Dr. Brun observing a typical saline seep located in Divide county. Note the nearly bare, crusted area caused by concentration of salts at the surface.

CLASSIFICATION AND MANAGEMENT OF SALINE SEEPS IN WESTERN NORTH DAKOTA

B.K. Worcester, L.J. Brun and E.J. Doering

Saline seeps observed in western North Dakota can be classified into one of several general categories based on different geologic conditions. Present management practices lead to the formation of saline seeps and their growth. Suggestions are given for modification of these practices which may have a beneficial effect on control and abatement of seeps.

Introduction

Saline seeps develop when water percolates through the soil profile beyond the rooting zone in the upland, or recharge, area and transports soluble salts in the process. At some depth the water encounters a much less permeable layer which restricts further downward flow or a permeable layer which is conducive to lateral flow. The water then moves laterally to a position where the layer is truncated (i.e., terminated) near the surface, resulting in a saline seep. Saline seeps generally develop on hillsides, although they may appear at different landscape positions. Usually, the result is continuous surface wetness and an accumulation of soluble salts sufficiently concentrated to restrict or eliminate crop growth.

Saline seeps have increased in recent years and more land has become unproductive (Ballantyne, 1963, 1968; Greenlee *et al*, 1968; Luken, 1962). Estimates of seep-affected soils in North Dakota

Dr. Worcester and Dr. Brun are assistant professors, Department of Soils, and Doering is an agricultural engineer with the Agricultural Research Service, USDA, Northern Great Plains Research Center, Mandan. *This work was supported in part by funds from the North Dakota State Water Commission.*

range from 50 to 100 thousand acres. Frequently, the most productive land on lower landscape positions is affected by seep formation.

The small grain-fallow farming system in the northern Great Plains has been cited as a principal contributor to the increase in saline seeps (Black, et al., 1974; Halvorson and Black, 1974). Using such soil and water conservation practices as weed control, strip cropping, stubble mulching, and wind barriers for snow interception *in conjunction with fallow,* is also a contributing factor (Greb et al., 1970; Halvorson and Black, 1974).

To control saline seeps, or at least reduce their severity, more information is needed about the soil and geologic conditions conducive to seep formation. Then, appropriate management practices can be applied to reduce or eliminate the movement of water beyond the rooting zone and to remove water that has already accumulated. While saline seeps seem almost infinite in variety, geologic conditions provide a basis for describing six types of seeps that appear to include most of the seeps in western North Dakota.

Surficial Geology of Study Areas

The geology of northwestern North Dakota is complex. It is an area of relatively recent glaciation. In areas where seeps are prevalent, the landscape is composed of short, steep slopes, rounded hill tops, and narrow drainageways. This topography is the result of the furthest advance of a major glaciation. The glacial debris is very heterogeneous, containing till, sands and gravel, all mixed and interstratified in layers and pockets. Where the landscape is composed of longer and more gentle slopes, one can expect to find glacial till with occasional glacial melt-water channels of sandy material.

The bedrock underlying the glacially derived materials of northwestern North Dakota is mostly from the Tertiary System and is composed of the Tongue River and Sentinel Butte Formations of the Fort Union Group. Southwestern North Dakota was for the most part unglaciated and the bedrock buried in the northwest is similar to the surface material in the southwest. Two additional formations in the southwest are the Golden Valley Formation and the White River Formation (Carlson, 1973). The landscapes associated with these formations generally consist of gentle slopes, some buttes and ridges, and deeply eroded gullies.

The oldest surficial bedrocks and the most extensive in Stark county and the surrounding area are the Tongue River and Sentinel Butte Formations (Caldwell, 1954). Three distinct lignite beds are recognized within these formations in addition to many minor beds. There are also numerous exposures of scoria. Sand, silt and clay beds are interspersed throughout. The Golden Valley Formation, the next oldest, is composed of numerous sand beds, minor lignite beds and interspersed silt and clay layers. The youngest and uppermost bedrock is the White River Formation. The lower and middle members are predominantly clays and silts. The upper member is capped by sands and underlain by clay. This member has been mostly removed by erosion and remnants exist on high buttes and ridges.

