"HATFIELD VALLEY" AQUIFER SYSTEM IN THE WATERHEN RIVER AREA (73 K), SASKATCHEWAN.

Volume I

(Text and Appendices A to D)

H. Maathuis
B.T. Schreiner
Geology Division
Saskatchewan Research Council

Prepared for Saskatchewan Environment under the Canada-Saskatchewan Interim Subsidiary Agreement on Water Development for Regional Economic Expansion and Drought Proofing.

June, 1982

SRC Publication No. G-744-7-C-82

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1 INTRODUCTION

1.1 Purpose and Scope of Study

The work presented here is the second phase of a three-phase study of the "Hatfield Valley" Aquifer System in the Waterhen River area (73-K). This study was commissioned by the Saskatchewan Department of the Environment (Contract #97-80/81) under the Canada-Saskatchewan Interim Subsidiary Agreement on Water Development for Regional Economic Expansion and Drought Proofing.

The aim of this study is a definition of the aquifers and an evaluation of the quantity and quality of the groundwater resources in this buried valley aquifer system.

This report presents, explains, and illustrates the work carried out under Phase II which includes:

- Preparation of the field work program;
- supervision of approximately 4,878 m (16,000 ft) of test-drilling and E-logging;
- collection and analysis of water samples;
- supervision of piezometer installations;
- presentation and interpretation of data collected in the form of maps and cross-sections, including a preliminary evaluation of the aquifer system in terms of quantity and quality of groundwater, and
- preparation of a cost estimate for formal printing of the present report.

1.2 Location of Study Area

The study area is located between 54° and 55° latitude and 108° and 110° longitude and covers an area of approximately 14,385 km^2 (Figure 1). This area corresponds to the NTS map sheet Waterhen River (73-K).

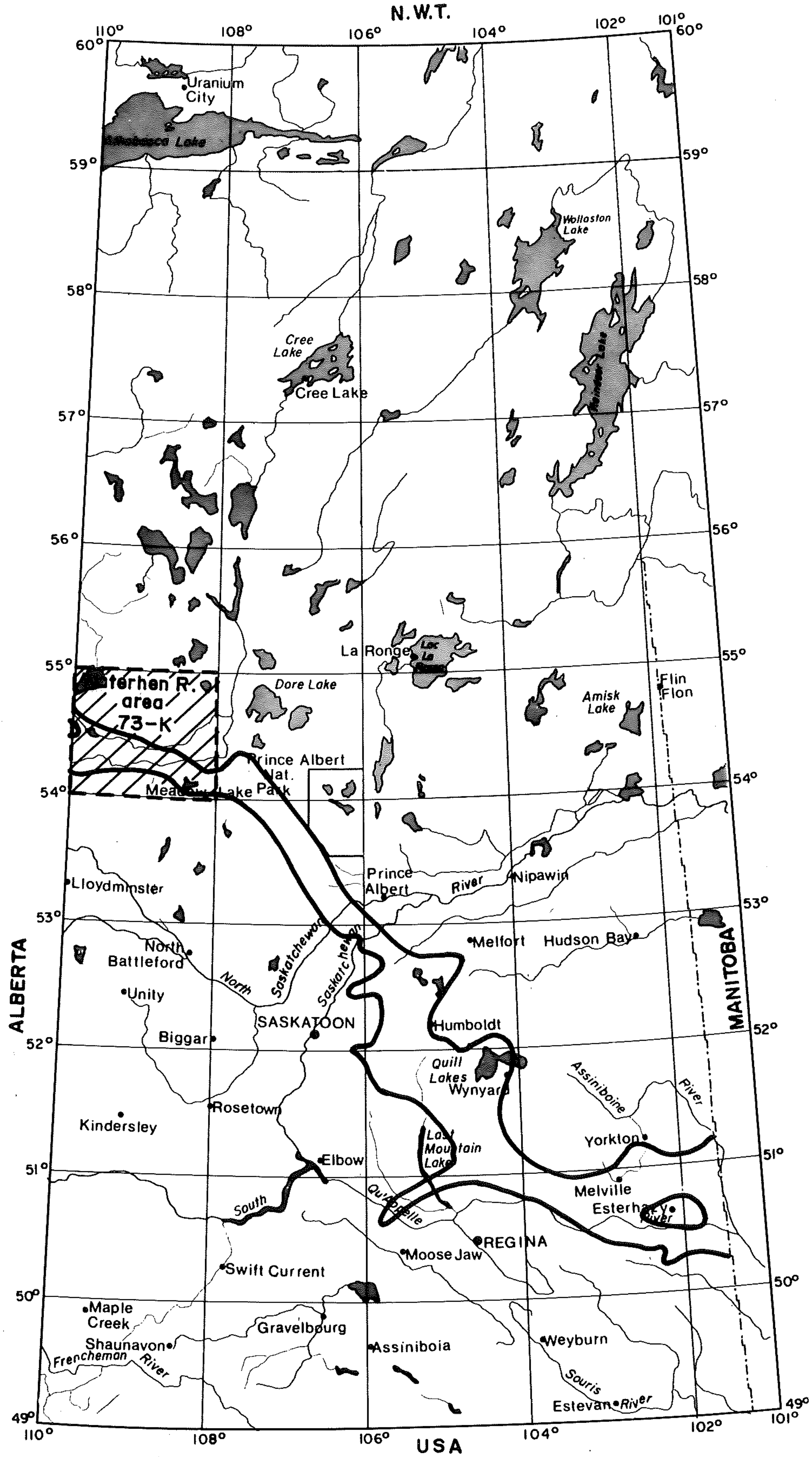


Fig. I Location map of study area and Hatfield Valley Aquifer system.

1.3 Data Collection

1.3.1 Existing Data

Data collected include testhole and augerhole logs from the Saskatchewan Research Council, drill hole information from the Family Farm Improvement Branch and oil company logs. Other logs such as water well records have not been used because of the lack of electric logs which make these data incompatible with other logs.

Geohydrological data compiled include information on water quality, water levels, flowing wells, hydraulic properties, and groundwater allocations.

