HYDRO-CHEMICAL MOVEMENT AT A DRYLAND SALINITY SITE NEAR GULL LAKE

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The Gull Lake salinity site was established in 1974 by the Research Station at Swift Current in conjunction with the Saskatchewan Department of Agriculture and the Department of Soil Science, University of Saskatchewan, in order to serve as a demonstration site for salinity reclamation and control. The salinity site is located within the Bridge Creek Watershed (Fig. 1) on a quarter section owned and managed by Mr. R. Benallack (legal location N.W. 20-13-18-W3). The farm is 2 miles east of Gull Lake, approximately 30 miles WSW of Swift Current. A detailed description of this site is given by Warder, et al. (1978).

One of the objectives of Agriculture Canada's involvement in this study was to examine the hydrological and chemical factors affecting the saline seep development at this site. In order to do this some deep test holes varying from 49 to 205 feet in depth were drilled with the aid of a P.F.R.A. drill truck and crew. These holes were used to characterize the strata and geology of the site. Transect I in Figure 2 (1', 2, 3, 4, 5, 6', and 6) shows the location of the seven holes drilled on the salinity site. The geology of the Gull Lake salinity site obtained from the seven holes is displayed in Figure 3.

GEOLOGICAL INFLUENCES

It is believed that during glaciation a compressive flow existed at the interface between the advancing ice and the Cypress Hills Uplands. This phenomena called "ice thrusting" lead to the incorporation of large blocks of bedrock material as relatively intact units within the glacier, often surrounded by till. It appears that glacial thrusting has incorporated at

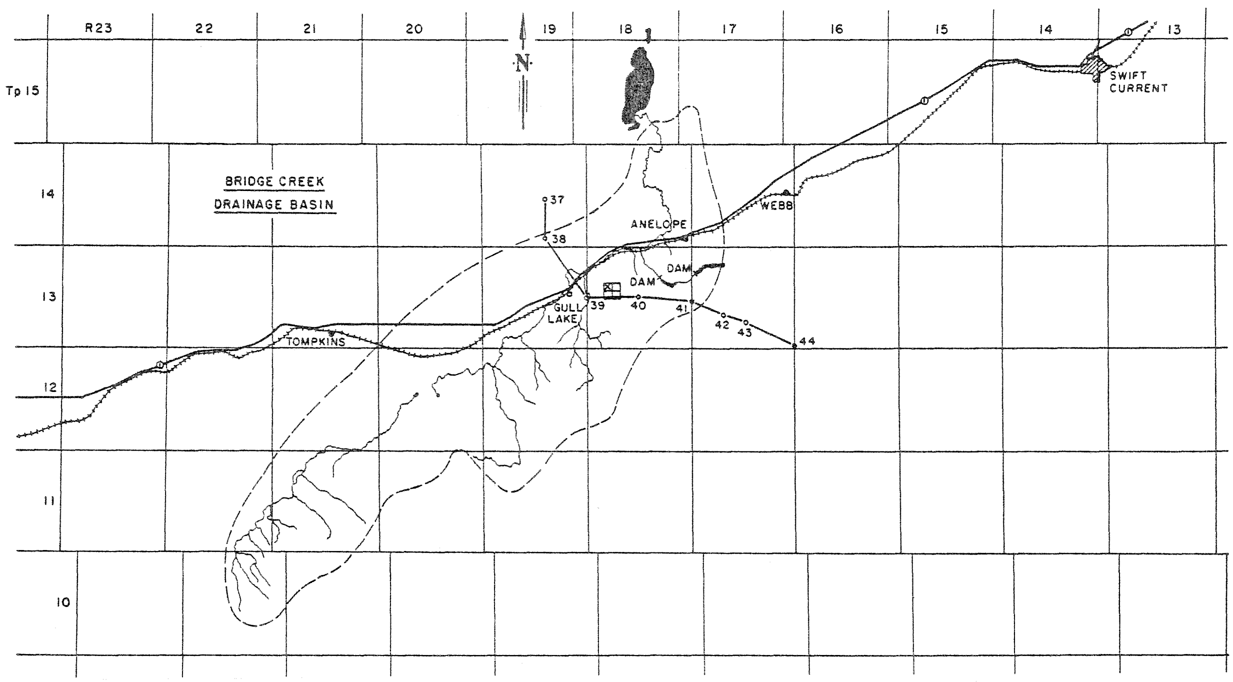

Figure 1. Map of the Bridge Creek drainage basin showing the location of the Gull Lake salinity demonstration site

