application rate and associated WQI-nar

Application Rate	WQI-nar
No Fertilizer Applied	10
MN UMN recommendations	10
1-10% over the UMN recommendations	9
11-20% over the UMN recommendations	7
21-30% over the UMN recommendations	5
31-40% over the UMN recommendations	3
>41%% over the UMN recommendations	1

2.2.2 Nutrient Timing, Source and Placement (WQI-nst)

The timing, source and placement of fertilizer application play an important role in the fate of nutrients because of the physiological effectiveness of the plant to uptake the applied nutrients. If applied at the optimum time and place, a large percentage of nutrients are taken up by the plants, thus minimizing negative impact on the water quality. In addition plants need nutrients at different growth stages. **Table 8** presents ratings for the synthetic timing, source and placement factors of nutrient management for the water quality index.

Table 8: Synthetic Fertilizer Source, Timing and Placement and associated WQI-ntt

Regional Synthetic N Recommendations	Source	Timing	Placement
Recommended	10	10	10
Acceptable with Risk	6	6	6
Not acceptable	1	1	1

2.2.3 Manure Application Timing and Placement (WQI-nms)

The method and soil condition at the time of manure fertilizer application are two factors that play a key role in plant nutrient uptake and impact on water quality. Manure fertilizer directly injected into dry/well drained soils is best for plant uptake and reduces impact on water quality when compared to unincorporated applications, thus getting a higher ranking **(Table 9a).**

Table 9a: Manure Fertilizer Timing and Placement and associated WQI-ntt

Manure Recs.	Spring	Fall Soil Temp < 50° F	Fall Soil Temp > 50° F	Frozen Soil
Incorporated / Injected	10	10	4	N/A
Unincorporated	6	3	2	1

In areas with high native levels of soil test phosphorus or long histories of manure application, producers using manure are by default scored as having a high risk to water quality, regardless of their management practices.

University of Minnesota studies show that there is little crop response to additional P application once soil test phosphorus (STP) levels are >21 ppm Bray P1. Therefore, no additional P is recommended once STP reaches this level. For producers who have STP levels greater than 21 ppm and apply livestock manure to meet nitrogen needs, the current scoring schedule would place them at '50% or greater' as *any* P applied is greater than the crop response recommendation.

This scoring does not necessarily align with water quality risk as it assumes all P applied greater than crop response rate is lost to the environment. This ignores the soil's sorption potential. To more accurately measure the risk of P loss, over 40 states, including Minnesota, have adopted the Phosphorus Index concept. This concept examines the risk of soluble and insoluble P to water quality as it relates to a host of parameters, including slope, runoff timing and buffers. The index concept also takes into consideration existing STP levels.

The concepts in the index approach have also been incorporated into the regulatory Minnesota

Pollution Control Agency (MPCA) 70.20 rules and the non-regulatory Natural Resource Conservation Service (NRCS) 590 Nutrient Management standards. Basic principles are as follows. 1) As STP levels increase the risk of P loss to the environment increases. 2) Vegetative buffers are instrumental in reducing P loss. 3) The ability of the harvested crop to remove phosphorus removal rates should be considered.

To comprehensively address these issues and align the program with regulatory and voluntary practices, alternative scoring for P manure is proposed. A summarized table is presented below:

Table 9b: Alternative scoring for P manure.

		Buffer*			No buffer		
STP Levels Bray P1 (ppm)	STP Levels Olsen (ppm)	application =crop response rate	crop response< application ≤P205 removal**	application >P205 removal	application =crop response	crop response< application ≤P205 removal	application >P205 removal
<21	<16	10	9	1	10	8	1
22-75	17-60	n/a	7	1	n/a	6	1
76-150	61-120	n/a	5	1	n/a	4	1
>150	>120	n/a	1	1	n/a	1	1
>150	>120	n/a	1	1	n/a	1	1
Sheet and rill erosions >6 tons acre-1 year-1		1	1	1	1	1	1

*non-manured permanent vegetation strip that is min. 100 feet wide. **P205 removal is defined as manure application rates that are based on the ability of the crop to remove P2O5 over the course of the cropping year or rotation not to exceed 6 years.

To determine the score, locate the STP level along the left side of the table. Both Olsen and Bray tests are presented. Next, determine if there is a buffer present along waterway or area of concentrated flow. Lastly, determine if the actual P application rate (denoted as ‘application’) corresponds to the crop response rate or if it is above/below the crop’s ability to remove phosphate over the rotation.

