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TECHNICAL NOTE

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TDS LIMITS FOR LIVESTOCK DRINKING WATER

The purpose of this Technical Note is to provide guidance and suggestions concerning livestock drinking water quality needs. Emphasis is placed on issues involving various salts measured as Total Dissolved Solids (TDS). Pond water in South Dakota is often high in TDS during drought due to excess evaporation and little runoff inflow. South Dakota well water may also be high in TDS. TDS is related to other measurements, such as, specific conductance, sodium, selenium, and sulfate. Lowering TDS is likely to lower the other related measurements. Since TDS and conductance are easy to measure, TDS serves as the key measurement for salt level improvement efforts.

Much of the information presented is derived from documents available on the Internet in March of 2003. Information sources were various Canadian and USA federal and state government agencies. University and Cooperative Extension Service publications were particularly helpful in preparation of this document.

This document presents general livestock drinking water limits for use by engineers, range specialists, and others in dealing with economically limited water source options.

Part A
Livestock Drinking Water Quality Needs
(In addition to being clean and pathogen free)

Measurements other than TDS are included in this part for completeness and to help identify related water quality problems (such as excess selenium). In reviewing the enclosed tables, the units mg/L (milligrams per liter) and ppm (parts per million) are interchangeable for practical purposes.

Table 1 presents recommended maximum levels of various measurements. Reference to human needs is for comparison only. Water for human consumption must meet South Dakota Department of Health requirements. Water test results reported as sulfate-sulfur should be multiplied by three to convert to sulfate. Test results reported as nitrate-nitrogen should be multiplied by 4.4 to convert to nitrate. Multiply P_2O_5 results by 0.437 to obtain P.

Total Dissolved Solids (TDS) or salinity is a measure of the over all mineral content of water. TDS includes common salts such as sodium chloride, calcium, magnesium, sulfates, and bicarbonates. Table 2 presents detailed TDS information for cattle. Note that “hardness” is not an estimate of TDS and using a softener will not lower TDS. Softeners trade sodium for calcium and magnesium rather than lower TDS.

Specific Conductance (SC) is a measure of the ability of water to conduct an electrical current for a unit of length and cross sectional area. Measurements are adjusted to a temperature of 25°C. Specific Conductance is the reciprocal of resistance in ohms. Specific Conductance is an easily measured estimate of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron. Distilled water measures at least 1 and sea water measures approximately 50,000 uS/cm. In South Dakota, county Extension agents can often provide SC measurements for producers.

Divide SC by 1.55 to estimate TDS. Note, however, that the constant (1.55) varies by type of water, so this calculation is only a rough estimate. Testing may provide a more precise constant for each water source.

Sulfate (sulphate) measures the presence of sulfate compounds. Preliminary observations in South Dakota suggest that at higher levels of TDS, the majority of the salt is sodium sulfate. At moderate levels of TDS, the proportion from sulfate is variable. At low levels of TDS, sulfate levels are likely to be low enough so no problems occur. Sulfates are the most common cause of South Dakota livestock drinking water problems. Sulfates may be involved in taste and odor problems as well as health problems. Lowering TDS (or conductance) in South Dakota waters will normally lower sulfates. Table 3 presents guidance on Sulfate Levels for cattle. Test results reported as sulfate-sulfur should be multiplied by 3 to convert to sulfate.

Table 4 further defines reduced performance ranges and upper limits for beef cattle.

