# Final Report to the U.S. EPA:

# Test of the Technical Criteria for Identifying and Delineating Calcareous Fens in Minnesota

## and

# Draft Revised Technical Criteria For Identifying Calcareous Fens in Minnesota

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## ACKNOWLEDGEMENTS to the CALCAREOUS FEN TECHNICAL COMMITTEE

The following committee, listed with their current affiliations, developed the initial technical criteria for identifying calcareous fens in Minnesota in 1994. The 1994 report summarized the published and unpublished scientific data, research findings, and literature available at that time. The committee stated in its initial report and in the 1995 revision that their effort was the start of a process to define the technical criteria for calcareous fens.

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# TEST OF THE TECHNICAL CRITERIA FOR IDENTIFYING AND DELINEATING CALCAREOUS FENS IN MINNESOTA

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## SUMMARY

A test of the Calcareous Fen Technical Criteria as revised in 1995 was conducted. The technical criteria consider vegetation, water chemistry, soil and hydrology attributes. The results show that the statewide Technical Criterion for vegetation is too restrictive and may lead to false negatives, while the remaining criteria are so inclusive that they may lead to false positives. Revised sets of criteria are herewith proposed that refine the vegetation criterion with the addition of bryophytes and regionalizes the vascular plant list. In our opinion this will reduce the tendency toward false negatives without resulting in false positives.

### Results:

The habitat for the calcareous fen plant community is often larger than the area within a wetland complex that the calcareous fen plant community currently occupies. This difference is particularly often observed when the wetland has suffered anthropogenic impacts and the calcareous fen plant community has retreated from the boundaries of its potential habitat. Thus the boundaries of the calcareous fen must be defined as the boundaries of that part of the wetland complex that meets the soils and/or hydrology criteria.

The water chemistry, soil, and hydrology attributes of calcareous fens are characteristic but not on their own definitive because all can be met in certain non-fen wetlands. Of 53 known calcareous fens included in the water chemistry, soil, and hydrology portion of the study, none failed the pH criterion, 14 (29%) failed the conductivity criterion, 1 (2%) failed the alkalinity criterion, and none failed the calcium, soils, and hydrology criteria. Of 19 known non-fen sites included in the water chemistry, soil, and hydrology portion of the study, all (100%) passed the pH criterion, 11 (55%) passed the conductivity criterion, 18 (90%) passed the calcium criterion, 19 (95%) passed the alkalinity criterion, 4 (20%) passed the hydrology criterion, and 8 (40%) passed the soils criterion.

The vegetation criterion alone has the potential to adequately and definitively identify calcareous fens in unimpacted and undegraded wetlands with the addition of bryophytes to the calciphile plant list. Of 26 known calcareous fens included in the vegetation portion of the study 6 (23%) failed the vegetation criterion. Of 7 known non-fen sites included in the vegetation portion of the study, none passed the vegetation criterion.

The gathering of data about the vegetation of calcareous fens under the 1995 technical criteria is dependent upon the season of the year. This interferes with responsive customer service when the Minnesota Department of Natural Resources is asked to determine if a specific wetland is a calcareous fen. We attempt to resolve this issue by including Minnesota's calciphile bryophyte species in the revised vegetation criterion. Mosses are collectible in all seasons, impacted typically only by the hardiness of the wetland scientist.

Regionalizing the vegetation criterion for vascular plants and including bryophyte calciphiles will eliminate most if not all false positive determinations that a site is a calcareous fen.

We continue to believe, as did the original committee, that technical criteria and guidelines for identifying calcareous fens will continue to evolve with continued field surveys and repeated applications. In particular we acknowledge the need for a more work on the soils, water chemistry, and bryophytes of Minnesota's calcareous fens. We believe that regionalization of these criteria, after collection of adequate data, will further improve identification of calcareous fens.

# INTRODUCTION

Legal references to Calcareous Fens are found in Minnesota Statutes and Rules. These references imply that it is possible to know definitively that an activity is occurring in or near an area that is ‘a calcareous fen’. The Wetland Conservation Act of 1991, M.S. 103G.223, and Minnesota Rules 8420 expressly direct the Commissioner of Natural Resources to protect "calcareous fens". M.R. 8420.1010 establishes the purpose "... to provide minimum standards and criteria for the identification, protection, and management of calcareous fens as authorized by Minnesota Statutes, section 103G.223. Calcareous fens may not be drained or filled or otherwise altered or degraded except as provided for in a management plan approved by the commissioner", where ‘commissioner’ is the Commissioner of the Department of Natural Resources (DNR).

Calcareous Fens and other Outstanding Resource Value Waters are also protected by the Minnesota Pollution Control Agency (M.R. 7050.0180) from any new discharges of sewage or other waste. The listing of calcareous fens in the Rules of the Minnesota Pollution Control Agency is derived from the Minnesota DNR Natural Heritage Database Listing of Calcareous Fens. Clearly, it is the responsibility of the DNR to identify calcareous fens. See Appendix 1 for the text of these regulations.

Calcareous fens as a natural community as identified by DNR are defined as follows (DNR Natural Heritage Program, 1991, “Minnesota’s Native Vegetation: A Key to Natural Communities”):

***Calcareous Seepage Fen***

Calcareous Seepage Fen is an open sedge and rush community that occurs throughout Minnesota. The groundlayer is usually dominated by wiregrass sedge (*Carex lasiocarpa*), *Carex sterilis*, beakedsedge (*Rhynchospora capillacea*), spike-rush (*Eleocharis rostellata*), and *Scirpus cespitosus*. Marsh muhly (*Muhlenbergia glomerata*), grass of Parnassus (*Parnassia glauca*) and Kalm's lobelia (*Lobelia kalmii*) are often present in Calcareous Seepage Fens (as well as in Rich Fens). Shrubs, including bog birch, sage-leaved willow, and shrubby cinquefoil, are common in the community. Mosses range in cover from abundant to scarce.

Calcareous Seepage Fens occur on shallow or deep peaty soils in areas of calcareous groundwater discharge. The surface water is usually circumneutral (pH 6.8 - 8.0) with high concentrations of dissolved salts ([Ca2+] = 10-100 mg/l) that often form a visible marl precipitate. The discharge water is low in oxygen (anoxic), which is believed to be important in inhibiting dense vegetation growth, thereby promoting the occurrence of several rare heliophytic vascular and bryophyte plant species in the community.

There are two subtypes of Calcareous Seepage Fen, a Prairie Subtype and a Boreal Subtype. The Prairie Subtype (which occurs in both the prairie and deciduous forest-woodland zones) contains many characteristically prairie species, including big bluestem (*Andropogon gerardi*), yellow stargrass (*Hypoxis hirsuta*), Virginia mountain-mint (*Pycnanthemum virginianum*), starry false Solomon's-seal (*Smilacina stellata*), and golden alexanders (*Zizia aurea*). The Prairie Subtype also commonly contains patches of emergent aquatic species such as broad-leaved cattail (*Typha latifolia*, hard-stemmed bulrush (*Scirpus acutus*), *Scirpus americanus*), and common reed grass (*Phragmites australis*). The Prairie Subtype is divided into three geographic sections, a Southeast Section, a Southwest Section, and a Northwest Section. The Boreal Subtype occurs in the Conifer-Hardwood Forest Zone and contains species characteristic of high-boreal peatlands, including bog-rosemary (*Andromeda glaucophylla*), small cranberry (*Vaccinium oxycoccos*), and pitcher plant (*Sarracenia purpurea*). The Boreal Subtype has no recognized geographic sections.

Community names/designations will be changed as the DNR moves to a classification of natural communities that starts at the landscape level. There will then be several geographic sections because calcareous fens occur in several Ecological Classification System (ECS) regions/subregions. In order to conform with the terminology in use in other countries, professional ecologists and other scientists will begin referring to these very same communities as “extremely rich fens”.

A draft of this new description is found in an Appendix.

Calcareous Fen plant communities as defined above are highly diverse, contain an unusual proportion of uncommon, even threatened species, and it is concern for these communities that led to the Statutes and Rules previously mentioned.

The 1994 Calcareous Fen Technical Committee was convened by the DNR. The Committee established four criteria for identifying and delineating calcareous fens: hydrology, soils, water chemistry, and vegetation. These criteria were compatible with the Minnesota Rules 8420 (Appendix).

The Criteria were based on the data for Minnesota calcareous fens available at the time, which for the vegetation was primarily obtained from calcareous fens in the northwestern part of the state, and which for the other criteria was primarily obtained in the southwestern part of the state and in the Minnesota River Valley. This report shares the results of an effort to test the criteria on known fens in all areas of the state where fens occur and presents the resulting refined Calcareous Fen Technical Criteria.

Use of the Calcareous Fen Technical Criteria as revised in 1995 during the intervening years had made DNR staff aware of several issues with their use that we attempt to improve with this revision.

1. The habitat for the calcareous fen plant community is not exclusively the area within a wetland complex that the calcareous fen plant community currently occupies. This difference is often observed when the wetland has suffered anthropogenic impacts or natural disturbance and the calcareous fen plant community retreats from the boundaries of its potential habitat. Thus the delineation of a "calcareous fen" as a separate entity from any wetland complex within which it exists is not possible; the boundaries of the calcareous fen must be defined as the boundaries of the wetland complex within which a calcareous fen plant community exists.
2. The water chemistry, soil, and hydrology attributes of calcareous fens are characteristic but not on their own definitive because other types of wetlands can meet each of these criteria under certain circumstances.
3. The gathering of data about the vegetation of calcareous fens under the 1995 technical criteria is dependent upon the season of the year. This interferes with responsive customer service when the Minnesota Department of Natural Resources is asked to determine if a specific wetland is a calcareous fen. We have come a long way toward resolving this issue by including Minnesota's calciphile bryophyte species in the revised vegetation criterion. Mosses are collectible in all seasons, impacted typically only by the hardiness of the wetland scientist.
4. Regionalizing the vegetation criterion for vascular plants, whereby the resultant regions include a distinct category for site in the Minnesota River Valley, and including bryophyte calciphiles will eliminate most if not all false positive determinations that a site is a calcareous fen.
5. We continue to believe, as did the original committee, that technical criteria and guidelines for identifying calcareous fens will continue to evolve with continued field surveys and repeated applications. In particular we acknowledge the need for a more work on the soils of Minnesota's calcareous fens and on the bryophytes of Minnesota's calcareous fens. We believe that regionalization of the bryophyte calciphiles list will further improve identification of calcareous fens.

# RESTATEMENT OF CRITERIA TESTED

Descriptive characteristics and technical criteria for the hydrology, soils, water chemistry, and vegetation of calcareous fens follow (MDNR, 1995):

### HYDROLOGY TECHNICAL CRITERION

An area meets the hydrology technical criterion when the hydrology is characterized by having stable, typically upwelling groundwater inflows sufficient to maintain saturation for the development of a histosol or a histic epipedon soil.

### SOILS TECHNICAL CRITERION

An area meets the soils technical criterion when the soils are characterized by the presence of either a histosol or a histic epipedon. Calcium carbonate precipitates, such as tufa deposits, may frequently be associated with calcareous fens.

### WATER CHEMISTRY TECHNICAL CRITERION

Water chemistry of calcareous fens should be characterized by measurement of the following parameters: specific conductance (µS/cm), pH, dissolved oxygen (mg/l), alkalinity (mg/l $CaCO_3$), ratio of the concentration of calcium plus magnesium ions ([Ca+Mg]) to total cations (% meq/l), and alkalinity/total anions (% meq/l). Of these parameters, it is imperative that specific conductance, pH, alkalinity, and dissolved oxygen be measured in the field (*in situ*). Samples would be collected for laboratory determination of the other parameters. Standard methods should be used for sample collection techniques and sample preparation and handling.

An area meets the water chemistry technical criterion when the following conditions are met: pH of 6.7 or more; calcium of 30 mg/l or more; alkalinity of 1.65 meq/l or more; dissolved oxygen of 2.0 mg/l or less; and, specific conductance of 500 µS/cm or more. [Data for other parameters must be collected to provide further water chemistry definition of calcareous fens.]

### VEGETATION TECHNICAL CRITERION

An area meets the vegetation technical criterion when the vegetation is characterized by using a modification of the Mandatory Technical Criteria for Wetland Identification--Hydrophytic Vegetation in the *FEDERAL MANUAL FOR IDENTIFYING AND DELINEATING JURISDICTIONAL WETLANDS JANUARY 1989*. Hydrophytic vegetation is defined as macrophytic plant life growing in the soils, water, and water chemistry characteristic of calcareous fens. The Minnesota DNR has developed a list of 27 statewide calciphiles indicative of calcareous fens (Table 1). This list was further divided into vascular calciphile indicator classes of "strong", "moderate", and "weak".

**Two alternative methods are available to determine the vegetation criterion.** An area meets calcareous fen vegetative technical criterion when, under normal circumstances, either:

1. **50 Percent Cover Method**
   More than 50 percent of the composition of the dominant species from all strata are calciphiles from any of the indicator classes,

or

2. **Calciphile Species Occurrence Method**
   When the area has a natural community index value of 50 or more by summing the index values of the 27 calcareous fen indicator species. This natural community index value provides a workable floristic surrogate for a full vegetation analysis.
   Plot size and shape are dependent upon the professional judgment of field personnel. Identification plots may be large (400 square meters or larger) whereas delineation plots or other techniques may be smaller to provide more definite margin boundaries.
   ***NOTE:*** *If a site has calcareous fen soil, hydrology, and water chemistry but the calciphile point total ranges from 30 to 50, the area will be considered to meet calcareous fen criteria. If a disturbed site has calcareous fen soil, hydrology, and water chemistry but a calciphile point total of less than 30, the disturbed area may have the potential to support a calcareous fen plant community*

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Table 1. 1995 State-wide list of 27 calciphiles distinguishing "strong" (6 species), "moderate" (11 species), and "weak" (10 species) indicators to identify and delineate calcareous fens in Minnesota (MDNR 1994). [Adapted from: *MINNESOTA LIST OF PLANTS THAT OCCUR IN WETLANDS* by Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: North Central Region (Region 3). U.S. Fish and Wildlife Service

| Family | Species Indicator Abbrev. | Scientific Name | Common Name | Habit | Status |
|---|---|---|---|---|---|
| Strong state-wide indicators (**25 calciphile point value**) | | | | | |
| CYPERACEAE | CAPR6 | CAREX PRAIREA | SEDGE, PRAIRIE | PNGL | FACW+ |
| CYPERACEAE | CAST16 | CAREX STERILIS | SEDGE, DIOECIOUS | PNGL | OBL |
| CYPERACEAE | ELRO2 | ELEOCHARIS ROSTELLATA | SPIKERUSH, BEAKED | PNGL | OBL |
| CYPERACEAE | RHCA11 | RHYNCHOSPORA CAPILLACEA | BEAKRUSH, NEEDLE | PNGL | OBL |
| CYPERACEAE | SCVE2 | SCLERIA VERTICILLATA | NUTRUSH, LOW | ANGL | OBL |
| SCHEUCHZERIACEAE | TRPA6 | TRIGLOCHIN PALUSTRE | ARROW-GRASS, MARSH | PNF | OBL |
| Moderate state-wide indicators (**5 calciphile point value**) | | | | | |
| CYPERACEAE | CAVI5 | CAREX VIRIDULA | SEDGE, LITTLE GREEN | PNGL | OBL |
| CYPERACEAE | CLMA | CLADIUM MARISCOIDES | SAWGRASS, SMOOTH | PNEGL | OBL |
| JUNCACEAE | JUALAR | JUNCUS ALPINO-ARTICULATUS | RUSH, JOINTED | PNGL | OBL |
| JUNCACEAE | JUBR4 | JUNCUS BREVICAUDATUS | RUSH, NARROW-PANICLE | PNGL | OBL |
| SAXIFRAGACEAE | PAGL3 | PARNASSIA GLAUCA | GRASS-OF-PARNASSUS, WAXY | PNF | OBL |
| PRIMULACEAE | PRMI | PRIMULA MISTASSINICA | PRIMROSE, MISTASSINI | PNF | FACW |
| SALICACEAE | SACA4 | SALIX CANDIDA | WILLOW, HOARY | NS | OBL |
| SAXIFRAGACEAE | SAPE8 | SAXIFRAGA PENSYLVANICA | SAXIFRAGE, SWAMP | PNF | OBL |
| CYPERACEAE | SCCE2 | SCIRPUS CESPITOSUS | BULRUSH, TUFTED | PNGL | OBL |
| LILIACEAE | TOGL2 | TOFIELDIA GLUTINOSA | FALSE-ASPHODEL, STICKY | PNF | OBL |
| VALERIANACEAE | VAED | VALERIANA EDULIS | VALERIAN, EDIBLE | PNF | FACW+ |
| Weak state-wide indicators (**1 calciphile point value**) | | | | | |
| BRASSICACEAE | CABU3 | CARDAMINE BULBOSA | BITTER-CRESS, BULBOUS | PNF | OBL |
| CYPERACEAE | CAGR3 | CAREX GRANULARIS | SEDGE, MEADOW | PNGL | FACW+ |
| CYPERACEAE | CAHY4 | CAREX HYSTERICINA | SEDGE, PORCUPINE | PNEGL | OBL |
| CYPERACEAE | CAIN11 | CAREX INTERIOR | SEDGE, INLAND | PNGL | OBL |
| ORCHIDACEAE | LILO | LIPARIS LOESELII | ORCHID, FEN | PNF | FACW+ |
| CAMPANULACEAE | LOKA | LOBELIA KALMII | LOBELIA, BROOK | PNF | OBL |
| APIACEAE | OXRI | OXYPOLIS RIGIDIOR | COWBANE, STIFF | PNF | OBL |
| SAXIFRAGACEAE | PAPA8 | PARNASSIA PALUSTRIS | GRASS-OF-PARNASSUS, NORTHERN | PNF | OBL |
| ROSACEAE | POFR4 | POTENTILLA FRUTICOSA | CINQUEFOIL, SHRUBBY | NS | FACW |
| SCHEUCHZERIACEAE | TRMA4 | TRIGLOCHIN MARITIMA | ARROW-GRASS, SEASIDE | PNF | OBL |

Table 1 (continued)

## DEFINITIONS AND EXPLANATIONS

*General Indicator Status*

| | |
|---|---|
| OBL | Always found in wetlands; wetland occurrence >99% |
| FACW | Usually found in wetlands but occasionally in non-wetlands; wetland occurrence 67-99% |
| FAC | Sometimes found in wetlands but also occur in non-wetlands; wetland occurrence 34-66% |
| FACU | Seldom found in wetlands and usually occur in non-wetlands; wetland occurrence 1-33% |
| *UPL* | May occur in wetlands; wetland occurrence <1%; unlisted species do not occur in wetlands |
| + | A modifier to indicate a more frequent occurrence in wetlands |
| -- | A modifier to indicate a less frequent occurrence in wetlands |
| * | The indicator was derived from limited ecological information |
| NA | No unanimous agreement by the Review Panel as to the indicator status |
| NI | Species with little or no information to establish an indicator status |

*Habit*

This is a general classification of the plant characteristics. Symbols are combined to describe the life form of the species.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **A** | Annual | **F3** | Fern | **N** | Native | **Z** | Submerged |
| **B** | Biennial | **G** | Grass | **P** | Perennial | **$** | Succulent |
| **C** | Clubmoss | **GL** | Grasslike | **+** | Parasitic | **T** | Tree |
| **E** | Emergent | **H** | Partly woody | **P3** | Pepperwort | **V** | Herbaceous vine |
| **@** | Epiphytic | **HS** | Halfshrub | **Q** | Quillwort | **W** | Waterfern |
| **F** | Forb | **H2** | Horsetail | **S** | Shrub | **WV** | Woody vine |
| **/** | Floating | **I** | Introduced | **-** | Saprophytic | | |

## STUDY METHODS

### REGIONALIZATION

The Department has stratified that part of the state having calcareous fens into the following three separate regions, based on the Ecological Classification System (ECS) used by the Department (Hanson and Hargrave, 1996). Field studies were conducted in (Figure 1 and Table 2):

Red River Valley/Lake Agassiz, Aspen Parklands (NW)
North Central Glaciated Plains (SW)
Minnesota & NE Iowa Morainal/Paleozoic Plateau (SE)

