

AE1637 (Revised May 2018)

Compatibility of North Dakota Soils for Irrigation

**Tom Scherer**

NDSU Extension Agricultural Engineer

Steve SielerNatural Resources Conservation Service
State Soil Liaison**Dave Franzen**

NDSU Extension Soils Specialist

Irrigation increases the productivity of soils and the effectiveness and consistency of certain soil-applied herbicides, and provides a stable supply of farm products for food product processors. However, irrigation can degrade the quality of soil and cause crop yields to decline, even to the point of field abandonment when soil and irrigation water are not compatible.

Examples of soil degradation and land abandonment due to improper irrigation exist throughout history. When irrigation acreage expands to new areas, determining soil and water compatibility is critical for sustaining yields at high levels.

NDSU | EXTENSION

North Dakota State University
Fargo, North Dakota

How to Use This Information

This publication is intended as a first step to help current and prospective irrigators understand the principles behind the irrigability of soils in North Dakota.

This publication should be used in combination with soil survey information for the land to be irrigated.

Soil surveys of every county in North Dakota have been completed and documented.

Many counties have printed copies, but official,

up-to-date soil survey information can be found only on the internet at <http://websoilsurvey.nrcc.usda.gov/>. Your local Natural Resources Conservation Service office or county office of NDSU Extension can help you obtain soil survey information for the fields of interest.



Understanding the irrigability of the soil in a field begins with knowledge of the local soil series and the way they are represented on the soil survey map. When soil boundaries are drawn on soil maps, the soil-mapping unit is not purely one soil.

The other soils present are of lesser extent and are called minor components. These minor components need to be considered when making irrigation management decisions.

Each soil description may have different phases of slope and other properties that modify its suitability for irrigation. We highly recommend you consult with a qualified soil scientist before making the decision to irrigate.

The photo on the cover is of a lateral-move irrigation system (sometimes called a linear-move system) at the Nesson Valley Irrigation Research Site. It is about 30 miles east of Williston on the north side of Lake Sakakawea.

You can check out the research site at www.ag.ndsu.edu/willistonrec/nesson-valley-irrigation-project.

(Photo by Tyler Tjelde)

Classification of Soils for Irrigation Suitability

All soil series in North Dakota have been classified for irrigation suitability. A soil series is based on distinguishing characteristics, including the number of subsoil layers, or horizons; the depth of each horizon; and the texture, color, carbonate content, sodium content, structure, organic matter and other diagnostic characteristics of each horizon.

Soil series are grouped into three irrigation categories: nonirrigable (n), conditional (c) and irrigable (i).

Nonirrigable soils should not be irrigated by any water source under any circumstances ([Table 1, Pages 4-5](#)).

The decision to classify a soil as nonirrigable is based on the knowledge that irrigation will not benefit the irrigator in the short term economically and may decrease the productivity of the soil.

A conditional soil can be irrigated under a high degree of management that will vary according to the quality of water and soil properties. Specific recommendations for conditional soil management are important for sustaining irrigation and soil health for the future.

An irrigable soil generally can be irrigated from most water sources. A high level of management is advised to improve nutrient uptake and decrease collateral pollution due to excess water movement through the soil.

Some fields will contain soils that fall into two or perhaps all three irrigation categories. A qualified soil professional can provide assistance for fields with conditional soils. An irrigation system should be designed to exclude irrigation on areas that fall into the nonirrigable category, but this may not be possible.

If most of the field falls into the irrigable category, but significant areas are conditional and nonirrigable, the soils in these categories will influence management decisions strongly.

Required management may include annual soil testing for nitrates, sodium and salts; annual addition of calcium amendments; lower nitrogen fertilizer rates; the use of no-till or reduced tillage; or other special activities. Special management methods will depend on the reason for placement into conditional or nonirrigable classes.

The special requirements for irrigating small areas of conditional or nonirrigable soils should be part of the estimate of the total irrigation investment. As site-specific farming techniques are developed, more practical methods of managing soil inclusions will become available.

Commercial center-pivot irrigation systems now have site-specific water application technology that will vary the amount of water applied to a particular area in the field. The improved water application technology, along with reduced or no-till technology, will make a big difference in how conditional soils will be irrigated.

Irrigation Water Management

Irrigation water management is recommended for all irrigation systems. Irrigation scheduling is an important part of irrigation water management. Irrigation scheduling will minimize the use of water without loss of yield. It also is important for reducing nitrate leaching from overirrigation.

Three irrigation scheduling tools are available to North Dakota irrigators. They are:

- A manual method outlined in NDSU Extension publication "Irrigation Scheduling by the Checkbook Method"
<https://tinyurl.com/IrrigationScheduling>
- A site-specific web-based application available through the North Dakota Agricultural Weather Network (NDAWN) website:
<http://ndawn.ndsu.nodak.edu/>
- An online spreadsheet version of the checkbook method and a user manual at
www.ag.ndsu.edu/irrigation/irrigation-scheduling

Table 1. Alphabetical list of soil series and associated irrigability group. Irrigability groups are from 1 to 29, where “i” is for irrigable, “c” is for conditionally irrigable and “n” is for not irrigable. Groups 1 to 7 are irrigable soils, 8 to 22 are conditional soils and 23 to 29 are nonirrigable. Irrigation group ratings listed do not address series phases such as saline, wet, flooded, drained, undrained and slope.

