Wind Transport of Salts in the Old Wives Lake Area of Saskatchewan

-by-

L.D. Luba, J.L. Henry, T.J. Hogg, and H. Harder

Introduction and Objectives

Salt and dust storms are a phenomena that could originate over playas (closed dry saline basins) and have been documented in parts of North America (Young and Evans, 1986, Ballantyne, 1978) and Central Asia (Kabulov, 1984, Kostyuchenko, 1984, Mozhaitseva and Nekrasova, 1984, Bel'gibaev, 1984, Kes, 1983, Orlova, 1979, and Slavnyi and Mel'nikova, 1977). Reducing water levels followed by the crystallization and accumulation of salt on basin floors and the drying of these floors leave salts vulnerable to wind erosion.

Deflation and transport of salts may occur in many areas of Saskatchewan where saline lakes have become dry. Transport of salts from a dried saline lake onto agricultural land was noted by Ballantyne (1978). Salinity research in western Canada with respect to wind transported salts is extremely limited.

Recent research in Saskatchewan showed that soil salinity was largely due to groundwater discharge from glacial and bedrock aquifers (Henry et al., 1985). Saline soils were classified and models were based upon cause(s) of salinity (Bullock, 1985). These models did not include salinization as a result of wind transport and deposition. Other than Ballantyne's (1978) investigation, salinization as a result of wind blown salts was not considered, studied nor mapped in Saskatchewan.

This study was initiated in response to public concern about wind blown salts near Old Wives Lake. The objectives of this investigation were: (1) to determine if recent accumulations of wind blown salt could be measured in the field by use of standard methods, and (2) to map areas of salt accumulation as related to wind transport and deposition.

Location

Old Wives Lake is located in the Old Wives Lake drainage basin in southern Saskatchewan (Figure 1). The drainage basin occupies an area of about 14,355 square kilometers with no outlet to the sea (Freeze, 1969). Old Wives Lake covers an area of about 177 square kilometers and is the fourth largest inland saline lake in North America (Freeze, 1969 after Bue, 1963).

Physiography

The drainage basin forms a large triangular wedge between the major basins of the Saskatchewan, Assiniboine, and the Missouri Rivers (Freeze, 1969). The Old Wives Lake basin is bounded by the Wood Mountain Upland on the south, the Cypress Hills Upland on the northwest, and the Missouri Coteau Upland on the northwest (Acton et al., 1960). Old Wives Lake is located in the northeastern sector of the basin.

Drainage in the basin is integrated only along the northern slopes of Wood Mountain Upland, which gives rise to the Wood River, and along the eastern slopes of the Cypress Hills Upland