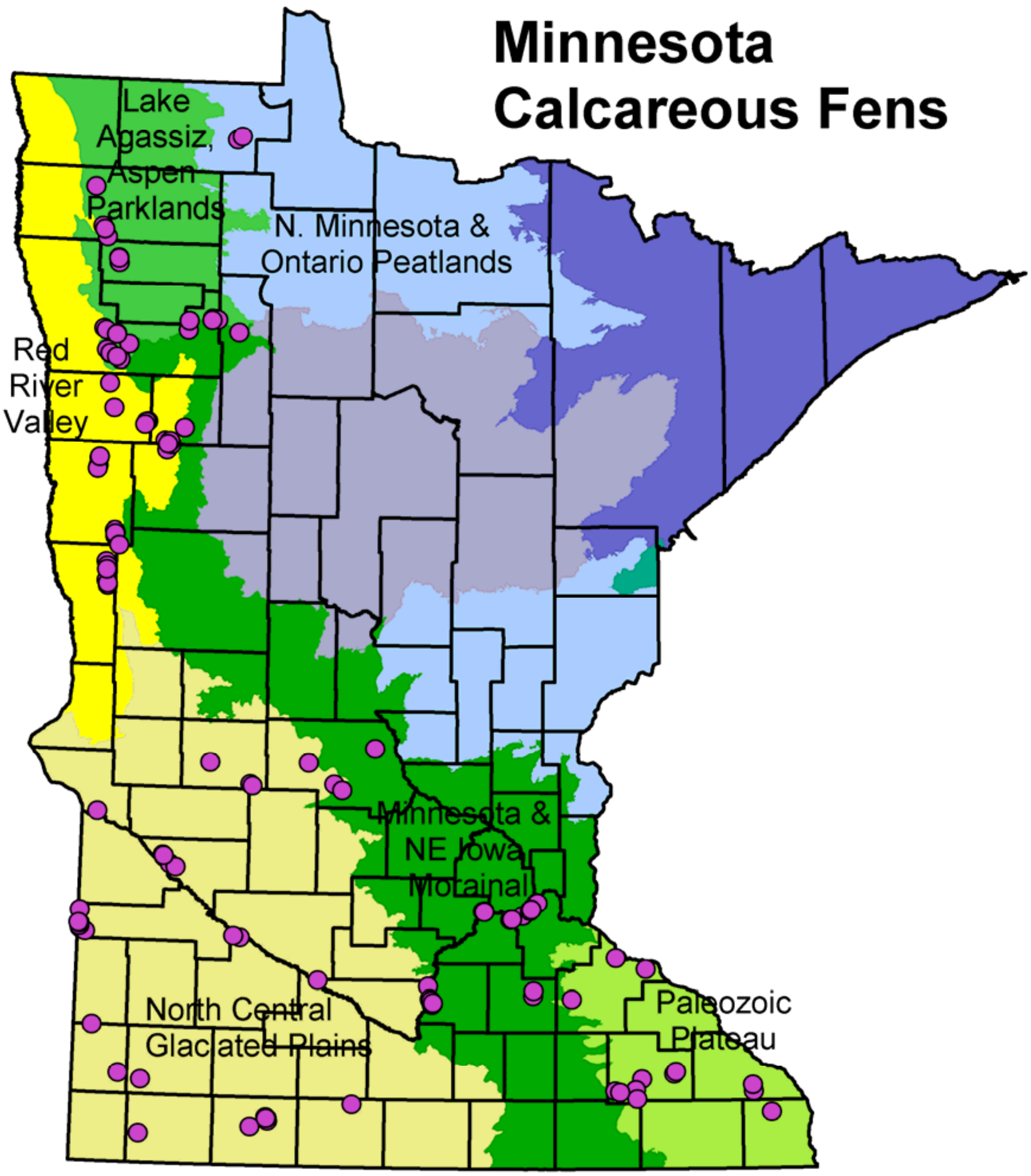


Figure 1: Calcareous Fens in the State of Minnesota overlain on ECS regions.

**Table 2: Sites grouped by ECS Section**

| ESC Section | County | Type | Site Name | Bryo | Vasc | Hydro | Soil | Chem |
|---|---|---|---|---|---|---|---|---|
| Red River Valley | BEC | Fen | Ogema Spring Prairie Fen | x | x | x | X | x |
| Red River Valley | BEC | Control | Spring Creek WMA | | | x | X | x |
| Red River Valley | CLA | Fen | Barnesville State WMA | x | x | | | |
| Red River Valley | CLA | Control | Felton WMA | x | x | x | | |
| Red River Valley | CLA | Fen | Felton Fen N | x | x | x | X | x |
| Red River Valley | CLA | Fen | Felton Fen S | x | x | x | X | x |
| Red River Valley | MAH | Fen | Waubun Fen | x | x | x | X | x |
| Red River Valley | NOR | Fen | Faith Prairie | | x | | | |
| Red River Valley | NOR | Fen | Green Meadow Fen | x | x | x | X | x |
| Lake Agassiz, Aspen Parklands | PEN | Control | Higenbotham WMA | | | x | X | x |
| Lake Agassiz, Aspen Parklands | PEN | Control | Pembina WMA | | x | x | X | x |
| Lake Agassiz, Aspen Parklands | PEN | Fen | Sanders 18 Fen | x | x | x | X | x |
| Lake Agassiz, Aspen Parklands | PEN | Fen | Sanders 7 Fen | x | x | x | X | x |
| Lake Agassiz, Aspen Parklands | PEN | Control | Sanders Cattail | | | x | X | x |
| Lake Agassiz, Aspen Parklands | POL | Fen | Gully Peatlands | x | x | | | |
| Lake Agassiz, Aspen Parklands | RDL | Control | Crane Wetland | | x | x | X | x |
| N. Minnesota & Ontario Peatlands | ROS | Fen | Bemis Hill Swamp | x | x | | | |
| Red River Valley | WIL | Fen | Rothsay Prairie Fen | x | x | | x | |
| North Central Glaciated Plains | CHI | Control | Watson WMA | | | x | x | x |
| North Central Glaciated Plains | CHP | Fen | Kragero Township Fen | x | x | x | x | x |
| North Central Glaciated Plains | CHP | Fen | Zion Lutheran Church Fen | x | x | x | x | x |
| North Central Glaciated Plains | COT | Fen | Jeffers Calcareous Fen | x | | x | x | x |
| North Central Glaciated Plains | COT | Fen | Muller Calcareous Fen | x | | x | x | x |
| North Central Glaciated Plains | DUE | Control | South Slough (SD/MN border) | | | x | x | x |
| North Central Glaciated Plains | JAC | Fen | Holte Prairie Fen | x | x | x | x | x |
| North Central Glaciated Plains | JAC | Fen | Thompson Fen | | x | | | |
| North Central Glaciated Plains | JAC | Fen | Yonker Prairie Fen | x | x | x | x | x |
| North Central Glaciated Plains | LAC | Control | Hamlin WPA | | | x | x | x |
| North Central Glaciated Plains | LYO | Fen | Sam Tutt Fen | x | x | x | x | x |
| North Central Glaciated Plains | MUR | Fen | Lost Timber Fen | x | x | x | x | x |
| North Central Glaciated Plains | NIC | Fen | Fort Ridgely Fen | x | | x | x | x |
| North Central Glaciated Plains | NOB | Fen | Adrian Calcareous Fen | x | x | x | x | x |
| North Central Glaciated Plains | NOB | Control | Adrian Spring | | | x | x | x |
| North Central Glaciated Plains | PIP | Fen | Altona Fen | x | x | x | x | x |
| North Central Glaciated Plains | PIP | Control | Altona Meadow | x | x | x | x | x |
| North Central Glaciated Plains | PIP | Fen | Burke WMA Fen | x | x | x | x | x |
| North Central Glaciated Plains | PIP | Control | Prairie Coteau Wetland | | x | x | x | x |
| North Central Glaciated Plains | RED | Fen | Redwood County Fen | | x | x | x | x |
| North Central Glaciated Plains | STR | Fen | Spring Hill Fen | x | x | x | x | x |
| North Central Glaciated Plains | YEL | Fen | Fairchild Calcareous Fen | x | x | x | x | x |
| North Central Glaciated Plains | YEL | Control | Fortier WPA | | | x | x | x |
| North Central Glaciated Plains | YEL | Fen | Sioux Nation Calcareous Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | CLE | Fen | Clearbrook Spring Fen | x | x | | | |

**Table 2 continued: Sites grouped by ECS Section and the types of activities conducted at each site**.

| ESC Section | County | Type | Site Name | Bryo | Vasc | Hydro | Soil | Chem |
|---|---|---|---|---|---|---|---|---|
| Minnesota & NE Iowa Morainal | DAK | Fen | Nichols Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | CRV | Fen | Seminary Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | DAK | Fen | Black Dog Preserve SNA | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | DAK | Fen | Fort Snelling State Park | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | DOD | Control | Iron Horse Prairie | | x | x | x | x |
| Paleozoic Plateau | DOD | Fen | Pheasants Forever WMA | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | DOD | Fen | Wasioja Calcareous Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | FIL | Control | Beaver Creek Wetland | | x | x | x | x |
| Paleozoic Plateau | GOO | Fen | Cannon Valley Trail | x | x | x | x | x |
| Paleozoic Plateau | GOO | Fen | Perched Valley Calcareous Fen | x | x | x | x | x |
| Paleozoic Plateau | GOO | Fen | Red Wing 21 Fen | x | x | x | x | x |
| Paleozoic Plateau | HOU | Fen | Houston 26 Fen | x | x | x | x | x |
| Paleozoic Plateau | HOU | Fen | Sheldon 16 Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | LES | Fen | Ottawa Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | MEE | Control | Sucker Creek | x | | x | x | x |
| Paleozoic Plateau | OLM | Fen | Eyota 13 Fen | x | x | x | x | x |
| Paleozoic Plateau | OLM | Fen | Mutchler Fen | x | x | x | x | x |
| Paleozoic Plateau | OLM | Fen | Nelson Fen WMA | x | x | x | x | x |
| Paleozoic Plateau | OLM | Fen | Stewartville Calcareous Fen | x | x | x | x | x |
| Paleozoic Plateau | OLM | Fen | Stonehedge Calcareous Fen | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | RIC | Fen | Cannon River Wilderness Area | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | SCO | Fen | Savage Spring Fen SNA | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | SCO | Fen | Savage Spring Fen USFW | x | x | x | x | x |
| Minnesota & NE Iowa Morainal | STE | Fen | Pogones WMA | | x | x | x | x |
| Paleozoic Plateau | WAB | Fen | McCarthy Lake WMA | x | x | x | x | x |
| Paleozoic Plateau | WIN | Fen | Kennedy Fen | x | x | x | x | x |
| Paleozoic Plateau | WIN | Control | Whitewater 1 | | | x | x | x |
| Paleozoic Plateau | WIN | Control | Whitewater 2 | | | x | x | x |
| Paleozoic Plateau | WIN | Fen | Wiscoy Valley East Fen | x | x | x | x | x |
| Paleozoic Plateau | WIN | Control | Wiscoy Wetland | | | x | x | x |

Data of at least one type were collected on 52 calcareous fen sites and on 20 control sites. In some cases there are multiple sampling sites within a given fen wetland complex. For a given analysis there may be a different total number of sites. A major factor in selection of sites for study is public land ownership or landowner permission. Many of the sites are fen on private land. Permission of the landowners was obtained for access, but no new permanent monitoring sites were established on private land.

A new component has been a study to investigate the classification, indicator value, and regional differentiation of bryophyte species in Minnesota's calcareous fens. Initial work on this topic is very promising, and the revised list of calciphiles includes bryophytes. Wetland project proposals can now be reviewed for the presence of calcareous fens throughout the year.

## HYDROLOGY STUDY METHODS

Upwelling conditions are typically identified by establishing that an upward ground water gradient exists and that an upward ground water flow path also exists. Methods for technically establishing upwelling conditions include installation and monitoring of a pair, or nest of water level monitoring wells: when the water level elevation is higher in the well that has the deeper screen, then an upward gradient exists and an upward flow path can occur in relation to the permeability of the intervening materials. Indeed, four of the calcareous fens we studied already had flowing wells.

In the case of a wetland where the water table is at the surface, only one well is needed to establish the ground water gradient, as the comparison in water level elevation can be made to the water table.

Well installation in calcareous fens cannot be accomplished using normal well construction methods. To avoid severe damage to the fen, all work must be done by hand and grouting and subsequent sealing cannot follow the normal Minnesota Department of Health Well Construction Code. Variances from the Code were obtained and we ultimately had water level elevation monitoring wells in a total of 18 calcareous fens.

In spring-pond or mound settings actively discharging ground water is evidence of upwelling.

In side-slope settings a downward flowpath that intersects the ground surface will also result in the emergence of groundwater at the surface, which we are also classifiying as 'upwelling' for our purpose in this study.

Hydrogeologic settings were classified as: seasonally inundated or depressional, spring pond or mound, and side-slope seepage face.

## SOILS STUDY METHODS

The soils of a calcareous fen have either a histic epipedon or are histosols. If the soil at a given fen or control site is an organic soil or if the soil has a histic epipedon, the following types of qualitative observations were likely to be made:

- Previously mapped as an organic soil
- Partially decomposed plant materials observable
- Black soil, greasy when rubbed between the fingers
- Very soft soil, perhaps to the point of feeling uncertain of one's footing
- A rod penetrates the soil easily
- Odor of sulfur
- Very low bulk density

If the soil at a given fen or non-fen wetland is a mineral soil, textural analysis by feel was done following the guidelines used for classification of natural plant communities (MNDNR 2003).

Soil samples from a select number of calcareous fen and non-fen wetlands sites were collected and quantitatively analyzed for bulk density, organic matter content, soil color, and carbonate content. Methods used for these analytical tests are described in the Natural Resources Conservation Service, 1996, Soil Survey Laboratory Methods Manual, Soil Survey Investigations Report No. 42.

## WATER CHEMISTRY STUDY METHODS

Field methods and sampling procedures follow guidelines in “Field and Laboratory Methods” by Scott C. Alexander and E. Calvin Alexander, University of Minnesota Hydrogeochemistry Laboratory in the Department of Geology and Geophysics. Samples were submitted to the University of Minnesota Hydrogeochemistry Laboratory.

### Conductance

Conductance is measured with a Hach SensIon Conductivity Meter with automatic temperature correction. A conductivity standard is checked daily.

### pH

Calibration of the pH meter is done at each sampling site by a two buffer calibration. Fresh buffers are prepared daily. Several types of meters and electrodes have been used over time. Buffers are selected to bracket the pH of the sample, in most cases pH 7 and 10 buffers are used.

### Cations

The sample to be analyzed for cations is collected in a 15 ml polypropylene bottle. The sample bottles are rinsed three times with sample water before the final sample is collected. The sample is acidified with 1 drop of 6N trace metal grade HCL and stored on ice for transport. These samples are analyzed by Inductively Coupled Plasma - Mass Spectrometry Perkin-Elmer/Sciex Elan 5000 ICP-MS (EPA Method: 200.8)

Detection Limits: all values reported as µg/g. 1 µg/g = 1 ppm ( ≅ 1 mg/l in dilute solutions)

| | | | |
|---|---|---|---|
| Ca = 0.1 | Mg = 0.1 | Na = 0.1 | K = 0.1 |
| Al = 0.001 | Fe = 0.02 | Mn = 0.001 | Sr = 0.001 |
| Ba = 0.001 | Si = 0.1 | P = 0.02 | |

### Anions

The sample to be analyzed for anions is collected in a 15 ml amber high density polyethylene bottle. The sample bottles are rinsed three times with sample water before the final sample is collected. These samples are cooled to ice water temperature for transport and storage. These samples are analyzed by Ion Chromatography
Dionex Series 4000I
EPA method 300.0, "The Determination of Inorganic Anions in Water by Ion Chromatography."

Detection limits: all values reported as µg/g. 1 µg/g = 1 ppm ( ≅ 1 mg/l, dilute solutions)

| | | | |
|---|---|---|---|
| Major anions | Cl = 0.10 | NO3-N = 0.005 | SO4 = 0.1 |
| Other anions | Br = 0.010 | NO2-N = 0.005 | S2O3 = 1.0 |
| | F = 0.05 | PO4-P = 0.02 | CH3COO=0.5 |

### Alkalinity

Alkalinity samples can be analyzed in the field, at an off-site location or in the lab within 24 hours of sample collection. Repeated measurements have indicated that holding times for refrigerated samples of several weeks show no significant degradation for carbonate saturated ground waters; this would not be true for waters with a high degree of supersatuation. Titrations are performed in triplicate with a Hach digital titrator using a 1.6N $H_2SO_4$ titrant to a bromcresol green-methyl red color end-point. The traditional color indicator solutions are bromocresol green and methyl red along with phenolphthalein for high pH waters.

Sample aliquots are measured in the field with a portable scale having a minimum accuracy of 0.1 g. The advantages of weighing samples are that for triplicate samples a slightly different mass is used for each titration and then normalized to 100 g thus preventing biasing the second and third values towards the first and that no particular mass is required allowing each aliquot to be easily prepared by weighing out a mass near 100 g. The normalized alkalinity is calculated using a simple proportional relationship.

## Dissolved Oxygen

Dissolved Oxygen can be analyzed in the field by the Winkler Titration Method. However, results depend upon the type of sample: pools and springs can have high dissolved oxygen levels, despite the fact that the upwelling groundwater is essentially devoid of oxygen. Upwelling ground water absorbs atmospheric oxygen almost immediately – only samples drawn from wells typically result in dissolved oxygen levels under 2 mg/l, only if the sampling method is carefully devised to eliminate exposure to the atmosphere as the sample is recovered and as the sample is transferred and analyzed, all of which is difficult to ensure under field conditions. Data from a single fen site have ranged from near zero mg/l dissolved oxygen to over 8 mg/l oxygen.

On the other hand, stagnant pools in closed depressions can have low dissolved oxygen levels because of the warm water temperatures and decomposition of organic matter – which results in low dissolved oxygen levels. Dissolved oxygen cannot be used to distinguish between calcareous fens and non-fen wetlands, despite the fact that, in the subsurface, low oxygen content would be a characteristic of ground water which is upwelling into calcareous fen wetlands. For this reason, we recommend that dissolved oxygen be dropped from the technical criteria.

# VEGETATION TECHNICAL CRITERION TESTING METHODOLOGY

## Vascular Plants

Study sites were selected based on a number of criteria. Geographical representation, public ownership to assure repeated access, determination that the vegetation of the site is typical of undisturbed calcareous fens in the region, and whether or not there were preexisting data (species lists) that could be utilized. Criteria for selecting non-fen comparison sites were similar. Each site was visited at least twice in a year: once in late spring or early summer to be able to identify the sedges and other early-appearing species, and again in late summer or early autumn to be able to identify the grasses, composites and other late-appearing species. During each visit a list was made of all the vascular plant species seen within the boundaries of the fen. Several fens had comparable species lists from previous studies and it was not necessary to revisit those sites. This is essentially the procedure used to test method number two. Method number one was considered untestable (see results section for an explanation of this evaluation of method number one).

## Bryophytes

The methods used to sample bryophytes are described in “Bryophytes of Calcareous Fens: Minimum Requirements for Submission of Collections for Identification and Suggestions on Survey Procedure”, 2004, Lambda Max Ecological Research, Minneapolis, Minnesota and included here as an Appendix.

# RESULTS

## HYDROLOGY TECHNICAL CRITERION TESTING RESULTS

In each case we were able to show that ground water in the area of the calcareous fens we studied had the potential to emerge at the surface (Table 3), thus maintaining saturated conditions sufficient to allow organic matter to accumulate. In side slope hydrogeologic settings many non-fen wetlands will also receive ground water inputs.

Our site investigations revealed that all of the calcareous fen settings provided adequate drainage to keep the sites from being inundated. For example, none of the Minnesota River Valley calcareous fen sites were flooded during the 1993 floods. Site investigations in winter also revealed that most calcareous fens build ice sheets or domes during the winter because of the discharging ground water. Fen sites were rendered clearly visible for a few weeks between snowmelt and the melting of the accumulated ice (Figure 2). During the growing season ground water discharge may almost be equaled by evapotranspiration and thus be much less evident. These facts may help distinguish between calcareous fens and non-fen wetlands in side-slope seepage face settings.