For example, a producer’s soil test shows STP levels based on the Bray P1 test of 50 ppm. The producer has a functional 100’ wide buffer of permanent vegetation along a stream. Upon review of the manure lab tests and the manure application plan, it is determined that producer’s actual phosphate rate is below crop P205 removal rate across a four-year rotation. This score in this case would be 7.

2.2.4 Integrating Nutrient Management factors into a single WQI-nm

The nutrient management factors are combined into a single WQI-nm value by a simple arithmetic weighted mean of their values. A weighting factor is assigned to each component. Because not all nutrient management components apply in all scenarios, the weighting factors are dynamically applied based on the operation. These weighting factors are displayed in **Table 10a.**

Table 10a: Nutrient management scenarios and associated weighting

Nutrient management scenarios	**N rate**	**P rate**	**Comm. fert timing**	**Comm. fert timing**	**Comm. fert timing**	**Manure**
No commercial fertilizer	.5	.5	n/a	n/a	n/a	n/a
Commercial fertilizer	.3	.3	.2	.1	.1	n/a
Commercial fertilizer and manure	.21	.21	.14	.075	.075	.29
Manure only	.3	.3	n/a	n/a	n/a	.4

Scenarios showing use of commercial fertilizer with and without manure are presented in **Table 10b** and **Table 10c**, respectively.

Table 10b: Integrating Nutrient Management factors into a single WQI-nm

Nutrient Management Component	**Nutrient Management Option**	**WQI Ranking (WR)**	**Weighing Factor (WF)**[1]	**WR*WF**
N Application Rate	>30% over BMP recommendation	2	0.21	0.42
P Application Rate	UMN Recommendation	10	0.21	2.10
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.14	0.84
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.075	0.45
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.075	0.45
Manure Application Timing & Placement	Incorporated / Injected Fall > 50° F	4	0.29	1.16
Mean WQI-nm (Sum total of all six rows)			**1.00**	**5.42**

[1] The sum total of rows should equal to 1

Table 10c: Integrating Nutrient Management factors into a single WQI-nm with no manure application

Nutrient Management Component	**Nutrient Management Option**	**WQI Ranking (WR)**	**Weighing Factor (WF)**[1]	**WR*WF**
N Application Rate	>30% over BMP recommendation	2	0.3	0.6
P Application Rate	UMN Recommendation	10	0.3	3.00
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.2	1.20
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.1	0.60
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.1	0.60
Manure Application Timing & Placement	No Manure Applied	0	0	0
Mean WQI-nm (Sum total of all six rows)			**1.00**	**6.0**

[1] The sum total of rows should equal to 1

2.3 Tillage Management (WQI-tm)

The effect of soil tillage on soil erosion is well established. The more the soil is tilled, the more susceptible it becomes to erosion. Thus, it is an important factor in evaluating the quality of runoff water from a field. Soil Tillage Intensity Rating (STIR) is a tool that has been widely used for evaluating the soil disturbance as well as the severity of the disturbance caused by tillage operations (Al-Kaisi, 2007 and Boetger, undated). Specific components of STIR value include: Operational speed of tillage operation, tillage type, depth of tillage operation and percentage of soil surface area disturbed.

The STIR value can range between 0-200. Low STIR value reduces likelihood of sheet rill erosion.

Table 11 presents different tillage systems with their possible STIR ranges and associated WQI-tm values. These designations and associated STIR ranges generally follow NRCS recommendations. One can use the table by identifying the tillage system most representative of existing conditions or use the RUSLE2 database to obtain the STIR value for the tillage system; and then selecting the corresponding WQI-tm value.

Table 11: Tillage description / STIR ranges and associated WQI-tm

Tillage Description	STIR Value	WQI-tm
No Till	</=10	10
Zone/Strip Till	>10-30	9
Reduced Till	>30-80	8
Conventional Till	>80	2

2.4 Pest Management (WQI-pm)

Pests (weeds, insects, and diseases) are expected elements of a farming system. Considerable amount of effort and resources are devoted on controlling and/or managing them. Modern pest management approach uses combination of practices generally referred to as Integrated Pest Management (IPM).