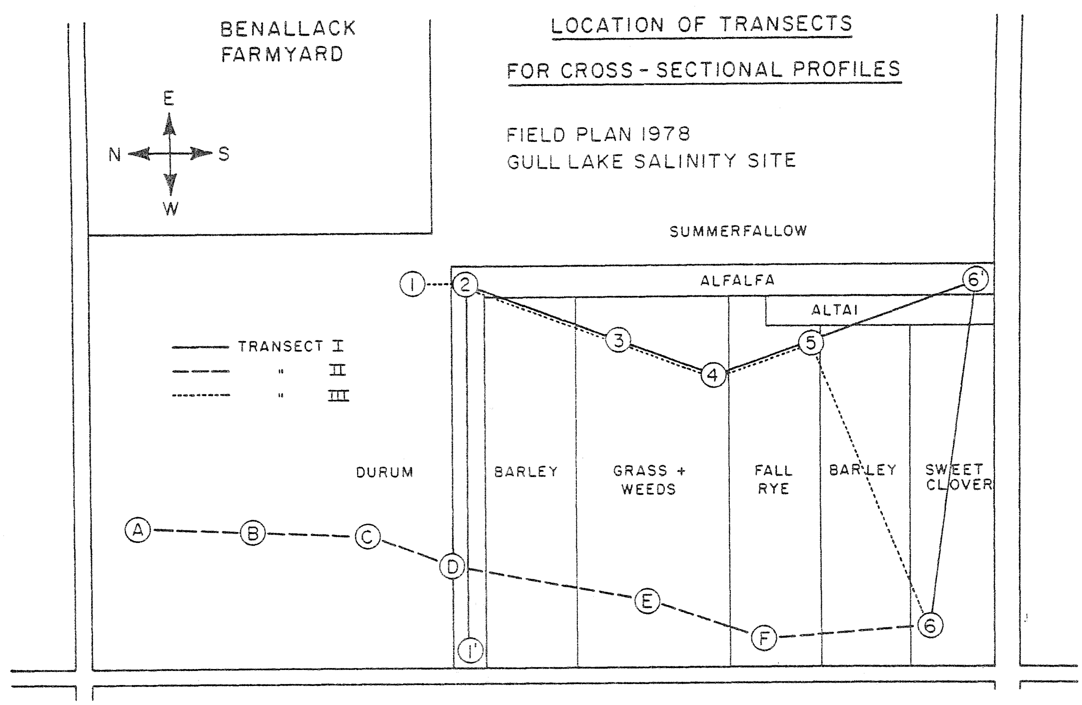

Figure 2. Gull Lake salinity study area showing location of test hole transects used to characterize strata and salinity of the site

least two layers of a till bedrock mixture in the underlying strata of the site area.

A laminated silty clay unit (glacio-lacustrine clay), 10 to 30 feet thick mantles the site area. Under the surface of the glacio-lacustrine clays and surrounding the ice-thrust materials is a dark brown to grey glacial till. This unit occurs to a depth of at least 200 feet below the surface of the site and overlays the Bearpaw Formation (not encountered in the current drilling program). Several small sand layers occur within the till.

Included in the ice-thrust unit are several fine to coarse sand layers of varying thickness. In test hole 2 the central portion of the ice-thrust material consists of 30 feet of sand, silt and coarse gravel containing water under high artesian pressure. In other test holes the sandy layers of the ice-thrust unit vary from a few inches to 2 feet to over 45 feet in thickness, but are not continuous over the entire site area.

Of particular interest, however, is a thin but persistent, fine to medium sand layer that occurs at the contact between the glacio-lacustrine clay mantle and the upper till surface. While the sand layer is not continuous over the entire site area and was never more than 2 feet thick in any of the test holes, a substantial amount of seepage was experienced at this contact in all test holes. Some coarse sand and gravel were encountered at this horizon in test hole 6'. This sand layer and the weathered surface of the upper till appear to act as a permeable layer to store and transmit water throughout the site area.

Peizometers were installed at various depths in five drill holes and their recorded water levels and salt contents (EC = mmho/cm) are shown in Figure 4. Some very high artesian pressures occur within several of the deeper groundwater zones, and especially within the ice-thrust gravel layer in test hole 2 where water levels rise from a depth of 156 feet to within 13 feet of the surface. At test hole 4 water levels were within 3 feet of the surface in a peizometer placed at a depth of 34 feet. Both sources of this deep water were relatively salt-free with EC values near 1.2 mmho/cm. The shallower wells within the glacio-lacustrine sediments generally yielded higher concentrations of salts; at times approaching 7.0 mmho/cm in the fall, but having lower concentrations in the spring.