**Table 3: Hydrology Technical Criterion**

| Wetland Category | Site Descriptions | Number of Sites in this Category | Number of Sites Passing the Criterion |
|---|---|---|---|
| Calcareous Fens | Peat Domes Sustained by Upwelling Ground Water | 7 | 7 |
| | Seepage Face with Discharging Ground Water | 26 | 26 |
| all 49 pass criterion | Spring Ponds with Discharging Ground Water | 16 | 16 |
| Non-Fen Wetlands | Seasonally inundated wetland in a closed basin | 10 | |
| | Flowing Spring (no pond) | 1 | 1 |
| | Terrace wetland along creek; seasonal inundation | 7 | |
| 3 of 20 pass criterion | Seepage Face with Discharging Ground Water | 2 | 2 |

Figure 2: Winter ice dome revealed immediately after snowmelt. Shelburne 22 fen, Lyon County, MN.

## SOILS TECHNICAL CRITERION TESTING RESULTS

In each case, calcareous fen sites were seen to have organic soils (Table 4). High carbonate content can lead to the perception that organic soils are less decomposed than they really are, indeed they are difficult to distinguish from mineral soils in some cases. We have termed such soils 'marly peat'.

Our site investigations revealed that 40% of the non-fen wetlands also passed the soils technical criterion.

**Table 4: Soils Technical Criterion from Field Investigation**

| **Wetland Category** | **Soil Descriptions** | **Number of Sites in this Category** | **Number of Sites Passing the Criterion** |
|---|---|---|---|
| Calcareous Fens | Muck | 23 | 23 |
| | Marly Peat | 7 | 7 |
| all 49 pass criterion | Peat | 19 | 19 |
| Non-Fen Wetlands | Inorganic | 12 | |
| | Muck | 6 | 6 |
| 8 of 20 pass criterion | Peat | 2 | 2 |

Soil scientists working in the Southeastern Minnesota are quick to point out that the typical calcareous fen in their experience does not accumulate 'peat', rather the soils are typically mucks. The term 'peat' implies a presence of fibers that are only partially decomposed. True peats are identifiable by lay persons because of these identifiable fibers. In the southeast the distinction by feel or appearance between mineral soils and organic soils is more difficult for the non-soil-scientist. None-the-less, a black, soft, perennially wet soil that may also fizz with acid is a promising calcareous fen soil candidate.

Thirty-eight soil samples were submitted for determination of organic matter and carbonate content.

**Table 5: Laboratory Results: Soil Bulk Density, Calcium Carbonate Equivalent and Organic Matter**

| | Bulk Density (g/cc) | | Calcium Carbonate Equivalent (%) | | O.M. (%) LOI 400C | |
|---|---|---|---|---|---|---|
| | Fen | Non-Fen | Fen | Non-Fen | Fen | Non-fen |
| Number of Samples | 27 | 11 | 27 | 11 | 27 | 11 |
| Minimum | 0.12 | 0.19 | 1.6 | 0.6 | 15.8 | 0.9 |
| Maximum | 0.70 | 1.43 | 69.0 | 30.0 | 70.9 | 76.0 |
| Mean | 0.342 | 0.821 | 26.98 | 9.88 | 37.57 | 12.25 |
| Standard Deviation | 0.133 | 0.391 | 23.16 | 8.34 | 17.58 | 21.38 |

Soils of calcareous fens have higher organic matter and calcium carbonate content and lower bulk density than the soils of the non-fen sites. If an organic matter content threshold of 12% is chosen, then all of the fen site's soils are above the threshold and all but one of the non-fen site's soils are below the threshold. Calcium carbonate content varies with the depth of the sample. More work is needed before we understand the implications of these changes with depth, but preliminary results from this and previous work indicate that the carbonate/depth profile of a calcareous fen is an indicator of stability of the hydrologic regime and thus the 'health' of a calcareous fen.

## WATER CHEMISTRY TECHNICAL CRITERION TESTING RESULTS

The technical criteria are meant to be used to decide if a site is indeed a calcareous fen. This implies that one could visit a site and collect limited data from which to make the determination. For many of the sites for which we have data, that is exactly what we have done. However, several of our sites have been visited many, many times and we have numerous water chemistry sampling events. To carry out this test of the criteria, it was decided to randomly select data from one site visit per distinct location to more accurately represent a calcareous fen determination. In many cases, a calcareous fen which did not pass a given criteria as shown here, may well have passed that criterion at a different location within the fen wetland complex or on a different date.

**pH**

All but one of the calcareous fen sites studied passed the criterion for pH, while all of the non-fen wetland sites passed the criterion (Table 6). The usefulness of this criterion is to distinguish between calcareous fens and northern (bog) peatlands, none of which were included in this study.

**Table 6: pH Technical Criterion**

| Wetland Category | PH | Number of Sites Passing the Criterion |
|---|---|---|
| Calcareous Fens | pH >= 6.7 | 48 |
| 48 of 49 pass criterion | pH < 6.7 | 1 |
| Non-Fen Wetlands | pH >= 6.7 | 20 |
| all 20 pass criterion | pH < 6.7 | 0 |

**Conductivity**

The conductivity criterion is not as useful as was theoretically thought to be the case. Only 35 of 49 calcareous fens passed the criterion, while 11 of 20 non-fen wetlands passed (Table 7). The threshold of 500 mS/cm was set because the source waters sustaining calcareous fens are thought to be ground water, and ground water is characterized by a conductivity of 500 mS/cm or greater. However, calcareous fens are at the ground surface and thus receive water from at least two sources: precipitation and ground water. In addition, many fens have more than one ground water flow path that brings water to the surface at the fen's location. The shorter, local flow paths and the precipitation derived waters have much lower conductivity than the deeper ground water sources. Thus, waters within calcareous fens may vary due to antecedent conditions.

**Table 7: Conductivity Technical Criterion**

| Wetland Category | Conductivity mS/cm | Number of Sites Passing the Criterion |
|---|---|---|
| Calcareous Fens | Conductivity >= 500 | 35 |
| 35 of 49 pass criterion | Conductivity < 500 | 14 |
| Non-Fen Wetlands | Conductivity >= 500 | 11 |
| 11 of 20 pass criterion | Conductivity < 500 | 9 |

**Calcium**

All of the calcareous fen sites studied passed the criterion for calcium, while all but one of the non-fen wetland sites passed the criterion (Table 8). The usefulness of this criterion is to distinguish between calcareous fens and typical northern (bog) peatlands, none of which were included in this study. The results of this work reveal that field titrations of calcium hardness (Table 9), from which a representative calcium concentration value can be calculated, is just as useful and much much faster, than submittal of samples to a laboratory for testing. In addition, due to the need for field titration of alkalinities, the equipment is already at hand during site visits to calcareous fens.

**Table 8: Calcium Technical Criterion**

| Wetland Category | Calcium ppm (≅ mg/l) | Number of Sites Passing the Criterion |
|---|---|---|
| Calcareous Fens | Calcium >= 30 | 49 |
| all 49 pass criterion | Calcium < 30 | 0 |
| Non-Fen Wetlands | Calcium >= 30 | 18 |
| 18 of 19 pass criterion | Calcium < 30 | 1 |

**Table 9: Calcium Technical Criterion (Field Titration)**

| Wetland Category | Calcium ppm (≅ mg/l) as titrated in the field | Number of Sites Passing the Criterion |
|---|---|---|
| Calcareous Fens | Calcium >= 30 | 49 |
| all 49 pass criterion | Calcium < 30 | 0 |
| Non-Fen Wetlands | Calcium >= 30 | 19 |
| all 19 pass criterion | Calcium < 30 | 0 |

**Alkalinity**

All but one of the calcareous fen sites studied passed the criterion for alkalinity and all but one of the non-fen wetland sites passed the criterion (Table 10). As with pH and calcium concentration, the usefulness of this criterion is to distinguish between calcareous fens and typical northern (bog) peatlands, none of which were included in this study. Alkalinity is always titrated in the field because the samples would tend to change too much if they were transported back to a laboratory under the field conditions usually encountered in this type of work (the samples cannot be immediately chilled to ice water temperature because there is no vehicle close by).

**Table 10: Alkalinity Technical Criterion (Field Titration)**

| Wetland Category | Alkalinity ppm meq/l as titrated in the field | Number of Sites Passing the Criterion |
|---|---|---|
| Calcareous Fens | Alkalinity >= 1.65 | 48 |
| 48 of 49 pass criterion | Alkalinity < 1.65 | 1 |
| Non-Fen Wetlands | Alkalinity >= 1.65 | 19 |
| 19 of 20 pass criterion | Alkalinity < 1.65 | 1 |

**Ratio of Calcium + Magnesium to Total Cations**

The original committee that created the 1995 Technical Criteria had suggested that two ratios should be examined as soon as adequate data were available. Calcium and magnesium compared to total cations and alkalinity compared to total anions were evaluated; the results are tabulated below. The number of samples is still limited, but the results are not promising. The resulting values at non-fen sites overlap the values at calcareous fen sites. Even if there should prove to be a statistically significant difference between the populations, the very sparse sampling conducted for calcareous fen identification will not distinguish between calcareous fens and non-fens using these ratios.

| **Table 11: Ratios** | | | | |
|---|---|---|---|---|
| | Ratio of Ca + Mg to Total Cations | | Ratio of Alkalinity to Total Anions | |
| | Fen | Non-Fen | Fen | Non-Fen |
| Number of Samples | 73 | 28 | 52 | 17 |
| Mean | 0.931 | 0.905 | 0.756 | 0.716 |
| Minimum | 0.71 | 0.74 | 0.23 | 0.36 |
| Maximum | 0.98 | 0.98 | 0.99 | 0.89 |
| Standard Deviation | 0.049 | 0.065 | 0.163 | 0.176 |

## VEGETATION TECHNICAL CRITERION TESTING RESULTS

The vegetation criterion, if properly constructed, must have the potential to adequately and definitively identify calcareous fens in unimpacted and undegraded wetlands. It may also be useful in impacted areas where natural vegetation still survives.

**Vascular Plants**

There are two alternative testing methods in the "Vegetation Technical Criteria". The first method is called the "50% cover method", and is described as giving a positive result when "more than 50% of the composition of the dominant species from all strata are calciphiles from any of the indicator classes". The wording of this method is rather cryptic and problematic, and the original document gives no explanation. This method could easily be interpreted several ways; the four most likely ways are listed below.

- More than 50% of the species present in the plot are indicator species.
- More than 50% of the aerial cover within a plot is composed of indicator species.
- More than 50% of the cover within a plot is composed of a single species (the "dominant" species), which is an indicator species.
- The dominant species in more than 50% of the plots is an indicator species.

Since the original document gives no statistical or biological basis for this method, and no clear hypothesis is stated, it is difficult to know how to apply this method on the ground. Aside from being ambiguous, this method fails to address the fact that the plant species in a natural community are not distributed uniformly or randomly, and that any sampling scheme must take patchiness into account if subsequent analysis is to be meaningful. So without specific methodology or at least some clarification of intent, it is not possible to test this method. However, it is quite clear that in any calcareous fen it is possible to obtain a positive result using any of the four possible interpretations presented above. It would only depend on the size and placement of the plot(s).

The second method is called the "Calciphile Species Occurrence Method". This method is described as resulting in a positive determination "when the area has a natural community index value of 50 or more by summing the index values of the 27 calcareous fen indicator species" This is apparently intended to be a qualitative alternative to the preceding semi-quantitative method. In the second method each indicator species that is determined to be present is recorded regardless of its cover value or whether it is the dominant species or not. As in the first method, the relationship between sampling technique and floristic composition is not made clear. Since the supposed intent is only to determine which, if any, indicator species occur on the site, the plot size and shape was assumed to be coincident with the boundaries of the calcareous fen ecotope. Using this interpretation, the second method is not a sample but a floristic inventory, and no statistical analysis is necessary. However, this interpretation would seem to require that the boundaries of the fen be determined prior to the floristic inventory, rather than allowing the results of the inventory to determine the boundaries of the fen. It is unclear if this was the intent of the technical criteria, or even if the role of a floristic inventory as a method of delineation vs. designation was ever considered. However, it is clear that because of the non-random distribution of plant species within a community, and the inherent patchiness and discontinuity of species associations, a floristic inventory cannot serve as a useful tool for delineating community boundaries. But it does serve well as a simple and biologically-based method for comparing the floristic composition of one site to another site or to a designated type.

Comparable datasets for evaluation of the vegetation technical criteria were acquired for a total of 26 fens and 7 non-fens (Summarized in Table 12 and detailed in Table 13), where for this purpose, the Minnesota River Valley fens are treated as their own class.

**Table 12: Vascular Plant Technical Criterion (Species List Scores)**

| **Wetland Category** | Calciphile score as determined from species list | **Number of Sites Passing the Criterion** |
|---|---|---|
| Calcareous Fens | Calciphile Score >= 50 | 21 |
| 21 of 26 pass criterion | Calciphile Score < 50 | 5 |
| Non-Fen Wetlands | Calciphile Score >= 50 | 0 |
| none pass criterion | Calciphile Score < 50 | 7 |

**Table 13: Detailed Results of the Vegetation Criterion Test**

| | | | |
|---|---|---|---|
| Northwestern fen sites | | | |
| Faith Fen | Norman Co. | T111N R43W SW NW 25 | 159 points |
| Waubun WMA | Mahnomen Co. | T143N R42W NW SW 25 | 199 points |
| Spring Creek WMA | Becker Co. | T142N R42W NE NE 13 | 202 points |
| Felton WMA | Clay Co. | T142N R45W SE NW 31 | 160 points |
| | | | |
| Northwestern non-fen sites | | | |
| Crane WMA | Red Lake Co. | T151N R13W NE NW 13 | 1 point |
| Felton WMA | Clay Co. | T142N R45W NW NE 31 | 29 points |
| Pembina WMA | Pennington Co. | T152N R45W NE NW 18 | 12 points |
| | | | |
| Southwestern fen sites | | | |
| Thompson Fen | Jackson Co. | T103N R35W NE NE 7 | 83 points |
| Holthe SNA | Jackson Co. | T103 R 35W NW NW 8 | 87 points |
| Altona WMA | Pipestone Co. | T108N R46W NE NW 1 | 87 points |
| Sioux Nation WMA | Yellow Med Co | T114N R46W NW xx 17 | 89 points |
| Burke WMA | Pipestone Co. | T106N R44W SESE 28 | 85 points |
| Yonker's Fen | Jackson Co. | T101N R34W NW SE 27 | 33 points |
| Adrian Fen | Nobles Co. | T102N R43W SW SW 11 | 58 points |
| | | | |
| Southwestern non-fen sites | | | |
| Altona WMA | Pipestone Co. | T108N R46W NE NW 1 | 1 point |
| Prairie Coteau SNA | Pipestone Co. | T108N R44W SW SE 32 | 2 points |
| | | | |
| Southeastern fen sites | | | |
| Wiscoy Valley East | Winona Co. | T105N R7W NW SW 3 | 58 points |
| Perched Valley WMA | Goodhue Co. | T112N R13W NW SW 8 | 75 points |
| Rice Co. Park | Rice Co. | T111N R20W NE NE 34 | 67 points |
| Nelson Fen WMA | Olmsted Co. | T105N R 15W SW SE 16 | 156 points |
| Pogones WMA | Steele Co. | T105N R19W NW SE 18 | 29 points |
| Pheasants Forever WMA | Dodge Co. | T107N R17W SW SE 24 | 71 points |
| Wasioja WMA | Dodge Co. | T107N R17W SE SW 17 | 48 points |
| | | | |
| Southeastern non-fen sites | | | |
| Beaver Creek WMA | Fillmore Co. | T101N R13W NE SW 21 | 11 points |
| Iron Horse SNA | Dodge Co. | T105N R12W NW SE 27 | 7 points |
| | | | |
| Minnesota Valley fen sites | | | |
| Redwood Co. Fen | Redwood Co. | T114N R37W NE NW 27 | 91 points |
| Ottawa Fen | LeSueur Co. | T110N R26W NW SE 3 | 135 points |
| St. Peter Fen | Nicollet Co. | T111 R26W NE NE 16 | 34 points |
| Seminary Fen | Carver Co. | T116 R23W NE SW 35 | 156 points |
| Nicols Meadow | Dakota Co. | T27N R23W NE SW 18 | 71 points |
| Fort Snelling SP | Dakota Co. | T27N R23W SE NW 4 | 43 points |
| Savage Fen | Scott Co. | T115N R21W SE NE 17 | 194 points |
| Black Dog SNA | Dakota Co. | T27N R24W NW NE 34 | 162 points |

Highlighted Sites scored less than 50 points and thus fail the Vegetation Criterion

The average number of species recorded in each fen statewide was 61 (range 18-90), and the average number of species recorded in the non-fens statewide was 58 (range 46-71). The fens in the Minnesota Valley were the most diverse and averaged 74 species per site. The fens in the southwest were the least diverse and averaged 42 species per site.

Subjecting the species lists from each site to "method number two" resulted in 21 correct determinations and 5 incorrect determinations. Of the incorrect determinations, there was one in the southwest and two each in the southeast and the Minnesota Valley. None of the non-fen sites were misidentified as calcareous fens. The northwest region had no incorrect determinations at all. The sites for which there were incorrect determinations had lower total species diversities than the average for their respective regions.

The regional differences in floristic diversity seen in the fens is comparable to that in non-fen wetlands, and uplands as well. It is a well established in the literature that there is simply a greater number of plant species in the northwestern and southeastern portions of the state than in the southwestern portion. This is generally attributed to differences in climate and glacial history. It is also not surprising that this designation method gave adequate results in the northwest region, but not in the other 3 regions, since the method was created using data primarily from the northwest region.

Using the additional data collected during this project it is possible to create a single set of new floristic criteria that would serve to identify fens statewide. However, the sensitivity of such criteria would be greatly increased if the data were stratified regionally rather than statewide. This would result in a lesser chance of a non-fen being incorrectly identified as a fen. Designation of a calcareous fen should be based on the following regionalized, with the inclusion of a “Minnesota River Valley” category, floristic criteria. We further recommend a similar criteria for bryophytes, whereby the threshold that identifies a calcareous fen is a sum of both vegetation criteria of 50 points.

