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**GLACIAL LOADING AND UNLOADING:
A POSSIBLE CASUE OF SALT DISSOLUTION IN THE
WESTERN CANADA BASIN**

by

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**Glacial loading and unloading:
a possible cause of salt dissolution
in the Western Canada Basin**

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ABSTRACT

Each of the five main bedded Devonian rock salts in the Western Canada Basin has, in places, been more-or-less continuously leached since shortly after deposition. For the most part, salt dissolution has been self-sustaining and relatively slow. At various times however, leaching has been significantly accelerated by large-scale external processes such as regional uplift and erosion during the pre-Cretaceous, and regional deformation (shearing) during the mid-Late Cretaceous. The most recent phase of accelerated salt dissolution occurred during the Quaternary, probably as a result of glacial loading and unloading. The principal evidence in support of an accelerated rate of leaching during the Quaternary is a demonstrable correlation between surface drainage patterns and the active margins of the rock salts.

Accelerated rates of dissolution during the Quaternary are attributed to glacial loading and unloading, and associated processes. Glacial loading induces subsurface compaction and the further expulsion of interstitial water. An increase in geothermal gradient and the thermal expansion of the deep aquifers can result as well. Thus it is conceivable that the rate of centrifugal flow within a basin might increase, and the associated dissolution of salt accentuated.

Glacial unloading can also affect subsurface salts. This rapid decrease in applied load is manifested as glacial rebound, a process which can increase gross porosity and fracture permeability of the subsurface, and decrease geothermal gradient. Consequently, centripetal flow can be enhanced. (It is conceivable that the flow regime might change from centrifugal to centripetal.) An increase in centripetal flow, and an influx of unsaturated glacial melt waters would

enhance the rate of salt dissolution.

INTRODUCTION

There are five main Devonian-age bedded rock salt-bearing formations in the Western Canada Basin: Lotsberg, Cold Lake, Prairie (and equivalents), Cairn and Stettler (Figure 1). Comprehensive regional overviews of one or more of these rock salts have been published by Anderson (1991, 1992b), Anderson and Brown (1992), Belyea (1966), Gorrel and Alderman (1968), Hamilton (1971), Holter (1969), Meijer Drees (1986), Reinson and Wardlaw (1972), Wardlaw and Reinson (1971).

As noted in the literature, there are significant differences between the six main Devonian salts: some are thick (>150 m) - others are thin (<50 m); some are areally extensive - others are areally restricted. In spite of all of the differences, these salts have one common characteristic; each has been extensively dissolved in places (Anderson and Knapp, 1993; Meijer Drees, 1986).

Investigators have studied a number of localized salt-dissolution features in the Western Canada Basin (e.g., Alcock and Benteau, 1976; Anderson 1992a; Anderson and Brown, 1992a,b; Anderson et al. 1988a,b, 1989a,b; Anderson and Franseen, 1991; Anderson and Knapp, 1993; Brown and Anderson, 1991; Brown et al., 1990; Cederwall and Anderson, 1991; Barss, 1970; Bishop, 1974; Christianson, 1971; Gendzwill and Hajnal, 1971; Hopkins, 1987; Hriskevich, 1970; Oliver and Cowper, 1983; Smith and Pullen, 1967. Larger regional-scale studies of salt dissolution have been conducted by Anderson (1991, 1992a) and Anderson and Brown (1993).

Within the literature, it is generally concluded that the five main salts in the Western Canada Basin have, in places, been more-or-less continuously leached since shortly after deposition. For the most part, dissolution has been self-sustaining and relatively slow. At various times however, leaching has been significantly accelerated by large-scale external processes such as regional uplift and erosion during the pre-Cretaceous, and regional deformation (shearing) during the mid-Late Cretaceous (Anderson and Knapp, 1993). The most recent phase of accelerated salt dissolution occurred during the Quaternary, probably as a result of glacial loading and unloading (Anderson and Brown, 1992; Anderson and Knapp, 1993). Support for the thesis of glacially-induced salt dissolution is based principally on: 1) the understanding that surface drainage patterns in the Western Canada Basin area are Holocene in origin; and 2) the observation that lakes and streams in places, are preferentially distributed along the active margins of the bedded Devonian rock salts. The conclusions have been firstly, that significant salt-related surface subsidence occurred in these areas during the Holocene, secondly, that these subsidence features influenced surface drainage patterns, and thirdly, that glacial activity is a probable cause of this latest accelerated phase of dissolution.

ACCELERATED LEACHING DURING THE QUATERNARY

Evidence is presented herein in support the thesis that dissolution of bedded rock salt in the Western Canada Basin was accelerated during the Quaternary. Correlations are established between surface drainage patterns along the active margins of the five main Devonian rock salts and the thickness of residual salt. These correlations indicate that extensive salt dissolution has

occurred during the Holocene.

Surface drainage patterns

In support of our previous interpretations that surficial drainage in the immediate proximity of active salt margins has been influenced by salt dissolution and related surface subsidence during the Quaternary, we have compiled a suite of net-salt thickness maps from four separate study areas. These maps clearly demonstrate that lakes and rivers within the study areas are preferentially located above, along or immediately adjacent to the outer active margins of the residual rock salt (Figures 2 through 8). Our interpretations are predicated on the assumption that the study areas were glaciated and that the present-day drainage patterns developed during the Holocene.

Figure 2 depicts the net thickness of residual Stettler Formation rock salt and drainage patterns in the Stettler area, respectively. In Figure 3, the present-day net thickness of Cairn salt and surficial drainage are superposed on a base map of the Youngstown area. Figure 4 shows the net thickness of the Prairie salt and lakes and rivers in the Lloydminster South area. Similar presentations for the Prairie, Cold Lake and Lotsberg salts in the Lloydminster North area are shown as Figures 5, 6 and 7, respectively.

A common pattern is observed in Figures 2 through 7. In each case, many of the lakes and rivers in the respective study areas are situated along and oriented parallel to the active dissolutional margins of the residual rock salt. In Figure 2, for example, 70% of the lake area (including Buffalo Lake) is situated to the southwest of the Wabamun subcrop edge and in areas where net salt

thicknesses are less than 10 m. An additional 20% is located where in areas where net salt thicknesses range between 10 and 20 m. The observation that 90% of the lake area is distributed adjacent to or along the present-day active outer margin of the Stettler rock salt (comprising 50% of the study area), strongly suggests that significant salt dissolution in this area occurred during the Holocene.

