SF-1617

# Evaluation of Soils for Suitability for Tile Drainage Performance

**Larry J. Cihacek**
Associate Professor, Soil Science

**Dave Franzen**
Extension Soil Specialist

**Xinhua Jia**
Assistant Professor,
Ag and Biosystems Engineering

**Roxanne Johnson**
Extension Water Quality Associate

**Tom Scherer**
Extension Agricultural Engineer

Photo by Hans Kandel

The presence of salts and high water tables in North Dakota soils due to an extended climactic wet cycle recently has stimulated interest in the installation of tile drainage systems. The tile controls the water table and encourages the leaching and removal of salts from the soil above the tile lines. This improves soil productivity, culminating in improved crop yields.

Other advantages of drainage include lower crop production risks, increasing management options, reduced seasonal wetness and improved timeliness of field operations. On the other hand, the cost of installation and maintenance, wetland issues, outflow management, the need for water in dry seasons and strained relationships with neighbors may be disadvantages associated with drainage.

Although soil drainage is usually successful, instances may occur in which the tile functions properly when first installed, but within a few growing seasons, the efficacy or performance may appear to decrease and areas in fields may not appear to drain as expected. This may be from changes in soil chemistry due to the removal of salts and resulting soil swelling and dispersion rather than improper installation of the tile drains.

Due to the high cost of tile installation, poor subsurface drainage performance can have a significant economic impact on a farming operation.

The loss of subsurface drainage effectiveness may be due, in part, to tile being placed in or below a zone of sodic or saline-sodic subsoils. The sodic or saline-sodic characteristics often are not noted readily at the soil surface. Characteristics of saline, sodic and saline-sodic soils are shown in **Table 1**.

**Table 1. Characteristics of saline, sodic and saline-sodic soils (from USDA Handbook no. 60).**

| Soil type | pH | Electrical Conductivity (EC)† | Exchangeable Sodium Percentage (ESP) | Sodium Adsorption Ratio (SAR) |
|---|---|---|---|---|
| | | mmhos/cm | % | |
| Saline | <8.5 | >4 | <15 | <13 |
| Sodic | >8.5 | <4 | >15 | >13 |
| Saline-sodic | <8.5 | >4 | >15 | >13 |

† mmhos/cm – millimhos per centimeter; 1mmhos/cm = 1 deci-Siemen per meter (dS/m)

NDSU EXTENSION SERVICE

August 2012

Tile installed in soils or subsoils that are sodic or saline-sodic often will function normally for a period of time after installation because these soils often contain divalent ($2^+$ charged) calcium ($Ca2^+$) and magnesium ($Mg2^+$) salts that maintain the soil materials in an adequately flocculated state (maintain soil structure) under natural moisture conditions.

But, when the soils are drained and excess water is removed, the divalent salts also are removed, with the water leaving the soil material above or around the tile line saturated with monovalent (1+ charged) sodium ($Na^+$). When this occurs, the soils lose their natural structure and become dispersed. This could cause sealing of the soil above and/or around the tile lines, resulting in ineffective drainage.

Reduced drainage performance is more likely to occur in finely textured (silty or clayey) soils and to a much lesser extent in coarser-textured (sandy) soils. Once drainage performance is reduced, little can be done economically to restore the effectiveness of the drainage system.

However, producers can take precautions prior to tile installation on soils where drainage performance is likely to occur. These precautions include: (1) knowing the soil series (soil types) in the field under consideration for drainage, (2) evaluating the soil chemical characteristics for each of the soils mapped in the field, (3) evaluating the soil properties for suitability for having tile installed and (4) verifying soil types and chemical characteristics (items 1 and 2 above) by deep soil sampling and testing. Using these precautions can help avoid installation of drain lines where poor subsurface drainage performance is likely.

## Knowledge of Soil Series

The occurrence of a specific soil series, types or map units on a parcel of land under consideration for drainage can be obtained from a county soil survey map or online from the U.S. Department of Agriculture-Natural Resources Conservation Service's Web Soil Survey *(http://websoilsurvey.nrcs.usda.gov)*. The soil series listed in **Tables 2 and 3** are soils that are most likely to have dispersion problems when drained.