Several varieties of saline seeps are found within this setting The various seeps may appear very similar on the land surface, but the mechanism of formation, and therefore management, is different in each case. Basically, the geologic conditions permit distinctions to be made. Stratigraphy, or layering of different materials, seems to be the most significant geologic factor, but not the only one. The shape and form of the landscape are also important.

Classification of Saline Seeps

Within the geologic framework, saline seeps may be classified into general types. The seep situation illustrated diagrammatically in Figure 1 is relatively common in the glaciated parts of western North Dakota. The material in the recharge area on the hill top is moderately permeable glacial till. Runoff is considerable if the slopes are steep, but normally some rainfall and snowmelt percolates through the loamy till to underlying sandy layers. Sands occur both as continuous layers and as discontinuous pockets. Underlying the sands is dense, slowly permeable glacial till. Since the sand is very permeable, the water moves through it and, if the layer is truncated by the landscape, water is removed by evaporation, leaving the dissolved salts concentrated in the soil.

The second commonly observed saline seep situation is illustrated in Figure 2. The surface material in the recharge area is sandy and sandy loam textured. These sands are probably of glacial origin and can in most situations be related to glacial melt water. The permeability of this material precludes much runoff and considerable rain and snowmelt will percolate through the sand to a lower, gravelly layer. The dense glacial till underneath restricts further downward drainage and a perched water table develops. This drains laterally to the point where the layers are truncated. Evaporation removes the water and concentrates the salts.

Figure 3 illustrates an interesting but not widespread situation. Although the source of water and mechanism of formation do not fit the general definition of saline seep, the results appear the same on the landscape. Field observation can lead one to assume that the recharge area is the hill top. In fact, the glacial till is dense and evidence indicates there is considerable runoff. This runoff maintains the water level in the slough. Upland sloughs are

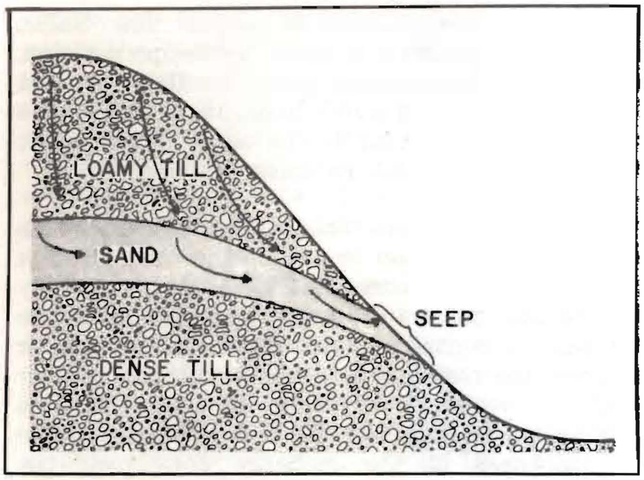

Figure 1.

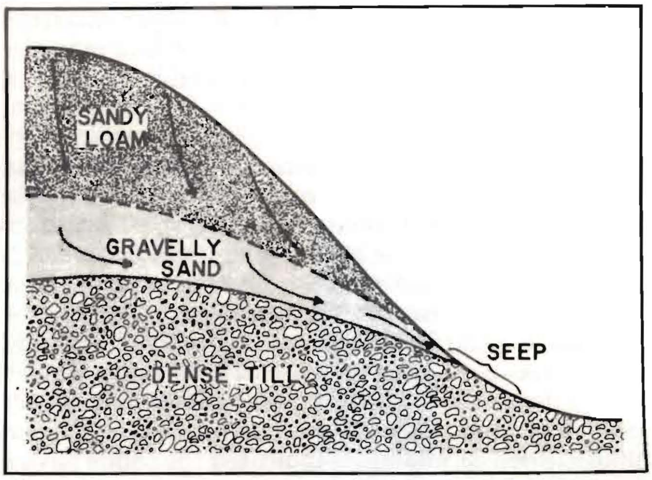

Figure 2.