Soil Series	Group	Soil Series	Group	Soil Series	Group	Soil Series	Group
AASTAD	8c	BRYANT	8c	EKALAKA	24n	GRAIL	10c
ABERDEEN	11c	BULLTOP	6i	ELMVILLE	17c	GRANO	22c
ABSHER	24n	BUSE	9c	EMBDEN	4i	GRASSNA	8c
ALKABO	11c	CABBA	26n	EMRICK	7i	GREAT BEND	8c
AMOR	12c	CABBART	26n	ENLOE	22c	GRIMSTAD	20c
ANTLER	15c	CASHEL	15c	ERAMOSH	27n	GWINNER	21c
APPAM	3i	CATHAY	11c	ESMOND	9c	HAMAR	18c
AQUENTS	27n	CAVOUR	24n	ESPELIE	20c	HAMERLY	15c
ARIKARA	23n	CEDAR PAN	26n	ETHRIDGE	10c	HAMLET	8c
ARNEGARD	7i	CHAMA	12c	EVRIDGE	24n	HANLY	3i2i
ARVESON	19c	CHANTA	6i	EXLINE	24n	HARRIET	24n
ARVILLA	3i	CHERRY	9c	FAIRDALE	9c	HATTIE	21c
AUGSBERG	15c	CHINOOK	4i	FALKIRK	8c	HAVRE	9c
AYLMER	2i	CLAIRE	2i	FALSEN	2i	HAVRELON	9c
BAAHISH	5i	CLONTARF	3i	FARFELD	26n	HECLA	3i
BAINVILLE	26n	COE	1i	FARGO	22c	HEDMAN	17c
BALATON	9c	COHAGEN	23n	FARLAND	8c	HEGNE	22c
BANKS	3i	COLVIN	15c	FARNUF	8c	HEIL	24n
BANTRY	18c	CORMANT	18c	FELOR	8c	HEIMDAL	7i
BARNES	8c	COZBERG	3i	FERNEY	24n	HIDATSA	5i
BEARDEN	15c	CRESBARD	11c	FLAMING	2i	HILAIRE	3i
BEARPAW	10c	CROKE	10c	FLASHER	23n	HOFFMANVILLE	21c
BECKTON	24n	DAGLUM	24n	FLAXTON	14c	HOVEN	24n
BEISIGL	13c	DARNEN	8c	FLEAK	26n	INKSTER	4i
BELFIELD	11c	DELAMERE	19c	FLOM	15c	JANESBURG	24n
BENZ	25n	DESART	24n	FOLDAHL	14c	KARLSRUHE	18c
BEOTIA	7i	DICKEY	14c	FORDVILLE	6i	KELVIN	10c
BIGSANDY	15c	DILTS	26n	FORMAN	8c	KENSAL	5i
BINFORD	3i	DIMMICK	27n	FOSSUM	18c	KINDRED	15c
BLANCHARD	2i	DIVIDE	16c	FRAM	17c	KIRBY	1i
BOHNSACK	17c	DOGTOOTH	24n	FULDA	22c	KLOTEN	26n
BORUP	17c	DOOLEY	14c	GALCHUTT	15c	KORCHEA	9c
BOTTINEAU	10c	DORAN	15c	GALLATIN	19c	KORELL	8c
BOWBELLSS	8c	DOVRAY	22c	GARBORG	18c	KRANZBURG	8c
BOWDLE	6i	DUNCOM	26n	GARDENA	7i	KRATKA	20c
BOXWELL	12c	DUPREE	26n	GERDA	24n	KREM	14c
BRANDENBURG	1i	EASBY	25n	GILBY	15c	KREMLIN	7i
BRANTFORD	5i	ECKMAN	7i	GLENDIVE	4i	LA PRAIRIE	8c
BREIEN	4i	EDGELEY	12c	GLYNDON	17c	LADELLE	8c
BRISBANE	6i	EGELAND	4i	GOLVA	8c	LADNER	24n

Soil Series	Group	Soil Series	Group	Soil Series	Group	Soil Series	Group
LAKOA	8c	MEKINOCK	24n	ROLLA	21c	TOTTEN	24n
LAKOTA	24n	METIGOSHE	3i	RONDELL	9c	TOWNER	14c
LALLIE	22c	MIDWAY	26n	ROSEGLEN	7i	TREMBLES	4i
LAMBERT	9c	MINNEWAUKAN	18c	ROSEWOOD	18c	TUSLER	13c
LAMOURE	15c	MIRANDA	24n	RUSKLYN	9c	ULEN	18c
LANGHEI	9c	MONDAMIN	21c 10c	RUSO	3i	URANDA	24n
LANKIN	8c	MOREAU	12c	RYAN	24n	VALENTINE	2i
LANONA	14c	MORTON	12c	SAKAKAWEA	9c	VALLERS	15c
LARSON	24n	MOTT	4i	SANDBERG	2i	VANDA	25n
LAWTHER	21c	MUSTINKA	22c	SAVAGE	10c	VANG	6i
LEFOR	13c	NAHON	24n	SCAIRT	24n	VEBAR	13c
LEHR	5i	NECHE	15c	SCHALLER	3i	VELVA	4i
LEMERT	24n	NIOBELL	11c	SCORIO	21c	VENLO	18c
LETCHER	24n	NOONAN	24n	SEARING	12c	VERENDRYE	18c
LIHEN	3i	NUTLEY	21c	SEELYEVILLE	27n	VIDA	9c
LINDAAS	22c	OBURN	24n	SEN	12c	VIKING	22c
LINTON	7i	OJATA	25n	SERDEN	2i	VIRGELLE	14c
LISAM	26n	OLGA	21c	SEROCO	2i	WABEK	1i
LISMORE	8c	OMIO	12c	SHAM	25n	WAHPETON	21c
LITTLEHORN	12c	OSAKIS	3i	SHAMBO	7i	WALSH	8c
LITTLEMO	6i	OVERLY	8c	SHIBAH	5i	WALUM	3i
LIVONA	14c	PARNELL	22c	SINAI	21c	WAMDUSKA	1i
LOHLER	28n 21c	PARSHALL	4i	SIOUX	1i	WANAGAN	5i
LOHNES	2i	PATENT	9c	SISSETON	9c	WARSING	5i
LONNA	9c	PEEVER	21c	SOUTHAM	22c	WATROUS	12c
LOWE	15c	PERELLA	15c	SPOTTSWOOD	6i	WAUKON	10c
LUDDEN	22c	PETA	15c	STADY	6i	WAYDEN	26n
MACHETAH	9c	PLAYMOOR	28n	STIRUM	24n	WERNER	23n
MADDOCK	3i	POPLETON	18c	STRAW	7i	WHEATVILLE	15c
MAGNUS	21c	PORTAL	24n	SUOMI	22c	WHITEBIRD	24n
MAKOTI	8c	PROMISE	21c	SUTLEY	9c	WIBAUX	1i
MALTESE	24n	RANSLO	24n	SVEA	8c	WILDROSE	21c
MANDAN	7i	RAUVILLE	15c 27n	SVERDRUP	3i	WILLIAMS	8c
MANFRED	24n	REEDER	12c	SWENODA	14c	WILTON	8c
MANNING	3i	REGAN	15c	SYRENE	15c	WINGER	15c
MANTADOR	19c	REGENT	12c	TALLY	4i	WOLF POINT	21c
MARIAS	21c	RENshaw	5i	TANNA	10c	WYARD	15c
MARKEY	27n	RHAME	13c	TANSEM	7i	WYNDMERE	20c 19c
MARMARTH	12c	RHOADES	24n	TELFER	3i	WYRENE	20c 18c
MARYSLAND	16c	RIDGELAWN	6i	TEMVIK	8c	YAWDIM	26n
MAUVAIS	15c 25n	RIFLE	27n	THIEFRIVER	22c	YEGEN	14c
MAX	8c	RINGLING	1i	TIFFANY	20c 19c	YETULL	2i
MCDONALDSVILLE	22c	ROCKWELL	20c	TINSLEY	1i	ZAHL	9c
MCKEEN	15c 27n	ROLETTE	21c	TOLNA	19c	ZEELAND	10c
MCKENZIE	22c	ROLISS	15c	TONKA	22c	ZELL	9c
						ZEONA	2i