Also, soils with the greatest probability of drainage problems are those soils with pH values greater than 8.5 in the surface or subsurface zones. A pH greater than 8.5 often indicates high sodium ($Na^+$) saturation, which could lead to tile sealing when salts are leached out of the soil above the tile line. If any of the soils listed in **Tables 2 and 3** occur in the parcel of land to be drained, the soil chemical characteristics need to be evaluated.

Most drainage system designers and installers evaluate soil texture in a field as a part of the system design process. However, soil chemical characteristics are not normally part of this process. Preliminary evaluation of soil chemical characteristics can be accomplished using the soil chemical data embedded in the Web Soil Survey. In addition, a soil drainage suitability rating for North Dakota soils is available in the Web Soil Survey.

## Using Web Soil Survey

The Web Soil Survey is an Internet-based digital product provided by the USDA Natural Resources Conservation Service at *http://websoilsurvey.nrcs.usda.gov*. Most soils in North Dakota can be evaluated from maps and information contained in the Web Soil Survey. **Figures 1-4** are an example of how to access this information from a personal computer or other device with Internet access.

**Table 2. Soil series with sodium-affected subsoils.**

| | | | |
|---|---|---|---|
| Aberdeen | Ferney | Mekinock | Ryan |
| Camtown | Harriet | Miranda | Stirum |
| Cathay | Heil | Nahon | Totten |
| Cavour | Larson | Niobell | Turton |
| Cresbard | Lemert | Noonan | Uranda |
| Daglum | Letcher | Ojata | |
| Easby | Ludden | Playmoor | |
| Exline | Manfred | Ranslo | |

**Table 3. Soil series with potentially sodium-affected subsoils.**

| | | | |
|---|---|---|---|
| Antler | Fargo | Karlsruhe | Reis |
| Arveson | Fossum | Kratka | Rockwell |
| Augsburg | Fram | Koto | Roliss |
| Bearden | Gilby | Lamoure | Rosewood |
| Bohnsack | Glyndon | Lowe | Thiefriver |
| Borup | Grano | McKranz | Ulen |
| Clearwater | Grimsted | Mantador | Vallers |
| Colvin | Gunclub | Marysland | Viking |
| Cubden | Hamerly | Moritz | Wheatville |
| Divide | Hedman | Nielsville | Winger |
| Eaglesnest | Hegne | Northcote | Wyndmere |
| Elmville | Holmquist | Putney | Wyrene |
| Enloe | Huffton | Regan | |

**Figure 1.**

To access the Web Soil Survey (**http://websoilsurvey.nrcs.usda.gov**), click on the large green "START WSS" button near the top of the page.


## Evaluation of Soil Chemical Characteristics

Soil chemical properties can be evaluated utilizing the "Soil Data Explorer" tab in the Web Soil Survey. Once a parcel of land is selected, choosing the "Soil Chemical Properties" menu in "Soil Data Explorer" provides options for soil evaluation, which will bring up a menu of several chemical characteristics that can be evaluated.

The characteristic of interest for this soil evaluation is the sodium adsorption ratio (SAR). Clicking on "Sodium Adsorption Ratio" will bring up an interactive area where depths to be evaluated can be specified in inches or centimeters (cm). A general evaluation of SAR to a depth of 5 feet (150 cm) can give a realistic evaluation of soil chemical properties.

However, for greater accuracy, the evaluation should be carried out for successive 1-foot increments to a minimum depth of 5 feet, or at least 2 feet below the deepest depth of the drain line. For each increment, a colored field map will appear over the photo base map showing the level of hazard related to each soil type.

A table with an interpretation and average electrical conductivity (EC) or SAR values accompanies the map and interpretative information. In this evaluation, red, green and yellow generally indicate lower hazards, while blue indicates higher hazards. Dark blue indicates the highest hazard. Maps for each depth increment can be printed for reference.

The information contained in these evaluations is generalized for each soil series or map unit based on the total composition of the map unit. The data for each map unit is populated with chemical and physical property information that is aggregated from various soil laboratories and the National Soil Survey Laboratory. This information may change from time to time as the database is updated.

Each mapping unit provides four options for evaluating the soil layers. Because each soil mapping unit includes small areas of varying size of soils that may not be suitable for drainage, using the worst-case scenario is important to identify soils that can contribute to problems with subsurface drainage.

