BEST MANAGEMENT PRACTICES FOR NITROGEN IN MINNESOTA

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__*ABSTRACT*__

Attention to nitrogen (N) management and to the influence of N on groundwater quality was significantly enhanced in Minnesota with the passage of the Comprehensive Groundwater Protection Act in 1989. That legislative act mandated the formation of a Nitrogen Fertilizer Task Force whose duty was to study the effects and impacts on water resources from N fertilizer use so that best management practice (BMPs), a fertilizer management plan, and N fertilizer use regulations could be developed. The task force met 10 times including two hearings out in the state to listen to the concerns of farmers, dealers and other interested citizens. Specialists were brought in from Iowa, Nebraska and the National Fertilizer and Environmental Research Center (TVA) as well as from numerous state agencies to share their experience and knowledge with the task force. The following paper describes the BMP section of the final document and how the three-tier strategy affects N management recommendations in Minnesota.

The Comprehensive Groundwater Protection Act of 1989 significantly altered the direction of water resource protection with regard to nitrogen (N) fertilizer management in Minnesota. This was a result of three separate but related components of the Act: (1) the development of a groundwater protection goal, (2) the enhanced regulatory authority for fertilizer practices within the Minnesota Department of Agriculture (MDA) and (3) the responsibility for development of a Nitrogen Fertilizer Management Plan (NFMP) by the Minnesota Department of Agriculture.

Because of the complexity of N fertilizer effects on water resources, and the controversial nature of associated management decisions, the Legislature authorized the MDA to establish a Nitrogen Fertilizer Task Force to make recommendations to the Commissioner of Agriculture on the structure of the NFMP. Legislative direction stated "the task force must include farmers, representatives from farm organizations, the fertilizer industry, University of Minnesota, environmental groups, representatives of local government involved with comprehensive local water planning, and other state agencies, including the pollution control agency, the department of health, the department of natural resources, the state planning agency, and the board of water and soil resources".

The primary goal of the NFMP developed by the N Task Force was to manage N inputs to crop production so as to prevent degradation of Minnesota water resources while maintaining farm profitability. The central tool for achievement of this goal is the adoption of **best management practices** which were based upon the concept of **total nitrogen management**. Because of the ability to manage and control plant nutrients, the primary focus of the BMPs is N fertilizer. However, consideration of other N sources and agronomic practices was necessary for an effective and practical total N management system.

Best Management Practices (BMPs) are defined in Minnesota Statute as:

> "... voluntary practices that are capable of preventing and minimizing degradation of groundwater, considering economic factors, availability, technical feasibility, implementability, effectiveness, and environmental effects".

The nitrogen BMPs recommended by the task force are based upon research, particularly that which has been conducted at the University of Minnesota and other land grant universities, and upon practical considerations. This ensures that the BMPs are technically sound and, at the same time, likely to be adopted by growers.

THE TREE-TIER BMP STRATEGY

The task force developed a three tier structure of BMPs for Minnesota. The first tier is a set of BMPs, which are not crop or region specific, to be adopted throughout the state. The second tier consists of five sets of regional BMPs, each designed to be adopted in one of the five general regions of the state. The third tier consists of BMPs for special situations which exist and present unique environmental or management concerns.

STATEWIDE BMPS (Tier 1)

Statewide BMPs can be considered to be "generic" in that they apply to all areas in the state. The succeeding tiers refine the statewide recommendations. In general, statewide BMPs are applicable to all cropping systems and agronomic practices. The statewide BMPs were based upon the concept that accurate determination of crop N needs is essential for profitable and environmentally sound N management decisions. The statewide BMPs are:

1) Develop realistic yield goals. The yield goal, specific for each field, should be based on the past five-year average and exclude the worst year.
2) Develop and utilize a comprehensive record keeping system to record field specific information.
3) Adjust N rate according to soil organic matter content, previous crop and manure application.
4) Use a soil nitrate test when appropriate.
5) Use prudent manure management to optimize N credit.
   a) Test manure for nutrient content.
   b) Calibrate manure application equipment.

c) Apply manure uniformly throughout a field and do not apply over the recommended rates.
d) Injection of manure is preferable, especially on strongly sloping soils.
e) Incorporate broadcast applications whenever possible.
f) Avoid manure application to sloping, frozen soils.