Soil Texture Abbreviations

Abbreviations for soil texture, from coarse to fine, used in this publication:

GR	Gravelly
S	Sand
COS	Coarse sand
FS	Fine sand
LCOS	Loam coarse sand
LS	Loamy sand
LFS	Loamy fine sand
COSL	Coarse sandy loam
SL	Sandy loam
FSL	Fine sandy loam
VFSL	Very fine sandy loam
L	Loam
SIL	Silt loam
CL	Clay loam
SCL	Sandy clay loam
SICL	Silty clay loam
SIC	Silty clay
C	Clay

Irrigability Groups

In the following text,

< = less than

> = greater than

dS/m = deciSiemens per meter

EC = electrical conductivity

SAR = sodium absorption ratio

Irrigable Soils (i)

Irrigable soils generally require less management than conditional soils. Even though the soils are in an irrigable class, good irrigation management is essential. Attention to the allowable irrigation water quality is important. The use of lower-quality water than recommended can lower the productivity of the soils from salts and sodium. Different phases of each soil series may modify irrigation recommendations.

1i. Brandenburg, Coe, Kirby, Ringling, Sioux, Tinsley, Wabek, Wamoduska, Wibaux

Drainage: excessively drained

Surface texture: L, SL

Substratum texture: sand and gravel

Surface intake rate for sprinkler irrigation: 0.5-0.7 inch/hour for slopes < 6 percent

Limiting permeability within 40 inches: 0.6 to 2 inches/hour in the upper part and > 6 inches/hour in the lower part

Profile characteristics: shallow/very shallow (< 20 inches) to sand, gravel and porcellanite (scoria)

Depth to lime: 0-10 inches

Surface pH: 6.6-8.4

EC (maximum within 40 inches in dS/m): 0

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	2 inches
3 feet	2.5 inches
4 feet	3 inches
5 feet	3 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/M; maximum allowable SAR < 12

Water Management Practices

Water management on these soils is critical because of low available water capacity and nutrient leaching hazard.

2i. Aylmer, Banks, Blanchard, Claire, Falsen, Flaming, Lohnes, Sandberg, Serden, Seroco, Valentine, Yetull, Zeona

Drainage: moderately well to excessively drained

Surface texture: CoS, S, FS, LCoS, LS, LFS, CoSL, SL, FSL

Subsoil texture: FS, S, LCoS, CoS

Surface intake rate for sprinkler irrigation: 0.5->1 inch/hour for slopes < 9 percent

Limiting permeability within 40 inches: 6-20 inches/hour
 Profile characteristics: sandy and moderately coarse-textured material
 Depth to lime: 10-30 inches
 Surface pH: 6.1-7.3
 EC (maximum within 40 inches in dS/m): 0
 SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1 inch
2 feet	2 inches
3 feet	2.5 inches
4 feet	3 inches
5 feet	4 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR <12

Water Management Practices

Water management on these soils is critical because of low available water-holding capacity and nutrient leaching hazard.

3i. Appam, Arvilla, Binford, Clontarf, Cozberg, Hanly, Hecla, Hilaire, Lihen, Maddock, Manning, Metigoshe, Osakis, Ruso, Schaller, Sverdrup, Telfer, Walum

Drainage: moderately well to somewhat excessively drained
 Surface texture: FSL, SL, CoSL, LFS, LS
 Subsoil and substratum texture: SL and L in the upper part and LS to sand and gravel in the lower part
 Surface intake rate for sprinkler irrigation: 0.4-1.5 inches/hour for slopes < 6 percent
 Limiting permeability within 40 inches: 2-20 inches/hour in the upper part and > 6 inches/hour in the lower part
 Profile characteristics: moderately coarse and medium-textured material in the upper part and coarse-textured material in the lower part
 Depth to lime: 10-30 inches
 Surface pH: 6.1-7.8
 EC (maximum within 40 inches in dS/m): 0
 SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3 inches
3 feet	3.5 inches
4 feet	4.5 inches
5 feet	5.5 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR <12

Water Management Practices

An irrigation scheduling system must be used.

4i. Breien, Chinook, Egland, Embden, Glendive, Inkster, Mott, Parshall, Tally, Trembles, Velva

Drainage: well and moderately well drained

Surface texture: SL, FSL, L

Subsoil texture: SL, FSL, L

Surface intake rate for sprinkler irrigation: .5-1 inch/hour for slopes < 6 percent

Limiting permeability within 40 inches: 0.6-6 inches/hour

Profile characteristics: moderately coarse and medium-textured material

Depth to lime: 10-20 inches

Surface pH: 6.1-8.4

EC (maximum within 40 inches in dS/m): 0-2

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2 inches
2 feet	4 inches
3 feet	5.5 inches
4 feet	7 inches
5 feet	9 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR <12

Water Management Practices

An irrigation scheduling system must be used.