The four choices for soil map unit evaluation are: (1) evaluation of all soil components, (2) evaluation of dominant soil components, (3) evaluation of dominant soil condition and (4) evaluation of a weighted average of all soil components.

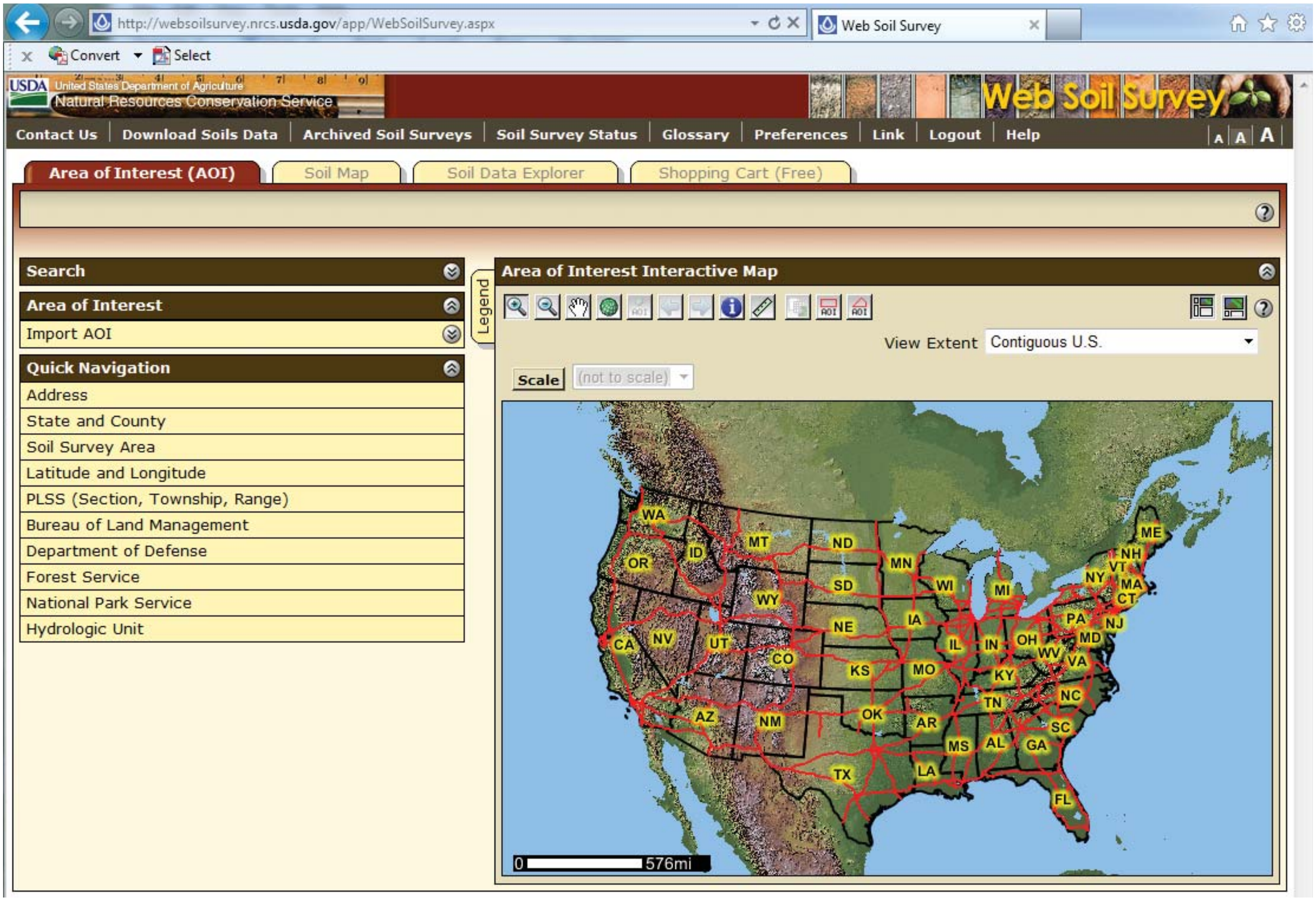


**Figure 2.**

The Web Soil Survey navigation page. Note the 10 different "Quick Navigation" methods to get the parcel of land of interest. Another method is to use the mouse to repeatedly draw a rectangle around the area of interest until the field of interest is highlighted.