6) Credit second year N contributions from alfalfa and manure.
7) Do not apply N fertilizer above recommended rates.
8) Nitrogen applications should be timed to achieve high N-use efficiency.

REGIONAL BMPS (Tier 2)

In order to achieve a goal of minimizing environmental impacts while optimizing agricultural profits, BMPs must account, to some extent, for local variation in soils, hydrogeologic conditions, and climatic conditions. In this interest, the state has been divided into five regions based upon general climatic conditions, soil characteristics and the resulting sensitivity to groundwater contamination. Figure 1 depicts the locations of the five regions in the state. The regional BMPs refine the prescriptions of the statewide BMPs.

Southeastern Minnesota

Southeastern Minnesota is characterized by permeable, silt loam soils with underlying fractured limestone bedrock. This karst region is very susceptible to groundwater contamination. Average annual precipitation in the region is greater than 30 inches. Cropping systems include corn, forages, oats and soybeans. Livestock production consists primarily of dairy, beef and hogs.

1) **Do not apply fertilizer N in the fall.**

   The risk of leaching loss of nitrate from fall N application is heightened in southeastern Minnesota due to the high average annual precipitation, the well-drained and permeable nature of the soils and the presence of karstic terrain. Spring pre-plant or sidedress N applications provide for more efficient use.

2) Anhydrous ammonia or urea sources of N should be used in spring preplant applications. Broadcast urea should be incorporated within three days of application. Consult the Soil Conservation Service for further information if soils are high erosive.

3) Sidedress applications to corn should be applied prior to the V4 stage of development.

4) Sidedress applications of urea and UAN-28 should be injected or incorporated to a minimal depth of four inches.