Table 1. Drinking Water Quality -- Recommended Maximum Levels

	HUMAN	LIVESTOCK	POULTRY	UNITS
ALKALINITY	30-500	<2,000	<1,000	mg/L
ALUMINUM	<0.2	<5.0	<5.0	mg/L
AMMONIA (as N)	<0.5			mg/L
ANTIMONY	<0.0002			mg/L
ARSENIC	<0.025	<0.05-0.2	<0.2	mg/L
BARIUM	<1.0	<1.0		mg/L
BERYLLIUM		<1.0		mg/L
BICARBONATE (HCO3)		<1,000		mg/L
BORON	<5.0	<5.0-30		mg/L
CADMIUM	<0.001	<0.05		mg/L
CALCIUM	200	<1,000	35-600	mg/L
CESIUM 137	<50			Bq/L
CHLORIDE	<250	<1,000	<14-200	mg/L
CHROMIUM	<0.05	<0.1		mg/L
COBALT		<1.0		mg/L
COPPER	<1.0	<0.5	<0.6	mg/L
CYANIDE	<0.20	<0.20		mg/L
FLUORIDE	<1.5	<1.2-2.0	<2.0	mg/L
HARDNESS (CaCO3)	180	<2,000	<2,000	mg/L
IODINE		1.0		mg/L
IODINE 131		<10		Bq/L
IRON	<0.3	<0.4	<0.4	mg/L
LEAD	<0.05	<0.05-0.1	<0.1	mg/L
MAGNESIUM	150	<90-250	<35-250	mg/L
MANGANESE	<0.05	<0.05	<0.05	mg/L
MERCURY	<0.001	<0.003-0.01		mg/L
MOLYBDENUM	<0.05-2.50	<0.06	<0.25	mg/L
NICKEL		<1.0		mg/L
NITROGEN (from NO2 +NO3)	<10	<23	<11	mg/L
NITRATE (NO3 as N)	<10	<100	<50	mg/L
pH	6.5-8.3	5.5-8.3	6.4-8.0	units
PHOSPHATE (total P)	<0.1	<0.7		mg/L
POTASSIUM	<10	<20	<300	mg/L
RADIUM		<1.0		mg/L
RESIDUE -- total	<1,000	<7,000	<1,000	mg/L
-- total fixed	<1,000	<7,000	<1,000	mg/L
-- filterable	<1,000	<7,000	<1,000	mg/L
SELENIUM	<0.01	<0.01-0.05		mg/L
SILVER	<0.05			mg/L
SODIUM	<10	<150-800	<50	mg/L
SPECIFIC CONDUCTANCE		<3,000	<1,000	uS/cm
STRONTIUM 90		<10		Bq/L
SULPHATE (sulfate)	<250	<500	30-50	mg/L
SULPHIDE (as H2S)	<0.05			mg/L
URANIUM	<0.02	<0.2		mg/L
VANADIUM		<0.1		mg/L
ZINC	<5.0	<5.0-25	<2.5	mg/L

(Source: Minderal Levels in Animal Health, Diagnostic Data, R. Puls. 1994, Sherpa International)

Table 2 - Interpretation of Water Quality Based on TDS for Cattle in South Dakota

TDS (ppm)	Interpretation	Suggested Action
Less than 2,000	Safe. Levels greater then 1000 may reduce availability of trace minerals	None required
2,000-3,000	Generally safe. May reduce performance, should not affect health	Monitor water, especially as weather gets hot
3,000-5,000	Marginal. May reduce performance and affect health	Test water for sulfates. Monitor water.
5,000-8,000	Poor water. Performance and health depression expected in times of high temperatures	Test for sulfates. Use for low producing stock
8,000-10,000	Dangerous. Performance and health depression expected.	Do not use for pregnant or lactating cattle. Sulfates likely to be high.
Greater than 10,000	Dangerous. Not suitable for livestock.	Do not use.

Note – TDS in South Dakota pond water has been measured at over 18,000 ppm.

Table 3 - Interpretation of Water Sulfate Levels for Cattle in South Dakota

Sulfate (ppm)	Interpretation
<500	Safe
500-1,000	Generally safe. A mild laxative effect may be seen. Trace mineral availability may begin to be reduced. This level has decreased performance in feedlot cattle.
1,000-2,500	Marginal. Sporadic cases of "polio" (PEM or polioencephalomalacia) may be seen in confined cattle. Performance may be affected.
2,500-4,000	Poor water. Sporadic cases of "polio" may occur, especially in confined cattle. Performance of grazing cattle may be affected.
>4,000	Dangerous. Health problems expected.

Note: See web site http://wri.sdstate.edu/cattle.htm.