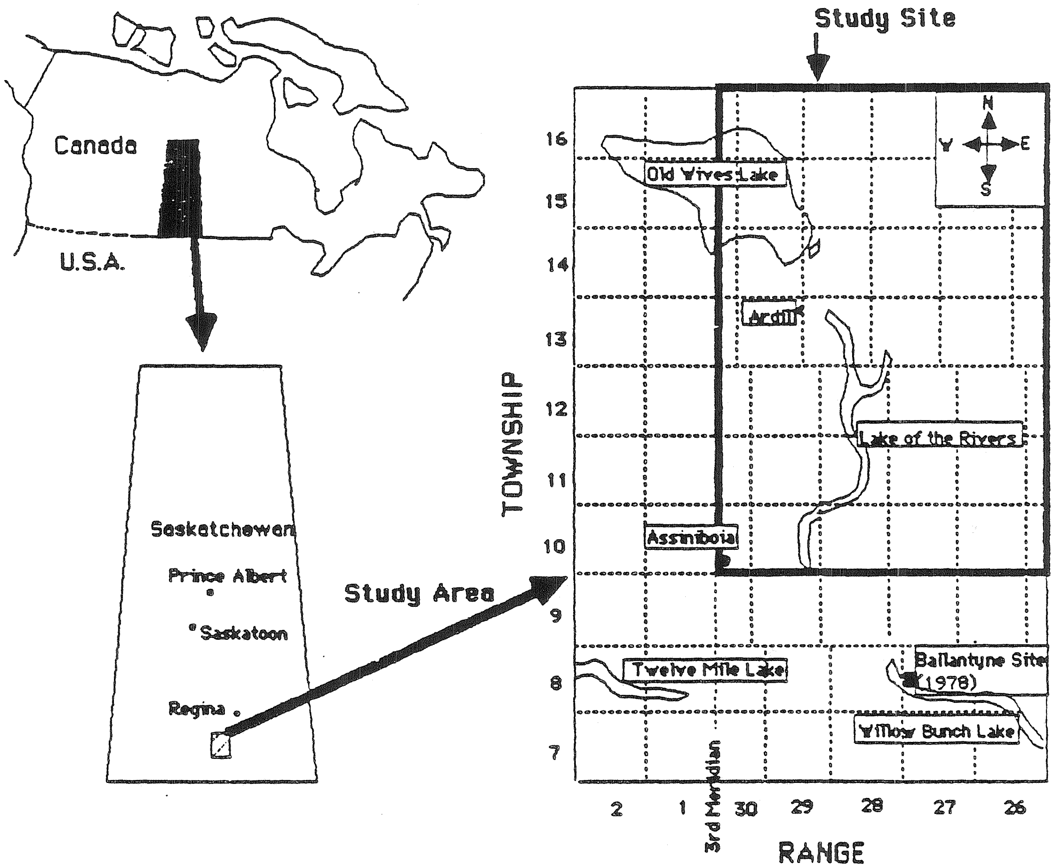

Figure 1. Location of study area and study site in the Old Wives Lake area.

which form the headwaters of Notukeu Creek (Freeze, 1969). A series of closed saline lakes extend southeastward from Old Wives Lake and include the Lake of the Rivers, Willowbunch Lake, and Big Muddy Lake.

Measurements of past water levels in Old Wives Lake are rare. Godwin (1961, after Freeze, 1969) reported that Old Wives Lake did not overflow into Chaplin Lake since 1931, while another report indicates that Old Wives Lake was completely dry during 1894 and the summer of 1936 (Saskatchewan Minerals, 1970).

Climate

The climate is that of a cool, semi-arid continental type (Ellis et al., 1967). The closest meteorlogical station to Old Wives Lake is situated at Coderre which is about 6.5 kilometers west of the northwest tip of Old Wives Lake. Moose Jaw and Gravelbourg meteorlogical stations are also near the lake being situated about 48 kilometers to the northeast and southwest, respectively.

Average annual precipitation and temperature recorded between 1951 and 1980 at the Coderre station was 36.26 cm and 2.6 C. Similarly, at the Moose Jaw and Gravelbourg stations precipitation and temperature was 37.78 cm and 3.5 C and 35.95 cm and 3.6 C, respectively (Environment Canada, 1982).

Land Use and Soils

Soils immediately adjacent to and east and south of Old Wives Lake support large acreages of native vegetation which are primarily used for grazing. Soils in this area largely belong to the Chaplin and Hatton Associations. Chaplin and Hatton soils are developed from coarse to moderately coarse textured glacial-fluvial deposits and coarse to moderately coarse textured, alluvial lacustrine deposits, respectively (Ellis et al., 1965).

In areas a few kilometers east and south of this location soils are largely used for grain production and most soils belong to the Ardill and Sceptre Associations. Ardill soils were developed from moderately fine textured calcareous and gypsiferous glacial till while Sceptre soils were developed from uniformily fine textured, calcareous lacustrine deposits (Ellis et al., 1965). Several small and isolated areas exist near the southeastern tip of the lake that are mapped as Alluvium. These soils consist of calcareous and saline meadows developed from undifferentiated alluvium parent material (Ellis et al., 1965).

Materials and Methods

Due to prevailing northwesterly winds, the direction of observed salt movement in the atmosphere, and requests from individual land owners, soil sampling sites were located in areas east and south of Old Wives Lake. Surface salt crusts were sampled at five sites while soils were sampled at fifty-five summerfallow and twenty-one native pasture sites. Soils at summerfallow sites were sampled at a depth of 0-7.6 cm while soils at native pasture sites were sampled at depths of 0-7.6 cm and 7.6-15.2 cm.

Sampling Salt Crusts

Wind transported salts were deposited several weeks prior to and during the investigation. At all sites salt crusts were clearly visible on the soil surface. To establish whether standard techniques could be used for measuring the amount of salt in the soil, five salt crusts were sampled and analysed. At each of the sites, salt crusts were generally less than 0.3 cm and a thin layer of surface soil (~1 cm thick) was often sampled with the crust.