**Table 14: Regionalized List of 29 Vascular Plant Indicators to Identify Calcareous Fens in Minnesota**

| **Species** | **NW** | **MN valley** | **SE** | **SW** |
|---|---|---|---|---|
| Aster borealis | 1 | 5 | 5 | 5 |
| Berula pusila | - | 5 | 5 | - |
| Betula pumila | 1 | 5 | 5 | - |
| Bidens coronata | - | 5 | 5 | - |
| Bromus ciliatus | 1 | 5 | 5 | - |
| Cardamine bulbosa | 5 | 5 | 5 | 5 |
| Carex aquatilis | 1 | 5 | 25 | 25 |
| Carex hystericina | 1 | 5 | 5 | 25 |
| Carex interior | 1 | 5 | 5 | 5 |
| Carex prairea | 25 | 25 | 25 | 25 |
| Carex sterilis | 25 | 25 | 25 | 25 |
| Cladium mariscoides | 5 | 25 | - | - |
| Eleocharis rostellata | 25 | 25 | - | - |
| Eriophorum angustifolium | 1 | 1 | 5 | 5 |
| Gentianopsis procera | 1 | 5 | 25 | 25 |
| Liparis loeselii | 1 | 5 | 5 | 5 |
| Lobelia kalmii | 1 | 25 | 25 | 25 |
| Oxypolis rigidior | - | 5 | 5 | - |
| Parnassia glauca | 5 | 25 | 25 | 25 |
| Potentilla fruticosa | 1 | 25 | 25 | - |
| Primula mistassinica | 25 | - | - | - |
| Rhynchospora capillacea | 25 | 25 | 25 | 25 |
| Salix candida | 5 | 5 | 5 | - |
| Scirpus cespitosus | 5 | 25 | 25 | - |
| Scleria verticillata | 25 | 25 | 25 | 25 |
| Tofieldia glutinosa | 5 | 25 | - | - |
| Triglochin maritima | 1 | 25 | 25 | 25 |
| Triglochin palustris | 25 | 25 | 25 | 25 |
| Valeriana edulus | - | 5 | 5 | - |

*Note: Where the table does not contain a value in a regional column, that plant is not expected to occur in that region. In the unlikely case that it should occur, it will receive the maximum score for that plant.*

**Table 15: Results of the Regionalized Scoring Method Applied to 26 Complete Lists**

| | | | |
|---|---|---|---|
| Northwestern fen sites | | | |
| Faith Fen | Norman Co. | T111N R43W SW NW 25 | 148 points |
| Waubun WMA | Mahnomen Co. | T143N R42W NW SW 25 | 208 points |
| Spring Creek WMA | Becker Co. | T142N R42W NE NE 13 | 215 points |
| Felton WMA | Clay Co. | T142N R45W SE NW 31 | 154 points |
| Northwestern non-fen sites | | | |
| Crane WMA | Red Lake Co. | T151N R13W NE NW 13 | 3 point |
| Felton WMA | Clay Co. | T142N R45W NW NE 31 | 35 points |
| Pembina WMA | Pennington Co. | T152N R45W NE NW 18 | 11 points |
| Southwestern fen sites | | | |
| Thompson Fen | Jackson Co. | T103N R35W NE NE 7 | 185 points |
| Holthe SNA | Jackson Co. | T103 R 35W NW NW 8 | 250 points |
| Altona WMA | Pipestone Co. | T108N R46W NE NW 1 | 250 points |
| Sioux Nation WMA | Yellow Med Co | T114N R46W NW xx 17 | 220 points |
| Burke WMA | Pipestone Co. | T106N R44W SESE 28 | 245 points |
| Yonker's Fen | Jackson Co. | T101N R34W NW SE 27 | 130 points |
| Adrian Fen | Nobles Co. | T102N R43W SW SW 11 | 160 points |
| Southwestern non-fen sites | | | |
| Altona WMA | Pipestone Co. | T108N R46W NE NW 1 | 10 point |
| Prairie Coteau SNA | Pipestone Co. | T108N R44W SW SE 32 | 15 points |
| Southeastern fen sites | | | |
| Wiscoy Valley East | Winona Co. | T105N R7W NW SW 3 | 75 points |
| Perched Valley WMA | Goodhue Co. | T112N R13W NW SW 8 | 160 points |
| Rice Co. Park | Rice Co. | T111N R20W NE NE 34 | 70 points |
| Nelson Fen WMA | Olmsted Co. | T105N R 15W SW SE 16 | 225 points |
| Pogones WMA | Steele Co. | T105N R19W NW SE 18 | 55 points |
| Pheasants Forever WMA | Dodge Co. | T107N R17W SW SE 24 | 190 points |
| Wasioja WMA | Dodge Co. | T107N R17W SE SW 17 | 85 points |
| Southeastern non-fen sites | | | |
| Beaver Creek WMA | Fillmore Co. | T101N R13W NE SW 21 | 15 points |
| Iron Horse SNA | Dodge Co. | T105N R12W NW SE 27 | 20 points |
| Minnesota Valley fen sites | | | |
| Redwood Co. Fen | Redwood Co. | T114N R37W NE NW 27 | 201 points |
| Ottawa Fen | LeSueur Co. | T110N R26W NW SE 3 | 246 points |
| St. Peter Fen | Nicollet Co. | T111 R26W NE NE 16 | 91 points |
| Seminary Fen | Carver Co. | T116 R23W NE SW 35 | 275 points |
| Nicols Meadow | Dakota Co. | T27N R23W NE SW 18 | 141 points |
| Fort Snelling SP | Dakota Co. | T27N R23W SE NW 4 | 105 points |
| Savage Fen | Scott Co. | T115N R21W SE NE 17 | 381 points |
| Black Dog SNA | Dakota Co. | T27N R24W NW NE 34 | 351 points |

Highlighted Sites scored less than 50 points and thus fail the Vegetation Criterion

This analysis shows that, for the sites with the most complete data we could obtain, the new criterion provides a correct assessment for all calcareous fens without causing false positive determinations.

Because, for sites with data from only one or two visits, false negatives are a great concern, we tested the new criterion on lists in the records of other known calcareous fens.

**Table 16: Results of the Regionalized Scoring Method Applied to Typical Lists in Site Records ....................**

| | | | old | new |
|---|---|---|---|---|
| Northwestern fen sites | | | | |
| Felton Prairie Felton WMA | Clay | T142N R46W 0ESE36 | 112 | 113 |
| Waubun WMA East | Mahnomen | T143N R41W SWSE30 | 159 | 175 |
| Green Meadow 35 | Norman | T145N R45W SW36, SESE35 | 32 | 34 |
| Sanders Fen North | Pennington | T153N R44W 0WNE07 | 64 | 67 |
| Sanders Fen South | Pennington | T153N R44W SE18, NE19" | 69 | 72 |
| Spring Hill Fen | Stearns | T124N R33W 0N16, SE16, NWSW15 | 127 | 125 |
| St. Wendel Swamp SW (St.Stephan) | Stearns | T125N R29W 0S17 | 70 | 77 |
| Southwestern fen sites | | | | |
| Sam Tutt Fen | Lyon | T109N R43W SE22 | 33 | 80 |
| Lost Timber Prairie | Murray | T105N R43W SWSE02 | 27 | 100 |
| Fairchild Fen | Yellow Medicine | T114N R46W SESWSW05 | 85 | 220 |
| Southeastern fen sites | | | | |
| Red Wing 21 | Goodhue | T113N R15W 0SSE21 | 57 | 65 |
| Houston 26 | Houston | T104N R06W 0NNW26 | 31 | 35 |
| Sheldon 16 | Houston | T103N R06W NWNE16 | 32 | 35 |
| Dover 13 (Eyota 13) | Olmsted | T106N R12W NENESW13 | 68 | 145 |
| High Forest 35 (Stewartville) | Olmsted | T105N R14W NENESW35 | 5 | 30 |
| Mutchler Fen | Olmsted | T106N R14W SWNW23 | 82 | 60 |
| Stonehedge Fen | Olmsted | T107N R13W NENW19 | 27 | 35 |
| Wiscoy 15 | Winona | T105N R07W SESW15 | 63 | 100 |
| Minnesota Valley fen sites | | | | |
| Watson Sag Fen | Chippewa | T118N R41W NWNW06 | 33 | 105 |
| Zion Lutheran Church Fen | Chippewa | T118N R41W 0NSW06 | 31 | 81 |
| Fort Ridgely Fen | Nicollet | T111N R32W NWSE06 | 59 | 115 |
| Savage Fen SNA | Scott | T115N R21W SENW17 | 147 | 286 |

Highlighted Sites scored less than 50 points and thus fail the Vegetation Criterion

The results reveal that the new scoring method improved results for Southwestern fen sites and Minnesota Valley sites. Incomplete lists from the southeastern fen sites received higher scores, but those that failed under the old criterion also failed under the new.

Plant lists created from relevé records from calcareous fen sites statewide were scored using both scoring methods. These lists represent a complete list for the date of the visit, recorded from a plot selected to be representative of the site.

**Table 17: Results of the Regionalized Scoring Method Applied to All Calcareous Fen Relevés**

| Region | Calciphile score as determined from 'species list' (plants recorded in relevé plot) | Number of Sites Scored under the Old Criterion | Number of Sites Scored under the New Criterion |
|---|---|---|---|
| Minnesota River Valley | Calciphile Score >= 50 | 13 | 14 |
| | Calciphile Score < 50 | 1 | 0 |
| Northwest | Calciphile Score >= 50 | 38 | 38 |
| | Calciphile Score < 50 | 19 | 19 |
| Southeast | Calciphile Score >= 50 | 1 | 2 |
| | Calciphile Score < 50 | 2 | 1 |
| Southwest | Calciphile Score >= 50 | 3 | 8 |
| | Calciphile Score < 50 | 6 | 1 |

The new vegetation criterion does improve the sensitivity of our technical criteria when applied to calcareous fen sites outside of Northwestern Minnesota, but a significant risk of false negative still exists where site information is not exhaustive or must be obtained within a limited time frame (and thus cannot adequately assess the plant community).

As detailed above, the physical criteria can assess the suitability of a site for a calcareous fen community, but cannot verify its existence. Thus assessment of the presence of calciphile bryophytes, a frequent component of calcareous fen communities, has been added to the technical criteria for the designation of calcareous fens in Minnesota.

**Bryophytes**

An analysis (Janssens, 2002, updated 2004) of all bryophytes collected in wetland habitats compared the frequency of occurrence in calcareous fens to the frequency of occurrence in non-calcareous fen habitats to determine which species are calcareous fen indicators based on a ranking of their importance value (IPV = frequency of occurrence in CF times the quotient of the frequency in CF with the frequency in non-CF ecotopes).

Figure 3 and perusal of the species list (Table 18) suggests there is a reasonable division in obligate and near-obligate calcareous fen indicators (OB) with an IPV above 1.000 (17 species), facultative (FA) calcareous fen species with an IPV between 0.100 and 1.000 (15 species), and the remaining 96 species with an occasional (OC) occurrence and an IPV of <0.100.

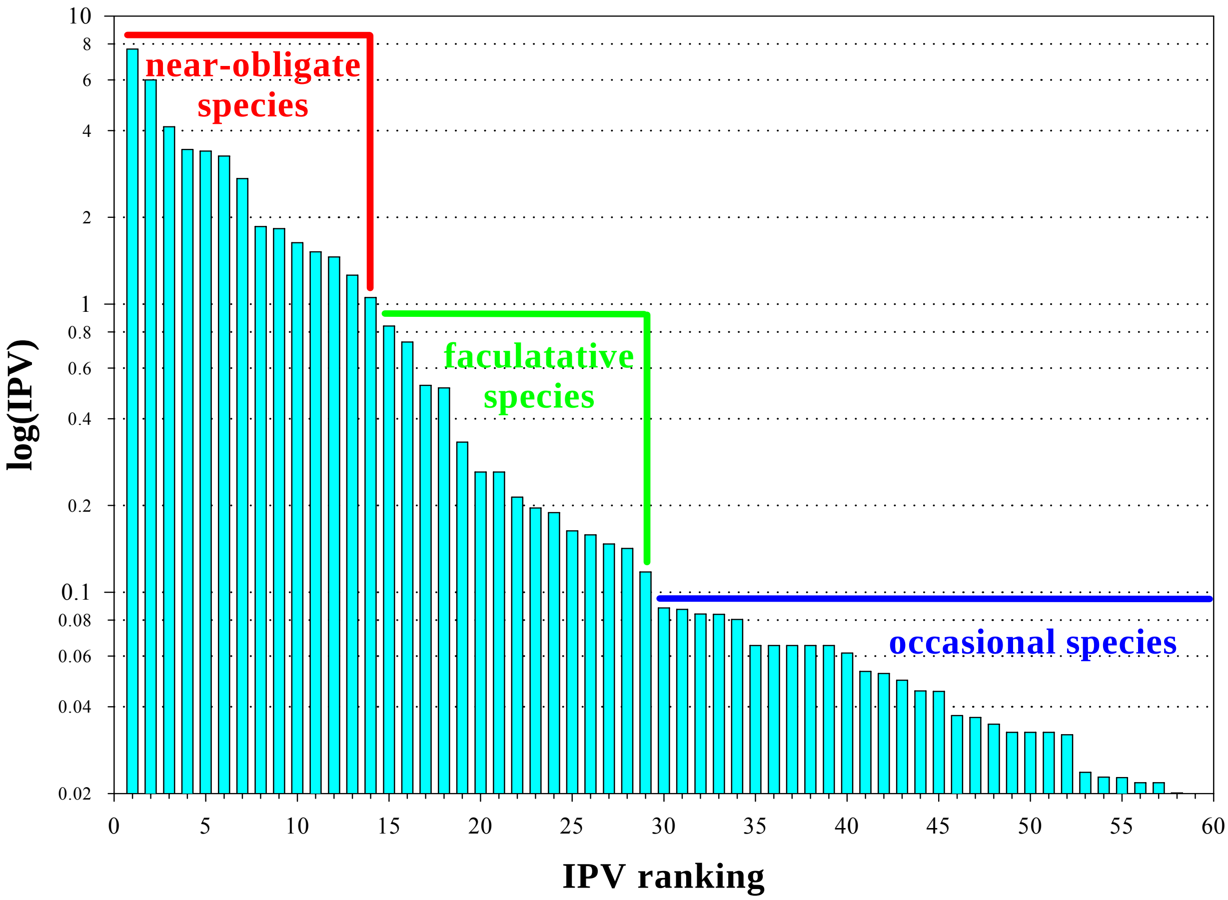


**Figure 3.** Ranking of bryophytes occurring in calcareous fens. Only those with an IPV (see text) above 0.200 are shown.

**Table 18. Bryophyte species occurring in Minnesota's calcareous fens in order of descending IPV.**
The species with an IPV >1.000 are obligate and near-obligate indicators, with and IPV >0.100 and <1.000 are facultative indicators, and those with an IPV <0.100 are occasional species. The column labeled 'n CF' lists the number of calcareous - fen ecotopes in which the species occurs (out of a total of 128), 'n tot' the total number of ecotopes in Minnesota where the species has been found (out of a total of 1128). The values in the columns labeled 'CFB', 'CFPnw', 'CFPsw', and 'CFPse' are the relative abundance of the species in the extreme rich fens of boreal forested region, and the calcareous fens of the NW, SW, and SE prairie sub-regions. The relative abundance is calculated as the 100 times quotient of the number of vouchers collected for the species over the total number of vouchers within the regions or sub-region (total number of vouchers for CFB = 928, CFPnw = 1806, CFPse = 1332, and CFPsw = 2339).

| | | | | | boreal | ----------prairie --------- | | |
|---|---|---|---|---|---|---|---|---|
| **acronym** | **species name** | **IPV** | **n CF** | **n tot** | **CFB** | **CFPnw** | **CFPse** | **CFPsw** |
| **obligate and near-obligate species (OB)** | | | | | | | | |
| BRYUULIG | *Bryum uliginosum* | inf. | 1 | 1 | | 0.06 | | |
| CATONIGR | *Catoscopium nigritum* | inf. | 5 | 5 | 0.86 | 0.06 | | |
| PALUSQUA | *Paludella squarrosa* | inf. | 3 | 3 | 1.29 | | | |
| ANEUPING | *Aneura pinguis* | 7.6766 | 52 | 75 | 1.62 | 4.26 | 3.53 | 7.52 |

| acronym | species name | IPV | n CF | n tot | boreal<br>CFB | ----------prairie ---------<br>CFPnw | CFPse | CFPsw |
|---|---|---|---|---|---|---|---|---|
| LIMPCOSS | *Limprichtia cossonii* | 6.0073 | 46 | 69 | 11.96 | 13.95 | 0.23 | 11.59 |
| CAMPSTEL | *Campylium stellatum* | 4.1284 | 67 | 138 | 15.52 | 39.76 | 9.53 | 15.82 |
| DREPADUN | *Drepanocladus aduncus* | 3.4381 | 74 | 178 | 4.09 | 2.60 | 14.04 | 16.84 |
| BRYUPSEU | *Bryum pseudotriquetrum* | 3.3978 | 76 | 187 | 6.68 | 18.22 | 3.60 | 10.94 |
| BRACRIVU | *Brachythecium rivulare* | 3.2648 | 50 | 100 | 2.48 | 1.94 | 15.24 | 3.72 |
| CALRCUSP | *Calliergonella cuspidata* | 2.7283 | 31 | 54 | 2.05 | 0.61 | 2.33 | 5.69 |
| SCORSCOR | *Scorpidium scorpioides* | 1.8590 | 22 | 39 | 4.74 | 5.09 | | |
| CINCSTYG | *Cinclidium stygium* | 1.8283 | 14 | 21 | 3.13 | | | |
| MOERHIBE | *Moerckia hibernica* | 1.6324 | 15 | 24 | 2.59 | 0.55 | | |
| CALLTRIF | *Calliergon trifarium* | 1.5196 | 16 | 27 | 3.34 | 1.33 | | |
| PLAGELLI | *Plagiomnium ellipticum* | 1.4570 | 59 | 215 | 2.91 | 1.38 | 14.19 | 7.48 |
| CAMPPOLY | *Campylium polygamum* | 1.2612 | 26 | 61 | 4.09 | 1.05 | 1.88 | 3.33 |
| FISSADIA | *Fissidens adianthoides* | 1.0535 | 22 | 52 | 4.85 | 0.50 | 1.13 | |
| **facultative species (FA)** | | | | | | | | |
| AMBLVARI | *Amblystegium varium* | 0.8392 | 28 | 89 | 0.54 | 0.28 | 3.90 | 1.07 |
| TOMENITE | *Tomenthypnum nitens* | 0.7384 | 21 | 60 | 2.37 | 0.72 | 0.15 | |
| EURHHIAN | *Eurhynchium hians* | 0.5224 | 12 | 30 | 0.43 | | 1.50 | |
| AMBLSEJU | *Amblystegium serpens var. juratzkanum* | 0.5119 | 14 | 39 | 0.86 | 1.72 | 0.53 | 3.51 |
| BRACSALE | *Brachythecium salebrosum* | 0.3318 | 25 | 148 | 0.32 | 0.11 | 4.65 | 8.85 |
| HAMALAPP | *Hamatocaulis lapponicus* | 0.2612 | 2 | 3 | 0.32 | | | |
| MEESTRIQ | *Meesia triquetra* | 0.2612 | 4 | 8 | 0.65 | | | |
| HELOBLAN | *Helodium blandowii* | 0.2137 | 12 | 56 | 0.22 | 0.39 | 0.53 | 0.21 |
| PSEATURG | *Pseudo-calliergon turgescens* | 0.1959 | 3 | 6 | 0.11 | 0.89 | | |
| CRATFILI | *Cratoneuron filicinum* | 0.1889 | 9 | 37 | 0.86 | 0.89 | 2.10 | |
| CONACOMP | *Conardia compacta* | 0.1632 | 5 | 15 | | 0.06 | | 0.43 |
| HYPNLIND | *Hypnum lindbergii* | 0.1582 | 19 | 168 | 0.86 | 0.72 | 2.85 | 0.09 |
| CAMPSTPR | *Campylium stellatum var. protensum* | 0.1469 | 3 | 7 | | 0.83 | | 1.71 |
| DREPADPO | *Drepanocladus aduncus var. polycarpus* | 0.1419 | 10 | 56 | 0.22 | 0.06 | 1.35 | 0.13 |
| RICDLATI | *Riccardia latifrons* | 0.1175 | 6 | 26 | 0.97 | | | |
| **occasional species (OC)** | | | | | | | | |
| PLAGCUSP | *Plagiomnium cuspidatum* | 0.0882 | 17 | 231 | 0.54 | 0.22 | 1.73 | 0.09 |
| DREPSEND | *Drepanocladus sendtneri* | 0.0871 | 2 | 5 | 0.11 | 0.22 | | |
| RICDPALM | *Riccardia palmata* | 0.0840 | 3 | 10 | 0.43 | | | |
| HYPNPRAT | *Hypnum pratense* | 0.0837 | 10 | 88 | 0.22 | | 2.18 | 0.09 |
| LEPDHUMI | *Leptodictyum humile* | 0.0804 | 4 | 17 | | | 0.45 | 0.13 |
| ATRIUNDU | *Atrichum undulatum* | 0.0653 | 1 | 2 | | | 0.08 | |
| DREPSORD | *Drepanocladus sordidus* | 0.0653 | 1 | 2 | 0.11 | | | |
| ORTHPUMI | *Orthotrichum pumilum* | 0.0653 | 2 | 6 | 0.11 | 0.06 | | |
| PHILCAPI | *Philonotis capillaris* | 0.0653 | 1 | 2 | | | 0.08 | |
| PHILMARC | *Philonotis marchica* | 0.0653 | 1 | 2 | | | 0.08 | |
| LESKPOLY | *Leskea polycarpa* | 0.0615 | 4 | 21 | 0.22 | 0.17 | 0.08 | 0.17 |
| AULAPALU | *Aulacomnium palustre* | 0.0531 | 14 | 255 | 1.08 | 0.28 | 0.83 | |
| BRYULICU | *Bryum lisae var. cuspidatum* | 0.0522 | 2 | 7 | | | 0.15 | |
| HYGATENA | *Hygroamblystegium tenax* | 0.0495 | 5 | 38 | 0.11 | | 0.45 | |
| CAMPRADI | *Campylium radicale* | 0.0454 | 4 | 27 | 2.05 | 0.06 | 0.08 | |
| CALLGIGA | *Calliergon giganteum* | 0.0452 | 6 | 58 | 0.97 | 0.17 | | |
| PLAHRIPA | *Platyhypnidium riparioides* | 0.0373 | 2 | 9 | | | 0.23 | |
| MYULJULA | *Myurella julacea* | 0.0367 | 3 | 19 | 0.32 | | | |
| HAMAVERN | *Hamatocaulis vernicosus* | 0.0348 | 4 | 34 | 0.75 | | | |
| BRACDIGA | *Brachythecium digastrum* | 0.0326 | 1 | 3 | | | 0.08 | |
| DICEVARI | *Dicranella varia* | 0.0326 | 1 | 3 | | | | 0.04 |
| PTEGFILI | *Pterigynandrum filiforme* | 0.0326 | 2 | 10 | 0.11 | | 0.08 | |
| AMBLSERP | *Amblystegium serpens* | 0.0320 | 5 | 56 | | 0.06 | 0.53 | 0.04 |
| HELOPALU | *Helodium paludosum* | 0.0237 | 2 | 13 | | | 1.65 | |
| BRACOEDI | *Brachythecium oedipodium* | 0.0228 | 6 | 109 | 2.16 | | 0.60 | |
| CAMPCHRY | *Campylium chrysophyllum* | 0.0227 | 4 | 50 | 0.22 | 0.17 | 0.23 | |
| HELOBLHE | *Helodium blandowii var. helodioides* | 0.0218 | 1 | 4 | | | 0.15 | |
| RICRNATA | *Ricciocarpos natans* | 0.0218 | 1 | 4 | | 0.06 | | |
| CLIMAMER | *Climacium americanum* | 0.0201 | 2 | 15 | | | 0.23 | |
| LESKGRAC | *Leskea gracilescens* | 0.0163 | 3 | 39 | 0.43 | | 0.15 | |
| ATRIALTE | *Atrichum altecristatum* | 0.0154 | 2 | 19 | | | 0.15 | |
| BRACPLUM | *Brachythecium plumosum* | 0.0154 | 2 | 19 | | | 0.15 | |
| SPHAWARN | *Sphagnum warnstorfii* | 0.0146 | 5 | 117 | 2.26 | | | |