The high artesian pressures within the ice-thrust unit suggests that

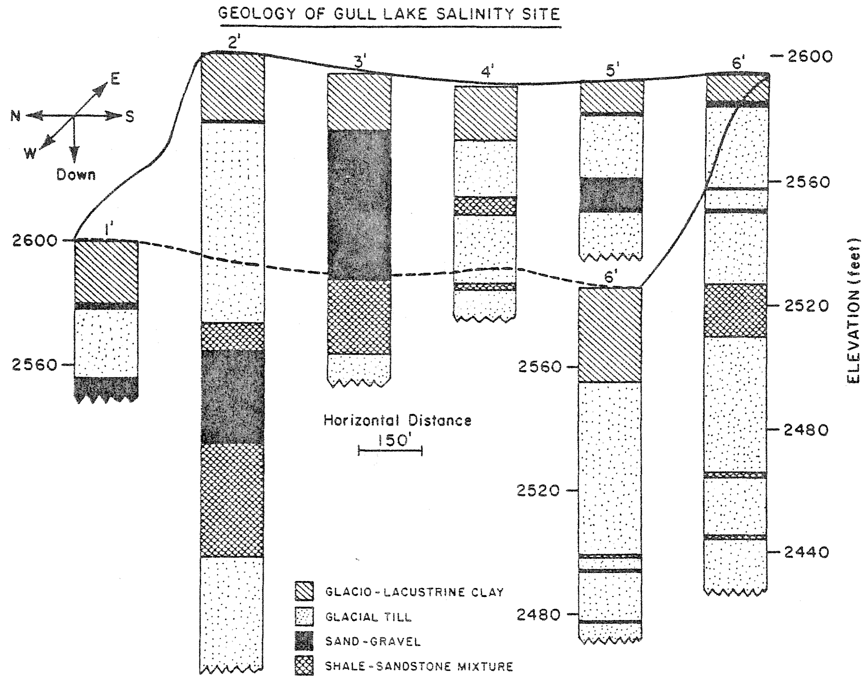

Figure 3. Geology of the Gull Lake salinity site obtained from the eight test holes drilled on the site

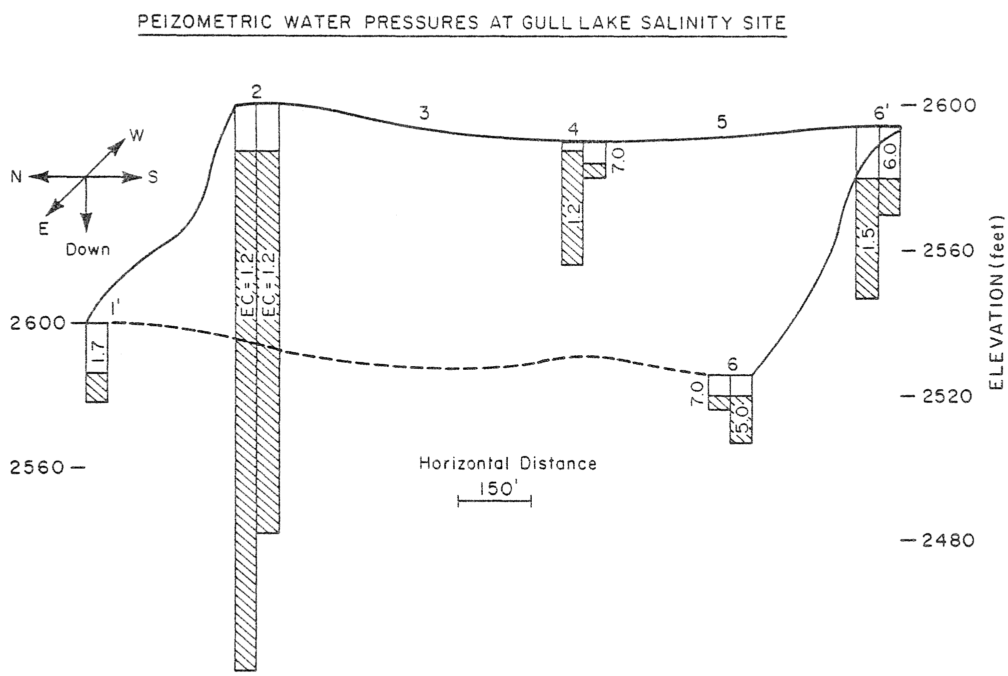

Figure 4. Peizometric water pressures and their salt contents (Ec = mmho/cm) at the Gull Lake salinity site