Sampling Summerfallow Soils

Soil sampling sites were selected along mid and upper slopes of landscapes where soil salinity, as a result of groundwater discharge, was not a factor. Nonsaline environments were confirmed using a Geonics EM-38 noncontacting terrain conductivity meter (Cameron et al., 1981).

Soils at summerfallow sites were sampled so that relative amounts of salt in the 0-7.6 cm depth could be compared between sites within the study area. At each site, duplicate soil samples (A and B) were obtained in composites of at least 30 subsamples. Samples were randomly selected over an area of about 400 X 100 m using a probe with a coring tip of 1.90 cm inside diameter.

Sampling Native Pasture Soils

Natural levels of salt in soils were determined from native pasture sites. Native pasture sites represented areas where soils had never been disturbed by farm operations and for this reason soils from the 7.6-15.2 cm depth were believed to represent the natural salt content of the surface soil.

Differentiation of the amount of wind deposited salt from the amount of natural salt present in the soil was determined at each native pasture site. Mean EC (electrical conductivity) values of soil from the 0-7.6 cm depth were assumed to represent the amount of wind blown salt plus the amount of natural salt present in soil whereas EC values from the 7.6-15.2 cm depth were assumed to only represent the amount of natural salt prior to wind deposition.

When mean EC values were similar from both soil depths the site was assumed to represent an area of little or no salt accumulation. When the mean EC value from the 0-7.6 cm depth was greater than the mean EC value from the 7.6-15.2 cm depth the site was assumed to represent an area of salt accumulation as a result of wind deposition.

A large portion of land in the study area was used for grain production and as a result native pasture sites were usually confined to areas smaller than those of summerfallow sites. In most cases native pasture sites were limited in area to about 30 m X 30 m.

Near the southeast tip of Old Wives Lake native pasture sites were usually spaced 2-4 kilometers apart with several summerfallow sites between each native site. Where low amounts of salt were found in 0-7.6 cm soil depths, distances between native pasture and summerfallow sites were generally spaced further apart so that more terrain could be covered in the study area.

Chemical Analysis

Chemical measurements were made on salt crust samples and soil samples from summerfallow and native pasture sites in a mobile laboratory located at Assiniboia. Soil electrical conductivity analysis was made on a 1:1 soil:water suspension according to Hogg and Henry (1984). Selected samples were filtered and ions determined on the extracts using selective ion electrodes.

Construction of an Isopach Map

Chemical analysis was completed on 152 soil samples from native and summerfallow sites. By calculating a mean EC value from duplicates A and B for each site an isopach map was prepared. The location of each sampling site, the mean EC from each sampling depth, and a description of whether the site was native pasture or summerfallow was indicated on the isopach map. Lines of approximate equal EC were drawn (isopach lines) defining soils having mean EC's greater than 1.9 dS/m, between 1.4 and 1.9 dS/m, between 0.9 and 1.4 dS/m, between 0.4 and 1.4 dS/m and less than 0.4 dS/m.

Soils in the study area were assumed to be of medium texture and salinity ratings, based on mean EC values from the 1:1 suspensions, were used to determine the degree of salinity (Henry et al., 1987).

Results and Discussion

Salt crusts were sampled at five summerfallow locations where soils were also sampled at the 0-7.6 cm depth. Ratios of approximate sodium percentage (ASP) to approximate calcium plus magnesium percentage (AC+MP) were determined for salt crusts and soil samples (Table 1).

ASP to ACMP ratios for soils from summerfallow fields indicated that calcium plus magnesium salts were present in greater quantity than sodium salts (Table 1). Ratios also indicated that only two salt crust samples yielded greater quantities of sodium salt than calcium plus magnesium salt (Table 1). However, when comparing ratios from salt crusts to those from soils, Table 1 indicates that salt crusts generally contained more than twice as much sodium than that of soils (Table 1).

Table 1. Approximate sodium salt to approximate calcium plus magnesium salt ratios for salt crusts and soils from the same summerfallow field.