5i. Baahish, Brantford, Hidatsa, Kensal, Lehr, Renshaw, Shibah, Wanagan, Warsing

Drainage: well and moderately well drained

Surface texture: SL, L

Substratum texture: 2C material is GrSL to sand and gravel

Surface intake rate for sprinkler irrigation: 0.5-0.7 inch/hour for slopes < 6 percent

Permeability within 40 inches: 0.6-2 inches/hour in the upper part and > 6 inches/hour in the lower part

Profile characteristics: moderately coarse and medium-textured material over sand and gravel that is shallow to moderately deep (< 40 inches)

Depth to lime: 10-20 inches

Surface pH: 6.1-7.8

EC (maximum within 40 inches in dS/m): 0 to 1

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2 inches
2 feet	3 inches
3 feet	3.5 inches
4 feet	4 inches
5 feet	4.5 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR < 9

Water Management Practices

An irrigation scheduling system must be used.

6i. Bowdle, Brisbane, Bulltop, Chanta, Fordville, Littlemo, Ridgelawn, Spottsworth, Stady, Vang

Drainage: moderately well and well drained

Surface texture: L, SIL, CL

Subsoil texture: L and CL in B horizons and GrL to GrS in the 2B or 2C horizons

Surface intake rate for sprinkler irrigation: 0.5-0.7 inch/hour for slopes < 6 percent

Limiting permeability within 40 inches: 0.6-2 inches/hour in the upper part and > 6 inches/hour in the lower part

Profile characteristics: moderately fine-textured material over moderately deep (20-40 inches) sand and gravel

Depth to lime: 15-30 inches

Surface pH: 6.1-7.3

EC (maximum within 40 inches in dS/m): 0-1

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	5.5 inches
4 feet	6 inches
5 feet	6.5 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR < 9

Water Management Practices

An irrigation scheduling system must be used.

7i. Arnegard, Beotia, Eckman, Emrick, Gardena, Heimdal, Kremlin, Linton, Mandan, Roseglen, Shambo, Straw, Tansem

Drainage: moderately well and well drained

Surface textures: VFSL, SIL, L

Subsoil texture: VFSL, SIL, L, SICL

Surface intake rate for sprinkler irrigation: 0.1-0.5 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.2-2 inches/hour

Profile characteristics: medium and moderately fine-textured material

Depth to lime: 15-30 inches

Surface pH: 6.6-7.8

EC (maximum within 40 inches in dS/m): 0-2

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	5 inches
3 feet	7 inches
4 feet	9 inches
5 feet	11.5 inches

Irrigation Water Quality

Maximum allowable EC < 2.25 dS/m; maximum allowable SAR < 6

Water Management Practices

An irrigation scheduling system must be used.

Conditional Soils (c)

Conditional soils can be irrigated under a high level of management. Soil conditions that contribute to conditional status are the presence of salts, poor drainage properties, the presence of subsurface layering, and the need for supplemental surface and subsurface drainage. Irrigation without high levels of management may degrade the soil quality for future generations but can be irrigated successfully if recommendations are followed. Soil phases of each soil series may modify irrigation recommendations.

8c. Aastad, Barnes, Bowbells, Bryant, Falkirk, Farland, Farnuf, Felor, Forman, Golva, Grassna, Great Bend, Hamlet, Korell, Kranzburg, La Prairie, LaDelle, Lakoa, Lankin, Lismore, Makoti, Max, Overly, Svea, Temvik, Walsh, Williams, Wilton

Drainage: moderately well to well drained

Surface texture: L, SIL, SICL

Subsoil texture: L, CL, SICL

Surface intake rate for sprinkler irrigation: 0.1-0.7 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.2-2 inches/hour

Profile characteristics: medium and moderately fine-textured material

Depth to lime: 10-20 inches

Surface pH: 6.1-7.8

EC (maximum within 40 inches in dS/m): 0-4

SAR (maximum within 40 inches): < 2

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	8.5 inches
5 feet	10 inches

Irrigation Water Quality

Maximum allowable EC < 1.5 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are conditional for irrigation due to moderate and moderately slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a

three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. An irrigation scheduling system must be used.

9c. Balaton, Buse, Cherry, Esmond, Fairdale, Havre, Havrelon, Korchea, Lambert, Langhei, Lonna, Machetah, Patent, Rondell, Rusklyn, Sakakawea, Sisseton, Sutley, Vida, Zahl, Zell

Drainage: moderately well and well drained

Surface texture: VFSL, FSL, SL, L, SIL, CL, SICL 2/

Subsoil texture: L, SIL, CL, SICL

Surface intake rate for sprinkler irrigation: 0.5-0.7 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.6-2 inches/hour

Profile characteristics: calcareous/medium and moderately fine-textured materials

Depth to lime: 0-10 inches

Surface pH: 6.6-8.4

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): < 2

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	8.5 inches
5 feet	10 inches

Irrigation Water Quality

Maximum allowable EC < 1.8 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are conditional for irrigation due to moderate and moderately slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. An irrigation scheduling system must be used.

10c. Bearpaw, Bottineau, Croke, Ethridge, Grail, Kelvin, Mondamin, Savage, Tanna, Waukon, Zealand

Drainage: moderately well and well drained

Surface texture: L, CL, SICL

Subsoil texture: CL, SICL, SIC, C (> 35 percent clay)

Surface intake rate for sprinkler irrigation: 0.1-0.5 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.06-0.6 inch/hour

Profile characteristics: moderately fine to fine-textured material

Depth to lime: 15-40 inches

Surface pH: 6.1-7.8

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): < 4

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	8.5 inches
5 feet	10.5 inches

Irrigation Water Quality

Maximum allowable EC < 1 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are conditional for irrigation due to moderately slow and slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. Subsurface drainage may be required for continued irrigation. An irrigation scheduling system must be used.

11c. Aberdeen, Alkabo, Belfield, Cathay, Cresbard, Niobell

Drainage: moderately well and well drained

Surface texture: L, SIL, SICL

Subsoil texture: CL, SICL (> 35 percent clay)

Surface intake rate for sprinkler irrigation: 0.1-0.7 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.06-0.2 inch/hour

Profile characteristics: moderately fine and fine-textured material that have a degraded natic horizon within 20 inches

Depth to lime: 20-30 inches

Surface pH: 5.6-7.3

EC (maximum within 40 inches in dS/m): 2-8

SAR (maximum within 40 inches): 5-15

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6 inches
4 feet	8 inches
5 feet	10 inches

Irrigation Water Quality

Maximum allowable EC < 1.5 dS/m; maximum allowable SAR < 4

Water Management Practices

These soils are marginal for irrigation, and irrigation of extensive areas should be avoided. Continued irrigation potentially could cause restricted water intake and permanent soil damage. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. Subsurface drainage may be required for continued irrigation.