Similar correlations between the active margins of the other main Devonian salts and surface drainage patterns are observed on Figures 3 through 7. As evidenced by Figure 3, all of the major lakes in the Youngstown area are located along or immediately adjacent to the outer active margin of the residual Cairn rock salt. In Figure 4, Jackfish and Murray lakes are located along the active margin of the remnant Prairie salt in the Lloydminster South area. Perhaps of more significance is the observation that the principal fluvial body in the region, the eastward-flowing North Saskatchewan River, is locally diverted to the southeast along an area of extensive leaching. Similar patterns are observed in the Lloydminster North area (Figure 5), where the course of the Monney River and the locations of several lakes including Cold, Marie, Brightsand, Turtle and Stoney can be correlated to net thickness of the residual Prairie salt. The locations of several of the other lakes in the Lloydminster North area (Figures 6 and 7), could similarly be related to the dissolution of the Cold Lake and/or Lotsberg rock salt during Holocene time.

The strong correlation between surface drainage patterns and the active dissolutional margins of the residual Devonian rock salts strongly suggests that significant salt dissolution and related surface subsidence occurred within the respective study areas during the Holocene. The rates of leaching and

subsidence were sufficiently high such that bodies of water meters deep and, in some instances, several kilometers wide developed over a period of some 10,000 years. These are accelerated rates (by at least two orders of magnitude) relative to the average long-term rates suggested by the overall regression of the rock salt units since deposition (Anderson (1991, 1992b), Anderson and Brown (1992b), Anderson and Knapp (1993). The formation of wide but shallow subsidence features in response to leaching is consistent with the observation that along its outer active margin, bedded rock salt is commonly leached in a step-wise manner from the top down and laterally (basinward) along its uppermost remaining soluble layers (Anderson et al., 1994a,b). This process in association with rock salt creep towards the zone of leaching, can result in shallow vertical subsidence over a broad lateral area (Anderson and Brown, 1992).

SUMMARY

Evidence is presented herein in support the thesis that dissolution of bedded rock salt in the Western Canada Basin was accelerated during the Quaternary. Correlations are established between surface drainage patterns along the active margins of the five main Devonian rock salts and the thickness of residual salt. These correlations indicate that extensive salt dissolution has occurred during the Holocene. The most probable cause of this latest phase of accelerated leaching is glacial loading and unloading.

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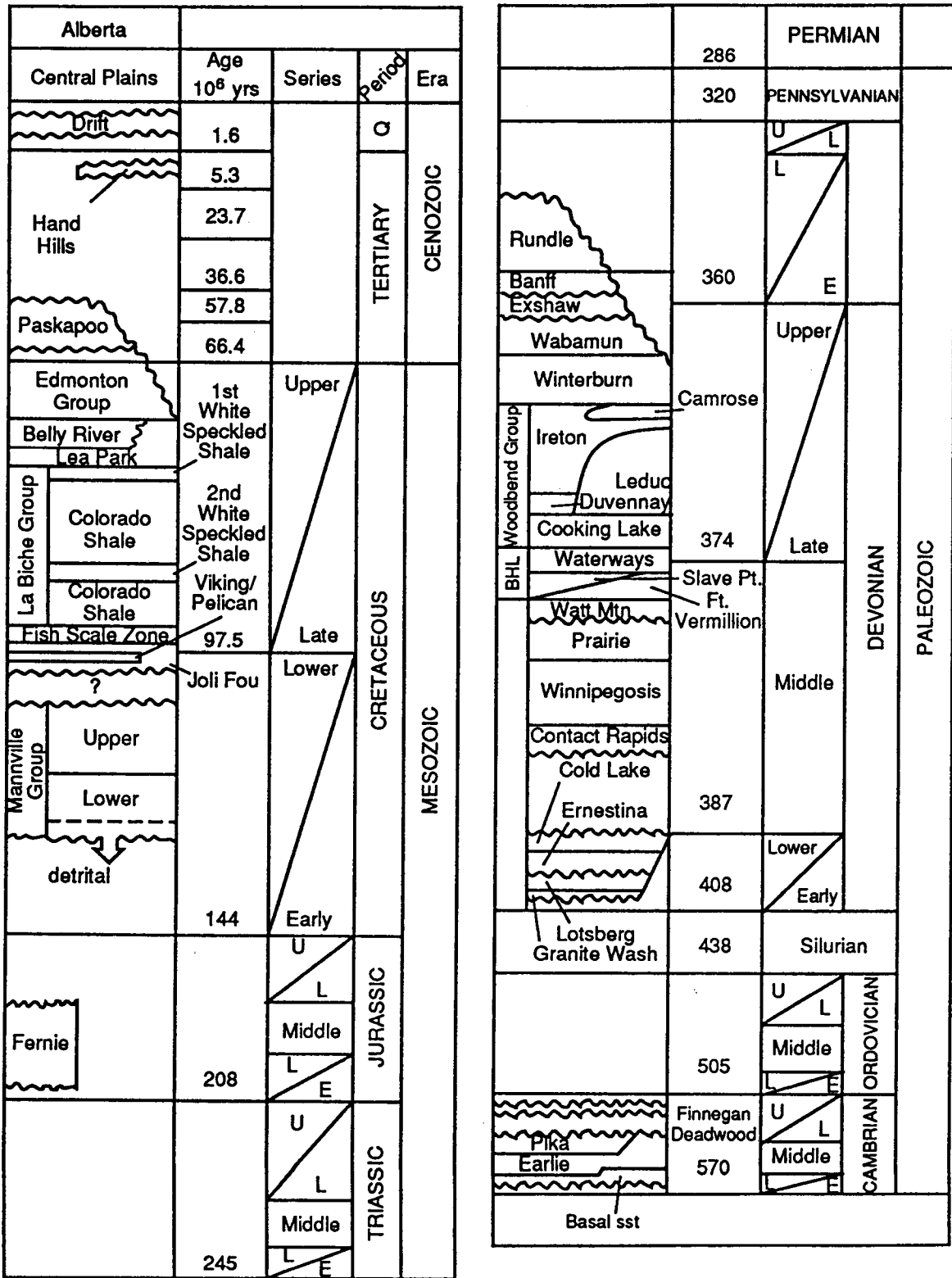


Figure 1. Stratigraphic chart for southcentral Alberta (modified after AGAT Laboratories, 1988). Halites of Devonian age are preserved within several stratigraphic intervals: Elk Point Group (Lotsberg, Cold Lake and Prairie Evaporite formations), Beaverhill Lake Group, Woodbend Group (Leduc Formation equivalent), and Wabamun Group.