**Figure 5 (page 7)** illustrates a comparison of these four choices for a general evaluation of the 5-foot (150-cm) depth zone of an actual parcel of land with sodium-affected subsoils.

**Table 4** shows a comparison of the associated soil SAR ratings with these evaluations. As shown in **Table 4**, evaluating the soil map units on the basis of all components will give the ratings for the most limiting soils within the map unit and provide for identification of the highest risk (or worst-case) scenarios.

Data embedded in the Web Soil Survey is based on typical characterization sites across the normal geographic range of the occurrence of a specific soil type. Due to natural variability, the soils in the parcel of interest may vary from the "typical" map unit of the soil designated when the soil survey was conducted.

In addition, detailed variability and small inclusions within a soil map unit are difficult to show at the scale of typical soil surveys. Thus, a more detailed survey of the field to be drained will be useful for determining whether problems with subsurface drainage may exist.

All soils with an SAR value of greater than 6 should be sampled for detailed chemical characterization. A qualified professional soil scientist or classifier should be consulted when making these evaluations.

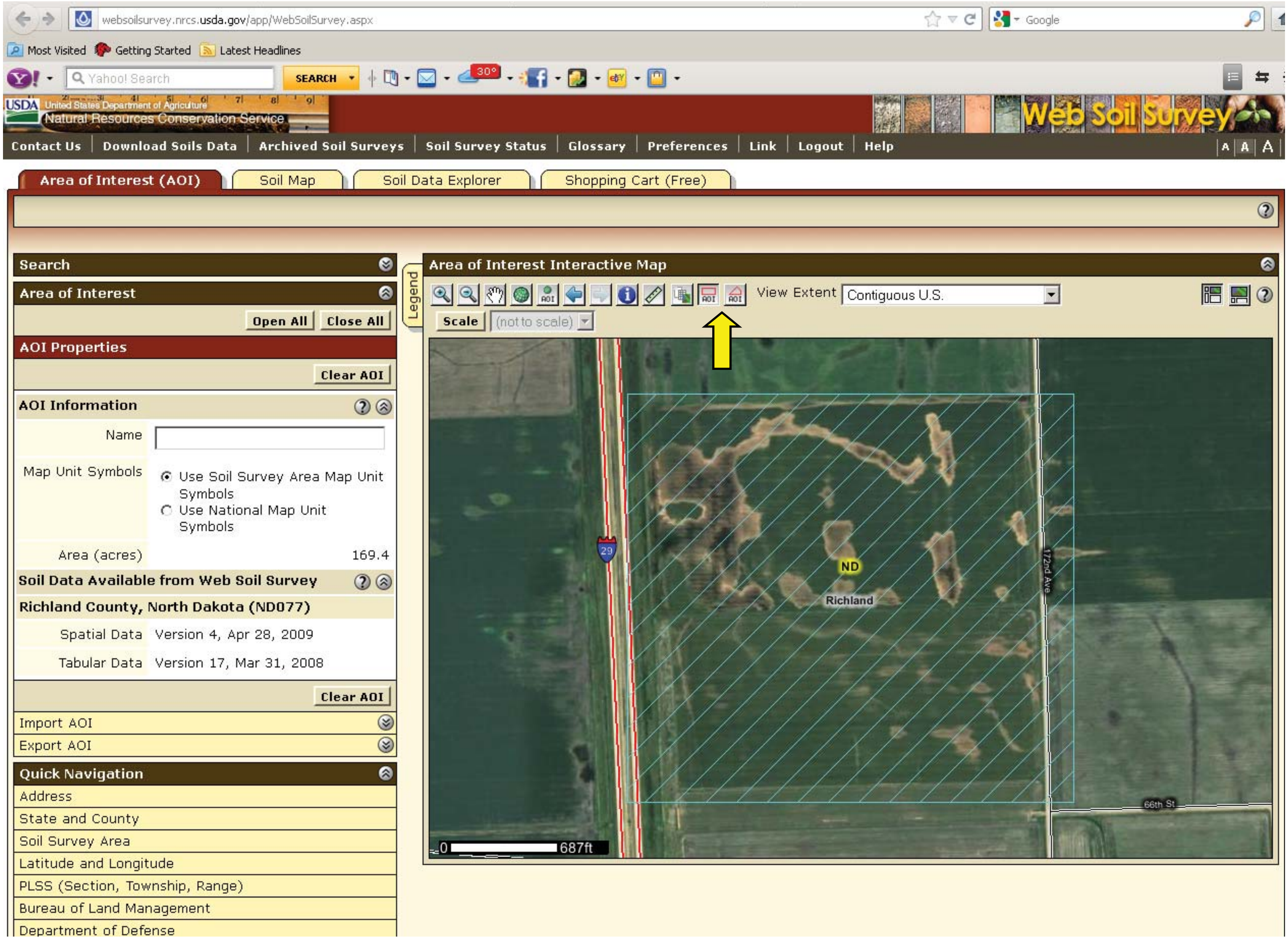