1.3.2 Fieldwork

During the period July 13 - August 27, 1981, a total of 35 testholes were drilled under contract to Hayter Drilling, Ltd., Watrous, Saskatchewan.

Samples from testholes were taken at an interval of about 1.5 m (5 ft), dried, and their lithological characteristics were described. Selected till samples were analyzed for carbonate content, and grain-size analysis were carried out on selected sand samples.

Based on the experience gained in the Wynyard (Maathuis and Schreiner, 1982) and the Melville area (Schreiner and Maathuis, 1982), the side hole core sampler was not used in this study area. Two permanent piezometers were installed at the site of testholes SRC Matchee 81 and SRC Johnston Lake. At the site of SRC Dorintosh 81-1 a piezometer was installed; however, it appeared to be defective and was abandoned. Temporary piezometers were installed in testholes SRC Four Corners 81 and SRC Dorintosh 81-3 to collect water samples. During the drilling program, flowing conditions were encountered at testholes SRC Mudie Lake and SRC Meadow Lake 81-1. Testhole logs, piezometer completion data, and flowing testhole data are included in Appendix E. Water quality data are included in Appendix F.

1.4 Data Presentation

A total of 12 cross-sections (A'A' to L-L') have been prepared showing the geometry and geological setting of the buried valley aquifer system in the Waterhen River area. The carbonate contents of till units are plotted as graphs on the testhole logs which are included on the cross-sections. A map has been prepared with bedrock surface elevations and contours, as well as the distribution of the units outcropping at the bedrock surface (Map A). A second map shows the distribution of the aquifer sediments, their depth and thickness, as well as reported water levels and available drawdown (Map B). The location of the testholes and piezometers drilled under this program are also shown on these maps.

Water quality data are presented in the form of water quality data bars on the cross-sections and in table form. Cross-sections and maps are included in Appendix A. Results of grain-size analyses are listed in tables in Appendix C along with calculated hydraulic conductivity values based on these analyses.

1.5 Acknowledgements

The cooperation and interest of the Rural Municipalitites and farmers within the study area are gratefully acknowledged. Officials of the Meadow Lake Provincial Park are thanked for their permission to drill in the Park and their assistance in locating testhole sites.

Mr. Harm Maathuis (SRC) compiled and interpreted the hydrologic information in this study. He also supervised the test drilling, piezometer

installation, and sample collection and analyses as well as all other field components at this investigation. Mr. Bryan Schreiner (SRC) assisted with the interpretation of the geologic information.

Testholes were drilled by Messrs. G. Gray, C. Higgins, and D. Schnell, of Hayter Drilling Ltd., Watrous, Saskatchewan.

Mr. D. Zlipko (SRC), Geology Division, assisted the author throughout the drilling program. Mr. E.J. Jaworski (SRC), Geology Division, provided additional assistance when needed.

Dr. R.G, Arnold (SRC), Head, Geology Division, read the manuscript.

By special request, Mr. H. Martin, Family Farm Improvement Branch (FFIB), Regina, prepared FFIB logs for the study area and attended the drilling of several testholes.

Carbonate analyses of tills were done by Mr. W.C. Ross and Ms. T. McKay, SRC Sedimentary Laboratory. Water samples were analyzed according to standard methods by the SRC, Chemical Laboratory.

Mrs. J. Rackel compiled all the testhole logs, and together with Mr. D. Zlipko, compiled, edited, and processed all the water quality data. Drafting was done by the Graphics Section, SRC.

2. PHYSIOGRAPHY

2.1 Topography

The study area can be subdivided into the following major physiographic divisions (Figure 2): Thickwood Hills Upland, Mostoos Hills Upland, and Beaver River Plain.

The topographic elevation in the Thickwood Hills Upland within the study area ranges from 520 to 655 m ASL. Elevations between 550 and 730 m ASL are characteristic for the Mostoos Hills Upland area. Its southern boundary is formed by a dissected escarpment. In the Beaver River Plain, elevations range from 460 to 530 m ASL.

2.2 Surface Drainage

The Beaver and Waterhen Rivers are the major rivers within the study area. The Beaver River originates in Alberta and flows through the study area in an easterly direction. Outside the area, the river changes course to a northerly direction and discharges into the Churchill River system. Originating in Cold Lake, the course of the Waterhen River is frequently interrupted by lakes, such as Lac des Isles and Waterhen Lake. This river also flows in an easterly direction and is confluent with the Beaver River outside the study area.

2.3 Climate

Pertinent climatological data are not available for the study area. However, it is assumed that the area has a Dfc type of climate which is of the Boreal type (Bergsteinsson, 1976). In this type of climate, the wettest month may have less than tenfold more precipitation than the driest month and has a cool summer with one to three months with mean temperatures above 10°C. Precipitation data for Meadow Lake, during the

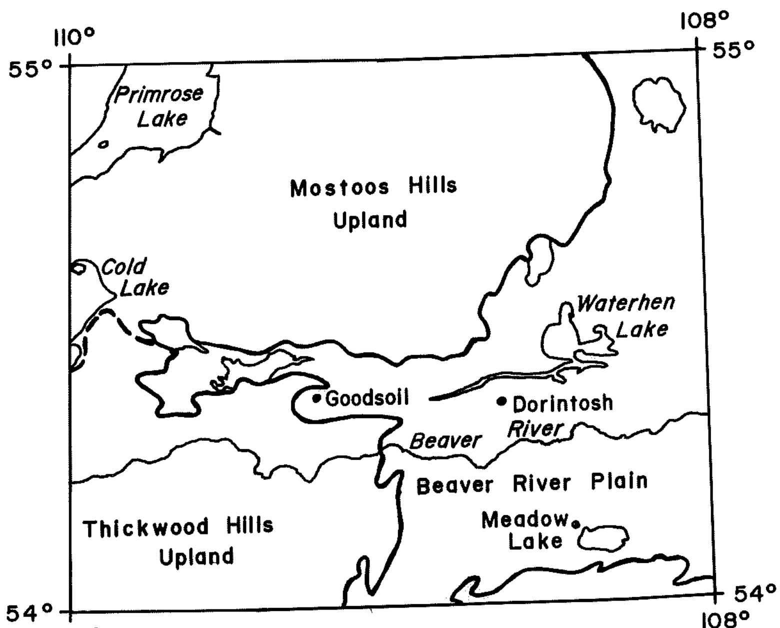


Fig.2 Physiographic divisions of Waterhen area (after Acton et al., 1960)

period 1968-1978, indicates a mean annual precipitation of 468 mm within a range of 355 to 693 mm (Environment Canada, 1968-1978).