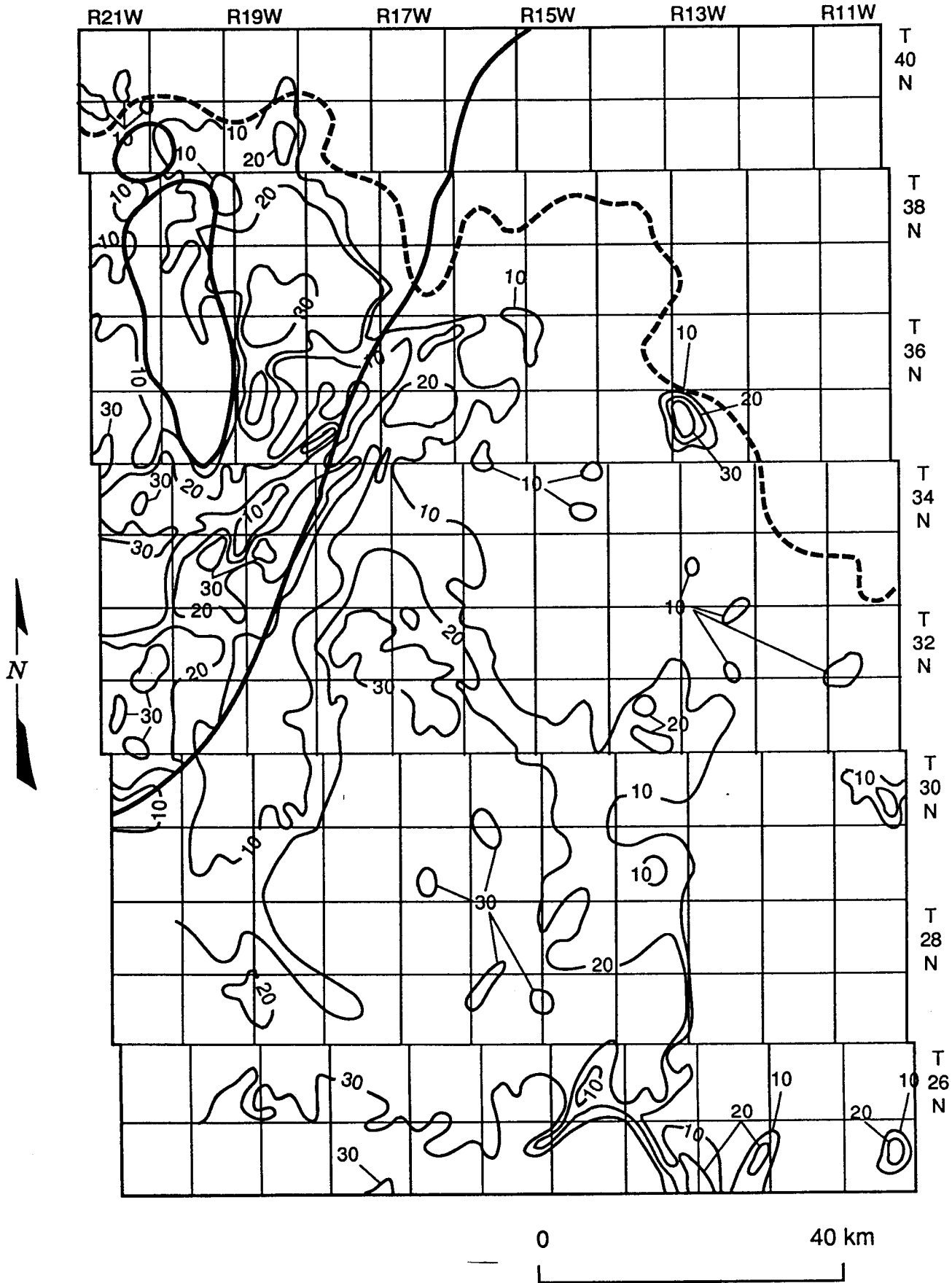


Figure 2. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Stettler Formation (upper Wabamun Group) salts in the Stettler area.