**Figure 3.**

The land parcel can be delineated by clicking on one of the two AOI (Area of Interest) buttons (yellow arrow) on the interactive map. Selecting the left button allows you to put a rectangle around the AOI and the right button can be used for irregular-shaped parcels. Selection of the AOI allows the Web Soil Survey to access soil survey information specific to that parcel of land.

## Table 4. A comparison of evaluation methods for soil SAR ratings based on soil chemical data in the Web Soil Survey.

| | | Web Soil Survey SAR Rating | | | |
|---|---|---|---|---|---|
| Map Unit Symbol | Map Unit Names | All Components† | Dominant Component‡ | Dominant Condition§ | Weighted Average of All Components¶ |
| I237A | Fargo-Enloe silty clay loams, 0 to 1 percent slopes | 8.1 | 0.9 | 0.9 | 0.9 |
| I242A | Ryan-Fargo silty clays, 0 to 1 percent slopes | 14.1 | 14.1 | 14.1 | 9.0 |
| I251A | Aberdeen-Galchutt-Fargo complex, 0 to 2 percent slopes | 14.1 | 8.1 | 8.1 | 4.5 |
| I361F | Orthents-Aquents-Highway complex, 0 to 35 Percent slopes | 0.0 | 0.0 | 0.0 | 0.0 |

† All soils normally occurring in a map unit.
‡ The major soil(s) making up a map unit.
§ The usual state of the soil chemistry of the major soil(s) in a map unit.
¶ The average rating based on the normal relative proportions of all soils within a map unit.