Pests (weeds, insects, and diseases) are expected elements of a farming system. Considerable amount of efforts and resources are devoted on controlling and/or managing them. Modern pest management approach uses combination of practices generally referred to as Integrated Pest Management (IPM).

They incorporate crop rotations, cultural practices, scouting, crop selections, and other field practices to prevent pest problems from occurring. When pest infestations do occur at damaging levels they are controlled using chemicals in the most effective way with minimum risk to environmental including water quality. **Table 12a** employs this criterion and presents the WQI-pm rating for different levels of pest management options. Highest rating of 10 to WQI-pm is assigned to a system where Advanced IPM is followed which primarily involves employing all lower-rated IPM practices as well as cultural practices that minimize pests, and the lowest rating of 2 is awarded to a system that uses Basic Pest Control that suppresses pests with label mitigation (i.e. setbacks).

Suppression of pests within the context of these ratings means the use of synthetic or organic chemical pesticides in farming systems. Because suppression does not necessarily lead to water quality impacts (or impacts of regulatory concern), and because a production system without suppression is technically not the goal of certification and is not the goal of IPM, the descriptions in Table 12a and related assessment factors in Table 12b do not preclude the use of pesticides nor award higher ratings for not using such chemicals. Instead, higher ratings are given to the adoption by farming operations of a number of IPM strategies. Each additional strategy beyond "Basic Pest Control" generally requires an increased level of effort on the part of the farmer. And while not all suggested MDA BMPs are appropriate for every farm, an effort has been made to simplify the detail provided in the original BMPs (http://www.mda.state.mn.us/protecting/bmps/voluntarybmps.aspx) by utilizing core concepts and pesticide-specific practices adoptable on any farm, as well as organizing them by ease of implementation. In this way, adoption of multiple strategies should reflect critical MDA WQ Pesticide BMPs designed to minimize the long-term potential for unreasonable adverse effects to water resources from the use of pesticides.

Of particular interest to MDA are the herbicides acetochlor and atrazine, and the insecticide chlorpyrifos. These pesticides have been identified by MDA as "surface water pesticides of concern," a non-regulatory designation based on frequency of detection and monitoring concentrations relative to state water quality standards. Although the designation is non-regulatory, the Minnesota Pollution Control Agency (MPCA) has declared surface water impairments for acetochlor and chlorpyrifos in select watersheds, resulting in contaminant reduction efforts within the context of the MPCA's Total Maximum Daily Load (TMDL) program.

While core MDA WQ Pesticide BMPs are designed to minimize loss of all pesticides, certain BMPs specifically address the use of acetochlor, atrazine and chlorpyrifos. Support material (Table 12b) provides guidance to the certification technician on how to apportion WQI-pm ratings based on a more refined assessment than afforded by use of Table 12a.

<u>Table 12a</u>: Pest management practices, MDA pesticide BMPs and associated WQI-pm

Description of Practice	WQI-pm
Advanced IPM: low risk IPM plus cultural practices that minimize pests	10
Low Risk IPM: basic IPM plus uses alternatives with lower risk for runoff and/or rotates pesticides	7.5
Basic IPM: low risk control plus uses threshold-based suppression	5.0
Low Risk Pest Control: basic control plus uses < maximum label rates and any pesticide-specific additional vegetative buffers or application setbacks	4
Basic Pest Control: suppression with only label-required mitigation (e.g., veg. buffers or application setbacks)	2

Table 12b is shown below and can be used to further assess IPM activities as they relate to both core and pesticide-specific MDA WQ Pesticide BMPs.

To obtain the assigned rating for a given practice (Column 1 of Tables 12a and 12b), the certification technician must assess additional factors used by the farmer for any pesticide(s), as well as those used if acetochlor, atrazine and chlorpyrifos are applied to fields.

A WQI-pm rating will be easiest to assign if there is no use of acetochlor, atrazine or chlorpyrifos and only core BMP factors are assessed by the certification technician; however, if one or more of those pesticides are used, assigning the WQI-pm rating will require that the certification technician also assess pesticide-specific factors that accompany related core BMP factors as indicated in Table 12b.