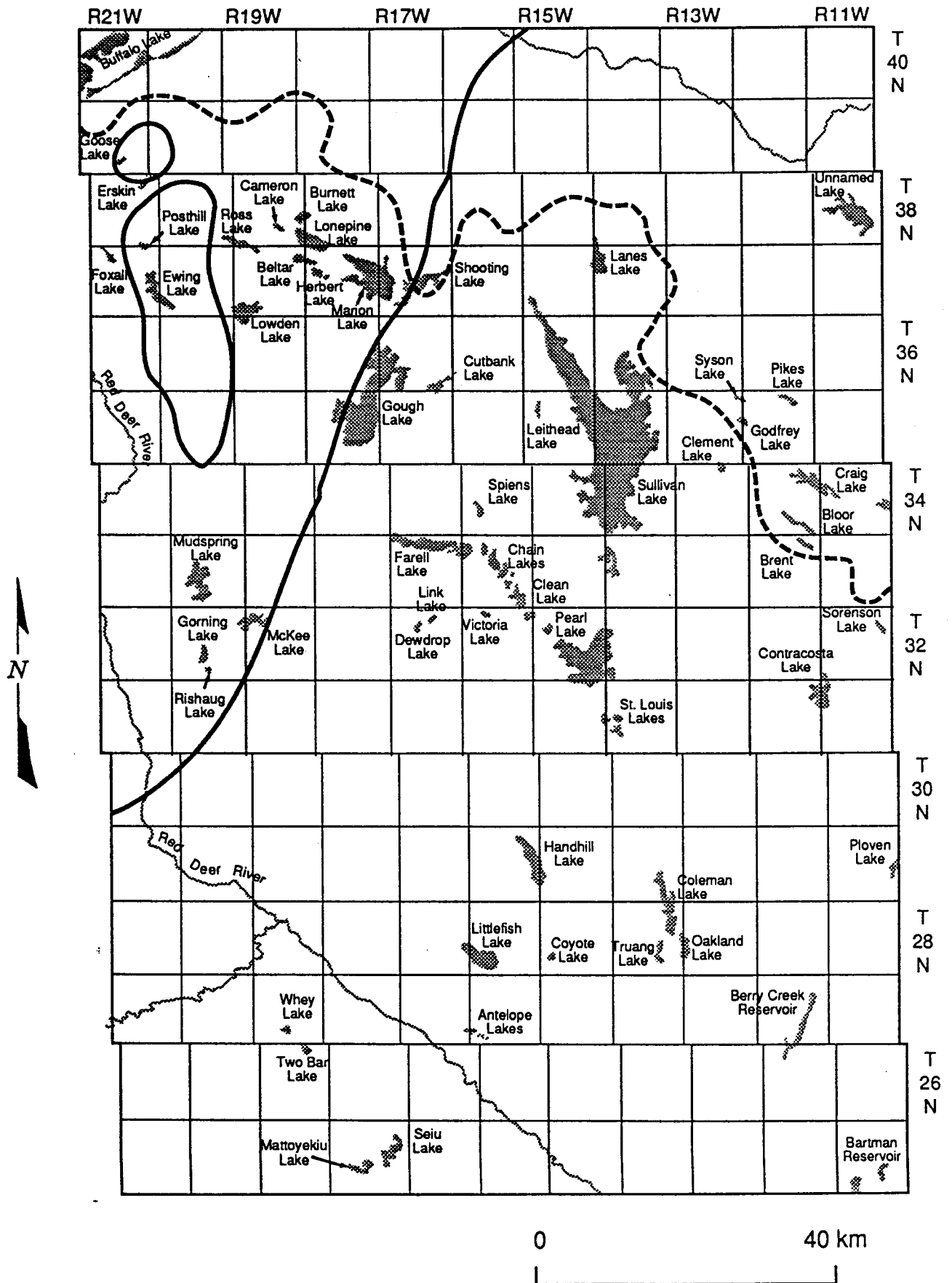


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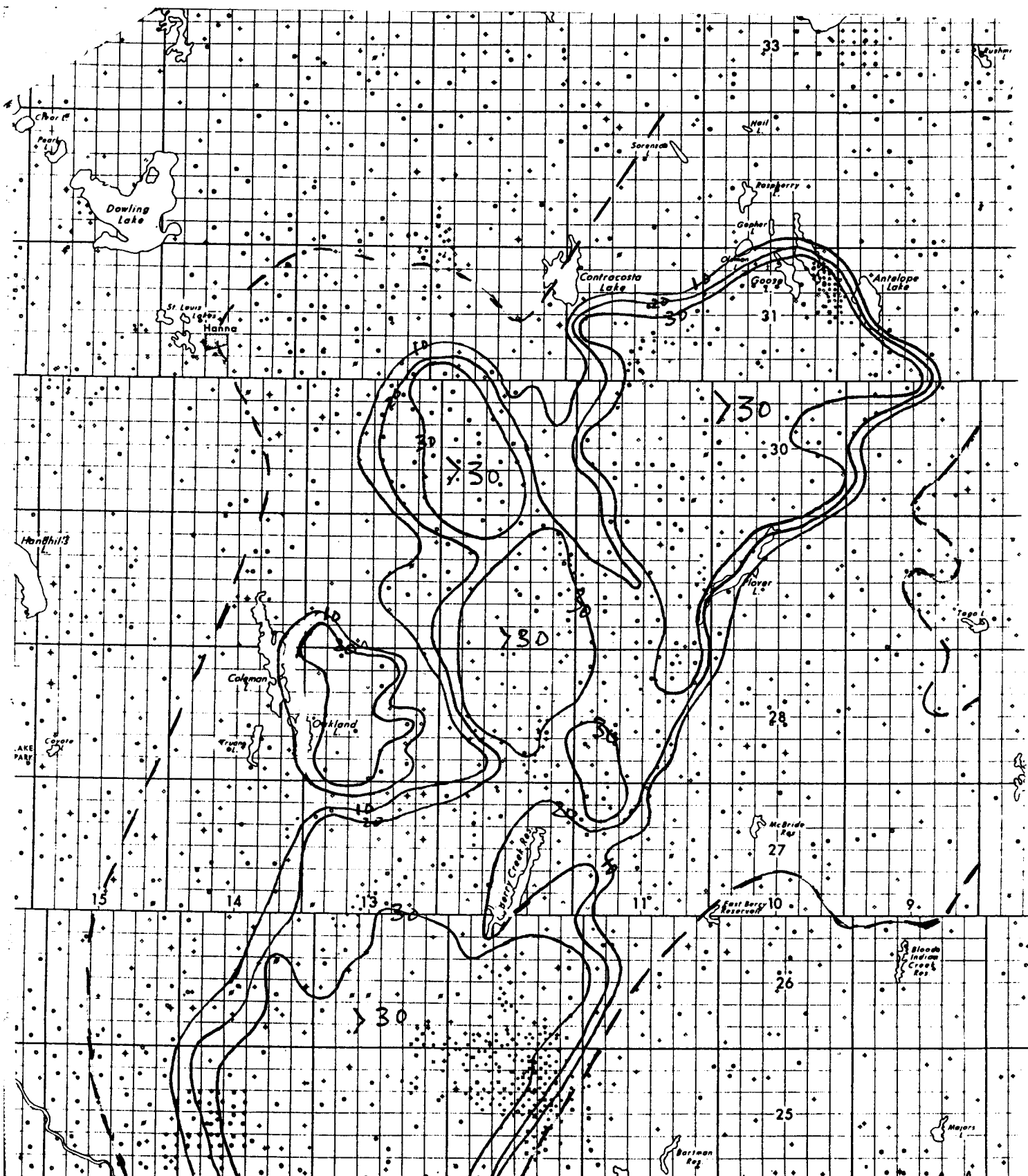
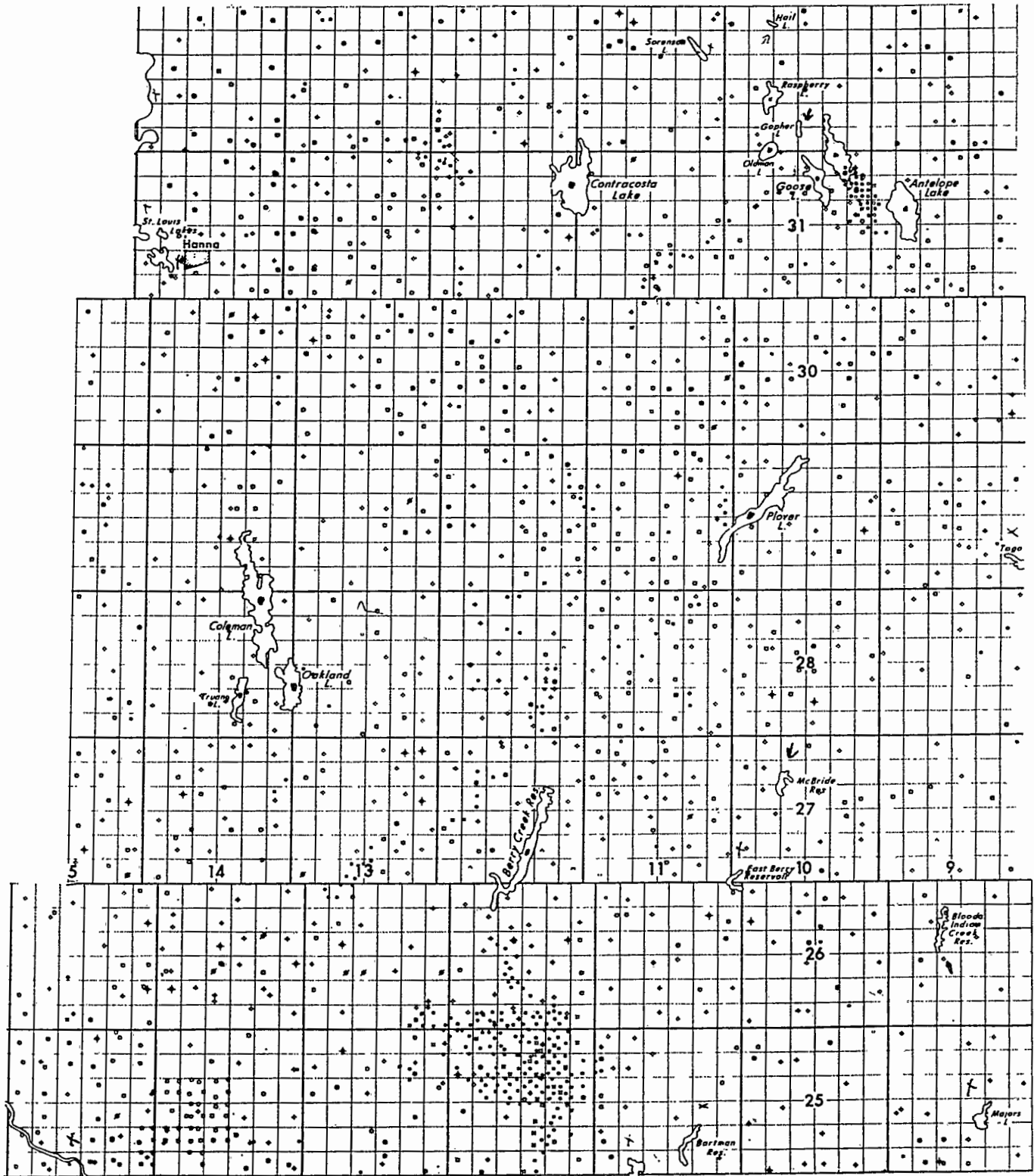