	Approximate percent of Na and Ca plus Mg salt for salt crusts			Approximate percent of Na and Ca plus Mg salt for soils		
Legal location	*ASP	**AC+MP	Ratio of *ASP to **AC+MP	*ASP	**AC+MP	Ratio of *ASP to **AC+MP
NW 10-12-28 W2	48.7	49.0	0.99	33.4	62.7	0.53
SW 13-12-28 W2	55.0	25.9	2.12	33.8	57.9	0.58
NW 26-11-28 W2	36.6	56.1	0.65	23.2	71.8	0.32
SE 26-11-28 W2	41.3	50.5	0.81	27.4	73.1	0.37
SW 30-11-29 W2	52.6	39.0	1.34	30.2	68.6	0.44

*Approximate Na+ percentage

{ASP= Na+ (mmol(+)/ l) / 10 EC (1:1 extract) (dS/m)}

**Approximate Ca++ plus Mg++ percentage

{AC+MP= Ca++ + Mg++ (mmol(+)/l) / 10 EC (1:1 extract (dS/m)}

The salt crusts therefore contained relatively high amounts of sodium salt. Wind transported sodium salts probably originated from Frederick and Old Wives Lakes. Cole (1926) noted that Frederick Lake, situated southeast of Old Wives Lake, contained a large supply of sodium salts.

Precipitation between April 1 and October 31, 1987 was normal at the Moose Jaw station, about 3 percent below normal at the Coderre station and about 15 percent below normal at the Gravelbourg meterological station (Environment Canada, 1987). Although precipitation records were normal to slightly below normal throughout the growing season, weekly precipitation records favoured below normal precipitation throughout late summer and autumn. Due to this general lack of precipitation the amount of surface salt present on ground surface could be assumed to represent the amount deposited since late summer and autumn.

Several important observations can be made from the isopach map of wind blown salts (Figure 2). The position of the isopach lines define areas of salt accumulation with respect to Old Wives Lake. Soils with highest amounts of wind blown salt occur in areas closest to the lake while soils with lowest amounts of wind blown salt occur in areas furthest from the lake (Figure 2).

As defined by the 1.90, 1.40, and 0.90 dS/m isopach lines, the pattern of the lines suggest the presence of a tapered salt plume in an area southeast of the lake. This plume extends about 15 kilometers from the southeast tip of the lake to it's most southeasterly point. Near the lake the plume is about 10 kilometers wide while at it's most southeasterly point it is about 5 kilometers wide.

Soil in this salt plume possesses higher amounts of salt than soils adjacent to it. Highest amounts of salt are shown