| acronym | species name | IPV | n CF | n tot | CFB | CFPnw | CFPse | CFPsw |
|---|---|---|---|---|---|---|---|---|
| BRACACUM | *Brachythecium acuminatum* | 0.0143 | 4 | 77 | | | 0.23 | 0.13 |
| ENTOSEDU | *Entodon seductrix* | 0.0137 | 2 | 21 | | | 0.08 | 0.04 |
| THUIRECO | *Thuidium recognitum* | 0.0137 | 5 | 124 | 0.97 | | 0.08 | |
| PLATDENT | *Plagiothecium denticulatum* | 0.0134 | 4 | 82 | 0.11 | 0.06 | 0.45 | |
| CEPHPLSP | *Cephalozia pleniceps ssp. sphagnorum* | 0.0131 | 1 | 6 | 0.11 | | | |
| FISSDUBI | *Fissidens dubius* | 0.0131 | 2 | 22 | | | 0.30 | |
| FRULINFL | *Frullania inflata* | 0.0131 | 1 | 6 | 0.11 | | | |
| PYLLSELW | *Pylaisiella selwynii* | 0.0122 | 3 | 51 | 0.32 | | 0.08 | |
| LOPCHETE | *Lophocolea heterophylla* | 0.0118 | 5 | 143 | 0.11 | 0.11 | 0.30 | 0.04 |
| MARCPOLY | *Marchantia polymorpha* | 0.0104 | 2 | 27 | | 0.06 | 0.15 | |
| WARNEXAN | *Warnstorfia exannulata* | 0.0104 | 2 | 27 | | 0.06 | 0.08 | |
| CAMPHISP | *Campylium hispidulum* | 0.0095 | 3 | 65 | 0.54 | | 0.08 | |
| BRACOXYC | *Brachythecium oxycladon* | 0.0093 | 2 | 30 | | | 0.15 | |
| PHYTPYRI | *Physcomitrium pyriforme* | 0.0093 | 1 | 8 | | | 0.08 | |
| SPHAFUSC | *Sphagnum fuscum* | 0.0084 | 4 | 129 | 0.65 | | | |
| CEPHCOCO | *Cephalozia connivens var. compacta* | 0.0082 | 1 | 9 | 0.32 | | | |
| PHILFONT | *Philonotis fontana* | 0.0082 | 1 | 9 | | | 0.53 | |
| PLADJUNG | *Platydictya jungermannioides* | 0.0082 | 1 | 9 | | | | 0.09 |
| RHIZGRAC | *Rhizomnium gracile* | 0.0082 | 1 | 9 | 0.11 | | | |
| FISSOSMU | *Fissidens osmundioides* | 0.0077 | 2 | 36 | 0.43 | | | |
| LEPDRIPA | *Leptodictyum riparium* | 0.0077 | 2 | 36 | | | 0.08 | 0.04 |
| SPHAFIMB | *Sphagnum fimbriatum* | 0.0069 | 2 | 40 | | | 0.75 | |
| FRULOAKE | *Frullania oakesiana* | 0.0065 | 1 | 11 | 0.11 | | | |
| CONCCONI | *Conocephalum conicum* | 0.0061 | 2 | 45 | 0.11 | | 0.08 | |
| THUIDELI | *Thuidium delicatulum* | 0.0060 | 3 | 101 | | | 0.38 | |
| PLACASPL | *Plagiochila asplenoides* | 0.0053 | 2 | 51 | 0.22 | | | |
| BRACPOPU | *Brachythecium populeum* | 0.0038 | 1 | 18 | | | 0.23 | |
| MYLIANOM | *Mylia anomala* | 0.0036 | 1 | 19 | 0.11 | | | |
| TORLFRAG | *Tortella fragilis* | 0.0036 | 1 | 19 | 0.22 | | | |
| CHILPALL | *Chiloscyphus pallescens* | 0.0034 | 1 | 20 | | | 0.08 | |
| POLYSTRI | *Polytrichum strictum* | 0.0032 | 3 | 187 | 0.43 | | | |
| ATRIOERS | *Atrichum oerstedianum* | 0.0028 | 1 | 24 | | | 0.08 | |
| DISTCAPI | *Distichium capillaceum* | 0.0028 | 1 | 24 | 0.11 | | | |
| LEPTPYRI | *Leptobryum pyriforme* | 0.0028 | 1 | 24 | 0.11 | | | |
| TAXIDEPL | *Taxiphyllum deplanatum* | 0.0027 | 1 | 25 | | | 0.08 | |
| SPHAANGU | *Sphagnum angustifolium* | 0.0026 | 3 | 227 | 0.22 | | 0.08 | |
| BRACERYT | *Brachythecium erythrorrhizon* | 0.0026 | 2 | 104 | 0.11 | 0.06 | | |
| BRYERECU | *Bryoerythrophyllum recurvirostre* | 0.0023 | 1 | 30 | | 0.06 | | |
| SPHACAPI | *Sphagnum capillifolium* | 0.0018 | 2 | 146 | 0.11 | | 0.15 | |
| STEESERR | *Steerecleus serrulatus* | 0.0017 | 1 | 39 | | | 0.08 | |
| CLIMDEND | *Climacium dendroides* | 0.0015 | 2 | 175 | | | 0.75 | |
| ORTHOBTU | *Orthotrichum obtusifolium* | 0.0015 | 1 | 45 | 0.11 | | | |
| PLAGCILI | *Plagiomnium ciliare* | 0.0014 | 1 | 47 | | | | 0.17 |
| SPHASUSS | *Sphagnum subsecundum s.s.* | 0.0013 | 1 | 50 | | | 0.08 | |
| SPHASQUA | *Sphagnum squarrosum* | 0.0013 | 1 | 51 | | | 0.08 | |
| CEPHCONN | *Cephalozia connivens* | 0.0012 | 1 | 56 | 0.11 | | | |
| ORTHELEG | *Orthotrichum elegans* | 0.0011 | 1 | 61 | 0.11 | | | |
| POLYCOMM | *Polytrichum commune* | 0.0011 | 1 | 63 | | | 0.08 | |
| BRACREFL | *Brachythecium reflexum* | 0.0010 | 1 | 64 | | | 0.08 | |
| ENTOCLAD | *Entodon cladorrhizans* | 0.0010 | 1 | 66 | | | 0.08 | |
| PLEUSCHR | *Pleurozium schreberi* | 0.0009 | 2 | 297 | 0.22 | | | |
| PYLLPOLY | *Pylaisiella polyantha* | 0.0009 | 1 | 76 | | 0.17 | | |
| DICRUNDU | *Dicranum undulatum* | 0.0008 | 1 | 79 | 0.11 | | | |
| CERAPURP | *Ceratodon purpureus* | 0.0008 | 1 | 83 | | | 0.08 | |
| EURHPULC | *Eurhynchium pulchellum* | 0.0008 | 1 | 84 | | | 0.30 | |
| SPHACENT | *Sphagnum centrale* | 0.0008 | 1 | 87 | | | 0.15 | |
| ANOMMINO | *Anomodon minor* | 0.0007 | 1 | 95 | 0.11 | | | |
| HYLOSPLE | *Hylocomium splendens* | 0.0007 | 1 | 96 | 0.11 | | | |
| CALLCORD | *Calliergon cordifolium* | 0.0007 | 1 | 101 | | | 0.15 | |
| PLAYREPE | *Platygyrium repens* | 0.0004 | 1 | 162 | 0.11 | | | |
| PTIDPULC | *Ptilidium pulcherrimum* | 0.0004 | 1 | 168 | 0.11 | | | |
| DICRPOLY | *Dicranum polysetum* | 0.0004 | 1 | 176 | 0.11 | | | |
| SPHAMAGE | *Sphagnum magellanicum* | 0.0003 | 1 | 241 | 0.11 | | | |

**Validation of the Calcareous Fens of the Prairie Region**

Assigning an arbitrary value of 25 points to the obligate and near-obligate bryophyte calcareous fen indicators, 5 to the facultative species, and 1 to the occasional species, the following validation is obtained of the calcareous fens of the prairie region (Table 19, the localities are mapped in Figure 4):

**Table 19. Validation of the calcareous fen localities of the prairie region of Minnesota, based on the presence of calcareous fen indicators among the bryophyte flora**. The *a priori* list of calcareous prairie fens studied has been provided by the Minnesota Department of Natural Resources (Aaseng *et al.* 1993 and pers. comm.) and the typing of the sites as calcareous fens is based on an independent assessment using vascular-plant indicators, and soil and water-chemistry characteristics (J.H. Leete and W.R. Smith, pers. comm.). This table can be used as part of the assessment to evaluate non-listed sites in the prairie region for their identification and potential as calcareous fens. Some of the localities listed consist of a complex of adjacent ecotopes.

| | value | locality name |
|---|---|---|
| **Northwester sub-region** | | |
| | 329 | Ogema Spring |
| | 243 | Barnesville State Wildlife Management Area |
| | 241 | Felton State Wildlife Management Area |
| | 226 | Gully |
| | 205 | Sanders 18 |
| | 125 | Holt Meadow |
| | 105 | Green Meadow |
| | 105 | Waubun |
| **Southeastern sub-region** | | |
| | 253 | Ottawa |
| | 249 | Cannon River Wilderness Area County Park |
| | 202 | Perched Valley WMA |
| | 196 | Wasioja |
| | 192 | Pheasants Forever WMA |
| | 191 | McCarthy WMA |
| | 169 | Fort Snelling State Park |
| | 156 | Stewartville |
| | 153 | Savage |
| | 114 | Nelson WMA |
| | 113 | Stonehedge |
| | 106 | Kennedy |
| | 100 | Nelson |
| | 100 | Red Wing 21 |
| | 87 | Perched Valley |
| | 85 | Mutchler |
| | 85 | Wiscoy Valley East |
| | 81 | Eyota 13 |
| | 75 | Houston 26 |
| | 70 | Sheldon 16 |
| | 59 | Cannon Valley Trail |
| | 51 | Nicols |
| | 26 | Black Dog Preserve SNA |
| **Southwester sub-region** | | |
| | 235 | Sioux Nation |
| | 186 | Holte Prairie |
| | 185 | Fairchild |
| | 180 | Zion Lutheran Church |
| | 175 | Burke WMA |
| | 150 | Watson Sag Fen (Kragero Township) |
| | 105 | Altoona Fen |
| | 100 | Adrian |
| | 89 | Fort Ridgely |
| | 80 | Yonker |
| | 76 | Jeffers |
| | 55 | Sam Tutt |
| | 50 | Fort Ridgely State Park |
| | 31 | Lost Timber |

Use of information about the bryophyte component of the calcareous fen community, where a bryophyte population exists at the site, will reduce false negatives due to inadequate data as bryophytes can be collected in all seasons. The sum of the vascular plant score and the bryophyte score will be used and the passing score will remain at 50 points. When bryophyte scores are added to the vascular plant scores of calcareous fen sites with partial data that did not initially pass the criterion, all then met the 50 point threshold (Table 20).

**Table 20: Results of the New Scoring Method Including Byrophytes Applied to Typical Lists in Site Records........**

| | | | | |
|---|---|---|---|---|
| Northwestern fen sites | | | new | +byro |
| Felton Prairie Felton WMA | Clay | T142N R46W 0ESE36 | 113 | no data |
| Waubun WMA East | Mahnomen | T143N R41W SWSE30 | 175 | 280 |
| Green Meadow 35 | Norman | T145N R45W SW36, SESE35 | 34 | 139 |
| Sanders Fen North | Pennington | T153N R44W 0WNE07 | 67 | no data |
| Sanders Fen South | Pennington | T153N R44W SE18, NE19" | 72 | 277 |
| Spring Hill Fen | Stearns | T124N R33W 0N16, SE16, NWSW15 | 125 | pending |
| St. Wendel Swamp SW (St.Stephan) | Stearns | T125N R29W 0S17 | 77 | pending |
| | | | | |
| Southwestern fen sites | | | | |
| Shelburne 22 Fen | Lyon | T109N R43W SE22 | 80 | 135 |
| Lost Timber Prairie | Murray | T105N R43W SWSE02 | 100 | 131 |
| Fairchild Fen | Yellow Medicine | T114N R46W SESWSW05 | 220 | 405 |
| | | | | |
| Southeastern fen sites | | | | |
| Red Wing 21 | Goodhue | T113N R15W 0SSE21 | 65 | 165 |
| Houston 26 | Houston | T104N R06W 0NNW26 | 35 | 110 |
| Sheldon 16 | Houston | T103N R06W NWNE16 | 35 | 105 |
| Dover 13 (Eyota 13) | Olmsted | T106N R12W NENESW13 | 145 | 226 |
| High Forest 35 (Stewartville) | Olmsted | T105N R14W NENESW35 | 30 | 186 |
| Mutchler Fen | Olmsted | T106N R14W SWNW23 | 60 | 85 |
| Stonehedge Fen | Olmsted | T107N R13W NENW19 | 35 | 148 |
| Wiscoy 15 | Winona | T105N R07W SESW15 | 100 | 206 |
| | | | | |
| Minnesota Valley fen sites | | | | |
| Watson Sag Fen | Chippewa | T118N R41W NWNW06 | 105 | 255 |
| Zion Lutheran Church Fen | Chippewa | T118N R41W 0NSW06 | 81 | 261 |
| Fort Ridgely Fen | Nicollet | T111N R32W NWSE06 | 115 | 204 |
| Savage Fen SNA | Scott | T115N R21W SENW17 | 286 | 439 |

Highlighted Sites scored less than 50 points and thus fail the Vegetation Criterion

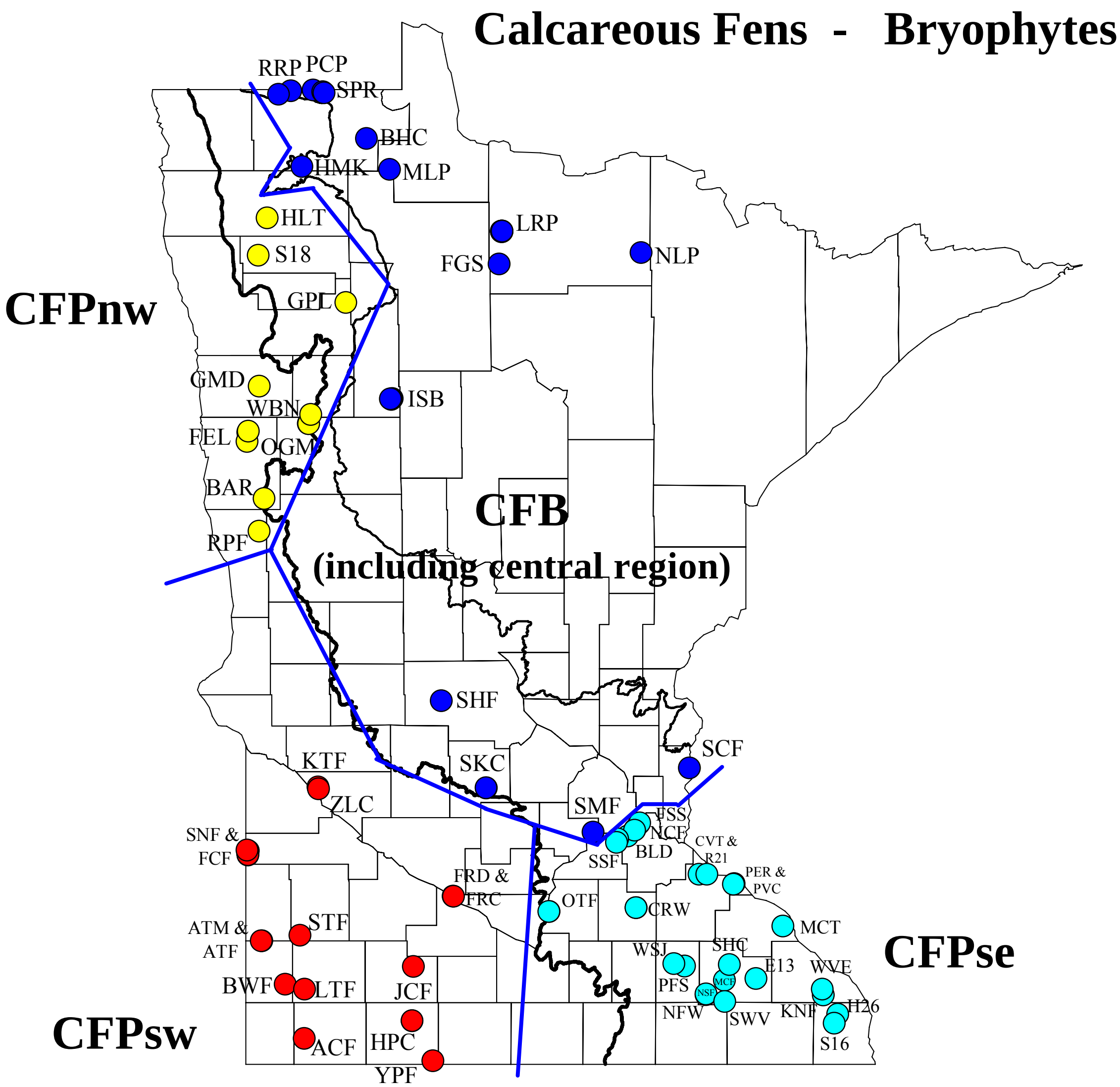


**Figure 4.** Localities of calcareous and extreme rich-fens in Minnesota studied for bryophytes. The localities are not yet regionalized pending collection of data from additional sites. Classification of a site as a calcareous fen was based on the 1995 criteria discussed above. The key to the site codes is provided in an Appendix.

A logical concern following this analysis would be whether these increased scores would also be recorded in non-fen wetlands. Investigation of this possibility was conducted by using these criteria to score all (n=240) non-calcareous fen wetland relevés for which proximate bryophyte data were available. None of these sites scored over 31 points based on vascular plants alone. Forty-six sites scored over 50 points based on the sum of bryophyte and vascular plant scores (these are false positives). Almost all of the false positives occur above 47 degrees latitude and have insignificant vascular plant scores. Thus, the criteria for scoring a site at a latitude above 47 degrees for which both vascular plant and bryophyte data are available should be 80 points.

# DRAFT REVISED TECHNICAL CRITERIA FOR IDENTIFYING CALCAREOUS FENS IN MINNESOTA

#### HYDROLOGY TECHNICAL CRITERION

An area meets the hydrology technical criterion when the hydrology is characterized by having stable, typically upwelling groundwater inflows sufficient to maintain saturation for the development of a histosol or a histic epipedon soil.