3 GEOLOGY

3.1 Introduction

The Cretaceous bedrock stratigraphy, in ascending order, includes the Mannville Group, Lower Colorado Group, Lea Park Formation and Upper Colorado Group, and an unnamed Tertiary-Quaternary unit. The distribution of bedrock units is shown in the cross-sections and on Map A. The glacial geology consists of a sequence of stratigraphic units which, in ascending order, may include the Empress, the Sutherland and Saskatoon Groups, and Surficial Stratified Drift. Within the framework of this present study only the Empress Group has been delineated. The extent of the Empress Group is indicated in the cross sections, and on Map B.

The geology in the study area is discussed by Christiansen and Whitaker (1974) and Christiansen _et al_. (1975). The history of final deglaciation of the area is described by Christiansen (1979).

3.2 Bedrock Stratigraphy

3.2.1 Mannville Group

The Mannville Group consists of interbedded, fine- and very fine-grained sand, and gray non-calcareous silt. This unit may reach a thickness of 180 m and occurs at depth throughout the study area. It does not outcrop at the bedrock surface and is only shown in a limited number of cross-sections due to insufficient data.

3.2.2 Lower Colorado Group

The Lower Colorado Group is up to 120 m thick and is composed of non-calcareous silt and clay. It forms the bedrock surface in the eastern portion of the study area where it includes a sandy to very sandy non-calcareous silt unit (cross-section L-L', log 69).

3.2.3 Lea Park Formation and Upper Colorado Group

Because the Lea Park Formation cannot be separated from the Upper Colorado Group on electric logs, the two units are combined. The Lea Park Formation and Upper Colorado Group are composed of 0 - 200 m of thick gray silt and clay. The upper portion of this unit is non-calcareous. The lower portion includes the First and Second White Speckled shale. The Second White Speckled shale can be easily defined on electric logs and the base of this shale was used to separate it from the underlying Lower Colorado Group.

The Lea Park Formation and Upper Colorado Group forms the major portion of the bedrock surface in the study area. In the Beaver River Valley, this unit is locally exposed where fluvial erosion removed the cover of glacial sediments (cross-section D-D', log 70).

3.2.4 Tertiary-Quaternary Unit

In the Loon Lake area about 30 m of Tertiary-Quaternary material forms the bedrock surface. This unit consists of 0 - 24 m of non-calcareous, yellow, brown, and light gray silt, which is sandy at the top and clayey at the base. The lower portion of this unit is composed of 0-6 m of fine-to-medium-grained sand.

Although these sediments were only found near Loon Lake, they undoubtedly occur in other parts of the area, but at the present time information is insufficient to delineate other occurrences.

3.3 Bedrock Surface Topography

3.3.1 Introduction

In the present investigation, the most recent 1:50,000 topographic maps were used to determine testhole locations and elevations. These maps generally have 25 ft contour intervals. These maps locally show a more detailed interpretation of the topography than the older maps which have 50 ft contour intervals. This necessitated a complete review of the topographic elevations of the testholes and, consequently, a reinterpretation of the bedrock surface elevations.

The elevations of SRC and FFIB testhole locations have been estimated from topographic maps. Elevations of oil company testhole sites were found to differ from those interpolated from the recent 1:50,000 topographic maps. Consequently, the bedrock surface elevation at each oil log testhole site was ascertained by estimating the topographic elevation from the maps, adding 10 ft, assuming that the kelly bar is that height above ground level, and subtracting the depth to bedrock taken from the log.

3.3.2 Bedrock surface topography

The bedrock surface topography (Map A) has been modified by fluvial and glacial erosion. A dominant feature on the bedrock surface is a west-east trending valley which, in the eastern part of the study area, splits into a southern and northern branch. This valley is believed to have formed prior to the first glaciation of the area. Due to lack of information it remains unclear, however, whether the northern branch existed prior to glaciation or was formed or re-shaped by glacial erosion during the initial advance of the glacier.

The Bronson Lake Valley, which occurs in the southwestern part of the area, is cut into bedrock and is believed to have been formed by fluvio-glacial erosion (Christiansen et al., 1975). A large depression, attributed to glacial erosion, occurs north of Dorintosh.

3.4 Glacial Geology

3.4.1 Empress Group

The Empress Group is composed of sand, gravel, silt, and clay of fluvial, lacustrine, and colluvial origin that overlies marine Cretaceous and non-marine Tertiary bedrock and underlies till of Quaternary age in southern Saskatchewan. Minor constituents include "till balls", wood, coal, and organic-rich silts and clays (Whitaker and Christiansen, 1972). In the study area, the Empress Group is the primary fill in the bedrock valleys.

The sediments may range in thickness from 6 to 60 m and mainly consist of fine- to coarse-grained sands with local gravel layers and rocks. These sands are generally unoxidized, and grayish in color, but have a greenish appearance, particularly in the central portion of the valley. Interbedded silts occur, in minor amounts, throughout the Empress Group deposits. East of Meadow Lake, the deposits tend to become finer-grained and more silty.

3.4.2 Basal Sand and Gravel Unit

Throughout the study area, oil logs indicate the presence of a basal sand and gravel unit. However, based on the E-log alone, it cannot be determined whether this unit is the Empress Group or a stratified glacial deposit, as no lithological description is available for these logs. Only if other logs, such as SRC and FFIB logs, are available in the vicinity, can a more definite interpretation be made. Therefore, in the area outside the "Hatfield Valley", this basal and gravel unit has been delineated only where it is in contact with the Empress group and where it has a significant continuity.