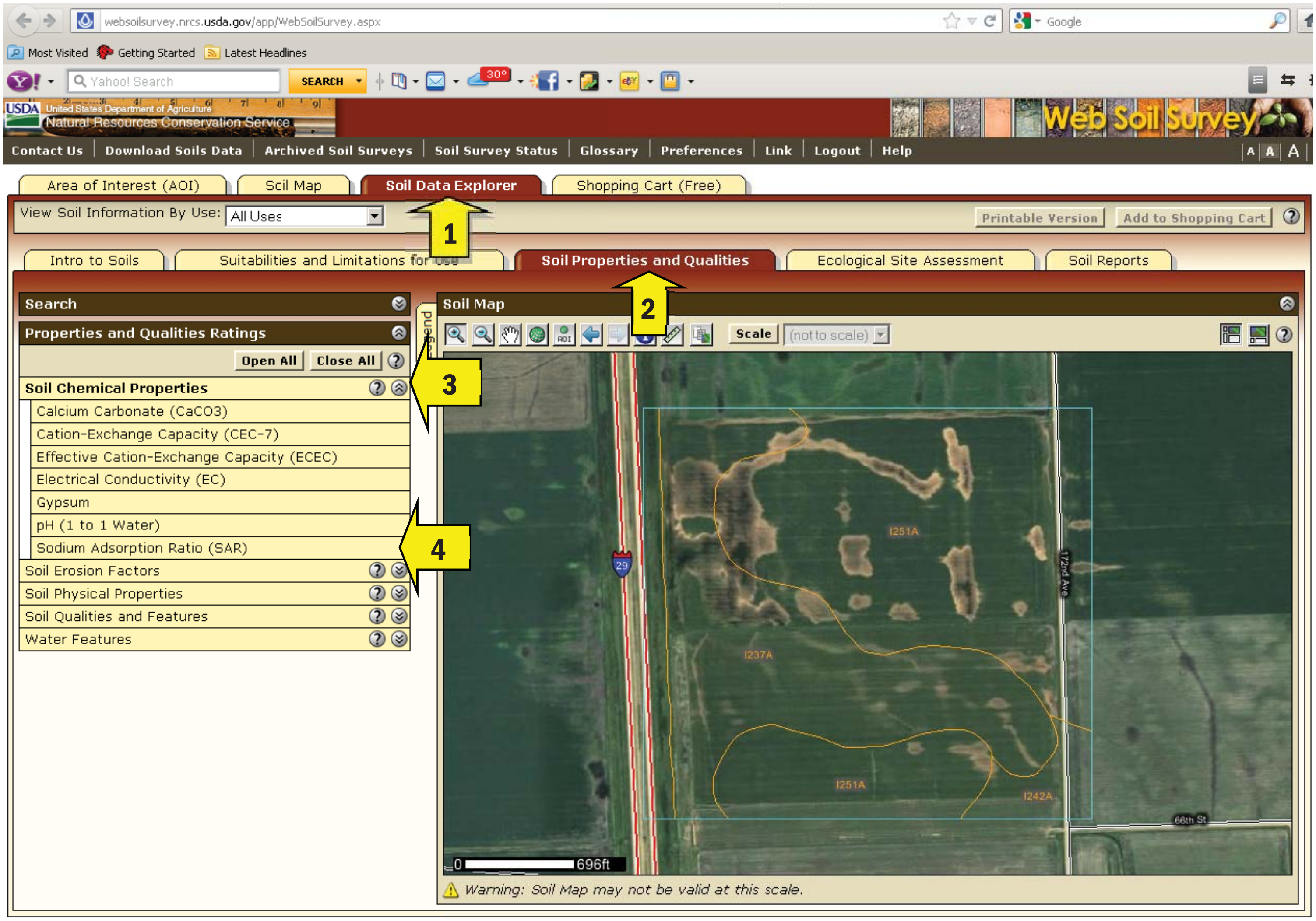


**Figure 4.**

Accessing the evaluation data. Once the soil map is retrieved from the database, click on the Soil Data Explorer tab near the top of the page (yellow arrow No. 1). Then click on the Soil Properties and Qualities tab below the Soil Data Explorer tab (yellow arrow No. 2). From the menu to the left of the map, select Soil Chemical Properties (yellow arrow No. 3) and Sodium Adsorption Ratio (yellow arrow No. 4). This will lead to a refreshed map with sodium adsorption ratio (SAR) ratings for each soil series mapped on the parcel.

## Subsurface Soil Drainage Suitability Rating

A soil drainage suitability interpretation has been incorporated into the Web Soil Survey. This rating evaluates all soils in a soil mapping unit on three criteria: installation, performance and outflow quality. **Table 5** illustrates the information covered by these criteria. What the soil drainage suitability rating ***will not*** *provide is a comprehensive site evaluation or determination of wetlands and flooding issues. Nor will it address social or environmental issues or soil productivity or design information.*

The suitability rating provides a numerical rating on a scale of 0 to 1 for each of the criteria listed above and provide a weighted rating based on the components of a soil map unit. A rating near 0 indicates no limitations for subsurface drainage, while a rating near to 1 is very limited. Soils with a rating greater than 0.15 for SAR performance should be subject to verification by soil sampling and testing.

This tool may give limitation ratings for multiple factors for each soil in a mapping unit. While most limiting factors are based on soil properties that do not change with drainage or management, soil SAR and EC factors are subject to change as soils are drained. However, other limitations identified by using this tool may respond to modifications in design and installation.