#### SOILS TECHNICAL CRITERION

An area meets the soils technical criteria when the soils are characterized by the presence of either a histosol or a histic epipedon. Calcium carbonate precipitates, such as tufa deposits, may frequently be associated with calcareous fens and high carbonate content in this case is not indicative of a mineral soil.

#### WATER CHEMISTRY TECHNICAL CRITERION

Water chemistry of calcareous fens should be characterized by measurement of the following parameters: specific conductance (µS/cm), pH, alkalinity (mg/l $CaCO_3$), ratio of the concentration of calcium plus magnesium ions ([Ca+Mg]) to total cations (% meq/l), and alkalinity/total anions (% meq/l). Of these parameters, it is imperative that specific conductance, pH, and alkalinity be measured in the field (*in situ*). Samples would be collected for laboratory determination of the other parameters. Standard methods should be used for sample collection techniques and sample preparation and handling.

An area meets the water chemistry technical criterion when the following conditions are met: pH of 6.7 or more; calcium of 30 mg/l or more; alkalinity of 1.65 meq/l or more; and, specific conductance of 500 µS/cm or more. [Data for other parameters must be collected to provide further water chemistry definition of calcareous fens.]

#### VEGETATION TECHNICAL CRITERION

The Minnesota DNR has developed a regionalized list of vascular plant calciphiles (Table 14) and a statewide list of bryophyte calciphiles (Table 18) indicative of calcareous fens of the State.

An area meets the calcareous fen vegetation technical criterion when, under normal circumstances, the area has a natural community index value of 50 or more by summing the appropriate regional index values of the vascular plant plus the bryophyte calcareous fen indicator species. Where both bryophyte and vascular plant data are available and the site's latitude is greater than 47 degrees, the natural community index value must exceed 80. Plot size and shape are dependent upon the professional judgment of field personnel.

> ***NOTE:*** *If a site has calcareous fen soil, hydrology, and water chemistry but the calciphile point total ranges from 30 to 50, the area will be considered to meet calcareous fen criteria. If a disturbed site has calcareous fen soil, hydrology, and water chemistry but a calciphile point total of less than 30, the disturbed area may have the potential to support a calcareous fen plant community*

# GLOSSARY

**Acid**

A chemical term for a water condition whereby there are more hydrogen ions ($H^+$) than hydroxyl ions ($OH^-$) and the pH is less than 7.

**Alkaline**

A chemical term for a water condition whereby there are more hydroxyl ions ($OH^-$) than hydrogen ions ($H^+$) and the pH is greater than 7.

**Bog**

A peatland type having 1) acidic waters (pH less than 4.2; calcium concentration less than 2 mg/l); 2) vegetation assemblages characterized by continuous coverage of mosses (e.g. *Sphagnum* spp.) and the general absence of fen-indicator species; and, most importantly, 3) largely dependent upon atmospheric sources of water and nutrients. They commonly occur as level bogs, or, lake filled depressions. An ombrotrophic bog has the above characteristics in addition to a topographically elevated crest or plateau which accentuates its rainfall dependency. (from Johnson 1985 and Glaser 1987)

**Calcareous Fen**

A peat-accumulating wetland dominated by distinct ground water inflows having specific chemical characteristics. The ground water is characterized as circum-neutral to alkaline, with high concentrations of calcium and low dissolved oxygen content. The chemistry provides an environment for specific and often rare hydrophytic plants. (See the definition of "Fen" and "Extremely Rich Fen") (Minnesota Rules 8420)

**Calcareous Seepage Fen Prairie Subtype**

A calcareous fen in the prairie/plains ecoregions of southern and western Minnesota. (See the definition of "Fen" and "Extremely Rich Fen")

**Calcicole**

Organisms, usually plants, that thrive in calcium-rich waters. (Hanson 1962)

**Calciphile**

Plants that thrive in calcium-rich waters. (Hanson 1962)

**Circum-Neutral**

A reference to water chemistry whereby the pH is close to 7.

**Fen** (adapted from Glaser 1987)

General A peatland type that receives a significant input of water and nutrients from a mineral source dominated by ground water discharge. A fen is therefore considered to be geogenous and its vegetation minerotrophic. Fens are generally characterized by 1) surface waters with pH greater than 4.2 and calcium concentration greater than 2 mg/l; and, 2) a more diverse flora including many fen indicator species. In Minnesota the division between poor, rich, and extremely rich fens is a continuum.

**Poor Fen** A fen containing at least one minerotrophic indicator species and weakly geogenous surface waters. Originally described in Sweden by Sjörs (1952) as having a pH range of 3.8-5.7. Minnesota poor fens have similar ranges in water chemistry with pH of 4.2-5.8 and calcium concentration of 2-10 mg/l.

**Rich Fen** A fen having a slightly higher range in pH (5.8-7.0) and calcium concentration (10-32 mg/l) than poor fens.

**Extremely Rich Fen** A fen having a very high pH (greater than 7) and calcium concentration (greater than 20 mg/l in Minnesota) and characteristic vegetative species assemblages. Extremely rich fens are generally found in discharge zones for ground water. Calcareous fens and calcareous seepage fens prairie subtype (CSFP) are generally part of the extremely rich fen type.

**Geogenous**

Water from a mineral source such as ground water and surface runoff from mineral soils.

**Histic Epipedon**

A 8- to 16-inch soil layer at or near the surface that is saturated for 30 consecutive days or more during the growing season in most years and contains a minimum of 12 percent organic matter when no clay is present or a minimum of 18 percent organic matter when 60 percent or more clay is present; generally a thin horizon of peat or muck if the soil has not been plowed.

**Histosol**

An order in "Soil Taxonomy" (Soil Survey Staff 1975) composed of organic soils (mucks and peats) that have organic soil materials in more than half of the upper 32 inches or that are of any thickness if overlying rock.

**Hydrophytic Vegetation**

Macrophytic plant life growing in water, soil, or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content. (MR8420)

**Macrophyte**

Any plant species that can be readily observed without the aid of optical magnification, including all vascular plant species and bryophytes (e.g. *Sphagnum* spp.) as well as large algae (e.g. *Chara* spp.). (Federal Interagency Committee for Wetland Delineation 1989)

**Marl**

Marl is an argillaceous, nonindurated calcium carbonate material formed partially by the action of some aquatic plants. Plants extract carbon dioxide for photosynthesis from the bicarbonate in water which locally reduces calcium carbonate solubility adjacent to the leaves and results in a precipitate formation. Moist marl has a color value of 5 or more and usually does not change color irreversibly on drying. It reacts with dilute (10%) HCl to evolve $CO_2$ and leave disintegrated plant remains. A layer of marl contains too little organic matter to coat the carbonate, even before it has been shrunk by drying. Most samples of marl from the U.S. studied to date have an organic matter content between 4 and 20 percent, inclusive. The horizon designation for marl is "Lca" while "Marly" is the mineralogy class modifier for characterizing subgroups or great groups of histosols. A soil would be marly if marl in the control section was 5 cm or more thick. (Soil Survey Staff 1975, Lapedes 1978)

**Organic Soil**

(See Histosol)

**Peat Accumulating Wetland**

A wetland developing a peat deposit as a result of the growth of organic matter whereby primary productivity is greater than total community respiration. (Glaser 1987)

**Peat** and **Peatland**

Peat is an organic soil deposit containing the dead remains of plants. It is distinguished from lake sediments by characteristic macro- or micro-fossils and from other terrestrial soils by the low percentage of mineral matter. A peatland is a waterlogged area containing at least 30 cm of peat in an undrained condition. (Glaser 1987)

**Specific Conductivity**

A measure of the ability of water to conduct electricity, affected by temperature and the type and concentration of ions present. Units are in micro-Siemens (μS; formerly micro mhos, μmhos).

**Technical Criteria**

Calcareous fens possess four specific characteristics: 1) calciphytic vegetation, 2) histosols or histic epipedons, 3) hydrology, and 4) water chemistry. These characteristics and their technical criteria are essential for identification and delineation purposes. The four technical criteria specified must all be met for an area to be identified as a calcareous fen.

**Travertine**

A dense, finely crystalline massive or concretionary limestone of white, tan, or cream color, often having a fibrous or concentric structure and splintery fracture. It is formed by rapid chemical precipitation of calcium carbonate from solution in surface and ground waters. The spongy or less compact variety is tufa. (Bates and Jackson 1987)

**Tufa**

Tufa is a spongy, porous calcareous material deposited from spring waters. When carbonate-rich spring waters reach the surface, carbon dioxide is released; the solubility of calcium carbonate is lowered; and, the precipitate forms. Tufa is the spongy, less porous form of travertine. (Bates and Jackson 1987 and Lapedes 1978)

**Wetland**

Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must 1) have a predominance of hydric soils; 2) be inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions; and 3) under normal circumstances, support a prevalence of hydrophytic vegetation.

"A wetland" or "the wetland" means a distinct hydrologic feature with the above characteristics surrounded by nonwetland and including all contiguous wetland types, except those connected solely by riverine wetlands. "Wetland area" means a portion of "a wetland" or "the wetland." (MR8420)

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# Appendix of Minnesota Regulations

The following are current references to Minnesota Statutes and Rules. For any possible updates, the Minnesota Revisor of Statutes maintains currently accurate listings at www.revisor.leg.state.mn.us.

**103G.223 Calcareous fens.**

Calcareous fens, as identified by the commissioner by written order published in the State Register, may not be filled, drained, or otherwise degraded, wholly or partially, by any activity, unless the commissioner, under an approved management plan, decides some alteration is necessary. Identifications made by the commissioner are not subject to the rulemaking provisions of chapter 14 and section 14.386 does not apply.

(HIST: 2004 not yet revised)

**8420.1010 PURPOSE.**

The purpose of parts 8420.1010 to 8420.1070 is to provide minimum standards and criteria for the identification, protection, and management of calcareous fens as authorized by Minnesota Statutes, section 103G.223. Calcareous fens may not be drained or filled or otherwise altered or degraded except as provided for in a management plan approved by the commissioner.

Part 8420.0122 does not apply to calcareous fens.

STAT AUTH: MS s 14.06; 103B.101; 103B.3355; 103G.2242
HIST: 18 SR 274; 22 SR 1877; 27 SR 135

**8420.1020 IDENTIFYING CALCAREOUS FENS.**

A calcareous fen is a peat-accumulating wetland dominated by distinct groundwater inflows having specific chemical characteristics. The water is characterized as circumneutral to alkaline, with high concentrations of calcium and low dissolved oxygen content. The chemistry provides an environment for specific and often rare hydrophytic plants.

STAT AUTH: MS s 14.06; 103B.101; 103B.3355
HIST: 18 SR 274

**8420.1030 PROCEDURES TO LIST CALCAREOUS FENS.**

A. The commissioner shall investigate wetlands to determine if the wetland is properly identified as a calcareous fen.

B. The commissioner shall maintain a current list of known calcareous fens in the state and their location.

C. The commissioner shall provide an updated list of calcareous fens to the board for further distribution.

STAT AUTH: MS s 14.06; 103B.101; 103B.3355
HIST: 18 SR 274

**8420.1040 MANAGEMENT PLANS.**

Calcareous fens may not be drained or filled or otherwise altered or degraded except as provided for in a management plan approved by the commissioner. The commissioner will provide technical assistance to landowners or project sponsors in the development of management plans.

STAT AUTH: MS s 14.06; 103B.101; 103B.3355; 103G.2242
HIST: 18 SR 274; 22 SR 1877

**8420.1050 RESTORATION.**

The commissioner may approve management plans to restore or upgrade a previously damaged calcareous fen.

STAT AUTH: MS s 14.06; 103B.101; 103B.3355
HIST: 18 SR 274

**8420.1060 APPEALS.**

A. A landowner or project proposer may challenge the commissioner's determination that a wetland is a calcareous fen or the commissioner's calcareous fen management plan by demanding a hearing. The hearing will be carried out in the same manner as water permit hearings under Minnesota Statutes, chapter 103G.

B. The hearing must be demanded within 30 days after mailed notice of the commissioner's decision to the project proposer, otherwise the decision becomes final and may not be challenged by the project proposer.

C. Appeal of the commissioner's decision after the hearing must be done in the manner provided for appeals from contested case decisions in Minnesota Statutes, chapter 14.

STAT AUTH: MS s 14.06; 103B.101; 103B.3355
HIST: 18 SR 274

**8420.1070 ENFORCEMENT PROCEDURES.**

Enforcement procedures for calcareous fens shall be conducted consistent with Minnesota Statutes, sections 103G.141 and 103G.2372, except that necessary restoration or replacement activities, if required, will be determined by the commissioner, in consultation with the local soil and water conservation district.

STAT AUTH: MS s 103B.3355; 103G.2242
HIST: 27 SR 135

*Current as of 11/14/03*

**7050.0180 NONDEGRADATION FOR OUTSTANDING RESOURCE VALUE WATERS.**

Subpart 1. **Policy.** The agency recognizes that the maintenance of existing high quality in some waters of outstanding resource value to the state is essential to their function as exceptional recreational, cultural, aesthetic, or scientific resources. To preserve the value of these special waters, the agency will prohibit or stringently control new or expanded discharges from either point or nonpoint sources to outstanding resource value waters.
…… Subp. 6. **Restricted discharges.** No person may cause or allow a new or expanded discharge of any sewage, industrial waste, or other waste to any of the following waters unless there is not a prudent and feasible alternative to the discharge:
……
E. calcareous fens identified in subpart 6b.

If a new or expanded discharge to these waters is permitted, the agency shall restrict the discharge to the extent necessary to preserve the existing high quality, or to preserve the wilderness, scientific, recreational, or other special characteristics that make the water an outstanding resource value water.

Subp. 6b. **Calcareous fens.** The following calcareous fens are designated outstanding resource value waters:

A. Becker County: Spring Creek WMA NHR fen, 34 (T.142, R.42, S.13);
B. Carver County: Seminary fen, 75 (T.116, R.23, S.35);
C. Clay County:

(1) Barnesville Moraine fen, 44 (T.137, R.44, S.18);
(2) Barnesville WMA fen, 10 (T.137, R.45, S.1);
(3) Barnesville WMA fen, 43 (T.137, R.44, S.18);
(4) Felton Prairie fen, 28 (T.142, R.46, S.36);
(5) Felton Prairie fen, 36 (T.141, R.46, S.13);
(6) Felton Prairie fen, 48 (T.142, R.45, S.31);
(7) Felton Prairie fen, 53 (T.141, R.46, S.24);
(8) Haugtvedt WPA North Unit fen, 54 (T.137, R.44, S.28, 29); and
(9) Spring Prairie fen, 37 (T.140, R.46, S.11);
D. Clearwater County: Clearbrook fen, 61 (T.149, R.37, S.17);
E. Dakota County:
(1) Black Dog Preserve fen, 63 (T.27, R.24, S.34);
(2) Fort Snelling State Park fen, 25 (T.27, R.23, S.4); and
(3) Nicols Meadow fen, 24 (T.27, R.23, S.18);
F. Goodhue County:
(1) Holden 1 West fen, 3 (T.110, R.18, S.1);
(2) Perched Valley Wetlands fen, 2 (T.112, R.13, S.8); and
(3) Red Wing fen, 72 (T.113, R.15, S.21);
G. Houston County: Houston fen, 62 (T.104, R.6, S.26);
H. Jackson County:
(1) Heron Lake fen, 45 (T.103, R.36, S.29); and
(2) Thompson Prairie fen, 20 (T.103, R.35, S.7);
I. Le Sueur County:
(1) Ottawa Bluff fen, 56 (T.110, R.26, S.3);
(2) Ottawa WMA fen, 7 (T.110, R.26, S.11); and
(3) Ottawa WMA fen, 60 (T.110, R.26, S.14);
J. Lincoln County: Hole-in-the-Mountain Prairie fen, 6; Pipestone (T.108, R.46, S.1; T.109, R.45, S.31);
K. Mahnomen County: Waubun WMA fen, 11 (T.143, R.42, S.25);
L. Marshall County:
(1) Tamarac River fen, 71 (T.157, R.46, S.2);
(2) Viking fen, 68 (T.155, R.45, S.18);
(3) Viking fen, 70 (T.155, R.45, S.20); and
(4) Viking Strip fen, 69 (T.154, R.45, S.4);
M. Martin County: Perch Creek WMA fen, 33 (T.104, R.30, S.7);
N. Murray County: Lost Timber Prairie fen, 13 (T.105, R.43, S.2);
O. Nicollet County:
(1) Fort Ridgely fen, 21 (T.111, R.32, S.6); and
(2) Le Sueur fen, 32 (T.111, R.26, S.16);
P. Nobles County: Westside fen, 59 (T.102, R.43, S.11);
Q. Norman County:
(1) Agassiz-Olson WMA fen, 17 (T.146, R.45, S.22);
(2) Faith Prairie fen, 15 (T.144, R.43, S.26);
(3) Faith Prairie fen, 16 (T.144, R.43, S.35);
(4) Faith Prairie fen, 27 (T.144, R.43, S.25); and
(5) Green Meadow fen, 14 (T.145, R.45, S.35, 36);
R. Olmsted County:
(1) High Forest fen, 12 (T.105, R.14, S.14, 15); and
(2) Nelson WMA fen, 5 (T.105, R.15, S.16);
S. Pennington County:
(1) Sanders East fen, 65 (T.153, R.44, S.7);
(2) Sanders East fen, 74 (T.153, R.44, S.7); and
(3) Sanders fen, 64 (T.153, R.44, S.18, 19);
T. Pipestone County:
(1) Burke WMA fen, 57 (T.106, R.44, S.28); and

(2) Hole-in-the-Mountain Prairie fen, 6 (see Lincoln County, item J);
U. Polk County:
(1) Chicog Prairie fen, 39 (T.148, R.45, S.28);
(2) Chicog Prairie fen, 40 (T.148, R.45, S.33);
(3) Chicog Prairie fen, 41 (T.148, R.45, S.20, 29);
(4) Chicog Prairie fen, 42 (T.148, R.45, S.33);
(5) Kittleson Creek Mire fen, 55 (T.147, R.44, S.6, 7);
(6) Tympanuchus Prairie fen, 26 (T.149, R.45, S.17); and
(7) Tympanuchus Prairie fen, 38 (T.149, R.45, S.16);
V. Pope County:
(1) Blue Mounds fen, 1 (T.124, R.39, S.14, 15);
(2) Lake Johanna fen, 4 (T.123, R.36, S.29); and
(3) Ordway Prairie fen, 35 (T.123, R.36, S.30);
W. Redwood County:
(1) Swedes Forest fen, 8 (T.114, R.37, S.19, 20); and
(2) Swedes Forest fen, 9 (T.114, R.37, S.22, 27);
X. Rice County:
(1) Cannon River Wilderness Area fen, 18 (T.111, R.20, S.34); and
(2) Cannon River Wilderness Area fen, 73 (T.111, R.20, S.22);
Y. Scott County:
(1) Savage fen, 22 (T.115, R.21, S.17);
(2) Savage fen, 66 (T.115, R.21, S.16); and
(3) Savage fen, 67 (T.115, R.21, S.17);
Z. Wilkin County:
(1) Anna Gronseth Prairie fen, 47 (T.134, R.45, S.15);
(2) Anna Gronseth Prairie fen, 49 (T.134, R.45, S.10);
(3) Anna Gronseth Prairie fen, 52 (T.134, R.45, S.4);
(4) Rothsay Prairie fen, 46 (T.136, R.45, S.33);
(5) Rothsay Prairie fen, 50 (T.135, R.45, S.15, 16); and
(6) Rothsay Prairie fen, 51 (T.135, R.45, S.9);
AA. Winona County: Wiscoy fen, 58 (T.105, R.7, S.15); and
BB. Yellow Medicine County:
(1) Sioux Nation WMA NHR fen, 29 (T.114, R.46, S.17); and
(2) Yellow Medicine fen, 30 (T.115, R.46, S.18).

Subp. 7. **Unlisted outstanding resource value waters.** The agency shall prohibit or stringently control new or expanded discharges to outstanding resource value waters not specified in subparts 3 to 6b to the extent that this stringent protection is necessary to preserve the existing high quality, or to preserve the wilderness, scientific, recreational, or other special characteristics that make the water an outstanding resource value water.