Table 4 – Other Water Constituents Effects on Beef Cattle Performance

Constituent	Reduced Performance	Unsuitable for Beef Cattle
Nitrate (ppm)	450 – 1,300	> 1,300
Fecal Coliform (No./100ml)	1,000 – 2,500	> 5,000
pH	> 8.5	> 10 (basic)

In ruminants, high sulfates result in “polio” (PEM or polioencephalomalacia) with physical signs including lethargy, anorexia, blindness, muscle tremor, exaggerated response to sound or touch, in coordination, staggering, weakness, and eventually convulsions and inability to get up. If severe, the animal will die from brain cell death. Water that can cause “polio” (Table 3) is not unusual in South Dakota.

In addition to “polio” concerns, livestock consume less water and perform poorly when water quality is poor. Poor quality drinking water results in decreased feed efficiency, decreased weight gain (or increased weight loss), decreased milk production, and decreased fertility.

High TDS and sulfate levels are common in South Dakota surface and well water. Available data suggest that livestock drinking water quality may be inadequate (TDS >1,000 ppm) for optimal livestock production in many areas of both eastern and western South Dakota. South Dakota State University (SDSU) research has shown that for growing steers drinking South Dakota water containing TDS between 1,000 and 5,000 ppm, water intake decreased linearly with increasing TDS and sulfates, but average daily gain, dry matter intake, and pounds of gain per pound of feed decreased quadratically (at a squared rate). The total gain in feed efficiency from improving drinking water from TDS 5,000 to 1,000 ppm may be more than 25 percent with most of the improvement occurring as the TDS 1,000 ppm level is approached. Improvement of water may be paid for by increased feed efficiency between TDS 1,000 and 5,000 ppm. At higher TDS levels, improvements in feed efficiency may not be realized until water with TDS below 5,000 ppm is offered. At these higher levels, reduced morbidity and improved animal health may pay for water improvements.

Please see Figures 1 and 2 for additional information in evaluating the water quality of deep well water resources. For selected deep wells in South Dakota, Figure 1 summarizes specific conductance and total dissolved solids data while Figure 2 summarizes sodium and sulfate data. The South Dakota Department of Environment and Natural Resources, U.S. Geological Survey, and the Natural Resources Conservation Service were the sources of this data.

Part B
Suggestions for Dealing with Poor Quality Livestock Drinking Water (TDS >1000)

The following are suggestions for situations where livestock drinking water contains levels of TDS above 1,000 ppm. Methods that reduce TDS are likely to also reduce sulfates and other objectionable materials. All reasonably and economically available sources should be tested as a first step in solving the problem or maximizing livestock production.

Find another water source. In most (but not all) South Dakota locations, alternate water sources are available that will meet livestock requirements at an economically acceptable price. Research has shown increased livestock production may pay for the change in water source. Where available, water from a rural water system can often be paid for by increased weight gain efficiency.

Mix water from different sources. This suggestion may apply where the main (or cheapest) source has high TDS, but much better water is available in smaller quantities or at a higher price.

Note that nearly TDS free water is available on every acre of South Dakota by rainfall. Annual rainfall of 12 inches on one paved acre area will produce 300,000 gallons of TDS free water. Of course the high quality water would need to be captured and stored. TDS free water would be the ideal additive for high TDS water.

Where rural water is available, it may be useful for livestock water even at a high price, if it has low TDS and can produce a more economical and productive water mix when combined with the high TDS source to increase livestock production efficiency.

To design the mix, measure, mix and test different mix proportions to determine the most economical mixture that will improve livestock performance.

Use higher TDS sources in cool weather, and lower TDS water in hot weather. Save limited (or high priced) low TDS water for hot weather when consumption is high. Use ponds or dugouts early in the spring and/or summer before evaporation increases TDS.

Match the water to the animal's need. Turkeys must have water with TDS clearly below 3,000. Other poultry and young livestock need water with TDS below 3,000. Mature livestock should be able to use water with TDS up to 5,000 ppm. Older livestock may subsist on water with TDS as high as 10,000 ppm.