3.4.3 Drift

Based on carbonate content, electric resistance, and lithologic parameters, stratigraphic units such as the Sutherland and Saskatoon Groups, along with subdivisions such as the Floral and Battleford Formations as described by Christiansen (1968), are evident in a number of cross-sections. Locally stratified gravel, sands, and silts are found between till units in drift. These deposits commonly form intertill aquifers. However, within the framework of the present study, no attempt has been made to subdivide the glacial deposits and delineate the intertill aquifers. Primarily, correlation of drift units was restricted to basal till units, which separate the glacial deposits from the Empress Group materials. The relationship of these deposits determine the surface configuration and thickness of the Empress Group materials.

On the cross-sections, the glacial deposits are referred to as undifferentiated drift. The thickness of the drift may range from 0 to 250 metres.

3.5 Postglacial Deposits

During the final deglaciation of the study area, Glacial Meadow Lake was formed, and into it both the Beaver and Waterhen Rivers flowed (Christiansen et al., 1975: Christiansen, 1979). Sand and gravel deltas were formed, and silts, and clays were deposited in the lake. These lacustrine sediments form the major postglacial deposit in the Meadow Lake area.

4. GEOHYDROLOGY

4.1 Introduction

The geohydrological setting of the study area is derived from the geological setting and is illustrated in a general way in Figure 3. An explanation of the geohydrological terms used in the text is provided in Appendix D.

The extent of the buried valley aquifer system in the Waterhen River area is shown on Map B and in the cross-sections. Also shown on Map B are the depth to the aquifer, the point thickness, the water level, and the available drawdown. Water quality data are shown as water quality bars on the cross-sections and in Table 1.

4.2 Origin of Bedrock Valley

The major bedrock valley in the study area is known in the literature as the Hatfield Valley and the aquifer formed by permeable sediments in the valley as the Hatfield Valley Aquifer (Meneley, 1972; Whitaker and Christiansen, 1974; Christiansen et al., 1975). However, the origin of this Valley may be more complex and different than previously assumed.

Christiansen et al. (1975) suggest that the bedrock valley was formed by fluvial erosion during the first continental glaciation and trended eastward from Cold Lake to Meadow Lake and continued further eastward. This valley drained the entire area between the Mostoos and Thickwood Hills uplands.

Prest (1970, Figure XII-9) infers a preglacial drainage path which passes through this area from the west and which flowed into the Churchill River system. Recently it has been suggested that this valley may be part of the preglacial Athabasca River System (C. Gold, personal communication, 1981).

STRATIGRAPHY	LITHOLOGY	GEOHYDROLOGY CLASSIFICATION	GENERALIZED GEOHYDROLOGY SETTING AND AQUIFER NAMES
POSTGLACIAL	LACUSTRINE: SAND, SILT AND CLAY	SEMI-CONFINING LAYER	SEMI-CONFINING LAYER
DRIFT UNDIFFERENTIATED	GLACIAL TILL	SEMI-CONFINING LAYER	
	STRATIFIED SAND, SILT AND GRAVEL	AQUIFER	UNNAMED INTERTILL AQUIFER
	GLACIAL TILL	SEMI-CONFINING LAYER	SEMI-CONFINING LAYER
	BASAL SAND GRAVEL AND SILT	AQUIFER	UNNAMED BASAL AQUIFER
EMPRESS GROUP	SAND, SILT AND GRAVEL	AQUIFER	HATFIELD VALLEY AQUIFER
TERTIARY-QUATERNARY UNIT	SILT AND CLAY	SEMI-CONFINING LAYER	"CONFINING" LAYER
	SAND AND GRAVEL	AQUIFER	
LEA PARK FORMATION AND UPPER COLORADO GROUP	CLAY AND SILT	SEMI-CONFINING LAYER	
LOWER COLORADO GROUP	CLAY AND SILT	SEMI-CONFINING LAYER	
MANNVILLE GROUP	SAND AND SILT	AQUIFER	MANNVILLE GROUP AQUIFER

NOTE: ⟶ INDICATES HYDRAULIC CONNECTION BETWEEN AQUIFERS

FIG. 3 GENERALIZED GEOHYDROLOGICAL SETTING IN STUDY AREA

It is of interest that both the preglacial hypotheses assume that flow through the valley was from west to east. Flow in the main Hatfield Valley, however, is assumed to be from the southeast to the northwest (Christiansen et al., 1977). In addition, the size of the valley in the Waterhen River area appears to be significantly smaller than the size of the Hatfield Valley elsewhere in the Province (Schreiner and Maathuis, 1982; Maathuis and Schreiner, 1982).

These observations suggest that the bedrock valley in the study area may not be the main Hatfield Valley but could be a branch or tributary of the main valley. Recently, a wide valley has been discovered in northern Alberta (Twp 71-74, Rgs 4-9, W 4); however, its continuation into Saskatchewan and its relation to the main Hatfield Valley remains unclear (C. Gold, personal communication, Dec. 1981). This is primarily due to the lack of testhole information in the northern half of the Waterhen River map sheet area and north of it.

If this newly discovered valley in Alberta is actually the continuation of the Hatfield Valley, it suggests that the main Hatfield Valley passes through the northeast part of the Waterhen River Area, or near it. This connection could be confirmed through test drilling; however, poor access limits test drilling in the area.

Since the location of the main Hatfield Valley is unconfirmed, the known bedrock valley identified in the study area and its fill are referred to as the "Hatfield Valley" Aquifer, respectively. These names are retained since they have been used previously, but are put in parentheses here to indicate the ambiguity concerning the actual relationship of the valley to the main Hatfield Valley.

4.3 "Hatfield Valley" Aquifer System

4.3.1 Definition

The "Hatfield Valley" Aquifer is defined as constituting the Empress Group deposits within the boundaries of the "Hatfield Valley". In addition to the Empress Group sediments, locally the aquifer may also include glacial sediments where they are in direct contact and form one geohydrological unit with the Empress Group (cross-section A-A', log 17).

Because of its complex interactions with surface water bodies, intertill aquifers, and possibly with an unnamed basal sand and gravel aquifer, the geohydrological units are referred to as the "Hatfield Valley" Aquifer System. At the present time, there is no justification to formally name the identified basal sand and gravel aquifer as these sediments cannot be uniquely defined.