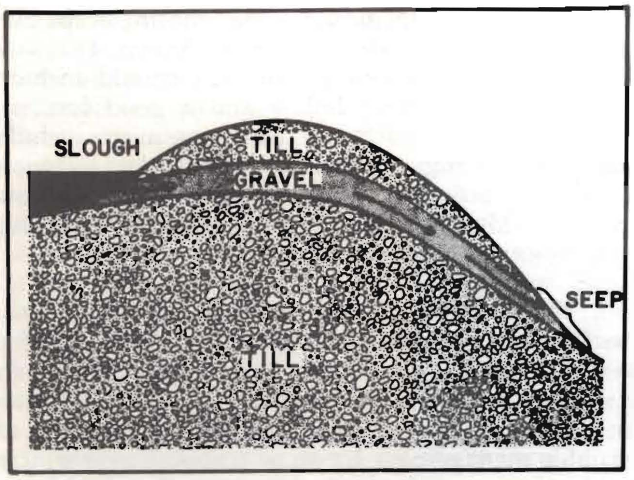

Figure 3.

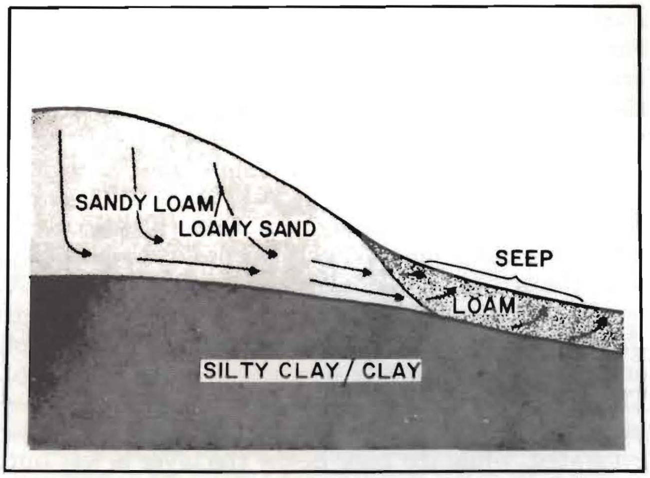

Figure 4.

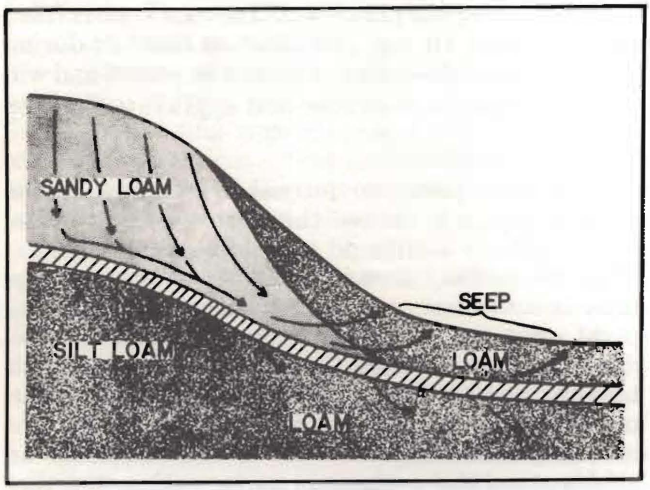

Figure 5.