If poor quality water must be used, keep it clean, keep it cool and aerate it. Livestock resist drinking poor quality water such as water containing fecal matter. The Journal of Range Management (September 2002) reported calves gained 9 percent faster when the cow was drinking clean pond water (delivered to a tank, etc.,) compared to drinking directly from the pond. Similarly, yearling heifers gained at least 20 percent more on clean water.

Livestock will drink more if the water is cool and also if the water is being aerated at the time of consumption. Aeration can reduce water concentrations of iron, manganese, ammonia, hydrogen sulfide (rotten egg odor) and organic compounds. Aeration may be accomplished by bubbling air into the bottom of the drinking location, or spraying water into the air at the drinking site. In some situations, aeration at the drinking site has been shown to increase livestock weight gain.

Adjust feed content. Animal health is affected by total sulfate intake from any source. Be sure producers using high TDS water are aware of the need to lower sulfur/sulfate levels in livestock feed.

For cattle, increased use of grasses in the diet may be an option. Grasses are generally low in sulfates compared to corn by-products or rape. For cattle, provide a trace-mineral fortified supplement.

Lower animal stress. Animals can tolerate poor quality water better when not also stressed by lactation, large body size, drafts, humidity, crowding, disease, animal social competition, high temperatures, very nutrient dense feed, and other factors.

Lower TDS by managed freeze-thaw. While it is unlikely to be economical (for livestock production) to remove salts by distillation, or reverse osmosis (RO), it may be economical to obtain low TDS water by winter freezing. Increased livestock production efficiency may pay for the effort.

Research by Stinson, University of Wyoming, 1968, has shown freezing can be used to separate water from salts, acids, bases, sugars, and organic materials. This research consisted of using lawn sprinklers in winter to spray water on ice piles that reached 22 feet height. Runoff carried much of the TDS away. TDS in the ice was reduced from 2,000 ppm to 60 to 400 ppm. Other research has also demonstrated heavy metal removal by freezing.

A simple design (example) for livestock producers to treat high TDS water might consist of a pond with a carefully graded flat bottom, perhaps three-foot depth, and drawdown facilities for draining the high TDS water trapped under the low TDS ice in late winter.

Managed freeze-thaw can also be used to improve livestock drinking water quality in other types of ponds. The ideal procedure might be to drain water from under the ice in late winter, refill the pond with "first off" snowmelt (before the ground thaws), and then divert later (higher TDS) excess runoff around the pond rather than letting it into the pond. Later small flows will likely have higher TDS.

If the managed freeze-thaw process produces very high TDS wastewater, it may necessary to route or pump it to an evaporation pond for storage. In most situations, the wastewater would not be worse than other naturally occurring water.