4.3.2 Geohydrological Setting

The "Hatfield Valley" Aquifer in the study area covers an area of approximately 1,940 km^2. The aquifer thickness may range from 6 to 60 m but along the centre of the valley is typically in the 30 to 45 m range (cross-section A-A'). The semi-confining layer overlying the aquifer may range in thickness from 45 to 165 m, but characteristically is 60 to 90 m thick.

Northwest of Rapid View, it is likely that the aquifer is hydraulically connected to the unnamed basal sand and gravel aquifer, but the nature of this connection remains unclear.

The "Hatfield Valley" Aquifer is underlain by a semi-confining layer of clay and at greater depth by the Mannville Group Aquifer.

4.3.3 Groundwater Flow Systems

Assessment of the groundwater flow systems in the "Hatfield Valley" Aquifer System is complicated by the presence of surface water bodies and the general absence of reliable water level data.

Cold Lake may be directly connected to the aquifer (E.A. Christiansen: personal communication). However, the nature of this connection remains unknown; in particular because the aquifer setting appears to be complex and variable in this area.

A piezometer (cross-section F-F', log 9) was completed in the "Hatfield Valley" Aquifer north of Lac des Isles to investigate the relationship between the lake level and the hydraulic head in the aquifer. A water level survey carried out in July 1982 indicated that the water level in the piezometer was about 1.5 metres above the Lac des Iles level. Consequently, the aquifer north of the lake discharges into the lake.

In the area of the "Hatfield Valley" Aquifer north of the Waterhen River, the aquifer is replenished by recharge from precipitation, which moves vertically downward into the aquifer. Flow in the aquifer itself is lateral toward the Waterhen River Valley.

The Waterhen River Valley was formed during the final deglaciation and was deeply cut into the underlying deposits and locally into the "Hatfield Valley" Aquifer (cross-section J-J^1, log 10). Subsequently, the Waterhen River Valley was filled with up to 75 m of sand and silt.

Because of this setting, not only the aquifer north but also south of the River discharges into the Waterhen River Valley. However, hydraulic head data in the Dorintosh - Meadow Lake area indicate a longitudinal flow towards Meadow Lake. This implies that somehwere south of the Waterhen River, a groundwater divide occurs. The location of this divide cannot be further indicated as insufficient hydraulic head data are available in the area between the River and south of Dorintosh.

The Beaver River, formed during the final deglaciation, was not cut as deeply into the underlying deposits and, therefore, acts less as a drain for the aquifer than the Waterhen River. In the Golden Ridge area (cross-section J-J', log 134) discharge occurs from the aquifer into the Beaver River. In the remainder of the area where this river overlies the aquifer, an upward flow component likely exists from the aquifer, through the overlying semi-confining layer, into the valley bottom. However, the amount of upward flow is small compared to the longitudinal flow because of the high hydraulic resistance of the layer separating the aquifer from the river. Furthermore, the area over which the upward flow occurs is small.

In the area south of Dorintosh, there also may be an upward flow component from the aquifer in topographically low areas. The flowing testhole SRC Meadow Lake 81-1 (cross-section C-C^1, log 60) is a typical example of such an occurrence.

East of Meadow Lake, the hydraulic head data indicate that the flow in the most eastern part of the aquifer is directed westward toward Meadow Lake. Based on the topographical and geological setting in this area such a flow direction is expected.

4.3.4 Hydraulic Properties

To date, no measured data on the hydraulic properties of the aquifer are available and, therefore, they can only be estimated from the testhole data. The fine- to medium and medium- to coarse-grained sands of the Empress Group are likely to have a hydraulic conductivity in the order of 5 to 50 m/day (Bouwer, 1978). The hydraulic conductivity, calculated from grain-size data on 34 samples, was found to range between 15 to 80 m/day (Appendix C). Taking into account the lithological variability of the aquifer sediments, these calculated values are compatable with the values reported in the literature. The storage coefficient of the aquifer is estimated to range from 1.0×10^{-4} to 2.0×10^{-4} (dimensionless), and the specific yield or the unconfined storage coefficient will be in the order of 0.1 to 0.2 (dimensionless). The transmissivity of the aquifer is a function of the aquifer thickness and the hydraulic conductivity and it is estimated to range from 30 to 3000 m^2/day. Although the thickness of the aquifer east of Meadow Lake is in the same order of magnitude as in the central portion of the aquifer, the transmissivity is lower than in the central portion as the Empress Group is finer-grained and siltier in this area.

Data on the bulk hydraulic conductivity of the semi-confining layer are not available. However, the semi-confining layer mainly consists of glacial till for which the hydraulic conductivity has been estimated to by 4.3×10^{-4} m/day (Maathuis and Schreiner, 1982). The vertical hydraulic resistance varies widely due to differences in thickness of the semi-confining layer and to the presence of intertill aquifers whose resistance does not significantly contribute to the total vertical resistance. Based on the typical thickness of the semi-confining layer, the vertical hydraulic resistance is estimated to be in the order of 140,000 to 210,000 days. The specific yield of the semi-confining layer is estimated to be 1% (Maathuis, 1982).

4.3.5 Water Quality

Available water quality data for the "Hatfield Valley" Aquifer are tabulated in Table 1. The type of water has been determined from a modified Piper Plot (Figure 4).

Groundwater in the "Hatfield Valley" Aquifer generally is of the sodium-bicarbonate type and has an average total concentration of approximately 1100 ± 150 mg/ℓ. In the Goodsoil area, water is of the calcium-bicarbonate type. The water quality data indicate that groundwater from the aquifer is suitable for municipal use, although some iron and manganese problems are likely to occur (Saskatchewan Environment, 1980: Appendix D). It is also fit for domestic and livestock use (Appendix D). Its suitability for industrial uses depends on the type of industry, as water quality guidelines for industries may vary widely (McNeely et al., 1979).