Figure 3. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Cairn Formation (Leduc equivalent) salts in the Youngstown area.



T32

T31

T30

T29

T28

T27

T26

T2

Figure 3. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Cairn Formation (Leduc equivalent) salts in the Youngstown area.

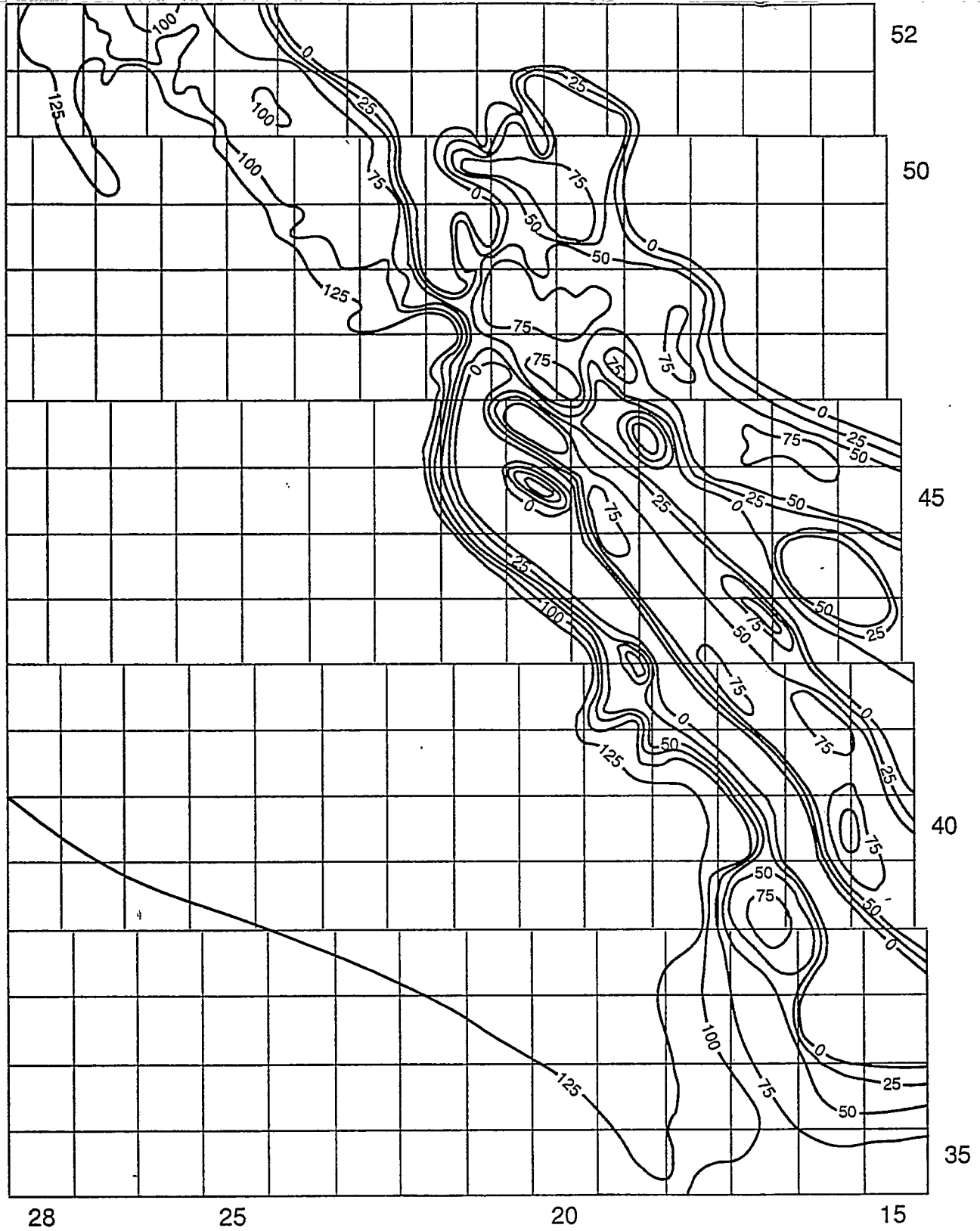


Figure 4. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Prairie Formation salts in the Lloydminster south area.