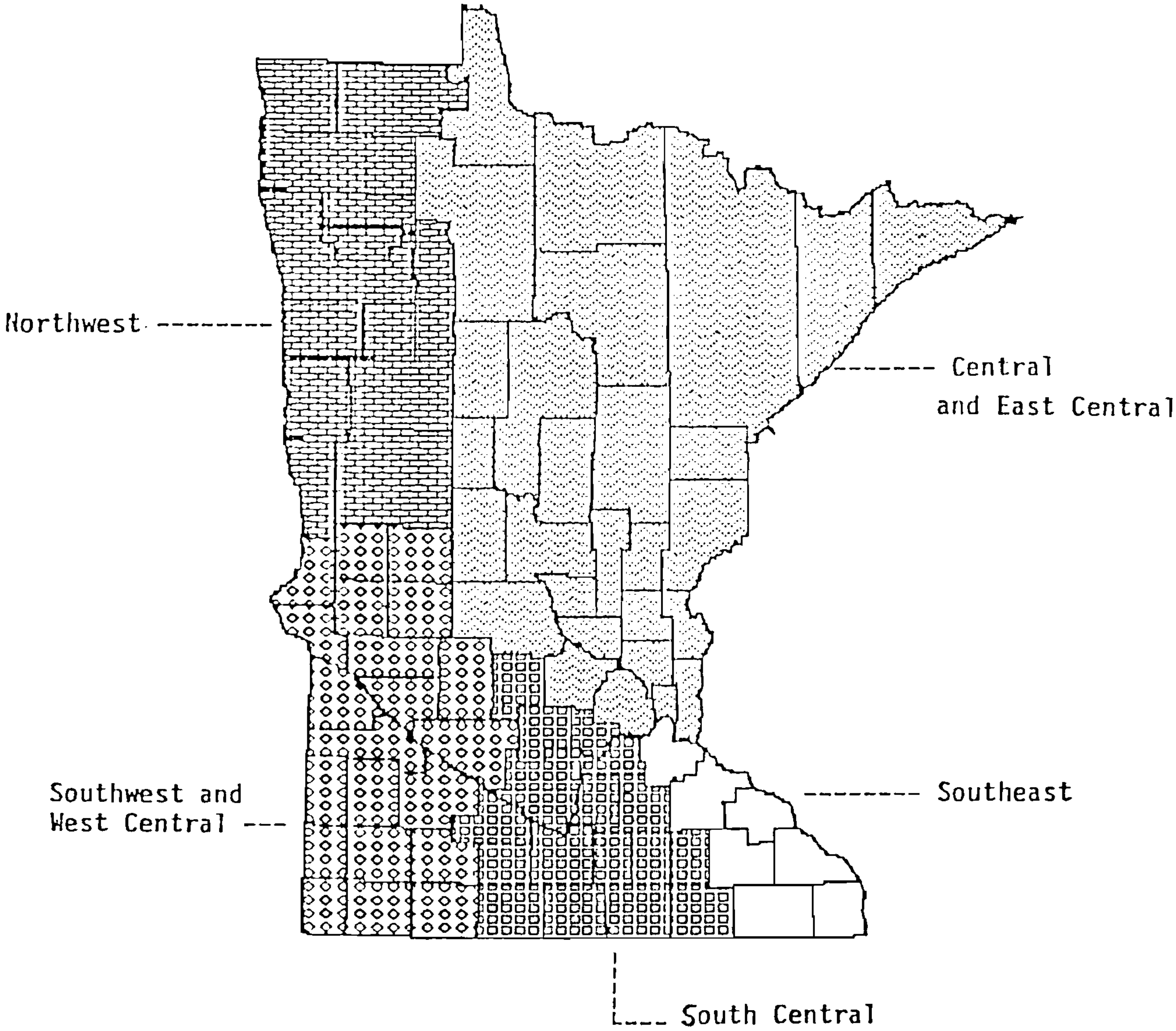

Fig. 1. The five regions for which BMPs are formulated.

5) A nitrification inhibitor should be used with pre-plant N applications if soils are poorly drained and soil moisture levels are high in the upper portion of the profile. Check label for registered crops.

6) Minimize direct movement of surface water runoff to sinkholes.

Results from University of Minnesota trials in southeastern Minnesota during the last few years reinforce the above BMPs. A continuous corn study started in 1987 clearly demonstrates that N should not be applied at above recommended rates and not in the fall (Table 1). Highest 4-yr average yields occurred with the 150-lb N rate; however, NO_3-N concentrations in the soil water at 5' also began to climb rapidly at this rate. Perhaps a N rate of about 120 lb/A would have optimized yield and profitability to the farmer while minimizing nitrates in the groundwater.

Fall application (Nov. 13) of anhydrous ammonia with and without N-Serve gave yields in 1990 that were 7 to 10 bu/A less than with the same N rate applied in the spring before planting (Table 1). Moreover, NO_3-N concentrations in the soil water were 50 to 70% higher with the fall applications. Split application of anhydrous ammonia (50% preplant + 50% sidedress at 8 to 10-leaf stage) did not improve yields over the preplant treatments but did result in higher NO_3-N concentrations in the soil water.

Table 1. Effect of N treatments on the 1990 and 4-yr average corn yields and NO_3-N concentrations in the soil water at 5' in Olmsted Co.

Tillage	N rate	Time/Method	Grain Yield 1990	Grain Yield '87-90	Nitrate-N[1/] Conc. in Water
	lb/A		-------- bu/A --------		----- mg/L -----
Chisel	0	--	76	84	1
"	75	Spr. preplant	145	156	11
"	150	"	155	172	29
"	225	"	156	167	43
"	150	Fall	145	169	43
"	150	Fall + N-Serve	148	169	50
"	75 + 75	Spr. + SD	154	168	47
No till	150	Spr. preplant	140	168	20

[1/]In ceramic cup samplers on Sept. 5, 1990.

South Central Minnesota

South-central Minnesota is characterized by fine-textured soils formed in glacial till and sediments. Most soils have naturally poor-to-moderate internal drainage and are tiled to improve drainage. Average annual precipitation in the region is 25 to 30 inches. Cropping systems are predominantly corn and soybeans.

1) Spring preplant applications of N are highly recommended over fall applications.

2) If the N is fall applied, delay application until the soil temperature is below 50°F at a six-inch depth. Anhydrous ammonia should be used for fall applications.