Table 12b: MDA WQ Pesticide BMPs – Additional Factors for WQI-pm ratings

<table>
<tr><th>IPM Practice Level (from Table 12-A)</th><th colspan="2">Pesticide BMP factors</th></tr>
<tr><td>Advanced IPM: low risk IPM <i><u>plus</u></i> uses cultural practices that minimize pests</td><td colspan="2">Adjusts planting rates, timing, crop rotations, irrigation schedules or field machinery cleaning to disrupt or otherwise minimize annual carryover of pests or field conditions for pest outbreaks.</td></tr>
<tr><td>Low Risk IPM: basic IPM <i><u>plus</u></i> uses alternatives with lower risk for runoff and/or rotates pesticides</td><td colspan="2">Works with professionals to select pesticides with low loss ratings for soil runoff and/or rotates among those with different modes of action.</td></tr>
<tr><td>Basic IPM: low risk control <i><u>plus</u></i> uses threshold-based suppression</td><td colspan="2">Scouts fields for pests, maps infestations each year. Determines if control results in crop yield benefits or longer term pest suppression.</td></tr>
<tr><td></td><th>Core BMP factors for farmer using any synthetic or organic pesticide</th><th>Pesticide-specific BMP factors for farmer using acetochlor, atrazine or chlorpyrifos</th></tr>
<tr><td>Low Risk Pest Control: basic control <i><u>plus</u></i> uses < maximum label rates and any pesticide-specific additional vegetative buffers or application setbacks</td><td>Reduces application rates based on a label “rate range” and/or precision application methods; scouts for weed escapes or pest outbreaks, with subsequent applications only when necessary.</td><td>Atrazine:
• Uses ≤ 0.8 lbs a.i./yr in SE MN except on medium and fine textured soils where up to 1.0 lbs a.i./yr can be used.
• Employs application setbacks or buffers around tile inlets.
Acetochlor:
• Uses lower, early-season post-emerge weed control in herbicide tolerant crop production.
• Installs a 30-ft. or wider vegetative filter strip (66 ft. if in a watershed with acetochlor impairments) at points of field runoff.</td></tr>
<tr><td>Basic Pest Control: suppression with only label-required mitigation (e.g., vegetative buffers or application setbacks)</td><td>Reads labels and abides by legally required water quality protection restrictions.</td><td>Atrazine: Does not apply within 200 feet of lakes and reservoirs, and 66 feet from points where runoff enters streams and rivers.
Acetochlor: If applied with atrazine, application setbacks for atrazine are followed.
Chlorpyrifos: For soil- or foliar-applied liquid products, does not apply:
• within 25 ft. of water bodies for ground applications;
• within 150 ft. of water bodies for aerial applications.
For soil applied granular products, does not apply:
• within 150 ft. of water bodies for aerial applications.</td></tr>
</table>

3. Combining sub-indices into a single index score

Table 13 presents a hypothetical scenario for WQIag calculation by aggregating values of different WQI sub-indices such as WQI-fs, WQI-nm, WQI-tm, and WQI-pm; and then adjusted for irrigation and tile-drain management systems and/or additional conservation practices if applicable (discussed later). The WQI-fs is arrived at by combining four field sensitivity/physical components namely K-factor (WQI-fkf), Hydrologic Soil group (WQI-fhg), OM factor (WQI-fom), and Rainfall/Vegetation interaction (WQI-fvr) as illustrated **Table 6**. The WQI-nm integrates the components of nutrient management namely nitrogen application rate, phosphorus application rate, synthetic source, timing and placement and manure application timing and placement as demonstrated in **Table 10a and 10b**. The overall WQIag is then arrived at by combining the WQI-fs, WQI-nm, WQI-tm, and WQI-pm (**Table 13**). The weighting of these sub-indices is 0.25, 0.35, 0.25 and 0.15 for WQI-fs, WQI-nm, WQI-tm and WQI-pm, respectively.

For the hypothetical scenario (**Table 13**), the overall WQIag is arrived at 7.92 in the scale of 1-10. This number is not reduced since there is no irrigation and no tile drains. In these models, the WQI ranking of 60 is classified as poor water quality which is expected for the runoff water from the agricultural fields, though in this example it has already been exceeded. When one or more additional conservation practice(s) are applied, WQIag improves based upon the cumulative impact of their effectiveness. For the current scenario, a single conservation practice namely the contour buffer strips increases the WQIag to 8.86. This increase is based upon the WQIag adjust factor of 45% using the model discussed later in the "**Integrating Conservation Practices in WQIag**" section.