## Appendix of Draft Native Plant Community Description for "Extremely Rich Fen"

# *OPp93*

### *Prairie Extremely Rich Fen*

*Open graminoid-dominated fens on permanently saturated peat sustained by mineral-rich groundwater discharge, with little influence from surface water inputs. Typically on slight slopes; peat sometimes mounded or domed. Small pools and sparsely vegetated marly peat areas commonly present. Occurs throughout the prairie region of the state.*

### *Vegetation Structure & Composition*

Description is based on summary of vegetation data from 78 plots (relevés).

● **Moss** cover variable; almost entirely "brown" mosses, *Sphagnum* spp. very rare. Characteristic species are *Limprichtia cossonii*, *Campylium stellatum*, *Bryum pseudotriquetrum*, *Drepanocladus aduncus*, *Brachythecium rivulare*, and *Plagiomnium ellipticum*. The last three are less common northward, the last two being mainly southeastern.

● **Graminoid** species dominate, usually constituting more than 75% of total plant cover. Of the most distinctive species, prairie sedge (*Carex prairea*) is important throughout the range of OPp93; sterile sedge (*Carex sterilis*) is typically a major component except in the southwest; tufted bulrush (*Scirpus cespitosus*) is fairly common from central Minnesota northward; and hair-like beak rush (*Rhynchospora capillacea*), absent from the southeast, is often abundant, especially.on the margins of marly pools. Important components shared with wet meadows are hard-stemmed bulrush (*Scirpus acutus*), tussock sedge (*Carex stricta*), and aquatic sedge (*Carex aquatilis*), the last apparently absent from the southeast. Several wet-prairie species are also significant components: clustered muhly grass (*Muhlenbergia glomerata*), mat muhly grass (*Muhlenbergia richardsonis*), and narrow reed grass (*Calamagrostis stricta*), the first throughout and the last two rare southeast. Big bluestem (*Andropogon gerardii*) is typically present except south of the Minnesota River Valley, where it is rare.

● **Forb** cover usually sparse (<25%). Among the more common distinctive species are American grass-of-Parnassus (*Parnassia glauca*), Kalm's lobelia (*Lobelia kalmii*), seaside arrowgrass (*Triglochin maritima*), marsh arrowgrass (*Triglochin palustris*), lesser fringed gentian (*Gentianopsis procera*). All are rare to absent in the southeast and most are rare in the southwest. Wet-meadow species common in OPp93 are spotted Joe-pye-weed (*Eupatorium maculatum*), common boneset (*Eupatorium perfoliatum*), and swamp thistle (*Cirsium muticum*). The last is rare in the southeast and the second rare northwest. Several wet-prairie species are common: flat-topped aster (*Aster umbellatus*), swamp lousewort (*Pedicularis lanceolata*), northern bedstraw (*Galium boreale*), Riddell's goldenrod (*Solidago riddellii*), Virginia mountain mint (*Pycnanthemum virginianum*), prairie loosestrife (*Lysimachia quadriflora*), and golden alexanders (*Zizia aurea*). Other wet prairie species such as tall meadow-rue (*Thalictrum dasycarpum*), northern plains blazing star (*Liatris ligulistylis*), and yellow stargrass (*Hypoxis hirsuta*) are often present at low densities.

● **Shrub layer** nearly absent to sparse (<25% cover). Red-osier dogwood (*Cornus sericea*) usually present. Except in the southwest, bog birch (*Betula pumila*) is often fairly common, and sage-leaved willow (*Salix candida*) typically present. Shrubby cinquefoil (*Potentilla fruticosa*) is often common in the northwest, rare to absent elsewhere.

● **Notes**: Several plant species are essentially restricted to OPp93 in Minnesota: sterile sedge, hair-like beak-rush, marsh arrowgrass, and whorled nutrush (*Scleria verticillata*), a rarer species. Beaked spikerush (*Eleocharis rostellata*) is known only from OPp93 and the closely related OPn93. Several species that occur in other classes in the northwest are confined to

OPp93 farther south: twig rush (*Cladium mariscoides*), tufted bulrush, American grass-of-Parnassus, Kalm's lobelia, seaside arrowgrass, and shrubby cinquefoil. Prairie sedge occurs in the related class WMs83, but it is otherwise a plant of OPp93. Occurrences of OPp93 are seldom homogeneous. Variations in groundwater flowpaths and in the topography of the setting can create noticeable variation in vegetation. Areas of open marly pools and low, tussocky graminoid "lawns" are most characteristic. But these may grade into denser, taller, often shrubbier vegetation where the substrate is less saturated or mineral soil is closer to the surface, or into marsh where ponding occurs below the fen.

### *Landscape Setting & Soils*
OPp93 occurs where there is an uninterrupted discharge of mineral-rich groundwater at the surface that is neither ponded nor flows rapidly away, and where surface water inputs (rainfall, runoff) are minor relative to groundwater input. Such conditions occur where surface slopes intersect groundwater-bearing layers perched above less-permeable layers or where permeable formations penetrate confining beds overlying aquifers with above-surface heads. Fens of the first type are most commonly found along down-gradient slopes of Glacial Lake Agassiz beach ridges, on side-slopes of large erosional features such as the Minnesota and Mississippi River valleys, of smaller glacial meltwater valleys in southwestern Minnesota, and of stream valleys in the dissected bedrock region of southeastern Minnesota. Fens of the second type are concentrated in the southwest, but occur sporadically northward. OPp93 is limited to regions of calcareous glacial drift or bedrock. Soils are histosols (more than half of the upper 80 cm is organic material) or have a histic epipedon (20-60 cm organic material).

### *Natural History*
Having flowed through calcareous glacial drift or bedrock the groundwater supply is alkaline (pH > 6.7) with a high calcium concentration (> 30mg/l). The constantly upwelling cold, anoxic water creates ideal conditions for peat formation provided it doesn't drain rapidly away, and peat formation further retards drainage. Conditions at the surface promote the precipitation of calcium carbonate as marl or tufa, which is incorporated into the accumulating peat. This material may give the peat a high mineral content. The elevated mineral concentrations and cold, anoxic substrate conditions exclude or suppress the growth of most wetland plants, allowing a few specialists to thrive. OPp93 does not occur in situations subject to flooding as none of the characteristic dominants can survive prolonged inundation.

### *Similar Native Plant Community Classes*
**● OPn93 Northern Extremely Rich Fen**
OPn93 and OPp93 have similar hydrology and water chemistry. OPn93 occurs within patterned peatlands or other settings within the northern forest, and has species from this pool that are absent from OPp93. Conversely, OPp93 has a number of species from the prairie that are absent from OPn93. Because of its prairie setting, OPp93 probably burned frequently, whereas fire return times in OPn93 would have been much longer.

| | Frequency (%) | |
|---|---|---|
| Species | OPp93 | OPn93* |
| Spotted Joe pye weed (*Eupatorium maculatum*) | 71 | 0 |
| Mat muhly grass (*Muhlenbergia richardsonis*) | 69 | 0 |
| Flat-topped aster (*Aster umbellatus*) | 67 | 0 |
| Narrow reed grass (*Calamagrostis stricta*) | 54 | 0 |

| | | |
|---|---|---|
| Big bluestem (*Andropogon gerardii*) | 49 | 0 |
| Northern bedstraw (*Galium boreale*) | 47 | 0 |
| Riddell's goldenrod (*Solidago riddellii*) | 45 | 0 |
| Marsh arrowgrass (*Triglochin palustris*) | 38 | 0 |
| Sundews (*Drosera anglica*, *D. rotundifolia*, *D. intermedia*) | 3 | 50 |
| White beak rush (*Rhynchospora alba*) | 0 | 50 |
| Buckbean (*Menyanthes trifoliate*) | 6 | 75 |
| Twig rush (*Cladium mariscoides*) | 4 | 75 |
| White cedar (*Thuja occidentalis*) seedling/sapling | 0 | 75 |
| Pitcher plant (*Sarracenia purpurea*) | 9 | 88 |
| Bladderworts (*Utricularia intermedia*, *U. cornuta*, *U. minor*) | 4 | 88 |
| Bog rosemary (*Andromeda glaucophylla*) | 0 | 88 |

* 8 plots

**● OPp91 Prairie Rich Fen**

Both OPp91 and OPp92 occur on saturated peat substrates, and while there may be some lateral flow in OPp91 there is no artesian pressure. OPp91 occupies depressional sites where the water table is persistently at or close to the surface. Shallow flooding is a regular event in OPp91, and the dominants of this type have adaptations to conduct oxygen to roots from emergent leaves. Fen wiregrass sedge (*Carex lasiocarpa*) almost always a dominant in OPp91, occasionally common in OPp93.

| | Frequency (%) | |
|---|---|---|
| Species | OPp93 | OPp91* |
| Sterile sedge (*Carex sterilis*) | 76 | 0 |
| Mat muhly grass (*Muhlenbergia richardsonis*) | 69 | 3 |
| American grass-of-Parnassus (*Parnassia glauca*) | 58 | 2 |
| Big bluestem (*Andropogon gerardii*) | 49 | 2 |
| Prairie sedge (*Carex prairea*) | 45 | 3 |
| Riddell's goldenrod (*Solidago riddellii*) | 45 | 2 |
| Marsh arrowgrass (*Triglochin palustris*) | 38 | 2 |
| Hair-like beak rush (*Rhynchospora capillacea*) | 28 | 0 |
| Silverweed (*Potentilla anserina*) | 0 | 19 |
| Northern blue flag (*Iris versicolor*) | 0 | 19 |
| Bog willow (*Salix pedicellaris*) | 0 | 23 |
| Marsh cinquefoil (*Potentilla palustris*) | 0 | 27 |
| Common mint (*Mentha arvensis*) | 0 | 29 |
| Marsh St. John's wort (*Triadenum fraseri*) | 0 | 31 |
| Water smartweed (*Polygonum amphibium*) | 1 | 35 |
| Tufted loosestrife (*Lysimachia thyrsiflora*) | 1 | 48 |

* 128 plots

**● WPn53 Northern Wet Prairie**

The seepage type WPn53a is more subtly influenced by grounwater seepage than OPp93. There is no actual discharge; pools are absent, and the substrate is moist, not saturated. The soil is very organically enriched mineral soil, not peat. The vegetation is lush, dominated by taller species than the distinctive low tussocky lawns of OPp93.

| | Frequency (%) | |
|---|---|---|
| Species | OPp93 | WPn53a* |
| Sterile sedge (*Carex sterilis*) | 76 | 0 |
| Sage-leaved willow (*Salix candida*) | 50 | 10 |
| Bog aster (*Aster borealis*) | 67 | 10 |
| Prairie sedge (*Carex prairea*) | 45 | 0 |
| Hard-stemmed bulrush group (*Scirpus acutus* & *S. heterochaetus*) | 42 | 0 |
| Aquatic sedge (*Carex aquatilis*) | 36 | 0 |
| Hair-like beak rush (*Rhynchospora capillacea*) | 28 | 0 |
| Fen wiregrass sedge (*Carex lasiocarpa*) | 28 | 0 |
| Maximilian's sunflower (*Helianthus maximiliani*) | 1 | 30 |
| Indian grass (*Sorghastrum nutans*) | 1 | 30 |
| Little bluestem (*Schizachyrium scoparium*) | 0 | 30 |
| Purple prairie clover (*Dalea purpurea*) | 0 | 60 |
| Heath aster (*Aster ericoides*) | 3 | 70 |
| Prairie cordgrass (*Spartina pectinata*) | 3 | 70 |
| Heart-leaved alexanders (*Zizia aptera*) | 4 | 80 |
| Prairie dropseed (*Sporobolus heterolepis*) | 0 | 80 |

* 10 plots

**● WPs54 Southern Wet Prairie**

The same similarities and differences apply to WPs54a and OPp93 as are described for WPn53a. Vegetation data are available from only one plot; no comparison table is presented, but the same contrasts in prairie and fen species are to be expected.

**● WMs83 Southern Seepage Meadow/Carr**

WMs83 distinctions are still under revision. From the floristic data we suspect that seepage water inputs are typically dominated by local flow systems and thus contain less carbonate. The dominants of WMs83 are more like deep meadow, with greater abundance of Carex stricta, Carex lacustris, bluejoint, and few if any fen indicators are present. Shrubs are much more important.

| | Frequency (%) | |
|---|---|---|
| Species | OPp93 | WMs83* |
| Sterile sedge (*Carex sterilis*) | 76 | 0 |
| Mat muhly grass (*Muhlenbergia richardsonis*) | 69 | 2 |
| American grass-of-Parnassus (*Parnassia glauca*) | 58 | 0 |
| Kalm's lobelia (*Lobelia kalmii*) | 58 | 0 |
| Seaside arrowgrass (*Triglochin maritima*) | 49 | 3 |
| Riddell's goldenrod (*Solidago riddellii*) | 45 | 2 |
| Marsh arrowgrass (*Triglochin palustris*) | 38 | 0 |
| Hair-like beak rush (*Rhynchospora capillacea*) | 28 | 0 |
| Water smartweed (*Polygonum amphibium*) | 1 | 22 |

| | | |
|---|---|---|
| Common mint (*Mentha arvensis*) | 0 | 28 |
| Tufted loosestrife (*Lysimachia thyrsiflora*) | 1 | 31 |
| Lake sedge (*Carex lacustris*) | 1 | 32 |
| Fowl bluegrass (*Poa palustris*) | 1 | 35 |
| Touch-me-not (*Impatiens* spp.) | 6 | 43 |
| Bluejoint (*Calamagrostis canadensis*) | 9 | 45 |
| Great water dock (*Rumex orbiculatus*) | 5 | 58 |

* 65 plots

***Native Plant Community Types in Class***

**● OPp93a Calcareous Fen (Northwestern)**

These fens occur primarily near the bases of Glacial Lake Agassiz beach ridges on their downgradient sides, but there are also examples of local upwellings from confined aquifers. A number are large (> 40 acres), and most are > 10 acres. This is the most species-rich type. Characteristic species in this type that are rare or absent in other types are tufted bulrush, candle-lantern sedge (*Carex limosa*), lead-colored sedge (*Carex livida*), marsh grass-of-Parnassus (*Parnassia palustris*), and sticky false asphodel (*Tofieldia glutinosa*). Bog birch, sage willow, and shrubby cinquefoil are much more common in this type than in the others.

**● OPp93b Calcareous Fen (Southwestern)**

Fens on local upwellings from confined aquifers and on sideslopes of erosional features. This type is the most species-poor in the class, and most are < 5 acres. Sterile sedge is absent, and the areas where this dominates in OPp93a are typically dominated instead by three species, hair-like beak rush, three-square bulrush (*Scirpus pungens*), and seaside arrowgrass (*Triglochin maritima*). Shrubs are nearly absent, with only stunted red-osier dogwood likely.

**● OPp93c Calcareous Fen (Southeastern)**

Fens mostly on sideslopes of erosional features, sometimes on terraces within valleys. Most small, but some in Minnesota River Valley large. Intermediate species richness; sterile sedge usually present, but other indicators rare or absent southeast of Minnesota River Valley. Several species in OPp93c rare or absent in other types are spring cress (*Cardamine bulbosa*), cowbane (*Oxypolis rigidior*), and edible valerian (*Valeriana edulis*). Bog birch and sage willow sometimes present, red-osier dogwood common.

## OPp93 Prairie Extremely Rich Fen

based on 78 plots

| | |
|---|---|
| ●●●●● | *>0.50* |
| ●●●● | *0.25-0.50* |
| ●●● | *0.10-0.25* |
| ●● | *0.05-0.10* |
| ● | *<0.05* |

| **Forbs, Ferns, & Fern Allies** | freq % | cover |
|---|---|---|
| Spotted Joe pye weed (*Eupatorium maculatum*) | 71 | ● |
| Northern bog violet (*Viola nephrophylla*) | 71 | ● |
| Bog aster (*Aster borealis*) | 67 | ● |
| Flat-topped aster (*Aster umbellatus*) | 67 | ● |
| Swamp lousewort (*Pedicularis lanceolata*) | 65 | ● |
| American grass-of-Parnassus (*Parnassia glauca*) | 58 | ●● |
| Kalm's lobelia (*Lobelia kalmii*) | 58 | ● |

| | | |
|---|---|---|
| Sawtooth/Giant sunflower complex (*Helianthus* spp.) | 54 | ●● |
| Seaside arrowgrass (*Triglochin maritima*) | 49 | ●● |
| Northern bedstraw (*Galium boreale*) | 47 | ● |
| Riddell's goldenrod (*Solidago riddellii*) | 45 | ● |
| Swamp thistle (*Cirsium muticum*) | 41 | ● |
| Marsh arrowgrass (*Triglochin palustris*) | 38 | ● |
| Virginia mountain mint (*Pycnanthemum virginianum*) | 32 | ● |
| Lesser fringed gentian (*Gentianopsis procera*) | 32 | ● |
| Common boneset (*Eupatorium perfoliatum*) | 31 | ● |
| Grass-leaved goldenrod (*Euthamia graminifolia*) | 29 | ● |
| Broad-leaf cattail (*Typha latifolia*) | 28 | ●● |
| Canada goldenrod (*Solidago canadensis*) | 28 | ● |
| Prairie loosestrife (*Lysimachia quadriflora*) | 28 | ● |
| Northern bugleweed (*Lycopus uniflorus*) | 28 | ● |
| Narrow-leaf and hybrid cattail complex (*Typha*) | 27 | ●● |
| Red-stemmed aster complex (*Aster puniceus* & *A. firmus*) | 23 | ● |
| Giant goldenrod (*Solidago gigantea*) | 23 | ● |
| Dwarf raspberry (*Rubus pubescens*) | 22 | ●● |
| Golden alexanders (*Zizia aurea*) | 22 | ● |
| Sticky false asphodel (*Tofieldia glutinosa*) | 22 | ● |
| New England aster (*Aster novae-angliae*) | 21 | ● |
| Labrador bedstraw (*Galium labradoricum*) | 21 | ● |
| Swamp milkweed (*Asclepias incarnata*) | 21 | ● |
| Tall meadow-rue (*Thalictrum dasycarpum*) | 19 | ● |
| Marsh bellflower (*Campanula aparinoides*) | 18 | ● |
| Marsh grass-of-Parnassus (*Parnassia palustris*) | 17 | ● |
| Cut-leaved bugleweed (*Lycopus americanus*) | 17 | ● |
| Golden ragwort complex (*Senecio aureus* & *S. pseudaureus*) | 15 | ● |
| Autumn sneezeweed (*Helenium autumnale*) | 15 | ● |
| Yellow stargrass (*Hypoxis hirsuta*) | 15 | ● |
| Common marsh marigold (*Caltha palustris*) | 13 | ● |
| Eastern panicled aster (*Aster lanceolatus*) | 13 | ● |
| Northern plains blazing star (*Liatris ligulistylis*) | 13 | ● |
| Gray goldenrod (*Solidago nemoralis*) | 13 | ● |
| Spring cress (*Cardamine bulbosa*) | 12 | ● |
| Poor gerardia (*Agalinis purpurea*) | 12 | ● |
| White camas (*Zigadenus elegans*) | 12 | ● |
| White rattlesnakeroot (*Prenanthes alba*) | 12 | ● |
| Black-eyed Susan (*Rudbeckia hirta*) | 10 | ● |
| Spotted water hemlock (*Cicuta maculata*) | 10 | ● |
| Small white lady's slipper (*Cypripedium candidum*) | 10 | ● |
| Cowbane (*Oxypolis rigidior*) | 8 | ● |
| Edible valerian (*Valeriana edulis*) | 6 | ●● |