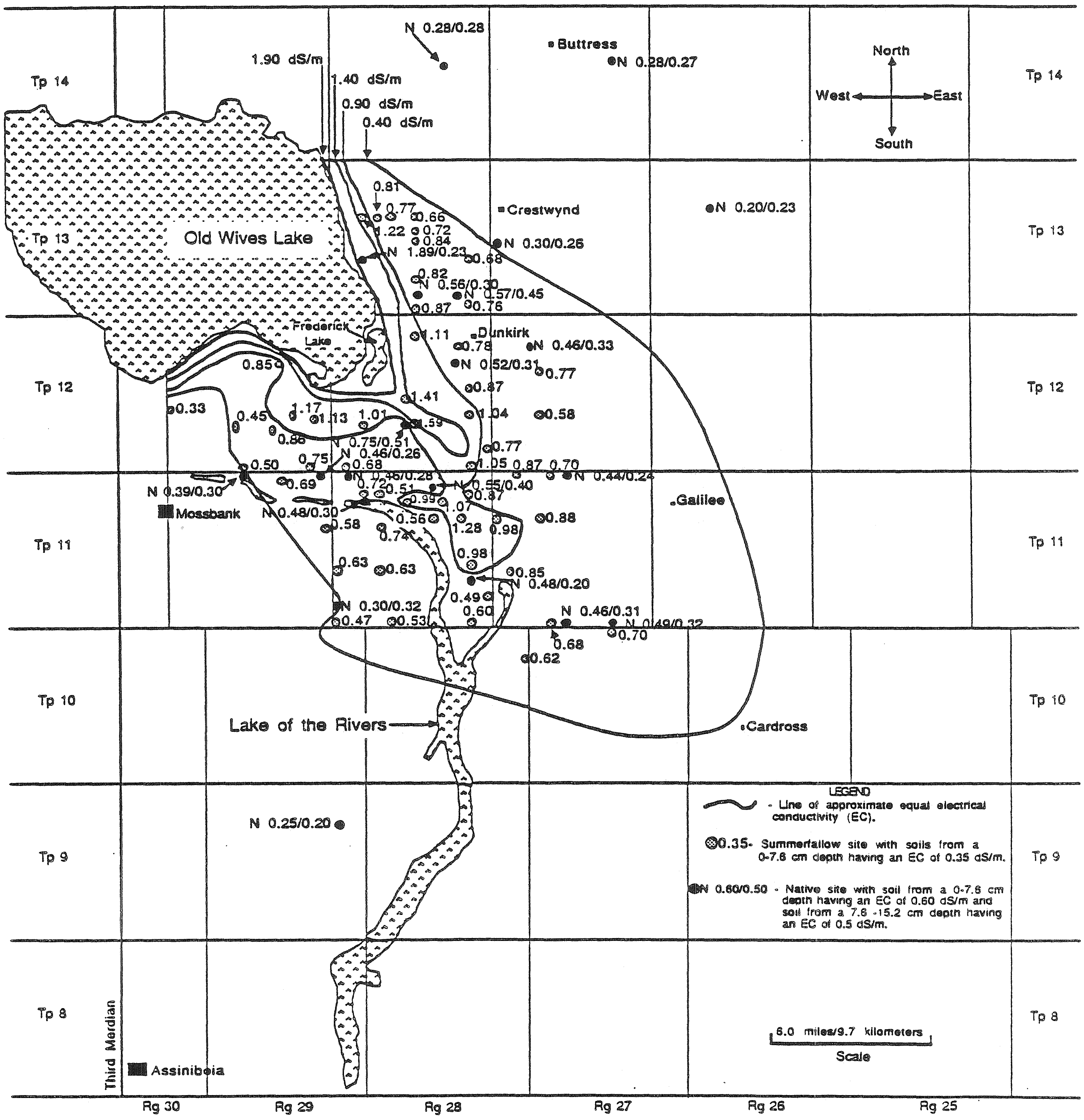

Figure 2. Isopach map of wind blown salts in the Old Wives Lake area.

to occur near the lake while lowest amounts occur along the edges of the plume (Figure 2).

The origin of this salt plume is believed to be related to wind direction. Prevailing northwesterly winds swept over Old Wives and Fredrick Lakes during late summer and autumn. During this time salts accumulated on the lake basin floor where they were later transported by the wind. Salts were then deposited on farmlands southeast of the lake.

Salt levels equal to or greater than 1.90 dS/m were mapped in areas closest to the lake. Soils, grasses, and trees were heavily encrusted. A mean EC of 1.89 dS/m was measured in surface soils at a site in SW17-13-28 W2 (Figure 2). A 1.90 dS/m isopach line was extrapolated between this point and the lake and represents highest amounts of wind deposited salt in the study area. Medium textured soils with an EC between 1.90 and 3.6 dS/m are classified as moderately saline (Henry et al., 1987).

Soils with mean EC values greater than 0.90 dS/m but less than 1.90 dS/m were found in areas further east and south of Old Wives Lake (Figure 2). Soils and vegetation did not appear as heavily encrusted as those found near the lake. Medium textured soils having an EC between 0.90 and 1.90 dS/m were classified as slightly saline (Henry et al., 1987).

Soils with a mean EC less than 0.9 dS/m were found in areas furthest from the lake (Figure 2). Very thin salt crusts were sometimes found on the soil surface being present on the leeward side of local obstructions such as field boulders, field furrows, and tree trunks. Medium textured soils in this area were classified as non-saline (Henry et al., 1987).

Summary and Conclusion

Past soil salinity models in Saskatchewan did not recognise salinization as a result of wind transported salts. When closed saline basins become dry there is a risk that salts could be transported by wind from the basin onto adjacent farmlands. Results from this investigation showed that standard techniques could be used to measure wind transported salts and by determining the relative amount of wind transported salt present in the soil, salt accumulation areas could be mapped. By assuming that the soil was of medium texture salinity levels of soil situated in areas southeast of Old Wives Lake was established.

Although present salinity levels are low, except for areas immediately adjacent to the lake, the investigation showed that wind transport and deposition of salt over the duration of one growing season could yield measureable quantities in the soil.

If Old Wives Lake were to remain dry for several more years and winds were to prevail from the northwest, soils in areas southeast of the lake could become increasingly saline. On the basis of this investigation it appears that soils situated in the salt plume nearest to the lake are in greatest risk of becoming more saline.