Although the total concentration is relatively low, the adjusted sodium adsorption ratios (ASARS) indicate generally that the water is unfit for irrigation purposes unless favourable soil and drainage conditions exist (Appendix D). The relatively high ASARS are caused by the relatively high concentrations of sodium and bicarbonate.

The $(NO_3 + NO_2) - NO_3$ concentrations vary widely but are generally greater than the 1 mg/ℓ. Concentrations less than 1 mg/ℓ were expected, based on what is known about the nitrate concentrations in deep aquifers

Table 1 Water quality data "Hatfield Valley" Aquifer in Waterhen River area

Location	Depth	Water Type	CO_3 HCO_3	SO_4	Cl	Ca	Mg	Na	K	Fe	Mn	NO_3	PO_4	F	Se	B	Conc	Cond.	pH	T.H.	T.A.	SAR	ASAR
SE9-32-59-14-W3	276	Na-HCO_3	516	152	25	63	29	156	7.1	7.3	0.21	20.0	0.19	0.08	N/D	N/D	968	1090	7.55	278	423	4.1	9.8
10-34-59-15-W3	322	Na-HCO_3	593	318	51	78	38	264	7.0	1.5	N/D	24.0	0.20	0.17	N/D	N/D	1375	1600	8.4	351	537	6.1	15.7
SW-2-60-16-W3	233	Na-HCO_3	492	85	186	33	15	283	6.0	0.8	0.04	26.0	0.85	0.29	N/D	N/D	1138	1480	7.67	142	404	10.3	22.5
NE1-28-60-17-W3	300	Na-HCO_3	569	167	70	80	19	196	9.1	3.4	0.43	9.1	0.35	0.17	<0.001	0.027	1120	1270	7.50	278	466	5.1	12.6
SW5-3-61-18-W3	210	Na-HCO_3	493	50	196	81	22	192	7.7	1.6	0.07	9.9	0.18	0.11	<0.001	0.013	1050	1380	7.60	294	404	4.9	12.1
10-14-61-18-W3	253	Na-HCO_3	744	188	57	66	24	283	6.0	3.7	0.02	8.4	0.25	0.12	N/D	N/D	1380	1570	7.56	264	610	7.6	19.4
SE3-10-62-18-W3	139	Na-HCO_3	554	98	52	72	22	166	7.8	2.1	0.09	11.0	0.48	0.16	N/D	N/D	985	1110	7.44	270	454	4.4	10.9
5-26-62-22-W3	283	Ca-HCO_3	570	119	< 1	136	42	33	6	4.8	N/D	5.0	<0.01	0.10	N/D	N/D	916	949	7.23	510	467	0.6	1.8
SE-33-62-22-W3	253	Ca/Mg-HCO_3	491	283	6	136	56	52	7	5.7	N/D	<1	<1	0.05	N/D	N/D	1037	1100	7.60	571	403	0.9	2.7
5-34-62-22-W3	277	Ca-HCO_3	562	229	4	144	53	53	8	6.1	N/D	NIL	NIL	N/D	N/D	N/D	1059	1180	7.25	580	461	0.9	2.8
NW-16-22-63-23-W3	224	Na-HCO_3	572	209	43	48	14	250	5.2	0.56	0.13	0.05	0.76	0.16	N/D	N/D	1143	1610	8.07	177	469	8.2	19.4

Notes: All values in mg/ℓ (ppm), except for conductivity which is in μS/cm, and pH