Table 13: Integrating field sensitive/physical and management (nutrient, tillage and pest) factors into a single WQIag

Factors	Description	Ranking WQI Ranking (WR)	WQI Ranking (WR)	WQI Ranking (WR)
	Field Sensitivity Factors (WQI-fs) (For field slope range between 2-5%)			
Hydrologic Soil Group	B- moderately low runoff potential	8	.1	0.8
K-Factor	0.30 (0.21- 0.32 moderate erodibility)	8	.1	0.8
OM Content	5% (4-6% range)	7	.4	2.8
Rainfall/Vegetation	Annual mean average for the example case	5.22	.4	2.09
WQI-fs (Aggregated value of slope, K-factor, OM Content, and Rainfall /vegetation rankings**)**			**1.00**	**6.49**
Nutrient Management (WQI-nu)				
N Application Rate	UMN BMP Recommendation	10	0.21	2.1
P Application Rate	UMN Recommendation	10	0.21	3.0
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.14	0.84
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.075	0.45
Synthetic Fertilizer Timing	Acceptable with Risk	6	0.075	0.45
Manure Application Timing & Placement	Incorporated / Injected Fall > 50° F	4	0.29	1.16
WQI-nu (Aggregated value of Application rate, N-Source Application & timing, P-Source Application & Timing, and Application methods & Soil Condition**)**			**1.0**	**8**
Tillage Management (WQI-tm)	Reduced till with a STIR value of >30-80			**8.0**
Pest Management (WQI-pm)	Advanced IPM: Low risk IPM plus cultural practices that minimize pests			**10.0**

	WQI-fs	WQI-nm	WQI-tm	WQI-pm
WQI Ranking (WR)	6.49	8	8.0	10.0
Weight Factor (WF)	0.25	0.35	0.25	0.15
Weighted Value (WR*WF)	1.62	2.8	2.00	1.5

WQIag (Weighted mean value of WQI-fs, WQI-nm, WQI-tm, & WQI-pm)		**7.92**
Irrigation Method and Adjustment	No Irrigation (0%)	**7.92**
Tile Drain System	No tile drain (0%)	**7.92**
Additional Conservation Practice(s) and their adjustment	Contour buffer strips (+45%)	**8.86**

4. Adjusting WQIag for Irrigation and Tile Drainage Systems

Irrigation is used to supplement rainfall for successful crop production. The negative effects of irrigation on the overall quality of water from an agricultural field have been documented (Trout, undated and URC, 2006). In addition, irrigation methods influence water quality based upon field slope and its soil physical properties such as organic matter (OM) content, hydrologic soil group and Kw factor. For example, if the producer decides to irrigate and saturate a field at the tail end of a dry spell; it would generate much higher runoff from a rainfall event than an adjacent field that did not get any irrigation -- thus leading to lower WQIag value. The impact of irrigation, however, depends upon a number of factors including well capacity to field size, droplet size and field slope.

There are some other considerations that certifiers should consider when scoring the irrigation section. Firstly, droplet size is a factor to consider especially before canopy closure. Soil impact and sealing can occur on fine textured soils when sprinkler guns, such as those found on center pivots or traveling guns, are employed.

Secondly, consider the size of the field in relation to the capacity of the irrigation system. A high field size to irrigation capacity ratio makes in more difficult to use all aspects of irrigation water management. For example, a producer may be more likely to leave an irrigation system running if they are uncertain about an upcoming rainfall event if they have a lower capacity irrigation system serving a large field. If the predicted rain does not occur, there could be soil water deficit and their irrigation system unable to quickly respond on large field. Based on Soil and Water Conservation District's irrigation experts, wells greater the 200 gpm on outsized fields move significant amounts of water to increase the risk of runoff events on certain soil types.

Irrigation induced runoff is also a factor of slope. While the assessment tool takes into consideration slope, it may be helpful in determining between irrigation scoring options to consider the Mid Elevation Spray Application (MESA) standard. The NRCS uses this standard for some conservation practices. MESA states that the slope shall not exceed 3% over 50% of the acres with fine textured soils, and 5% slope on coarse textured soils. If a producer is irrigating on steeper slopes, this could also be taken into consideration in your scoring consideration.

If an irrigation water management system is employed, such as Conservation Practice 449 or similar, the field is eligible for the lower score adjustment of -1.5%. **Table 14** gives the percentage used for adjusting the WQIag value for different irrigation methods.