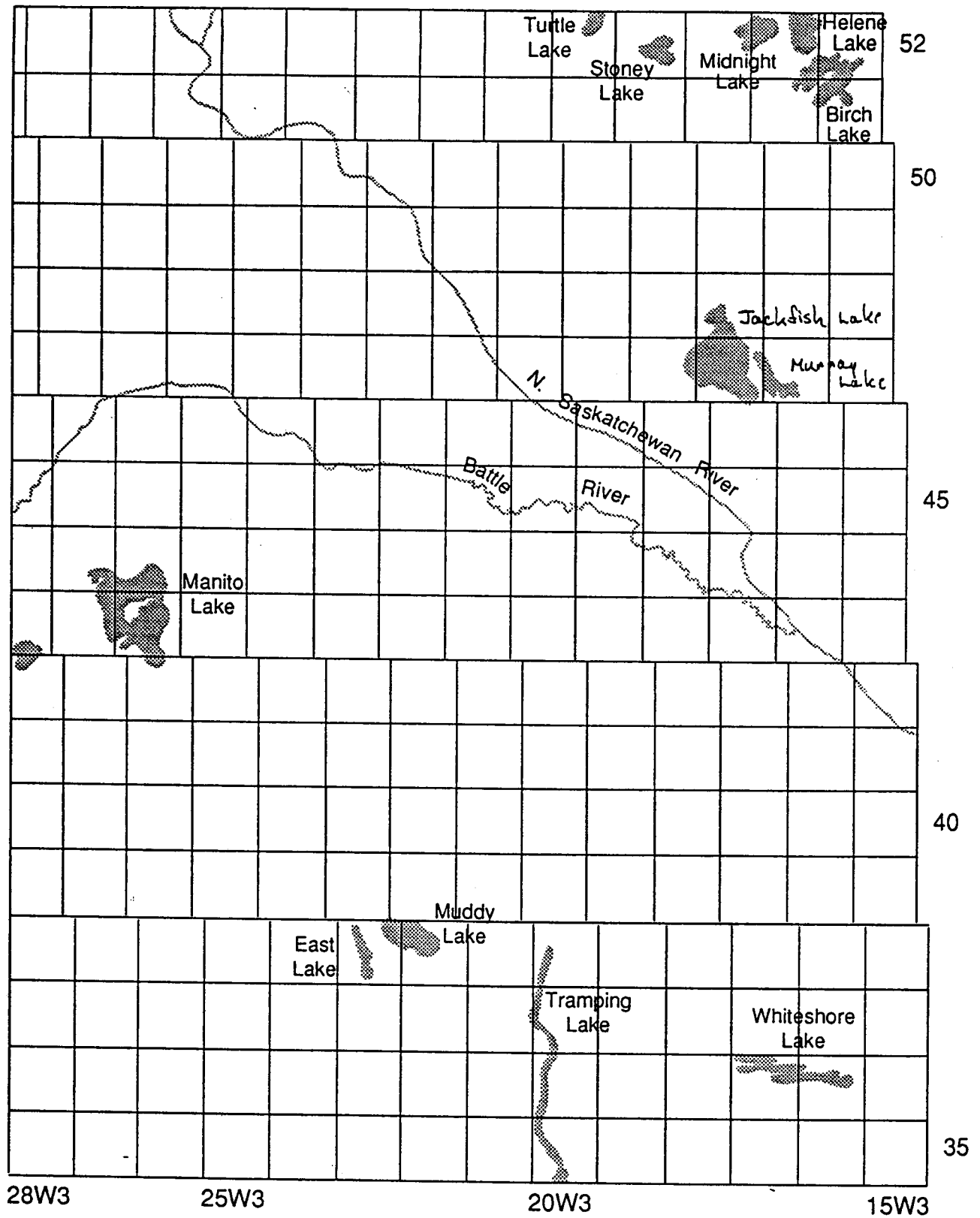


Figure 4. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Prairie Formation salts in the Lloydminster south area.