12c. Amor, Boxwell, Chama, Edgeley, Little Horn, Marmarth, Moreau, Morton, Omio, Reeder, Regent, Searing, Sen, Watrous

Drainage: well drained

Surface texture: L, SIL, SICL

Subsoil texture: L, SIL, SICL

Surface intake rate for sprinkler irrigation: 0.1-0.5 inch/hour
for slopes < 3 percent

Limiting permeability within 40 inches: 0.0-0.6 inch/hour depending
on texture of soft weathered bedrock

Profile characteristics: medium and moderately fine-textured materials
moderately deep (20-40 inches) to soft weathered bedrock

Depth to lime: 10-20 inches

Surface pH: 6.1-7.8

EC (maximum within 40 inches in dS/m): 2-8

SAR (maximum within 40 inches): 0-4

Waterholding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	0.08 inch
5 feet	0.08 inch

Irrigation Water Quality

Maximum allowable EC < 1.8 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are marginal for irrigation due to moderately deep (20-40 inches) bedrock and the potential for lateral seepage. Avoid irrigating extensive areas or where stratification is evident and seeps are present. Salinity monitoring should be done on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

13c. Beisigl, Lefor, Rhame, Tusler, Vebar

Drainage: well to somewhat excessively drained

Surface texture: LS, LFS, SL, FSL

Subsoil texture: LS, LFS, SL, FSL

Surface intake rate for sprinkler irrigation: 0.5-1.5 inches/hour
for slopes < 3 percent

Limiting permeability within 40 inches: 0.0-0.6 inch/hour

Profile characteristics: coarse and moderately coarse-textured material moderately deep (20-40 inches) to soft weather beds

Depth to lime: 10-20 inches

Surface pH: 6.1-7.8

EC (maximum within 4 inches in dS/m): 0

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3 inches
3 feet	3.5 inches
4 feet	0.08 inch
5 feet	0.08 inch

Irrigation Water Quality

Maximum allowable EC < 1.8 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are marginal for irrigation due to moderately deep (20-40 inches) bedrock and the potential for lateral seepage. Avoid irrigating extensive areas or where stratification is evident and seeps are present. Salinity monitoring should be done on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

14c. Dickey, Flaxton, Krem, Lanona, Livona, Swenoda, Towner, Virgelle, Yegen

Drainage: moderately well and well drained

Surface texture: LS, LFS, SL, FSL

Subsoil texture: L, CL, SICL

Surface intake rate for sprinkler irrigation: 0.5-1.5 inches/hour
for slopes < 3 percent

Limiting permeability within 40 inches: 0.2-0.6 inch/hour

Profile characteristics: coarse-textured material over medium and moderately fine-textured material

Depth to lime: > 15 inches

Surface pH: 6.1-7.3

EC (maximum within 40 inches in dS/m): 0-4

SAR (maximum within 40 inches): < 2

Waterholding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3 inches
3 feet	4.5 inches
4 feet	6.5 inches
5 feet	8 inches

Irrigation Water Quality

Maximum allowable EC < 1.8 dS/m; maximum allowable SAR < 9

Water Management Practices

These soils are conditional for irrigation due to the subsoil's moderately slow permeability and potential for increased salinity. Salinity in the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. An irrigation scheduling system must be used.

15c. Antler, Augsberg, Bearden, Bigsandy, Cashel, Colvin, Doran, Flom, Galchutt, Gilby, Hamerly, LaMoure, Lowe, McKeen, Neche, Perella, Rauville, Regan, Roliss, Styrene, Vallers, Wheatville, Winger, Wyard

Drainage: somewhat poorly and poorly drained

Surface texture: L, SIL, SICL, SIC, C

Subsoil texture: L, SIL, SICL, SIC, C

Surface intake rate for sprinkler irrigation: 0.1-0.7 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.2-0.6 inch/hour

Profile characteristics: medium to fine-textured materials

Depth to lime: 0-10 inches

Surface pH: 6.6-8.4

EC (maximum within 40 inches in dS/m): < 6

SAR (maximum within 40 inches): < 3

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	7 inches
4 feet	9 inches
5 feet	10 inches

Irrigation Water Quality

Maximum allowable EC < 1.5 dS/m; maximum allowable SAR < 6

Water Management Practices

Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

16c. Divide, Maryland

Drainage: somewhat poorly and poorly drained

Surface texture: L, CL, SIL

Subsoil texture: L, CL

Surface intake rate for sprinkler irrigation: 0.1-0.5 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.6-2 inches/hour in the upper part and > 6 inches/hour in the lower part

Profile characteristics: Aeric and Typic Calciaquolls, medium and moderately fine-textured material over sand and gravel

Depth to lime: 0-10 inches

Surface pH: 7.4-8.4

EC (maximum within 40 inches in dS/m): < 2

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	5 inches
4 feet	5.5 inches
5 feet	6 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR < 9

Water Management Practices

Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

17c. Bohnsack, Borup, Elmville, Fram, Glyndon

Drainage: somewhat poorly and poorly drained

Surface texture: FSL, SIL, L

Subsoil texture: FSL, SIL, L

Surface intake rate for sprinkler irrigation: 0.5-1 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.6-2 inches/hour

Profile characteristics: Aeric and Typic Calciaquolls, moderately coarse and medium-textured material

Depth to lime: 0-10 inches

Surface pH: 7.4-8.4

EC (maximum within 40 inches in dS/m): < 6

SAR (maximum within 40 inches): 0-1

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6 inches
4 feet	8.5 inches
5 feet	10.5 inches

Irrigation Water Quality

Maximum allowable EC < 2.25 dS/m; maximum allowable SAR < 6

Water Management Practices

Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

18c. Banks (variant), Bantry, Cormant, Fossum, Garborg, Hamar, Karlsruhe, Minnewaukan, Poppleton, Rosewood, Ulen, Venlo, Verendrye, Wyrene