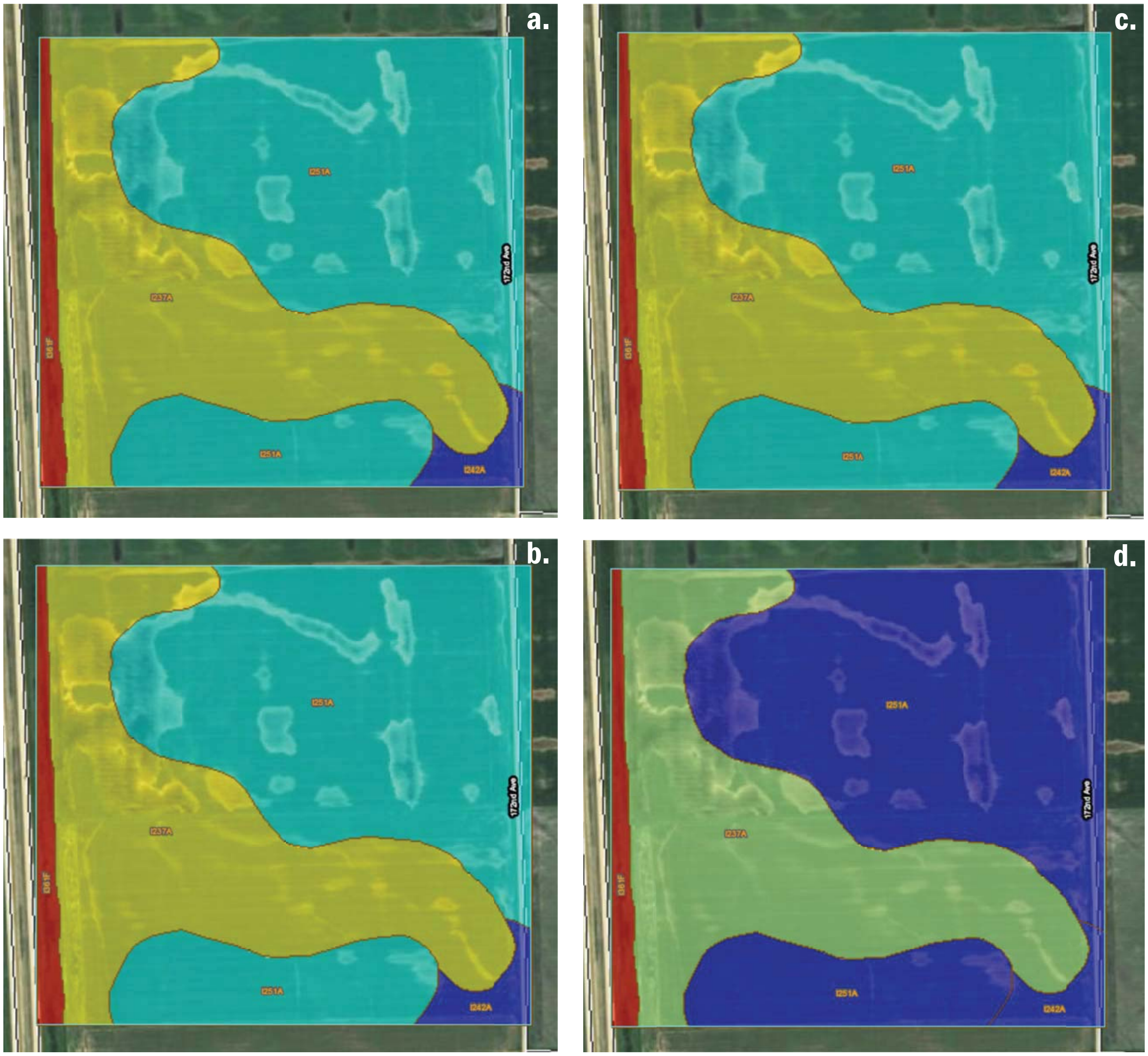


**Figure 5.**

General evaluation of soil SAR in the 5-foot depth zone: (a) evaluation of dominant component, (b) evaluation of dominant condition, (c) evaluation of weighted average of all components and (d) evaluation of all soil components in each map unit.

Note that for this field, Figures 5 a, b and c are identical, but that may not be true for all land parcels.

Evaluation of all components within each map unit provides the most stringent information regarding soil SAR conditions. Dark blue indicates a high degree of SAR hazard. (See Table 4 for SAR ratings.)

The soil drainage suitability rating is not designed to tell the landowner, land manager or tile installer that a field should or should not be drained. The rating mainly is designed to present information that can be used in making a decision whether drainage is a suitable option as a land treatment.