3) Anhydrous ammonia or urea sources of N should be used in spring preplant applications. Broadcast urea should be incorporated within three days of application. Consult the Soil Conservation Service for further information if soils are highly erosive.

4) Sidedress applications to corn should be applied prior to the V4 stage of development.

5) Sidedress applications of urea and UAN-28 should be injected or incorporated to a minimal depth of four inches.

6) A nitrification inhibitor should be used with fall or preplant N applications in poorly drained soils that have high moisture levels in the upper portion of the profile.

7) Carefully manage N applications on soils characterized by a high leaching potential.

    a) Do not apply fertilizer N in the fall to coarse-textured soils.

    b) When soils have a high leaching potential, application of N in a sidedress or split application program is preferred. Use a nitrification inhibitor with early sidedressed N on labeled crops.

Results obtained at Waseca corroborate these BMPs's. Fall application of ammonium sulfate in early November resulted in significantly lower corn yields than spring applications (Table 2). Moreover, NO_3-N lost out of the tile lines was markedly higher with the fall applications.

Table 2. Corn yields and NO_3-N lost thru the tile lines as influenced by N rate and time of application at Waseca.

N Treatment		1978-82	1978-81 NO_3-N lost
Rate	Time	Yield Avg.	thru tile lines
lb N/A		bu/A	lb/A
0	--	66	28
120	Fall	131	107
120	Spring	150	75
180	Fall	160	136
180	Spring	168	106

Since the data in Table 2 were obtained using ammonium sulfate, many farmers questioned whether the same results would occur if anhydrous ammonia (AA) was used. Results obtained on a Webster clay loam at Waseca in 1990 show the highest NO_3-N concentrations in the tile water and greatest NO_3-N losses with the fall-applied AA without N-Serve (Table 3). The addition of N-Serve to the fall AA reduced NO_3-N concentrations slightly but not to the level of the spring and split applications without N-Serve. Corn yields did not vary greatly among the four N treatments.

Southwest and West-Central Minnesota

The Southwest/West Central region of Minnesota is characterized by soils of medium-to-fine texture which were formed in glacial till. Many soils in the region have naturally poor to moderate internal drainage and are consequently tiled to improve drainage. Average annual precipitation is less than 26 inches. Cropping systems are dominated by corn, soybeans and small grains.

Table 3. Nitrate-N losses through tile lines at Waseca during 1990 and corn yield as influenced by time of N application to corn following soybeans.

Parameter	Time of Application: Fall No N-S	Fall N-S	Spr (No N-S)	Spr + SD (No N-S)
Drainage (acre-in)	13.9	10.3	9.9	11.7
NO_3-N Loss (lb/A)	109	69	60	74
Flow-weighted NO_3-N Conc. (PPM)				
May	36	30	29	28
June	38	34	30	29
July	41	38	32	28
August	25	19	20	23
Corn yield (bu/A)	146	146	142	151

1) Use a soil nitrate test with a two to four foot depth to determine N needs. Soil samples should be taken in the fall, after the soil temperature is below 50°F at the six-inch depth, or in early spring.

2) Anhydrous ammonia or urea are recommended in spring preplant applications. Broadcast urea and preplant applications of UAN-28 should be incorporated within three days of application. Consult the Soil Conservation Service for further information if soils are highly erosive.

3) In situations where fall N applications are used, delay application until the soil temperature is below 50°F at a six-inch depth. Use anhydrous ammonia or urea sources of N. UAN-28 should not be fall-applied.

4) Sidedress N to corn should be applied prior to the V4 stage of development.

5) Sidedress applications of urea and UAN-28 should be injected or incorporated to a minimal depth of 4 inches.

Benefits from using the soil NO_3-N test to provide fertilizer N recommendations in western Minnesota can be readily seen from data collected at Lamberton in 1990 (Table 4). Soil samples taken in the spring to a 5-foot depth and analyzed for NO_3-N show substantially more residual NO_3 in the profile following corn compared to following soybeans. Based on NO_3-N in the top four feet and a yield goal of 140 bu/A, fertilizer N recommendations of 31 and 116 lb/A for continuous corn and corn following soybeans, respectively, were applied. This amount for continuous corn was 120 lb N/A less than the recommendation without the soil NO_3-N test. Corn yields for the two cropping systems were not different. Nitrate-N concentrations in the tile water reflected the accumulation of NO_3 in the soil profile for continuous corn especially in May.