Table 14: Percentage reduction in WQIag for different irrigation methods

Irrigation Method	% WQIag Adjustment
No Irrigation	0%
Higher impact irrigation	-10%
Irrigation Scheduling (CP 449 or similar)	-1.5%
Trickle / Drip	0%
Lower impact irrigation	-5%

Contrary to irrigation needs in the drier regions, the lands in the humid regions need drainage for successful agricultural production. Although drainage allows production on wet soils, drainage water carries nutrients, sediment, pesticides and other pollutants to surface waters. Inlet type can influence the amount and sources of pollutants.

Systems 'without Open inlets', as the name implies include systems that are engineered without open inlets or those that contain rock inlets, French drains, water quality inlets or sufficient vegetative filters around inlets.

Fields that achieve a 9 or greater in both the nutrient management and tillage management sub-indices AND have closed inlets are eligible for a 0% adjustment on the tile drainage system. The logic behind this is that, under certain conditions, subsurface drainage may reduce the risk of surface runoff because saturated soil conditions are reduced. However, in turn, subsurface drainage may increase the risk to water quality by way of a different pathway: nitrate-nitrogen pollutants via the soluble pathway. However, a producer that is following the BMPs and building soil health through reduced tillage, is lowering the potential risk of nitrogen loss in the subsurface tile, and therefore negating the impact of tile on water quality risk.

Surface water quality problems caused by pollutants from the drained agricultural lands have been well documented. However, it has also been shown that a proper management of drained water prior to it entering a waterbody can nullify some of the negative effects of the drainage system. These systems could include controlled drainage, wetlands, bio-rectors, vegetative filters, etc. **Table 15** presents the percentage adjustment, negative or positive, for different type of tile drain systems with or without drainage water management system.

<u>Table 15:</u> Percentage adjustment in WQlag for different tile drains with and without drainage water treatment

Tile drain system	% WQIag Adjustment
No Tile Drain	0%
Tile Drainage with Open Inlets	-20.0%
Tile Drainage without Open Inlets	-15.0%
Tile Drainage with drainage water management	10%
Tile Drainage with Average Nutrient Management & Tillage Management >=9 and without open inlets	0%

5. Integrating Conservation Practices into WQIag

The quality of runoff water from an agricultural field can be improved considerably by implementing conservation practices also known as agricultural best management practices (BMPs). These practices can be field level practices which impact the entire field, such as contour strip-cropping; or site specific practices such as grassed waterways which address a specific gully issue on just a portion of the field. The effectiveness of these practices in controlling pollutants can vary significantly from one location to another. Furthermore how these effectiveness values should influence the WQIag is anybody's guess. Thus, for the present model we used effectiveness values reported by various studies with slight adjustment based upon authors' and other professional experiences. The practices receive adjustments of 35% or 45% to the Adjusted WQI score **Table 16** presents the list of conservation practices currently implemented in the WQIag model. More information on conservation practices is available from the Minnesota Department of Agriculture "The Agricultural BMP Handbook for Minnesota", September 2012.

Table 16: Conservation Practices and their effectiveness modeled in WQIag system

Conservation Practice		**WQIag Adjust Factor %**
Name	**Type**	
Contour Strip-cropping 1	Field	45%
Contour Buffer Strip 2	Field	45%
Cover crop 1	Field	45%
Sediment Basins 3	External	35%
Field Borders 2	Field	45%
Riparian Forest Buffer 4	External	45%
Filter Strip 2	External	45%
Grass Waterway 5	External	35%
Conservation Cover 7	Field	45%
Water & Sediment Control Basin 6	External	35%
Grade Stabilization Structure 7	External	35%

1. *Merriman et al. 2009; Gitau et al. 2005*
2. *Arora et al., 1996*
3. *MPCA, 2005*
4. *Miller, T. P., 2012*
5. *Fiener P, Auerswald K.2003*
6. *Mielke (1985)*
7. *Wilson et al. (2008)*

Table 16 that is implemented into the WQIag using the following model:

Assuming:
Water Quality Index prior to conservation practice = "WQIag "
Conservation Practice Adjust Factor = "Eff"

WQIag <= 5.5 ***mid-point range of the WQIag between 1 to***
= WQIag(1+Eff/100)

WQIag > 5.5
= (WQIag + ((10-WQIag)*Eff/100))