N/D means not determined

SAR means sodium adsorption ratio; ASAR mean adjusted sodium adsorption ratio

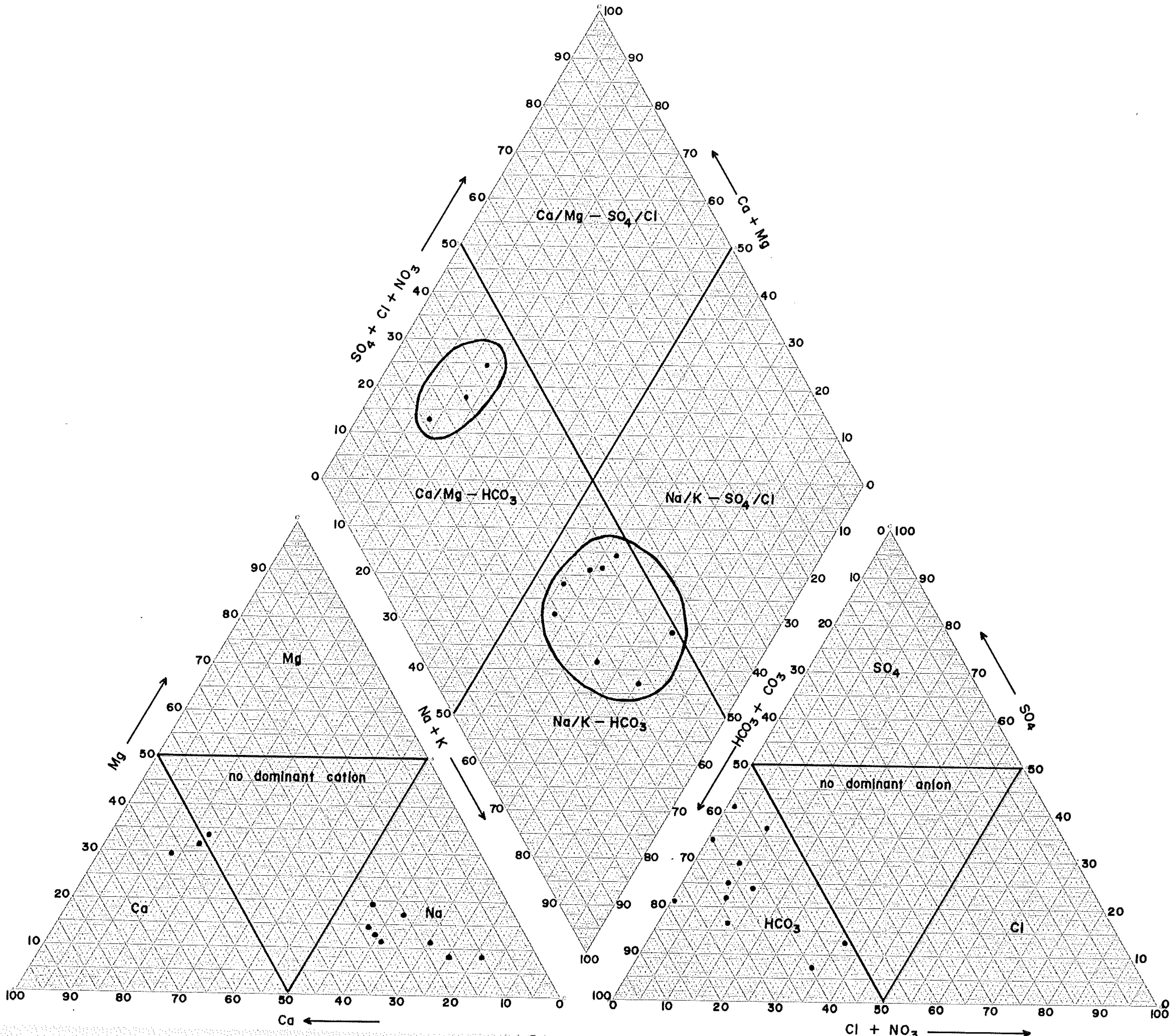


Fig. 4 Piper plot of "Hatfield Valley" Aquifer water in the Waterhen River area.

in Saskatchewan. To date, no explanation can be provided as to why the observed concentrations are above the 1 mg/ℓ level but an investigation is presently under way (Maathuis, in progress). No water quality data are available for the unnamed basal sand and gravel aquifer.

4.3.6 Assessment of Yields

The yields of the "Hatfield Valley" Aquifer System can only be assessed in a global and qualitative way because of insufficient data on the geohydrological properties. The assessment is further complicated by the fact that the aquifer is locally hydraulically-connected to surface water bodies.

A yield of an aquifer under development conditions is the amount of water that can be withdrawn from the aquifer without creating undesirable side effects. Undesirable side effects may include lowering of the water table and the dewatering of intertill aquifers (Meneley, 1972). This yield takes into account the amount of additional recharge from precipitation which occurs due to the development.

The yield can be calculated according to the following equations:

$$Q_A = \frac{\Delta H \times A \times 365}{c} \quad \text{[Equation 1]}$$

and $\Delta H = \Delta R \times c$ [Equation 2]

which combines to $Q_A = \Delta R \times A \times 365$ [Equation 3]

where Q_A is groundwater yield (m^3/year), A is surface area (m^2), c is vertical hydraulic resistance (days), ΔH is allowable drawdown (m), and ΔR is percentage of annual precipitation infiltrating the aquifer (m/day).

This estimate of the yield, called net groundwater yield, does not take the hydraulic properties of the aquifer and semi-confining layer into account, but only the estimate of additional recharge. It also implies that a new dynamic equilibrium with the climate is established and that the yield of the wells is derived only from induced recharge from precipitation.

Meneley (1972) assumed a value of 10% of the precipitation as the arbitrary upper limit of the additional percentage of precipitation which can be withdrawn. Based on ΔR values of 10%, 5%, and 3%, respectively, the net groundwater yield is calculated to be in the order of 9.1×10^7, 4.5×10^7, and 2.7×10^7 m^3/year, respectively. These values must be considered as crude estimates as no attempt has been made to calculate the number of wells and the production rate required to withdraw these amounts. Furthermore, because of the connections of the aquifer with surface water bodies, application of Equations 1 to 3 to the total area is invalid. In areas where these connections exist, the yield of wells comes from induced recharge through lake and river bottoms and this cannot be credited as a net gain to the groundwater resources (Appendix E). Assuming no drop in the lake levels, the yield of the aquifer in this area is limited to the unknown amount of surface water flow into the lakes.

The additional amount of vertical hydraulic head difference required to create the additional recharge can be calculated from Equation 3, assuming ΔR ranging between 3% and 10% and a c value between 140,000 and 210,000 days. Under these conditions, a lowering of the hydraulic head in the aquifer between 5.4 and 27 m is required. These values are less than the available drawdown which appears to be in the order of 45 to 53 m.

Under "drought" conditions recharge to the aquifer decreases and the water stored in the aquifer and in the overlying semi-confining layers and aquifers is "mined". Initially the yield from wells comes from storage within the aquifer itself, but when larger vertical hydraulic gradients have been created, it is derived from storage in the overlying semi-confining layers and aquifers. Consequently, the water table and hydraulic heads in overlying aquifers decreases systematically as drought conditions continue. Ultimately, the overlying layers are dewatered and the aquifer becomes unconfined. When average or above average precipitation conditions return, the propensity for recharge is increased because the hydraulic gradient is increased during the drought period.

The total volume of retrievable storage in the semi-confining layer can be calculated from

$$V_w = A \times S \times m' \qquad \text{[Equation 4]}$$

where V_w is volume of water (m^3), A is surface area (m^2), S is specific yield of the semi-confining layer (dimensionless), and m' is the saturated thickness of the semi-confining layer (m). This volume is calculated to be in the order of 1.2×10^9 to 1.8×10^9 m^3, assuming a conservative value of 1% for the specific yield of the semi-confining layer.

Equation 1 can also be used to calculate the maximum yield of the aquifer by taking ΔH as the available drawdown. This yield would be in the order of 1.5×10^8 to 2.3×10^8 m^3/year assuming a conservative value for ΔH at 45 m (Map B). This implies that it would take 5 to 12 years to drain the semi-confining layer, assuming no recharge during this period. Because of aquifer geometry, variations in transmissivity, and bulk vertical hydraulic conductivity, the calculated maximum yield is not achieved and could be an order of magnitude lower. Furthermore, under these conditions the vertical hydraulic gradient decreases as the water table decreases and therefore, the maximum yield decreases with time. However, during "drought" periods precipitation is not zero and, therefore, some recharge may occur.