Table 4. Residual soil NO_3-N, corn yield and NO_3-N losses from tile lines as influenced by continuous corn compared to a corn-soybean rotation at Lamberton in 1990.

1989 Crop: / Parameter 1990 Crop:	Corn / Corn	Corn / Soybeans	Soybeans / Corn
Nitrate-N in top 5' of soil (lb/A)	168	136	75
N recommended & applied based on soil NO_3-N (lb/A)	31	0	116
N rate recommended without soil test (lb/A)	150		120
1990 Corn Yield (bu/A)	120		123
May-June			
Tile flow (inches)	0.8	1.1	0.7
NO_3-N loss (lb/A)	5.3	6.2	3.6
NO_3-N Conc. (mg/L)			
May	27	20	16
June	34	33	27

East-Central and Central Minnesota

The Central/East-Central region of Minnesota is characterized by soils of coarse-to-medium texture. Most soils in the region were formed in glacial till. Outwash plains are common in this region. Many central/east-central soils are moderately- to excessively-drained. Average annual precipitation in the region is greater than 25 inches. Cropping systems are dominated by corn and forages.

1) Carefully manage N applications on soils that have a high leaching potential.

2) Anhydrous ammonia or urea sources of N should be used in spring pre-plant applications on fine and medium-textured soils. Broadcast urea should be incorporated within three days of application. Consult the Soil Conservation Service for further information if soils are highly erosive.

3) Sidedress applications of urea and UAN-28 should be injected or incorporated to a minimal depth of four inches.

Northwest Minnesota

The northwest region is generally characterized by fine textured soils formed in lacustrine deposits. The annual average precipitation in the region is less than 24 inches. The major cropping systems in the region are small grain, soybeans and sugar beets.

1) Use a soil nitrate test to a two or four foot depth to determine N needs. Soil samples should be take in the fall after the soil temperature is below 50°F at the six-inch depth or early spring.

2) Delay fall N application until the soil temperature is below 50°F at a six-inch depth. Anhydrous ammonia or urea sources of N should be used for fall applications. UAN-28 should not be fall applied. Broadcast urea and spring pre-plant applications of UAN-28 should be incorporated within three days of application. Consult the Soil Conservation Service for further information if soils are highly erosive.

3) Nitrification inhibitors are not recommended on fine-textured soils but are recommended on coarse-textured soils with high leaching potential.

SPECIAL SITUATION BMPS

The third tier of BMPs are referred to as Special Situations BMPs. The special situations are a result of certain combinations of management and environmental conditions that may render an area or site more susceptible to groundwater contamination than would be predicted by the general characteristics of the surrounding region. The third tier accounts for those management situations or sites which are interspersed throughout the state.

Irrigated Soils

Irrigation, especially on coarse-textured (sandy) soils and shallow-rooted crops, may increase the leaching potential of applied N. Irrigation increases the soil water content of the root zone, thus enhancing mass and diffusive transport of nitrate in the subsurface past the zone of effective crop utilization.

Irrigated soils in Minnesota were typically formed in outwash plains or alluvium and are consequently of coarse texture. Localized areas of irrigation occur throughout the state. Water use in these areas is variable depending upon soil and geologic conditions and average yearly precipitation. Commonly irrigated cropping systems include corn and potatoes.

1) **Do not fall-apply fertilizer N to soils in the following textural classes: sandy loam, loamy sand and sand.**

2) Follow proven water management strategies to provide effective irrigation and minimize leaching.

3) Test irrigation water for N content and adjust N fertilizer rates accordingly.

4) Use sidedress or split applications of N on irrigated soils. Do not rely on fertigation for delivering more than one-third of the required N. (Fertilizer chemigation rules are being developed by the Minnesota Department of Agriculture at this time. Backflow prevention, well head safety and other techniques are recommended until rules are adopted.)