Drainage: somewhat poorly and poorly drained

Surface texture: CoSL, LFS, LS, FS, S

Subsoil texture: LFS, LS, S, FS

Surface intake rate for sprinkler irrigation: 0.5-1.5 inches/hour for slopes < 3 percent

Limiting permeability within 40 inches: 2-20 inches/hour

Profile characteristics: coarse and moderately coarse-textured material

Depth to lime: 0-30 inches

Surface pH: 6.1-8.4

EC (maximum within 40 inches in dS/m): 0-2

SAR (maximum within 40 inches): 0-1

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	2.5 inches
3 feet	3 inches
4 feet	4 inches
5 feet	5 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR < 12

Water Management Practices

Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

19c. Arveson, Delamere, Fossum, Galatin, Mantador, Tiffany, Tolna, Wyndmere, Wyrene

Drainage: somewhat poorly and poorly drained

Surface texture: VFSL, FSL, SL

Subsoil texture: VFSL, FSL, SL

Surface intake rate for sprinkler irrigation: 0.5-1.25 inches/hour for slopes < 3 percent

Limiting permeability within 40 inches: 2-6 inches/hour

Profile characteristics: moderately coarse and medium-textured material

Depth to lime: Calciaquolls 0-10 inches, Aquolls > 20 inches

Surface pH: 6.1-8.4

EC (maximum within 40 inches in dS/m): 0-2

SAR (maximum within 40 inches): 0-1

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2 inches
2 feet	3.5 inches
3 feet	5 inches
4 feet	6.5 inches
5 feet	7.5 inches

Irrigation Water Quality

Maximum allowable EC < 3 dS/m; maximum allowable SAR < 12

Water Management Practices

Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

20c. Espelie, Grimstad, Kratka, Rockwell, Tiffany, Wyndmere

Drainage: somewhat poorly and poorly drained

Surface texture: L, FSL, SL, LFS, LS

Subsoil texture: SL, SIL, L, CL

Surface intake rate for sprinkler irrigation: 0.5-1.5 inches/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.2-2 inches/hour

Profile characteristics: coarse and moderately coarse-textured material over medium-textured material

Depth to lime: 0 -10 Inches

Surface pH: 7.4-8.4

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): < 2

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3 inches
3 feet	4.5 inches
4 feet	6.5 inches
5 feet	8 inches

Irrigation Water Quality

Maximum allowable EC < 1.8 dS/; maximum allowable SAR < 9

Water Management Practices

Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

21c. Gwinner, Hattie, Hoffmanville, Lawther, Lohler, Magnus, Marias, Nutley, Olga, Peever, Promise, Rolette, Rolla, Scorio, Sinai, Wahpeton, Wildrose, Wolf Point

Drainage: moderately well and well drained

Surface texture: SIC, C

Subsoil texture: SIC, C

Surface intake rate for sprinkler irrigation: 0.1-0.2 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.06-0.2 inch/hour

Profile characteristics: fine-textured material

Depth to lime: 0-20 inches

Surface pH: 7.3-8.4

EC (maximum within 40 inches in dS/m): 1-4

SAR (maximum within 40 inches): 0-1

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6 inches
4 feet	8 inches
5 feet	10 inches

Irrigation Water Quality

Maximum allowable EC < 1 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are conditional for irrigation due to moderately slow and slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a

three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. Subsurface drainage may be required for continued irrigation. An irrigation scheduling system must be used.

22c. Dimmick, Dovray, Enloe, Fargo, Fulda, Grano, Hegne, Lallie, Lindaas, Ludden, McDonaldsville, McKenzie, Parnell, Southam, Suomi, Thiefriver, Tonka, Viking

Drainage: poorly drained and drained phases of poorly and very poorly drained

Surface texture: L, SIL, SICL, SIC, C

Subsoil texture: SIC, C

Surface intake rate for sprinkler irrigation: 0.1-0.4 inch/hour for slopes < 3 percent

Limiting permeability within 40 inches: 0.06-0.2 inch/hour

Profile characteristics: medium to fine-textured material in the upper part and fine-textured material in lower part

Depth to lime: 0 > 40 inches

Surface pH: 6.1-8.4

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): 0

Water-holding Capacity

(rounded to the nearest 0.5 inch; on-site values may vary)

Depth	Average Cumulative Available Water Capacity
1 foot	2 inches
2 feet	4 inches
3 feet	6 inches
4 feet	7.5 inches
5 feet	9.5 inches

Irrigation Water Quality

Maximum allowable EC < 1 dS/m; maximum allowable SAR < 6

Water Management Practices

These soils are conditional for irrigation due to slow permeability, wetness and a potential for salinity increase. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring, when crop requirements for water are low. An irrigation scheduling system must be used.

Nonirrigable (n)

These are soils with very severe limitations to irrigation because of one or more of the following: slope, sodicity, salinity, excessively slow permeability, root restrictive subsoil layering. Irrigation is strongly discouraged. Irrigation will cause soil quality to be degraded and reduce the productivity of the soils for future generations of farm producers. Different phases of each soil series will modify irrigation recommendations.

23n. Nonirrigable because of relief (slopes > 6 percent), depth or root restrictive substrata

Arikara, Buse, Cabba, Cohagen, Dumps, Dune Land, Flasher, Sioux, Werner

24n. Nonirrigable because of relief (slopes > 6 percent), sodicity (SAR > 13 within 40 inches), salinity (EC > 4 dS/m), slow or very slow permeability, or root restrictive subsoil

Absher, Barkof, Beckton, Cavour, Daglum, Desart, Dogtooth, Ekalaka, Evridge, Exline, Ferney, Gerda, Harriet, Heil, Hoven, Janesburg, Ladner, Lakota, Larson, Lemert, Letcher, Maltese, Manfred, Mekinock, Miranda, Nahon, Noonan, Oburn, Portal, Ranslo, Rhoades, Ryan, Scairt, Stirum, Totten, Uranda, Whitebird

25n. Nonirrigable because of salinity (EC > 8 dS/m) and slopes < 6 percent

Antler, Arnegard, Arveson, Bearden, Belfield, Benz, Borup, Colvin, Divide, Easby, Elmville, Ojata, Fargo, Fossum, Fram, Gilby, Glyndon, Grano, Grassna, Hamerly, Hegne, LaDelle, Lallie, LaMoure, Lohler, Ludden, Mandador, Moreau, Ojata, Overly, Parshall, Patent, Playmoor, Regan, Savage, Scorio, Sham, Valler, Vanda, Velva, Wyndmere.