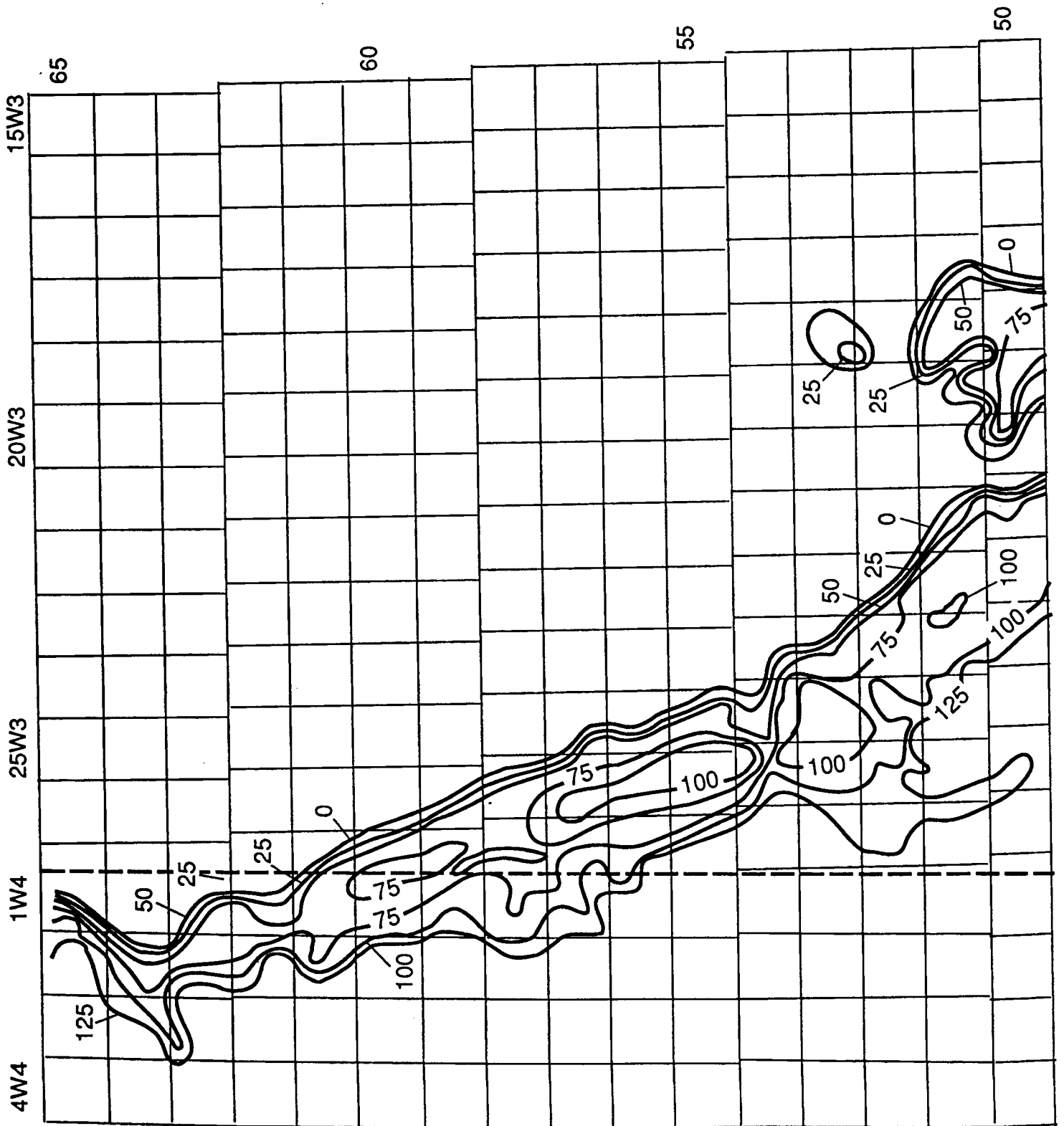


Figure 5. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Prairie Formation salts in the Lloydminster north area.

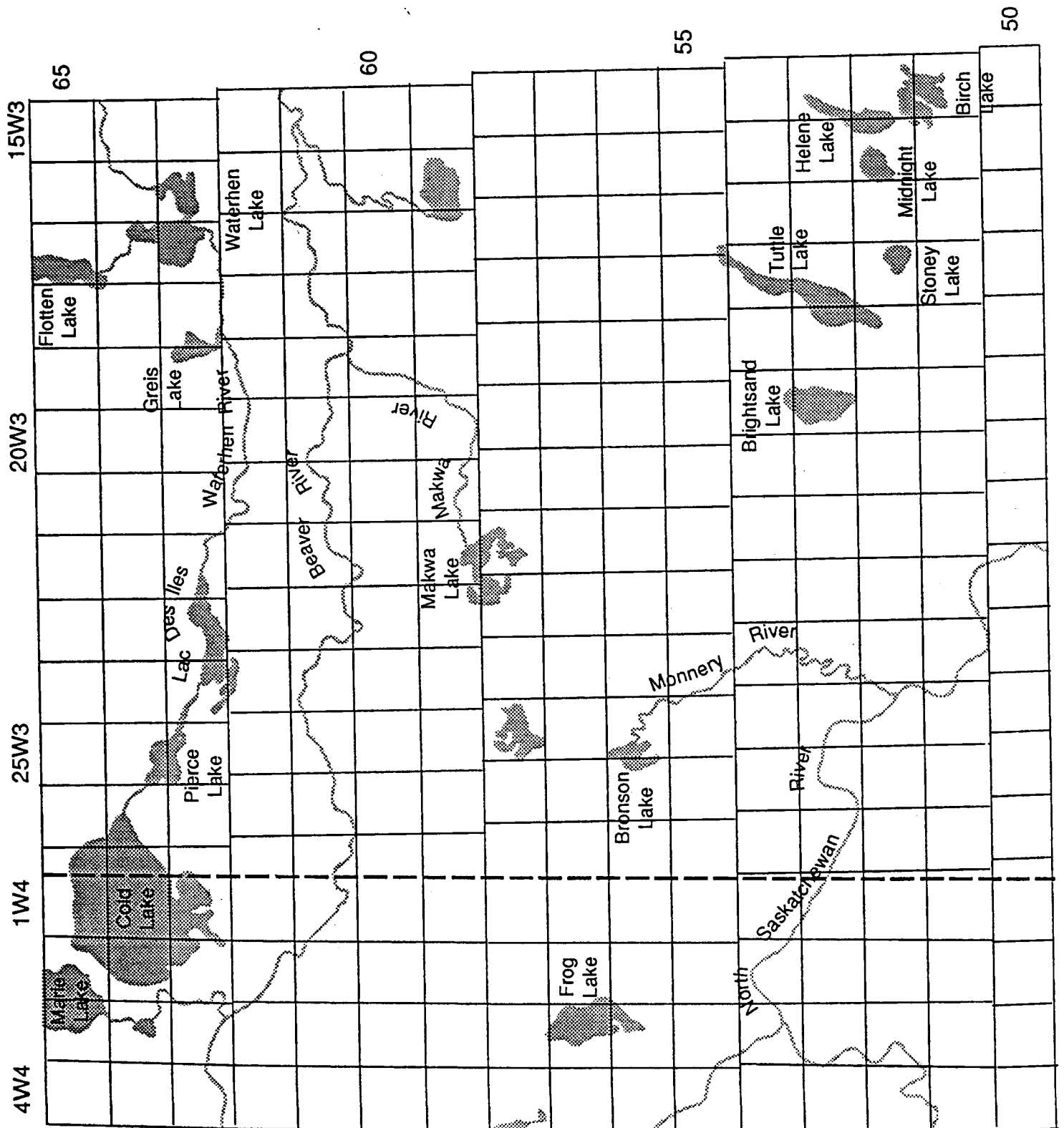


Figure 5. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Prairie Formation salts in the Lloydminster north area.