FIGURE 1

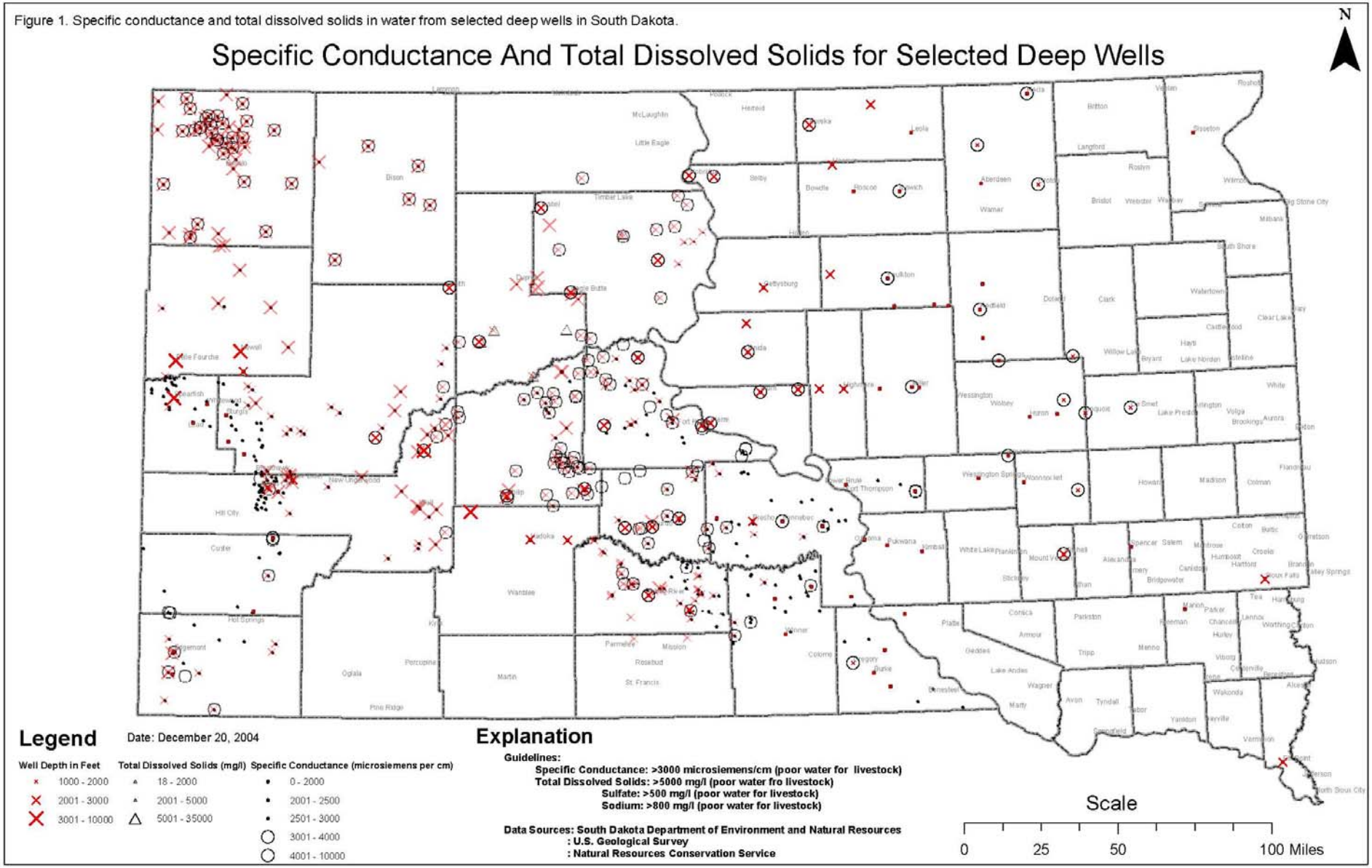
Figure 1. Specific conductance and total dissolved solids in water from selected deep wells in South Dakota.
Specific Conductance And Total Dissolved Solids for Selected Deep Wells
N
Legend
Date: December 20, 2004
Well Depth in Feet
1000 - 2000
2001 - 3000
3001 - 10000
Total Dissolved Solids (mg/l)
18 - 2000
2001 - 5000
5001 - 35000
Specific Conductance (microsiemens per cm)
0 - 2000
2001 - 2500
2501 - 3000
3001 - 4000
4001 - 10000
Explanation
Guidelines:
Specific Conductance: >3000 microsiemens/cm (poor water for livestock)
Total Dissolved Solids: >5000 mg/l (poor water fro livestock)
Sulfate: >500 mg/l (poor water for livestock)
Sodium: >800 mg/l (poor water for livestock)
Data Sources: South Dakota Department of Environment and Natural Resources
: U.S. Geological Survey
: Natural Resources Conservation Service
Scale
0
25
50
100 Miles