**Grasses & sedges**

| | | |
|---|---|---|
| Clustered muhly grass (*Muhlenbergia glomerata*) | 86 | ●● |
| Sterile sedge (*Carex sterilis*) | 76 | ●●● |
| Mat muhly grass (*Muhlenbergia richardsonis*) | 69 | ●●● |
| Rigid sedge (*Carex tetanica*) | 55 | ● |

| | | |
|---|---|---|
| Narrow reed grass (*Calamagrostis stricta*) | 54 | • |
| Big bluestem (*Andropogon gerardii*) | 49 | •• |
| Prairie sedge (*Carex prairea*) | 45 | ••• |
| Tall cottongrass (*Eriophorum polystachion*) | 45 | • |
| Hard-stemmed bulrush group (*Scirpus acutus* & *S. heterochaetus*) | 42 | ••• |
| Fringed brome (*Bromus ciliatus*) | 41 | • |
| Aquatic sedge (*Carex aquatilis*) | 36 | • |
| Tussock sedge (*Carex stricta*) | 35 | ••• |
| Flattened spikerush (*Eleocharis compressa*) | 35 | • |
| Hair-like beak rush (*Rhynchospora capillacea*) | 28 | ••• |
| Fen wiregrass sedge (*Carex lasiocarpa*) | 28 | ••• |
| Interior sedge (*Carex interior*) | 28 | • |
| Fowl manna grass (*Glyceria striata*) | 27 | • |
| Tufted hair grass (*Deschampsia cespitosa*) | 24 | •• |
| Tufted bulrush (*Scirpus cespitosus*) | 22 | •• |
| Three-square bulrush (*Scirpus pungens*) | 21 | •••• |
| Red-stalked spikerush (*Eleocharis palustris*) | 21 | • |
| Sartwell's sedge (*Carex sartwellii*) | 19 | •• |
| Lead-colored sedge (*Carex livida*) | 19 | • |
| Buxbaum's sedge (*Carex buxbaumii*) | 14 | • |
| Candle-lantern sedge (*Carex limosa*) | 13 | • |
| Knotty rush (*Juncus nodosus*) | 12 | • |
| Porcupine sedge (*Carex hystericina*) | 12 | • |
| Woolly sedge (*Carex pellita*) | 10 | • |
| Green sedge (*Carex viridula*) | 10 | • |
| Beaked spikerush (*Eleocharis rostellata*) | 8 | •••• |
| Whorled nutrush (*Scleria verticillata*) | 8 | • |
| Alpine rush (*Juncus alpinoarticulatus*) | 8 | • |
| Twig rush (*Cladium mariscoides*) | 4 | ••• |

**Shrubs**

| | | |
|---|---|---|
| Red-osier dogwood (*Cornus sericea*) | 55 | • |
| Bog birch (*Betula pumila*) | 54 | ••• |
| Sage-leaved willow (*Salix candida*) | 50 | • |
| Shrubby cinquefoil (*Potentilla fruticosa*) | 42 | ••• |
| Pussy willow (*Salix discolor*) | 33 | • |
| Bebb's willow (*Salix bebbiana*) | 29 | • |
| Autumn willow (*Salix serissima*) | 28 | • |
| Slender willow (*Salix petiolaris*) | 22 | • |

# APPENDIX OF SITE CODES

**Key to the Site Codes used for Calcareous Fen Site Locations in Figure 4.**

| | |
|---|---|
| ACF | Adrian |
| ATF | Altoona Fen |
| ATM | Altoona Meadow |
| BAR | Barnesville State WMA |
| BHC | Bemis Hill |
| BLD | Black Dog Preserve SNA |
| BWF | Burke WMA |
| CRW | Cannon River Wilderness Area County Park |
| CVT | Cannon Valley Trail |
| E13 | Eyota 13 |
| FCF | Fairchild |
| FEL | Felton State WMA |
| FGS | Forest Grove Spring |
| FRC | Fort Ridgely |
| FRD | Fort Ridgely State Park |
| FSS | Fort Snelling State Park |
| GMD | Green Meadow |
| GPL | Gully |
| H26 | Houston 26 |
| HLT | Holt Meadow |
| HMK | Homolka Beach Ridge |
| HPC | Holte Prairie |
| ISB | Iron Springs Bog |
| JCF | Jeffers |
| KNF | Kennedy |
| KTF | Kragero Township |
| LRP | Lost River |
| LTF | Lost Timber |
| MCF | Mutchler |
| MCT | McCarthy WMA |
| MLP | Mulligan Lake |
| NCF | Nichols |
| NFW | Nelson WMA |
| NLP | Net Lake |
| NSF | Nelson |
| OGM | Ogema |
| OTF | Ottawa |
| PCP | Pine Creek |
| PER | Perched Valley WMA |
| PFS | Pheasants Forever WMA |
| PVC | Perched Valley |
| R21 | Red Wing 21 |
| RPF | Rothsay |
| RRP | Roseau River |
| S16 | Sheldon 16 |
| S18 | Sanders 18 |
| SCF | St. Croix Watershed Research Station |
| SHC | Stonehedge |
| SHF | Spring Hill |
| SKC | Sucker Creek |
| SMF | Seminary |
| SNF | Sioux Nation |
| SPR | Sprague Creek |
| SSF | Savage |
| STF | Sam Tutt |
| SWV | Stewartville |
| WBN | Waubun |
| WSJ | Wasioja |
| WVE | Wiscoy Valley East |
| YPF | Yonker |
| ZLC | Zion Lutheran Church |

## APPENDIX OF BRYOPHYTE COLLECTION METHODS

# Bryophytes of Calcareous Fens:
# Minimum Requirements for Submission of Collections for Identification
# And
# Suggestions on Survey Procedure

June 2004

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## BRYOPHYTES OF CALCAREOUS FENS: MINIMUM REQUIREMENTS FOR SUBMISSION OF COLLECTIONS FOR IDENTIFICATION AND SUGGESTIONS ON SURVEY PROCEDURE

**Update June 2004**

**Herbarium-label information for potential calcareous fen (CF) sites**

To ensure proper herbarium labels for the deposition of collections in an herbarium, the following information is needed:

**date of collection**
**name of the primary collector**
**locality information**
**habitat information**

Please provide a middle initial, if available, for the primary-collector's name. The names are linked with 3-letter acronyms in the herbarium database.

The required locality information at each collection site can consist of either a legal description (township-range to at least 1/16$^{th}$ section accuracy), or a copy of the 1:24,000/25,000 topo quad (mention quad name) with locality or sites marked, or GPS coordinates in either lat/long or UTM. **Make sure to indicate in which datum system the GPS receiver was calculating the fixes (*i.e*, WGS-84)**. This is particularly important for UTM coordinates.

Habitat information should include a short description and visual estimate of the proportion of shrub, pool, short-sedge lawn, and spring seepage cover at the potential CF site. Provide information about water-chemistry parameters such as pH and specific conductance, if measured. A few digital photographs of the site and its different habitats are appreciated and will enhance the report.

## Procedures for collecting and preserving bryophyte samples

**Use 2-lb brown paper bags (never plastic bags!)** to collect samples in the field. Make sure the field staff is aware to **dry the samples as soon as possible** (no need to remove the bryophyte collections from the bags). Drying can be done either in front of a fan (often several days needed) or in a plant dryer @ 60°C (usually a single day suffices). Do not press bryophyte samples, but remove excess substrate from the bryophytes during collecting to limit abrasion of the specimens.

A single bag should not contain more than a single individual bryophyte patch (possibly with intimately associated species: no need to separate those out). **Do not put several collections of bryophyte patches that are physically separate in the field in a single bag**, even on the same site and when it appears that they might be the same species.

**Suggestions on recording:** a unique collection number of 5 digits maximum for each bag would be preferable. Pre-numbering the bags and keeping track of the collection-number range for each site or habitat in the field would speed things up, as there would be no need to write on the bags during the collecting in the field. Site and habitat information should be described in the field notes with the associated collection-number ranges. Keep freshly collected bryophyte samples in a large-mesh laundry or burlap bag so that they can breathe until they are dried properly.

## Measuring total bryophyte cover and calculating individual species abundance

Several techniques are employed to derive abundance measures of individual bryophyte taxa within an habitat or ecotope (Janssens 2002). I found that for potential CF sites a random-number point-intercept method is most suitable. Many of the bryophyte patches are hidden under thatch, the remaining litter of the graminoids, and are not readily apparent for visual cover estimates as used in plot and relevé methods. Line point-intercepts are easily converted into areal cover (Janssens 2002).

A random-number table (see Appendix) is employed along several 5-m long sections of a measuring tape. The tape is stretched along a line through the potential CF, intersecting its most prominent features. Do not record beyond what is clearly discernable as the fen habitat. As many 5-m long sections can be used as there is habitat available or until a suitable number of point-intercept samples are collected. In sites with sufficient bryophyte cover (>20% or bryophyte hits on average at least once every 5 intercept points), a minimum of 10 bryophyte samples should be collected (25 m of total transect in this case). If none of the linear dimensions of the habitat is long enough to accommodate such a transect, several parallel or intersecting transect lines can be laid out. Often a 15-m transect suffices if total bryophyte cover approaches 50%.

Each row in the random-number table (see Appendix) lists ten random numbers. These numbers, which range from 1 to 500, represent the distance in cm along a 5-m segment of the tape. The tape is put down as close to the surface as possible and a surface sample is taken through the thatch at each one of the 10 random-number cm marks read from the table (Figure 1). Either a plumb line

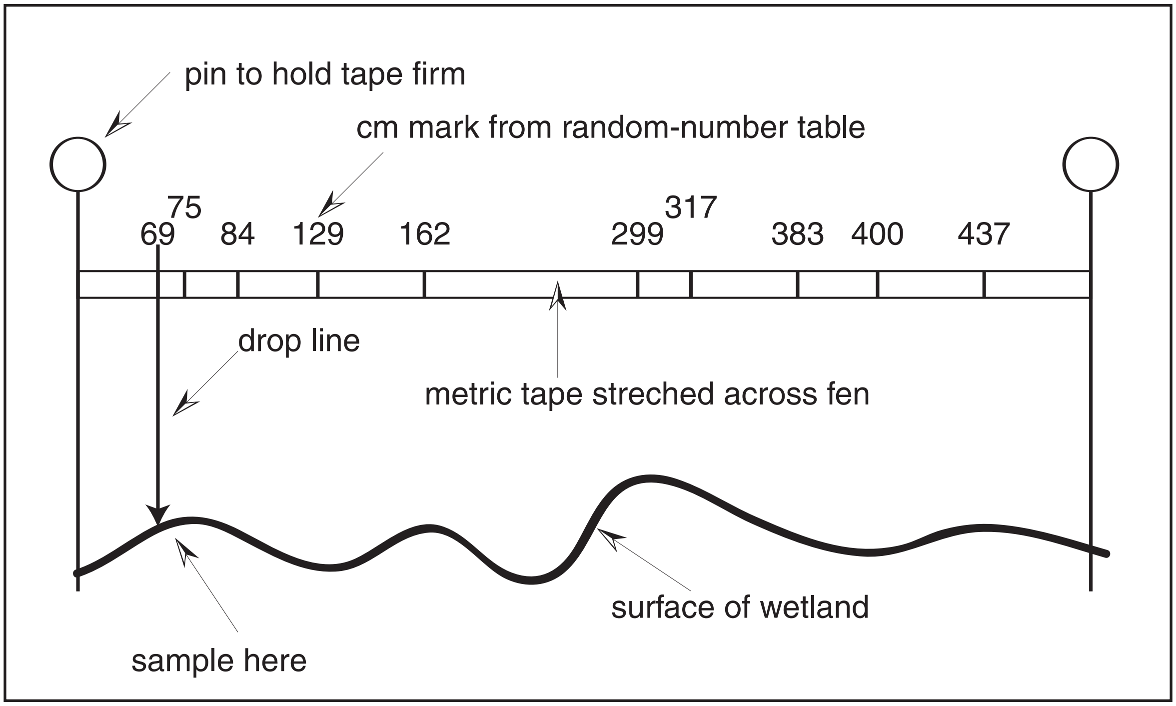


**Figure 1.** Point-intercept sampling. Sample at the reading along the tape (from 0 to 500 cm) that corresponds to the number in a row from the random-number table (see Appendix). In this example the sample is taken at 69 cm, 75 cm, 84 cm, etc., until 10 sample locations are identified for the 5-meter transect. Only samples with bryophytes are bagged.

or a visual drop line can be used from the tape down. A small surface sample, usually at or below the water interface, is grabbed between the thumb and forefinger of one hand and examined for the presence of bryophytes. If they are present the entire sample (minus some excess substrate if it can be removed) is dropped in a collection bag. Samples without any obvious bryophyte fragments you can discard in the field. If you are unsure if the sample contains bryophyte material, also drop it in a bag. We can easily confirm the presence or absence under the stereoscope in the lab. These bags without bryophytes will be subtracted from the total tally. [For each 5-m section use another row on the random-number sheet. For a site surveyed only once, this isn't important, but when permanent line transects are established for long-term monitoring, it is necessary to note down the random-number row that has been used to start the transect, so that future surveys can use a different starting point. The sampling method is in some degree destructive.]

In addition to the line-transect collections, some general collecting can be done in the ecotope (stay within the boundaries of the potential CF!). Those collection bags should be marked separately from those of the line transect. They are useful for (1) recording species that might have been missed along the transect, and (2) for preparing better-quality collections for herbarium deposition (vouchers), because well- developed clones of particular species can be sampled.

**Recording:** the following information is needed. (1) **The total length of transect** (in whole units of 5-m. (2) **The total number of collection bags used along the transect** (number of hits: either a tally of the bags, or calculated from the number range marked on the bags). Again, it is not necessary with this method to differentiate among species in the field. **Do not separate apparent individual species from each other that occur in a single point sample: put them in the same bag!**

**Calculation of total and individual bryophyte species cover:** (1) The overall bryophyte cover in % on the site is simple the number of bags with bryophytes (hits) divided by the total number of points dropped (10 for each 5-m transect section surveyed). Bags that turned out to have no bryophytes in them are subtracted from the number of hits recorded in the field. (2) The cover for an individual species equals the number of times the species was recorded among the collections times the total bryophyte cover of the site in % divided by the total tally of all species records. Often this total tally is larger than the number of hits, because several bags might contain a mixture of species.

## Calculating CF score

All Minnesota fen sites identified as calcareous fens and with comprehensive bryophyte analysis are ranked, both state-wide and regionally. This ranking is based on the presence of obligate, facultative, and occasional calcareous-fen species and is explained in detail in Janssens 2004a. An example of this validation is given with the Ottawa Fen report (Janssens 2004b).

## Equipment needed (**absolutely necessary**)

- **metric tape**, preferably at least 15-m long
- **2-lb brown paper bags**, preferably pre-numbered with your collection number
- **field notebook** to record collection-number ranges, and locality and habitat information
- **random-number table** (see appendix)
- waterproof pen
- handlens
- digital camera
- GPS receiver (note datum system employed!)
- stake or pole to start line transect with measuring tape
- plumb line
- laundry bag to store collections temporarily before proper drying
- rubber bands, to collate collection bags

## References


Janssens, J.A. 2002. Methods for the study of bryophyte ecology. Update April 2002. Available from the author janss008@tc.umn.edu.

Janssens, J.A. 2004a. Classification, indicator value, and regional differentiation of bryophyte species in Minnesota's calcareous fens and validation of calcareous fens, update June 2004. Available from janss008@tc.umn.edu or jeanette.leete@dnr.state.mn.us.

Janssens, J.A. 2004b. Bryophytes of the Ottawa Calcareous Fen, Le Sueur County, Minnesota, Preliminary Reconnaissance, update June 2004. Report to the Minnesota Department of Natural Resources, Division of Waters. Available from janss008@tc.umn.edu or jeanette.leete@dnr.state.mn.us.

# APPENDIX: RANDOM NUMBER TABLE FOR POINT-INTERCEPT LINE TRANSECTS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 7 | 28 | 43 | 48 | 153 | 338 | 415 | 441 | 452 |
| 47 | 81 | 228 | 236 | 320 | 377 | 423 | 436 | 466 | 478 |
| 13 | 25 | 82 | 88 | 109 | 193 | 332 | 371 | 408 | 444 |
| 10 | 54 | 97 | 212 | 220 | 237 | 265 | 328 | 421 | 441 |
| 4 | 32 | 78 | 121 | 152 | 203 | 253 | 296 | 370 | 489 |
| 13 | 48 | 126 | 152 | 222 | 293 | 376 | 392 | 423 | 483 |
| 47 | 73 | 73 | 77 | 78 | 167 | 291 | 382 | 447 | 477 |
| 12 | 72 | 94 | 98 | 132 | 193 | 301 | 409 | 420 | 481 |
| 31 | 65 | 113 | 167 | 184 | 251 | 281 | 299 | 369 | 370 |
| 27 | 30 | 40 | 203 | 253 | 296 | 310 | 346 | 396 | 412 |
| 8 | 48 | 49 | 96 | 148 | 222 | 316 | 325 | 346 | 420 |
| 29 | 77 | 135 | 211 | 245 | 319 | 379 | 407 | 460 | 478 |
| 0 | 56 | 62 | 91 | 131 | 134 | 254 | 265 | 371 | 467 |
| 17 | 66 | 160 | 180 | 189 | 256 | 290 | 401 | 405 | 458 |
| 40 | 91 | 93 | 95 | 233 | 249 | 255 | 256 | 313 | 490 |
| 18 | 24 | 124 | 175 | 191 | 257 | 311 | 335 | 455 | 486 |
| 40 | 41 | 112 | 189 | 208 | 260 | 299 | 336 | 337 | 364 |
| 70 | 248 | 273 | 286 | 317 | 330 | 354 | 410 | 484 | 495 |
| 11 | 57 | 99 | 124 | 147 | 171 | 295 | 312 | 370 | 464 |
| 11 | 28 | 84 | 116 | 140 | 224 | 307 | 421 | 439 | 481 |
| 39 | 99 | 120 | 166 | 302 | 360 | 387 | 389 | 442 | 454 |
| 56 | 65 | 89 | 126 | 197 | 240 | 258 | 285 | 366 | 413 |
| 3 | 123 | 126 | 147 | 187 | 197 | 205 | 241 | 302 | 354 |
| 35 | 56 | 128 | 138 | 235 | 236 | 267 | 390 | 422 | 450 |
| 32 | 82 | 92 | 174 | 222 | 307 | 435 | 437 | 449 | 479 |
| 84 | 256 | 277 | 304 | 388 | 402 | 447 | 459 | 483 | 499 |
| 34 | 89 | 108 | 118 | 271 | 300 | 323 | 381 | 423 | 465 |
| 73 | 133 | 174 | 187 | 234 | 253 | 256 | 317 | 379 | 482 |
| 152 | 236 | 329 | 339 | 362 | 394 | 402 | 449 | 458 | 484 |
| 6 | 49 | 52 | 126 | 186 | 284 | 294 | 340 | 362 | 485 |
| 169 | 182 | 279 | 282 | 296 | 306 | 341 | 364 | 378 | 407 |
| 59 | 64 | 82 | 152 | 173 | 193 | 205 | 270 | 322 | 360 |
| 69 | 75 | 84 | 129 | 162 | 299 | 347 | 383 | 400 | 437 |
| 65 | 155 | 161 | 285 | 299 | 326 | 342 | 395 | 429 | 496 |
| 99 | 161 | 172 | 214 | 255 | 256 | 322 | 367 | 418 | 430 |
| 83 | 109 | 120 | 123 | 137 | 191 | 258 | 278 | 353 | 357 |
| 72 | 277 | 338 | 351 | 352 | 411 | 418 | 419 | 461 | 464 |
| 65 | 68 | 149 | 183 | 275 | 326 | 411 | 451 | 455 | 469 |
| 103 | 280 | 318 | 336 | 363 | 380 | 387 | 389 | 415 | 467 |
| 18 | 30 | 31 | 51 | 194 | 263 | 329 | 371 | 401 | 413 |
| 11 | 53 | 206 | 207 | 225 | 297 | 302 | 337 | 442 | 469 |
| 6 | 14 | 22 | 85 | 135 | 261 | 301 | 361 | 367 | 472 |
| 100 | 164 | 201 | 215 | 238 | 363 | 371 | 471 | 472 | 485 |
| 40 | 104 | 158 | 209 | 214 | 216 | 274 | 342 | 371 | 389 |
| 26 | 93 | 114 | 129 | 164 | 227 | 278 | 355 | 412 | 447 |
| 110 | 144 | 188 | 243 | 266 | 277 | 355 | 386 | 403 | 471 |
| 58 | 84 | 144 | 190 | 218 | 263 | 323 | 329 | 490 | 491 |
| 35 | 64 | 85 | 194 | 259 | 294 | 408 | 413 | 442 | 443 |
| 173 | 191 | 242 | 318 | 330 | 340 | 361 | 396 | 412 | 473 |
| 67 | 124 | 234 | 264 | 324 | 365 | 418 | 438 | 445 | 452 |
| 62 | 109 | 110 | 114 | 227 | 244 | 312 | 344 | 416 | 448 |