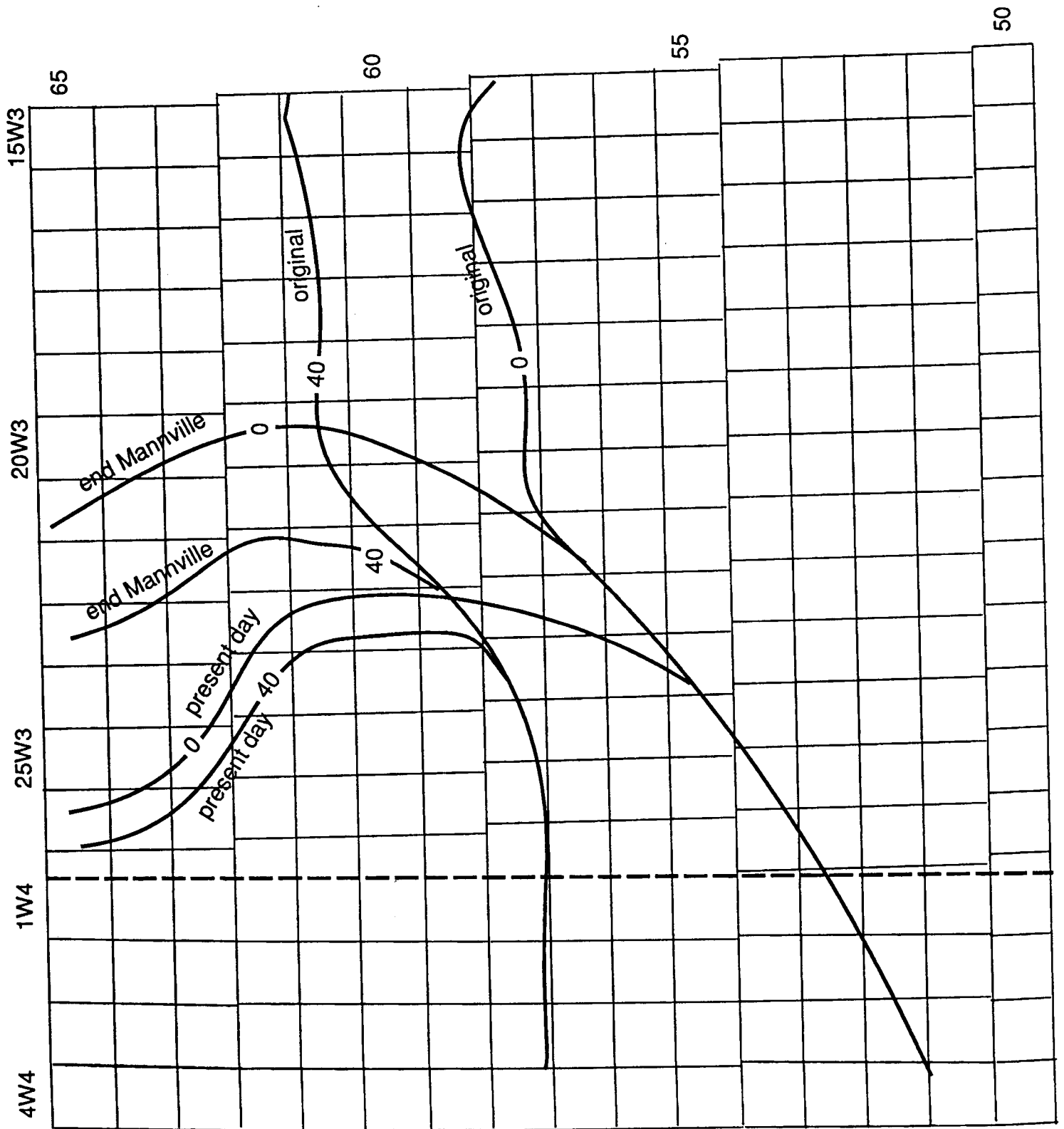


Figure 6. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Cold Lake Formation salts in the Lloydminster north area.

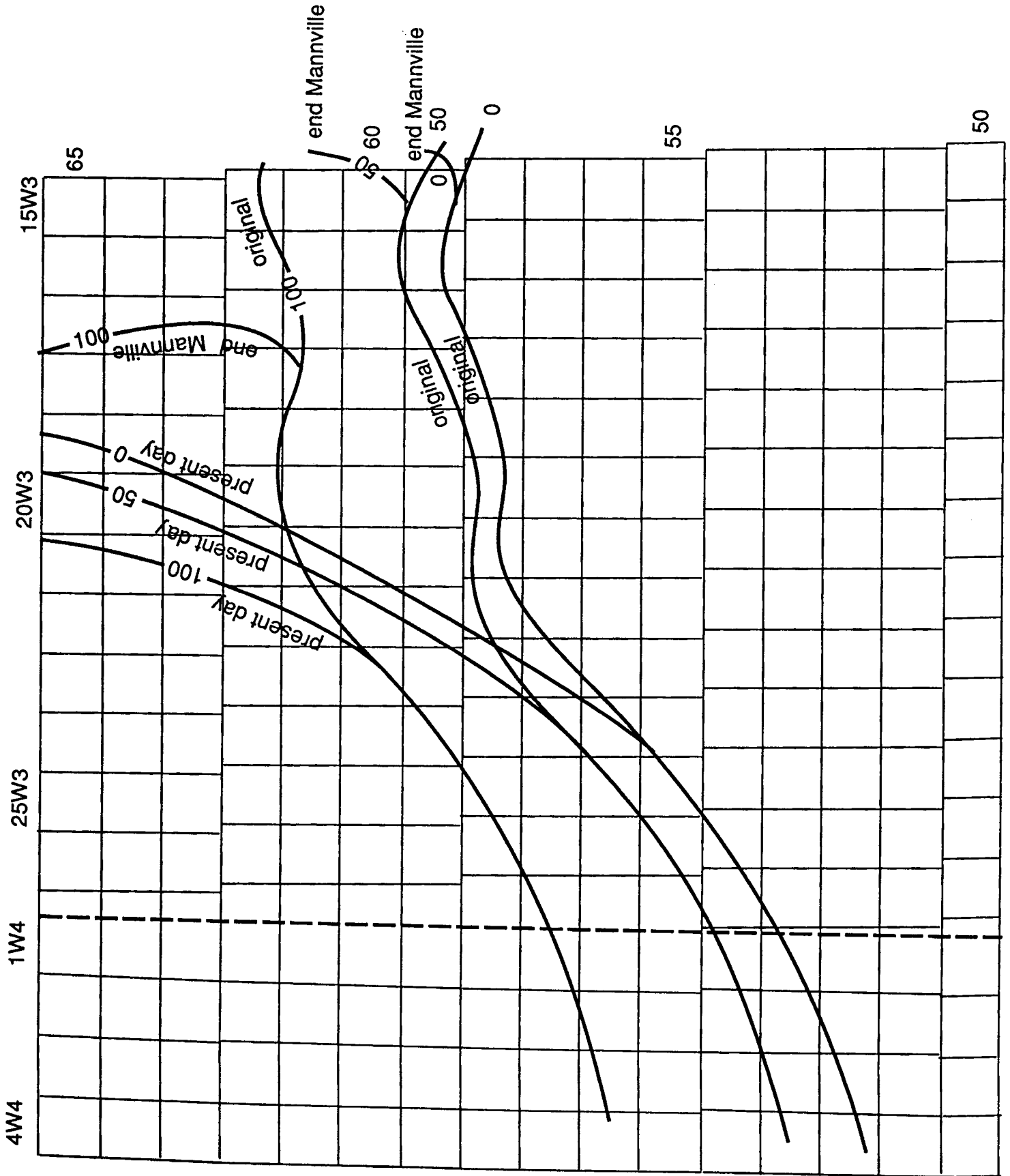


Figure 7. Contour map (m) depicting drainage patterns and our interpretation of the present-day distribution of the Lotsberg Formation salts in the Lloydminster north area.