FIGURE 2

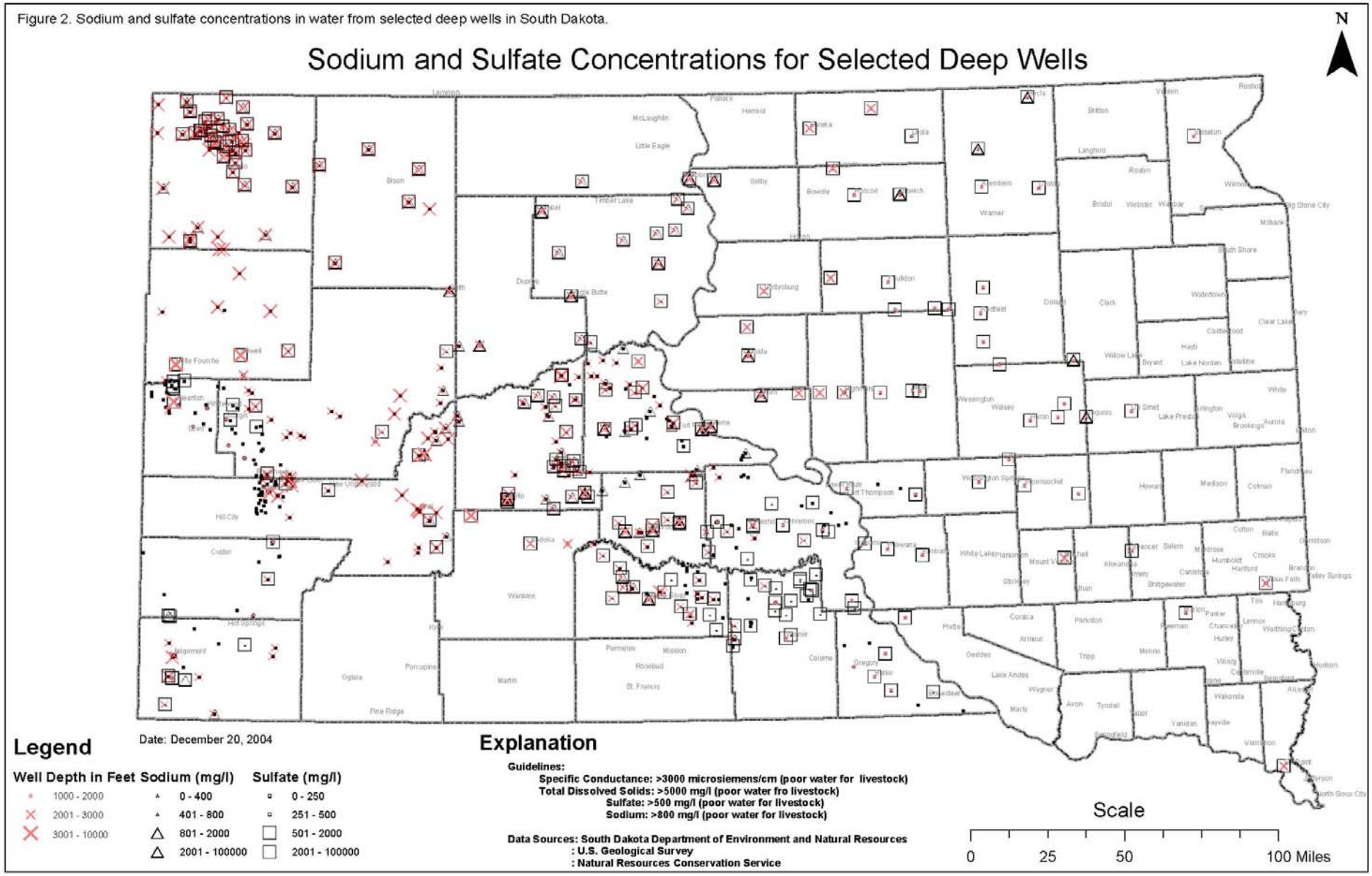
Figure 2. Sodium and sulfate concentrations in water from selected deep wells in South Dakota.
Sodium and Sulfate Concentrations for Selected Deep Wells
N
Legend
Date: December 20, 2004
Well Depth in Feet
1000 - 2000
2001 - 3000
3001 - 10000
Sodium (mg/l)
0 - 400
401 - 800
801 - 2000
2001 - 100000
Sulfate (mg/l)
0 - 250
251 - 500
501 - 2000
2001 - 100000
Explanation
Guidelines:
Specific Conductance: >3000 microsiemens/cm (poor water for livestock)
Total Dissolved Solids: >5000 mg/l (poor water fro livestock)
Sulfate: >500 mg/l (poor water for livestock)
Sodium: >800 mg/l (poor water for livestock)
Data Sources: South Dakota Department of Environment and Natural Resources
: U.S. Geological Survey
: Natural Resources Conservation Service
Scale
0
25
50
100 Miles