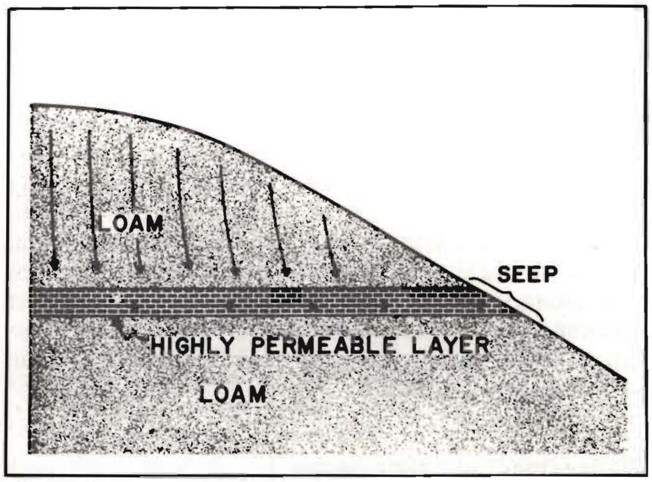

Figure 6.

Schematic diagrams of seep types identified in western North Dakota. Arrows indicate the direction of flow of water. Although the various layers are shown as being exposed at the surface, they are normally covered to a shallow depth by fine material eroded from upslope and redeposited at the lower landscape positions.

common. The gravel layer is usually separated from the water in the slough by a layer of fine material but acts as a transmitting material from the slough to the seep.

Seeps caused by coarse-textured soils overlying very dense clay-shale material are found in southwestern North Dakota (Figure 4). The texture of the material at the higher landscape positions is usually sandy loam or loamy sand (up to 90 per cent sand). The texture of the material at the lower landscape positions is finer, typically loam and sometimes clay loam or clay. These materials lie over a dense clay/shale material that is 90 to 99 per cent silt and clay. Measurements made from undisturbed core samples indicated the sands have a saturated hydraulic conductivity at least 600 times greater than the clay/shale layer. Consequently, when water moving downward through the sands encounters the clay layer it moves laterally and emerges at a lower landscape position. The sands are very low in soluble salts, but with evaporation at the seep, soluble salt concentrations become high enough to prevent growth of desirable plants.

Another seep type found in southwestern North Dakota is caused by a thin, fine-textured layer that has a much lower hydraulic conductivity than the soil above or below the layer (Figure 5). A small quantity of water will move down through this layer but most of the water from the recharge area will move laterally downslope to form a seep. This situation leads to formation of a perched water table. A zone above the restricting layer is saturated, while the zone below the layer is wet but not saturated.

Figure 6 illustrates a type of seep extensively studied in Hettinger county, but common throughout western North Dakota. Water moves beyond the root zone, encountering nearly horizontal layers of lignite, scoria, clinker, or other highly permeable material truncated by the landscape. If this permeable layer is underlain by less permeable material, the hydraulic pressure may become sufficiently high in the permeable layer to result in formation of a seep. When there are several layers of highly permeable materials at different elevations in the profile, several seeps can occur at different elevations on the same hillside. Textures range from sandy loam to clay loam, with loam probably most common.

Management of Saline Seeps

Even though there is a wide variety of saline seeps, the processes leading to the formation of a seep are essentially the same. Except for situations where sloughs act as water sources, water moves beyond the rooting zone in the recharge areas which are commonly coarse-textured, then moves vertically until it encounters a layer which is more conducive to horizontal than vertical flow. Saline water then emerges at a lower landscape position, most commonly surfacing due to capillary rise, but sometimes emerging under hydraulic pressure as a spring. The end result is the same in all cases; continuous wetness and increased soil salinity.

Control measures should be applied to the recharge area to stop or reduce the movement of water past the root zone. This approach is especially wise because soil water in the recharge area can be viewed as a nonsaline water resource. Stopping or reducing the recharge flow will eventually stop or reduce the water emerging at the seep. The time period required to reduce this flow will depend upon the thickness of the recharge zone over the conducting layer, the amount of water that has accumulated and the distance from the recharge area to the seep. Montana data indicate intensive annual cropping, including deeper-rooting crops like winter wheat, may dry this zone (Brown, 1971). A more intensive cropping program should include reduction of summer fallow and a good fertility program. Such a fertility program must include adequate nitrogen fertilizer to replace nitrogen normally accumulated during summer fallow periods. More frequent and intensive cropping requires more plant nutrients.