given a suitable hydraulic connection there is sufficient pressure to carry water upward into the surface glacio-lacustrine deposits. A possible hydraulic connection might be provided by the ice-thrust unit as it inclines towards the surface. The 30 feet of sand at test hole 2 and the massive 48 feet of sand and gravel at test hole 3 are sufficiently permeable to conduct water from the lower aquifer zones up toward the surface. The high artesian pressures (Fig. 4) associated with these deeper groundwater zones causes water to rise to the surface. The upward movement of the groundwater is halted by the much lower permeability of the surface till and glacio-lacustrine clays. The water is trapped in the weathered till zone and in the thin sand layer overlying the till where it provides a reservoir for capillary rise. Evaporation from the surface leads to a concentration of salts in the lake-clay near the soil surface.

DISTRIBUTION OF SALTS

A salt distribution profile with respect to depth (24 feet) was plotted for Transect II (1, 2, 3, 4, 5, and 6 - see Fig. 2) and the result is illustrated in Figure 5. Transect II aligns closely with Transect I and includes the results from test holes 2, 3, 4, 5 and 6. The highest salt concentrations (EC > 15 mmho/cm) were found in a narrow zone 2 to 4 feet below the groundlevel, but surfacing at the lower end of the site. The lowest salt concentrations (< 2 mmho/cm) were found directly below, and extending deep and downslope of the depressional area at location 1. The hypothesized flow regime, illustrated by the arrows, shows the movement of water vertically down from the depression with a tendency to move laterally as it intercepts the groundwater near the intercept of the glacio-lacustrine clay and till. The arrows at the bottom of Figure 5 pointing vertically upward illustrate the artesian water pressure that may be present from the ice-thrust unit, forcing water towards the surface and enhancing saline seep development at this site.

The small knoll at test hole 5 shows the effect of local topography on seep development. Here the two-foot rise in elevation above test hole 4 has helped prevent excessive salt accumulation near the surface, allowing reasonably good plant growth.

A salt distribution profile with respect to depth (12 feet) was

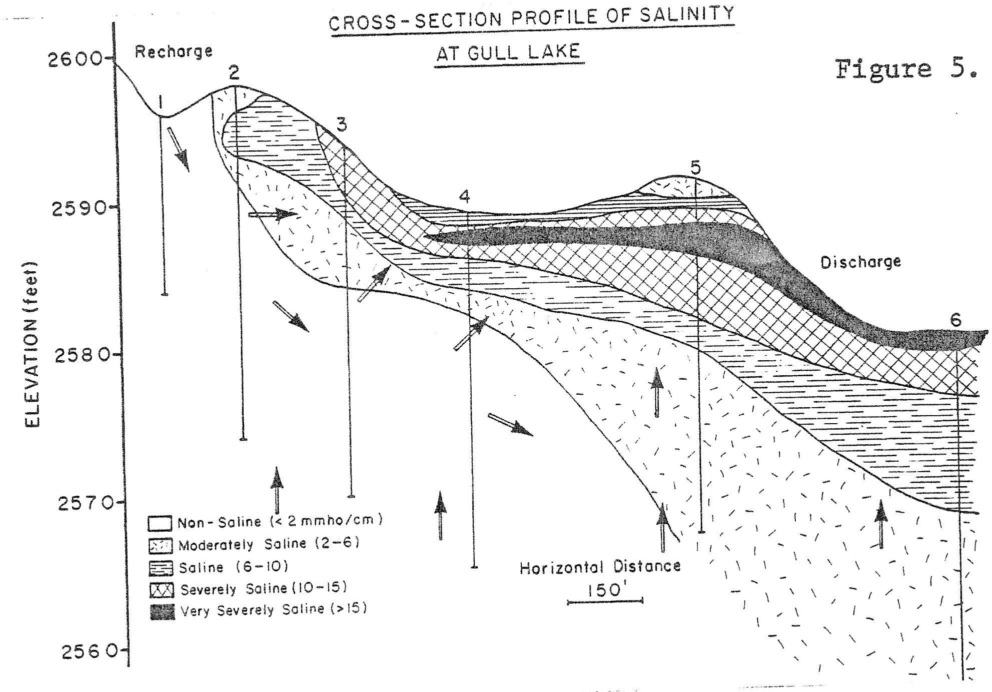

Figure 5.