These soils may be classified in other groups without salinity.

26n. Nonirrigable due to shallow depth of root restrictive substrata (slopes < 6 percent)

Bainville, Cabba, Cabbart, Cedarpan, Dilts, Duncom, Dupree, Farfeld, Fleak, Kloten, Lisam, Midway, Wayden, Yawdim

27n. Nonirrigable because of seasonal or semipermanant ponding. Slopes < 1 percent

Very poorly drained Arveson, Borup, Colvin, Dimmick, Fargo, Fossum, Hegne, Lallie, Ludden, Maryland, McKeen, Neche, Parnell, Rauville, Regan, Roliss, Rosewood, Southam, Venlo.

Peat and Muck soils: Eramosh, Markey, Rifle, Seelyeville.

These soils may be classified in other groups but are poorly drained.

28n. Nonirrigable because of frequent flooding (> 50 percent chance of flooding)

Banks, Breien, Cashel, Colvin, Divide, Fairdale, Glendive, Hanly, Havre, Havrelon, Korchea, Korell, La Prairie, LaDelle, Lallie, LaMoure, Lohler, Ludden, Magnus, Maryland, Minnewaukan, Neche, Ojata, Patent, Playmoor, Rauville, Regan, Rhoades, Scorio, Straw, Svea and Trembles, Velva, Wolfpoint.

These soils may be classified in other groups with a lower chance of flooding.

29n. Nonirrigable due to numerous surface stones or boulders

Amor, Barnes, Beisigl, Boxwell, Buse, Cabba, Cabbart, Forman, Marmarth, Max, Morton, Reeder, Ringling, Sioux, Svea, Valler, Vebar, Wabek, Wamoduska, Williams, Zahl.

These soils may be classified in other groups because they have less surface stones.

Important Topographic and Soil Properties Affecting Irrigability

Soil Depth

Soil depth depends on the potential rooting depth of the plants to be grown and any restrictions within the soil that may hinder root growth. The rooting depth of potatoes may be only 18 to 24 inches, while alfalfa has a rooting depth of more than 4 feet. Discontinuities in the soil from layers of sand, gravel or bedrock may serve to physically limit the depth of root penetration.

Soil Texture

The percentage of sand-, silt- and clay-sized particles determines the texture. Texture influences other properties, such as water-holding capacity, infiltration rate and internal drainage.

Soil Structure

Movement of water into and within soils is partially dependent on soil structure. Soil structure refers to how sand, silt and clay particles are arranged in the soil. Particles aggregate via organic matter and associated biological activity, roots, soil mineral composition, freeze-thaw cycles, wet-dry cycles and time. Outside forces can impact aggregation and soil structure, such as compaction. Soils containing aggregates are unstable under irrigation and may require special management.

Water-holding Capacity

Water-holding capacity is defined as the soil water retained between a suction of 0.1 to 0.5 bars (field capacity) and 15 bars (permanent wilting point). Water held between these two suction values is regarded as plant-available water. A silt loam soil holds about 2.25 to 2.5 inches of water per foot of soil. A sandy loam can hold only about 1 inch of water per foot. Soil with high organic matter can hold more water than a soil with similar texture and lower organic matter.

Slope

Slope is important in determining the runoff potential of water from a field. Water and soil losses from runoff reduce short-term and long-term economic returns. Generally, more runoff will occur on fine-textured soils, compared with coarser-textured soils on similar slopes.

Infiltration Rate (also called intake rate)

The infiltration rate is the relative rate that water penetrates and moves into the soil after a rain or irrigation event. The rate of infiltration is dependent on soil texture and structure but primarily is controlled by the surface conditions such as slope, roughness, residue and soil moisture. At the beginning of a rain or irrigation event, a dry soil surface will absorb more water than a wet surface, thus affecting the amount of potential runoff. A faster infiltration rate allows less runoff than soil with slower rates.

Internal Drainage

Internal drainage describes the degree and persistence of soil wetness and is influenced by slope, soil infiltration rate, soil texture (percent gravel, sand, silt and clay) and depth to the water table or impermeable layers. Excessively drained soils often have crop production problems related to lack of water and nutrients due to rapid movement of water through the soil profile. On the other hand, soils with poor internal drainage that remain wet may increase disease potential to crops, or cause denitrification losses of nitrogen fertilizer or the accumulation of salts. Soils with good internal drainage respond well to irrigation. Soil retains irrigation water for crops to use while allowing sufficient movement of water within the soil to minimize saturation of pore space.

Salinity

High levels of soluble salts at or near the surface usually are the result of a high water table but also can accumulate through the years from dissolved salts in the irrigation water. High salt levels may reduce crop yields and increase the water requirement of plants. Irrigation may decrease the depth to the water table through time in some soils, thus increasing the risk of salinization. As salinity increases, crop productivity will decrease. Salinity is a soil property that changes

relatively quickly with time, compared with other properties such as texture. Soil testing for salts is necessary to not only follow possible increases through time in irrigated fields but also determine if irrigation should be attempted in the first place.

Salts are detected by measuring the flow of electrical current through a sample of soil or water. The more salts in a sample, the less resistance to electrical current and greater the electrical conductivity.

Sodicity (sodium buildup in soil)

Sodium (Na) affects the physical condition of the soil by dispersing soil aggregates. The soil becomes pasty when wet and develops a condition called "puddling," where water remains on the surface for an extended period. The soil becomes hard when dry and its permeability to water and air is reduced.

If irrigation causes sodium salts to accumulate near the soil surface, yields may be reduced. Sodium buildup usually occurs slowly and may not be detected easily from year to year. Excess sodium accumulation in the root zone is a major threat to good productivity on some soils. Include the sodium absorption ratio in your regular soil testing checklist every three to five years to determine long-term trends in sodium accumulation.