The practice of summer-fallowing the coarse-textured recharge areas is questionable, except for weed control. Coarse-textured soils have an available water holding capacity of only about one inch per foot of rooting zone depth. A program of stubble management for snow trapping over winter with the possible inclusion of tall wheatgrass barriers will frequently bring these well-drained soils to field capacity by spring, thus making intensive cropping possible. If the root zone is filled to capacity by spring, precipitation received during the following fallow season cannot be stored and will move beyond the root zone and aggravate the seep problem.

An alternative to intensive cropping of the recharge areas is to seed these areas to a perennial crop, such as alfalfa or an alfalfa-grass mixture. This is especially true if the depth of the recharge layer is seven feet or more. Alfalfa is a deep-rooting plant, so it can extract water from a deeper profile. An established alfalfa stand is moderately salt tolerant, so water can be extracted from the deeper, more saline zones. In the situation where sloughs act as the recharge source, establishment of an alfalfa stand and such water conservation structure as terraces between the slough and the seep area could intercept and use sufficient amounts of water to reduce or eliminate flow into the seep.

Data of Brun and Worcester (1974, 1975) and Brown (personal communication) indicated alfalfa has a great potential for extracting water under a wide range of soil conditions. The easiest way to gauge the "useful" period of alfalfa in extracting this accumulated water is to observe its recovery after mowing. If the alfalfa greens up and resumes some growth after cutting when the preceding weather has been dry, it is still utilizing accumulated soil water. If it does not recover, it probably has used all of the extractable water. The area could be returned to cultivation, preferably intensively cropped to prevent the accumulation of water beyond the rooting zone again. The authors have observed several situations where planting alfalfa on the recharge area has stopped seep discharge in two to three years. Precipitation was sufficient so that other seeps in the immediate vicinity remained actively flowing throughout this time period.

An alternative solution to eliminating flow of water into the seep area is the installation of interceptor tile lines. When a drain is used to eliminate a seep, hydraulic control of the seep is achieved by intercepting the water immediately above the seep and conducting it to a suitable outlet. Outlet considerations must include not only easement for transporting saline drainage water across intervening lands, but also the effect that those drainage waters might have on the quality of streams and reservoirs into which they flow. Since drainage treats the effect rather than the cause, and may involve serious environmental considerations, its future application may become more and more limited.

Once the flow of water from the recharge area has been stopped by agronomic practices or intercepted by drains, wetness at the seep will diminish, and reclamation of the seep-affected area can begin. To accomplish reclamation, soluble salts must be leached downward out of the root zone. Precipitation can be used effectively for leaching when the surface is fallowed and evaporation is reduced by using vegetative and soil mulches. The cultural practices that contribute to seep development when they are applied to the recharge area are, paradoxically, the practices that must be applied to the seep area to leach the accumulated salts downward *after recharge has been eliminated.* Vegetative growth, even weeds, can be beneficial in fall and winter because they will trap snow to increase the supply of water available for leaching in the spring.

Seep waters are often high in sodium, so seep-affected areas often become sodic or sodium affected. When a soil becomes more sodic, it becomes more subject to dispersion and less permeable. To reclaim a sodic soil, sodium must be displaced from the soil by calcium, which involves a chemical reaction, and the displaced sodium leached away (Doering and Reeve, 1965). Many soils in western North Dakota contain enough residual gypsum or lime so that enough calcium may be dissolved during the leaching process to correct the sodium problem. If the seep has been active for several years, however, the soil may have become so sodic that more highly soluble salts, like calcium chloride, may be applied to aid chemical reclamation. Incorporating manure into seep-affected areas adds organic matter, which increases the permeability and improves the tilth of sodic soils. Most manures contain considerable soluble salt, which most seep areas already have too much of, but the detrimental effects of soluble salt are usually outweighed by the beneficial affects manure has on permeability and tilth of sodic soils.

There are no magic potions or easy cures available for stopping the spread of saline seeps and reclaiming existing seeps. The problem can only be cured by changing present farming practices, which will require a high level of management skills and a willingness to accept and implement new management methods.

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