**Table 5. Criteria evaluated in subsurface drainage suitability ratings for subsurface water management in the Web Soil Survey.**

| Installation | Performance | Outflow Quality | Agronomic Concerns |
|---|---|---|---|
| Depth to bedrock or cemented pan | Presence of dense layers in soil | Soil salinity | Plant establishment |
| Stability of excavations | Soil permeability | Pesticide and nutrient potential | Plant growth |
| Amount of soil clay | Flooding | Soil cracking potential | Soil erosion |
| Presence of stones | Surface pH | | Physical limitations |
| Slope gradient | Soil sodium content<br>Soil gypsum content<br>Soil subsidence<br>Sedimentation | | Pesticide and nutrient management |

## Verification of Soil Properties by Soil Sampling and Soil Testing

**Table 6** provides SAR suitability ratings for soils based on the soil chemistry evaluation described above. Once soil areas that have a moderate or severe SAR hazard are identified, these areas should be sampled to a minimum depth of 6 feet in 1-foot increments. The soils should be sampled at a minimum of three locations within each soil map unit where an SAR hazard has been identified. Samples from these locations can be composited into one sample for each depth increment.

A minimum of one composite soil sample should be submitted for each five acres of a soil map unit in question. Each soil depth increment should be analyzed for electrical conductivity (EC) and SAR using standard soil saturation paste extracts for the evaluation. This allows for direct comparisons with the information contained in the Web Soil Survey database to verify the suitability for subsurface drainage.

If the soil analyses indicate that the SAR values are lower than the values shown in **Table 6**, then the soil is likely suitable for subsurface drainage. If soils are rated unsuitable for tile drainage, then alternatives such as leaving the soil area undrained or placing the area into permanent cover should be considered.

**Table 6. Interpretation of soil SAR values and subsurface drainage suitability ratings for suitability of soils for drainage.**

| SAR Values† | Drainage Suitability Rating‡ | Interpretation |
|---|---|---|
| < 6 | <0.15 | No limitation |
| 6-10 | 0.15-0.80 | Somewhat limited |
| >10 | >0.80 | Very limited |

† Based on data from Springer (1997).
‡ Based on Web Soil Survey.

Utilizing registered professional soil scientists or NRCS soil scientists can assist in making decisions about alternatives to subsurface drainage.

**Table 6** should be used only as a guide for drainage suitability. Dispersion of the soils under subsurface drainage conditions depends on several factors, including the composition of soil minerals, soil texture, composition of shallow ground water and composition of soil salts. Also recognize that soils subject to dispersion may be localized or only a small proportion of the soils in the field or land parcel to be drained.

Evaluating soils for subsurface drainage suitability prior to installation can reduce the incidence of poor tile performance and unrecoverable installation costs. If soils susceptible to poor drainage are identified prior to tile installation, then alternatives to drainage can be considered and implemented. Once soils disperse due to subsurface drainage, attempting to remediate the soils to near their original internal drainage condition is extremely difficult and costly.

## For more information, check out the following publications:


Curtin, D., H. Steppuhn and F. Selles. 1994. Clay dispersion in relation to sodicity, electrolyte concentration, and mechanical effects. Soil Sci. Soc. Am. J. 58:955-962.

Oster, J.D., and F.W. Schroer. 1979. Infiltration as influenced by irrigation water quality. Soil Sci. Soc. Am. J. 43:444-447.

Pearson, K.E. 2003. The basics of salinity and sodicity effects on soil physical properties.

Montana State Univ. Ext Ser. Fact Sheet. At *http://waterquality.montana.edu/docs/methane/basics_highlight.shtml.* Accessed March 15, 2011.

Springer, A.G. 1997. Water-dispersible clay and saturated hydraulic conductivity in relation to sodicity, salinity and soil texture. M. S. thesis. North Dakota State Univ., Fargo, N.D.

Springer, G., B.L Wienhold, J.L. Richardson and L.A. Disrud. 1999. Salinity and sodicity induced changes in dispersible clay and saturated hydraulic conductivity in sulfatic soils. Commun. Soil Science Plant Anal. 30(15-16):2211-2220.

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


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



1M-8-12