Quality of Irrigation Water

The quality of some water sources is not suitable for irrigating crops. Irrigation water must be compatible with the crops and soils to which it will be applied. The Soil and Water Environment Laboratory at NDSU provides soil water compatibility analysis and recommendations for irrigation. Lab personnel need an analysis of the water to be used for irrigation and a legal description of the land to make a recommendation.

Salinity and Sodicity of Irrigation Water

The salt (or mineral) content of irrigation water is important for the long-term irrigability of many soils. Irrigation water with large concentrations of salts, when applied to the soil, increases the salt content in the soil because the water is taken up by the plant or evaporates while the salt remains.

To determine the salt content in water, measure the flow of electrical current through a sample of the water. The more dissolved minerals in the water sample, the more easily it conducts electricity, which produces a high electrical conductivity (EC) number.

Distilled water has very high resistance and thus a very low EC, but when the salt content increases, the resistance decreases. The EC has units of deci-Siemens per meter (dS/m), millimhos per centimeter (mmhos/cm) or micromhos per centimeter (umhos/cm).

Here is how to convert from one to the others:

$$1 \text{ dS/m} = 1 \text{ mmho/cm} = 1,000 \text{ umhos/cm}$$

The sodium level in the soil in relation to the calcium and magnesium, as well as sodium content in the irrigation water, are important for the long-term productivity and health of the soil. The use of high-sodium water for irrigation depends on the level of salinity (EC) and sodicity in the soil and water.

The measure of the sodium impact is the sodium absorption ratio (SAR), whose units are dimensionless. It is the ratio of sodium concentration to the concentration of calcium and magnesium in soil or water. Generally, soil and water with SARs of less than 6 are acceptable.

Countering Sodium Buildup From the Use of High-SAR Irrigation Water

The sodicity buildup hazard for irrigation water is dependent on its SAR and salinity. As the salt content of the water increases, the sodicity hazard also increases. This means that lower SARs may cause significant sodium buildup in the soil. The reason for increased sodicity hazard is simply the greater number of sodium ions to replace calcium and magnesium in the soil.

The laboratory-derived SAR may not be a clear indicator of the actual dispersion of clay particles due to increased sodium levels or decreased soluble calcium and magnesium in a soil. A quick field test of suspected areas may help. Place $\frac{1}{2}$ cup of surface soil in a clear glass quart jar, add 1 pint of distilled water and shake well. Leave for an hour undisturbed. If the water has not cleared in that time, the clay has become dispersed and an amendment may need to be applied to keep the surface soil productive.

Calcium Amendments for Soil and Irrigation Water

Sodium accumulation and clay dispersion may be countered by the addition of soluble calcium amendments that replace more weakly held sodium on clay and organic-matter surfaces and increase flocculation (clay particles aggregate into clotlike masses or precipitate into small lumps). Free sodium then can be leached from the soil surface to below the root zone, where it will not interfere with plant growth.

Gypsum, which is the common name for calcium sulfate (CaSO_4), has been used successfully as a reclamation amendment when the soil was not already saturated with gypsum. In areas with low soil salt content, gypsum is the preferred method of reclaiming high-sodium soils.

Gypsum dissolves in the soil, and calcium ions replace sodium ions on clay and organic-matter surfaces. Water moving through the soil then leaches the sodium out of the root zone.

However, in many North Dakota soils, sodium and calcium levels are high together. The addition of gypsum to soils already high in gypsum will not result in a replacement of sodium because greater amounts of gypsum will not increase the number of free calcium ions in solution. Other amendments may be more useful.

For soils with high levels of calcium carbonate and low levels of gypsum, the application of elemental sulfur sometimes is used to produce gypsum. Sulfur is oxidized in soils by sulfur bacteria. The resulting sulfuric acid reacts with calcium carbonate to produce gypsum.

On a few soil series, subsurface gypsum layers can be incorporated into surface soils with high sodium levels through deep tillage. Mixing gypsum into high-sodium soils may be a practical way to reclaim some soils.

Before tillage, soil sampling surface and deep layers with for sodium and gypsum levels will be necessary. If excess gypsum is not present in the subsurface layers, deep tillage may not be helpful.

More soluble calcium amendments, such as calcium chloride, may be more useful in replacing sodium ions in sulfatic systems. Calcium chloride is more soluble in sulfatic systems than gypsum.

The economics of reclamation and effectiveness of amendments in reclaiming sodic soils or countering sodium accumulation should be evaluated before deciding to use soluble calcium and magnesium amendments.

NDSU Soil and Water Testing Laboratory

701-231-8942

U.S. Mail:

North Dakota State University
Soil and Water Environment Laboratory
NDSU Dept. 7680
P.O. Box 6050
Fargo, ND 58108-6050

FedEx, UPS:

NDSU
103 Waldron Hall
1360 Bolley Drive
Fargo, ND 58102

References

Franzen, D. 2012, NDSU Extension publication SF1087, Managing Saline Soils in North Dakota.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkaline soils. Agricultural Handbook No. 60, U.S. Department of Agriculture, U.S. Government Printing Office, Washington D.C.

Irrigation Water Quality – Soil Compatibility Guidelines, 1987. Saskatchewan Water Corporation, Outlook, Canada.

For more information on this and other topics, see www.ag.ndsu.edu

NDSU encourages you to use and share this content, but please do so under the conditions of our Creative Commons license. You may copy, distribute, transmit and adapt this work as long as you give full attribution, don't use the work for commercial purposes and share your resulting work similarly. For more information, visit www.ag.ndsu.edu/agcomm/creative-commons.

County commissions, North Dakota State University and U.S. Department of Agriculture cooperating. NDSU does not discriminate in its programs and activities on the basis of age, color, gender expression/identity, genetic information, marital status, national origin, participation in lawful off-campus activity, physical or mental disability, pregnancy, public assistance status, race, religion, sex, sexual orientation, spousal relationship to current employee, or veteran status, as applicable. Direct inquiries to Vice Provost for Title IX/ADA Coordinator, Old Main 201, NDSU Main Campus, 701-231-7708, ndsu.eoaa.ndsu.edu. This publication will be made available in alternative formats for people with disabilities upon request, 701-231-7881.