The above model improves the WQIag ranking directly proportional to the WQIag adjust factor (Eff) for low ranges of WQIag -- less than or equal to 5.5. For WQIag values higher than 5.5, the effect of conservation practice on the WQIag is reduced considerably. This model captures two fundamental behaviors of conservation practices in real world condition. When dirty water with low WQIag value passes through a conservation practice, there is high concentration of contaminants to capture thus it comes out much cleaner at the other end. On the other hand, when cleaner water passes through a conservation practice, it does not contain as many pollutants thus it would not impact the water quality as much related to initial WQIag. Furthermore the model would not allow the WQIag to ever exceed more than 10 as shown in **Table 17.** This table presents an example of changes in WQIag values with application of up to three conservation practices with starting WQIag value from 2 to 9 and their ability to improve water quality of the agricultural runoff

Table 17: Effect of multiple practices on WQIag

<table>
<tr><th colspan="2">Conservation Practice</th><th colspan="2">Average Effectiveness</th></tr>
<tr><td colspan="2">Con 1</td><td colspan="2">35%</td></tr>
<tr><td colspan="2">Con 2</td><td colspan="2">45%</td></tr>
<tr><td colspan="2">Con 3</td><td colspan="2">35%</td></tr>
<tr><th>WQIag</th><th>WQI (Con1)</th><th>WQI (Con1+2))</th><th>WQI (con1+2+3)</th></tr>
<tr><td>2</td><td>2.7</td><td>3.9</td><td>5.3</td></tr>
<tr><td>3</td><td>4.1</td><td>5.9</td><td>7.3</td></tr>
<tr><td>4</td><td>5.4</td><td>7.8</td><td>8.6</td></tr>
<tr><td>5</td><td>6.8</td><td>8.2</td><td>8.8</td></tr>
<tr><td>6</td><td>7.4</td><td>8.6</td><td>9.1</td></tr>
<tr><td>7</td><td>8.1</td><td>8.9</td><td>9.3</td></tr>
<tr><td>8</td><td>8.7</td><td>9.3</td><td>9.5</td></tr>
<tr><td>9</td><td>9.4</td><td>9.6</td><td>9.8</td></tr>
</table>

6. MAWQCP Assessment Tool

To track the fields being reviewed for the Minnesota Water Quality Certification Tool, we developed a simple and user-friendly website (https://mnwatercertify.mda.state.mn.us/). The website allows users to enter information into the assessment tool and then save it to their computer. No credentials or log-in is required. The online tool also has a mapping feature which allows users to draw in their field and then query and auto populate many variables such as slope, weather data, location information and soil attributes.

7. Concluding Remarks

The Water Quality Index (WQI) used for the Minnesota Water Quality Certification Program takes complex information and data regarding water quality risk and combines them into single value that represents an overall snapshot of the risk to water quality a particular time and location. Traditionally WQI has been developed and used for evaluating water quality of water resources such as streams, rivers and lakes (Lal, 2011).

This technical note is the first attempt to define a WQI model, referred to as WQIag, for evaluating the risk to water from agricultural fields. WQIag incorporates subjective judgment on ranking different factors that influence runoff water from agricultural fields. In addition, the concept of weighting factors has been introduced to incorporate site-specific local preferences for different subcomponents to the overall WQIag.

WQIag is not a form of water quality monitoring. The index is designed not only to track the aggregate score but also factors that contribute to this change in order to provide information back to the producer for adaptive management in farm operations. Although the WQIag is not an instrument of water quality monitoring it could in fact be correlated to data-driven monitoring at different spatial scales (reach, watershed or basin). A WQIag score or trend may have a relationship to nutrient load monitoring in stream studies conducted by other agencies or entities. Most information required to calculate a WQIag score could be available in NRCS planning files. Thus this index could be constructed retrospectively as well as with new or planned activities. As discussed above, the WQIag could represent an important gauge of water quality for the nation’s agricultural sector. In absence of quantitative monitoring, the WQIaq could play an important role in assessing water quality at the field level and across the landscape in a cost effective way.

The WQIag could also serve as a tool for evaluating the success of conservation practices for improving water quality. It could provide answers to commonly asked questions: how effective a conservation practice, cost-shared by NRCS, has been in improving the water quality. The simplicity of WQIag in expressing the water quality lends itself well to communicating the complex interrelationships involved with measuring water quality.

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