List of References

1) **Acton**, D.F., Clayton, J.S., Ellis, J.G., Christiansen, E.A., and Kupsch, W.O. 1960. Physiographic Divisions of Saskatchewan. Saskatchewan Soil Survey, University of Saskatchewan, Saskatoon, Saskatchewan.

2) **Ballantyne, A.K.** 1978. Saline soils in Saskatchewan due to wind deposition. Can. J. Soil Sci. 58: 107-108.

3) **Bel'gibaev, M.E.** 1984. Dust and salt gage: an instrument for collecting airborne dust and salts. In: Problems of Desert Development, Allerton Press, No.1: 72-74.

4) **Bue**, C.D. 1963. Principal lakes in the United States; U.S.G.S. Circular 476: 22 pages.

5) **Cameron, D.R.**, deJong, E., Read, D.W.L., and Oosterveld, M. 1981. Mapping salinity using resistivity and electromagnetic inductive techniques. Can. J. Soil Sci. 61:67-78.

6) **Cole, L.H.** 1926. Sodium sulphate of Western Canada. Canada Department of Mines, Ottawa, Ontario, Canada.

7) **Ellis, J.G.**, Acton, D.F., and Clayton, J.S. 1965. The soils of the Regina Map (72I) Area. Extension Division, University of Saskatchewan, Saskatoon, Saskatchewan.

8) **Ellis, J.G.**, Acton, D.F., and Moss, H.C. 1967. The soils of the Willow Bunch Lake Map (72H) Area. Extension Division, University of Saskatchewan, Saskatoon, Saskatchewan.

9) **Environment Canada.** 1982. Canadian Climatic Normals, Temperature and Precipitation (1951-1980). Atmospheric Environment Service, Downsview, Ontario.

10) **Environment Canada**. 1987. Prairie provinces weekly weather summary (Apri 1-October 31). Environment Canada, Atmospheric Environment, Downsview, Ontario.

11) **Freeze, R.A.** 1969. Regional groundwater flow - Old Wives Lake drainage basin, Saskatchewan, Scientific Series No. 5., Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

12) **Godwin, R.B.** 1961. Water supply and use in the Wood River Basin; P.F.R.A., Hydrology Report No. 30.

13) **Henry, J.L.**, Bullock, P.R., Hogg, T.J., and Luba, L.D. 1985. Groundwater discharge from glacial and bedrock aquifers as a soil salinization factor in Saskatchewan. Can. J. Soil. Sci. 65:749-768.

14) **Henry, J.L.**, Harron, B., and Flaten, D. 1987. The nature and management of salt-affected land in Saskatchewan. Saskatchewan Agriculture, Soils and Crops Branch, Regina.

15) **Hogg, T.J.**, and Henry, J.L. 1984. Comparision of 1:1 and 1:2 suspensions and extracts with the saturation extract in estimating salinity in Saskatchewan soils. Can. J. of Soil Sci. 64:699-704.

16) **Kabulov, S. K.** 1984. Phytocenotic conditions of the dried Aral sea bed in connection with salinization and aeolian processes. In: Problems of Desert Development, Allerton Press Inc., No.3: 17-22.

17) **Kes, A.S.** 1983. The study of deflation processes and salt and dust transport. In: Problems of Desert Development, Allerton Press, Inc., No.1: 1-14.

18) **Kostyuchenko, V.P.** 1984. Salinity of soils of the drying bottom of the Aral Sea as a precondition for aeolian removal of saline dust. In: Problems of Desert Development, Allerton Press, Inc., No.2: 29-35.

19) **Mozhaitseva, N.M.** and Nekrasova, T.F. 1984. A method for calculating windborne salt transport from dry Aral Sea bed. In: Problems of Desert Development, Allerton Press, Inc., No.6: 15-21.

20) **Orlova, M.A.** 1979. Wind transport of salts. Soviet Soil Sci., No.4:62-72.

21) **Saskatchewan Minerals.** 1970. History of the Old Wives Lake. Saskatchewan Minerals, Sodium Sulphate Division, Chaplin, Saskatchewan.

22) **Slavnlyi, Yu. A.** and Mel'nilkova, I.B. 1977. Eolian soil salinization. Soviet Soil Sci., vol.223, No.1: 232-234.

23) **Young J.A.** and Evans,R.A. 1986. Erosion and depostion of fine sediments from playas. Journal of Arid Environments 10: 103-115.