5) Use a nitrification inhibitor when the bulk of the N is applied in a single preplant or early sidedress application. For corn, N treated with a nitrification inhibitor should be applied prior to the V4 growth stage. Check label for registered crops.

6) Include a small amount of N in starter fertilizer in most situations (10 to 20 pounds/acre).

7) Do not delay N applications past optimum uptake period.

8) Establish a cover crop following early harvest of crops. Consult the Soil Conservation Service for further information if soils are highly erosive.

Coarse-Textured (Non-Irrigated) Soils

Coarse-textured soils need special management to prevent leaching losses. Coarse-textured soils are present in many different regions and can be found throughout the state in outwash plains, alluvial river valleys and ancient beach ridges. These soils have considerable leaching loss potential due to rapid infiltration characteristics and low water holding capacities which can easily be exceeded. Furthermore, these soils are often associated with unconsolidated sand and gravel aquifers that may have water tables that are near the soil surface.

1) **Do not apply N fertilizer in the fall to coarse-textured soils.**

2) Apply N in a sidedress or split application program

3) Use a nitrification inhibitor with early sidedressed N.

Turf

As a source of nitrates to groundwater, the lawn care industry has historically received less attention than the agricultural community. This is due, in part, to the reliance of rural populations on groundwater as a source of drinking water. However, fertilizer application rates to turf may be comparable to agronomic crops and urban fertilizer use is quite widespread. The resulting intensity of N application warrants the development and prescription of BMPs specifically for lawn care.

Turf management presents its own unique N fertilizer concerns. The following BMPs are applicable to a variety of turf situations, including private lawns, commercial properties and most golf course turf.

1) Avoid off-target applications.

2) Apply the majority of N during late summer to mid-fall. Spring N applications should be reduced or discontinued. Light applications of N may be applied in mid-summer to high-traffic areas.

3) Utilize a soil test to determine organic matter content which can be used to aid in determination of N needs; use the results of this test to adjust applications to the individual lawn.

4) Leave grass clippings on mowed lawns and account for residue N content in determining N load rates for subsequent applications.

5) Use slow release fertilizer formulations when possible.

6) Account for soil type in determining appropriate N application rate and frequency.

7) Select low-maintenance turf varieties which require less fertilizer and less water.

8) Do not apply insurance N to turf. Apply only the amount of N necessary to maintain plant nutrition.

BMPs For Areas Near Surface Water Bodies

Nitrogen from fertilizer as well as from other sources can have a direct impact on water quality of rivers and lakes. Nitrogen can move either through direct runoff, by means of erosion, via tile line drainage, subsurface flow, and shallow groundwater flow. Surface water is used for a public drinking water in a number of communities in Minnesota. These BMPs focus on areas near surface water bodies and primarily control erosion and runoff from agricultural fields to streams and lakes.

1) Filter strips should be developed and maintained between open bodies of water and agricultural fields.

2) Establish tillage and erosion control techniques, such as conservation tillage systems and terraces, where erosion contributes to surface water contamination.

3) For lawns located adjacent to surface water bodies, construct a berm (roughly six inches high) between the lawn and water body. The berm may also be covered in grass or turf. In addition to berms, an unmanaged fringe of natural vegetation may be utilized as a filter strip.

4) For all urban turf, avoid stray application of any fertilizer to sidewalks, streets or directly into water bodies that abut lawn areas.

FUTURE BMP DEVELOPMENT AND RESEARCH NEEDS

In the review and development of the BMP recommendations, the task force identified aspects of N management that require additional research. This research is necessary to further refine BMPs and enable N users to more precisely apply the optimum environmental and agronomic N practices. Funds should be directed to total N management research, especially that which incorporates water quality concerns. The following is a list of some of the needs identified by the task force. This list is not meant to be inclusive, but rather serves only to highlight some immediate needs.

(1) Nitrogen interactions and credits from non-fertilizer sources such as organic matter, legumes and manure need to be more thoroughly understood.

(2) Soil testing correlation and research into techniques useful in humid conditions needs to be accelerated.

(3) Manure management research needs to be increased and accelerated due to the lack of research available and the potential major impact that manure has on ground and surface water quality.

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