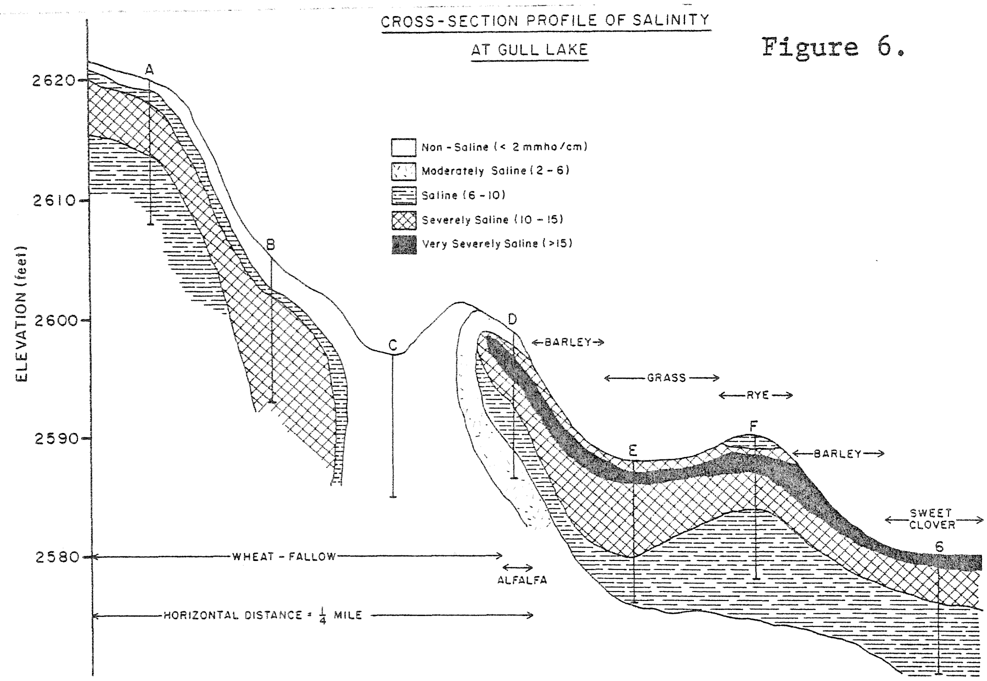

Figure 6.

TYPE OF SALTS AT GULL LAKE SALINITY SITE

Table 1.

	EC (mmho/cm)	Ca	Mg	Na
		(paste extract-mg/L)		
Upslope (3-6')	13	660	1600	2000
Depression (3-6')	0.3	34	13	22
Saline (3-6')	12	620	890	2660
Severely Saline (0-2')	18	690	1230	3950

plotted for Transect III (A, B, C, D, E, F, and 6 - see Fig. 2) and the result is illustrated in Figure 6. Test holes A, B, and C are located in a wheat field upslope of the salinity site, generally considered the recharge area. However, it is obvious from the salt profile distributions that there is a zone of high salt concentration (EC's of 10 to 15 mmho/cm) below the 2 to 3-foot depth in this upslope area (Fox Valley soil mapping association). The high salt contents were most likely present when the soil parent material was deposited and long-term weathering and leaching have produced the present salt distribution. However, there does not appear to be a major loss of salts.

The depressional area at test hole C collects spring melt water and appears to definitely be a recharge location. As illustrated previously in Figure 5, the soils below these depressional areas have lost most of their salts, which in turn has probably contributed to downslope salinity.

Concentrations of Ca, Mg and Na (saturated pasty extracts) in the 3- to 6-foot layer of soils in the upslope, depression, and saline areas are given in Table 1. Except for the depressional area, Ca concentrations are relatively stable near 650 mg/L, indicating an equilibrium with precipitated $CaSO_4$. Sodium concentrations nearly double from the upslope position (2000 mg/L) to the downslope, severely saline soils (3950 mg/L).

SUMMARY

A geological study of the strata below this site has suggested that artesian pressure at 150 feet forces groundwater upward through a permeable sand and gravel layer in an inclined ice-thrust unit. A sandy and weathered zone on the upper till stores the water and makes it available to the overlying glacio-lacustrine sediments, where through some upward pressure and capillary rise the groundwater evaporates near the soil surface and salts accumulate. Upslope areas, except for depressions, do not appear to contribute very much salt mass to the saline area. However, the depressional areas are almost devoid of salts and appear to contribute to the salinity of the downslope positions.

REFERENCES

WARDER, F.G., READ, D.W.L., CAMERON, D.R. and NICHOLAICHUK, W. 1978. Hydrology and reclamation of dryland salinity at Swift Current, Sask. Summary Technical Report prepared by Research Station, Swift Current, Sask. 55 pp.