In the hydraulic head of the aquifer drops below the top of the aquifer, it becomes unconfined. More water becomes available as the specific yield of an unconfined aquifer is larger than the specific storage coefficient of a semi-confined aquifer. Assuming a conservative value of 10% for the specific yield of the Empress Group sediments, it can be calculated [Equation 4] that under unconfined conditions, approximately 1.9×10^8 m^3 would becomes available per one metre head decline over the aquifer. If it is assumed that 50% of the aquifer thickness could be dewatered, a total volume in the order of 3.8×10^9 m^3 would become available. The above calculations of the total volume are hypotehtical, since a decrease in transmission and available drawdown as result of development would require an extremely large number of wells to actually withdraw this amount.

4.3.7 Assessment of single well yields

Single well yields can be calculated based on the available drawdowns or on the additional percentage of precipitation which can be withdrawn.

Based on the available drawdown, average aquifer characteristics, and assuming that up to 50% of the drawdown in the well may be due to well losses, it is estimated that up to 11,000 m^3/day (1650 Ispm) could be withdrawn from a well or well field. At these production rates, the recharge to the water table would be less than the induced recharge into the aquifer and some dewatering of the semi-confining layer would occur. However, the estimated production rate is an indication of the yield, which can be obtained for a limited period of time in case of an emergency, such as a drought. It essentially represents the maximum pumping rate from a well or well field without creating unconfined conditions near the well site. If it is assumed that an additional 10% of the precipitation can be withdrawn without creating undesirable effects, it is estimated that up to 2750 m^3/day (appr. 400 Igpm) can be withdrawn from a well or well field on a continuous basin. Again this calculation is based on average aquifer characteristics and on well losses accounting for up to 50% of the drawdown in a well.

In both cases, it is estimated that individual wells or well fields would have to be spaced at 10 to 15 km intervals to avoid drawdown interferences.

5 CONCLUSIONS

1. The origin of the major bedrock valley in the Waterhen River area may be different and more complex than previously assumed. It could be a tributary to the main Hatfield Valley. The existance and location of the main valley are unknown. For convenience the unnamed buried valley aquifer in the study area is referred to as the "Hatfield Valley" Aquifer.
2. The "Hatfield Valley" Aquifer is the most significant aquifer in the area and is comprised of sediments of the Empress Group and some stratified glacial deposits. This aquifer is probably hydraulically connected to an unnamed basal sand and gravel aquifer. The nature of the connection, however, remains unclear.
3. The nature of the hydraulic connections between the "Hatfield Valley" Aquifer, in the western part of the study area, and the lakes remains unclear. The Waterhen River and, to a much lesser extent, the Beaver River, act as drains for the "Hatfield Valley" Aquifer. The area east of the Town of Meadow Lake may be a discharge area.
4. Water in the "Hatfield Valley" Aquifer is of the sodium-bicarbonate type, except in the Goodsoil area where it is of the calcium-bicarbonate type.
5. Water from the "Hatfield Valley" Aquifer is suitable for municipal, domestic, and livestock use. The average total concentration of the water is 1100 ± 150 mg/ℓ ($n = 11$). However, it is unsuitable for irrigation use unless favourable soil and drainage conditions exist.
6. Calculation of net groundwater yield is complicated by the hydraulic connections of the "Hatfield Valley" Aquifer to surface water bodies.

The net groundwater yield is crudely estimated to be in the order of 2.7×10^7 to 9.1×10^7 m^3/year. This production is based on additional recharge from precipitation.

7. The maximum yield of the aquifer is estimated to be in the order of 1.5×10^8 to 2.3×10^8 m^3/year. The semi-confining layer overlying the aquifer could yield 1.2×10^9 to 1.8×10^9 m^3 and would be dewatered in 5 to 12 years, if no recharge occurs, and if the maximum yield is produced. Under unconfined conditions, the "Hatfield Valley" Aquifer could yield 1.9×10^8 m^3 per metre head decline over the aquifer.

8. Individual wells or well fields may yield up to 11,000 m^3/day (1650 Igpm) for a limited period of time in case of emergencies. On a continuous basin, they could yield up to 2750 m^3/day (400 Igpm). Wells or well fields should be spaced at 10 to 15 km intervals to avoid interference.

6 Considerations for future work

1. High priority should be given to additional-test drilling, in particular in the Waterhen Lake - Canoe Lake area, to determine the possible existance and location of the main Hatfield Valley. These testhole data may also provide some indication as to whether the recently discovered major buried valley aquifer in northern Alberta continues into Saskatchewan.

2. Based on the presently available data, an attempt should be made to model the "Hatfield Valley" Aquifer in order to provide for a more realistic estimate of yields and better understanding of the behaviour of the aquifer under development conditions. This model can only be simplistic in nature because limited data are available. Acquiring additional data is difficult due to the inaccessibility of the area. The lack at hydraulic property data is also a constraint.

7 REFERENCES

Acton, D.F., Clayton, J.S., Ellis, J.G., Christiansen, E.A., and Kupsch, W.O., 1960. Physiographic divisions of Saskatchewan. Map prepared by Saskatchewan Soil Survey, Saskatchewan Research Council, Geology Division, and University of Saskatchewan, Geology Department.

Bergsteinsson, J.L., 1976. Precipitation and temperature characteristics for southern arable Saskatchewan. Saskatchewan Research Council, Physics Division (unpublished map).

Bouwer, H., 1978. Groundwater hydrology. New York: McGraw-Hill Book Company, 480 p.

Christiansen, E.A., 1968. Pleistocene stratigraphy of the Saskatoon area, Saskatchewan, Canada. Canadian Journal of Earth Sciences. Volume 15, No. 5, pp. 1167-1173.

Christiansen, E.A., 1979. The Wisconsinan deglaciation of southern Saskatchewan and adjacent areas. Canadian Journal of Earch Sciences, Volume 16, No. 4, pp. 913-938.

Christiansen, E.A., and Whitaker, S.H., 1974. Geology and groundwater resources of the Waterhen River area (73K), Saskatchewan. Saskatchewan Research Council, Geology Division. Map No. 19.

Christiansen, E.A., Padbury, G.A., and Long, R.J., 1975. Meadow Lake Geolog, The Land - past and present. Saskatchewan Department of Tourism and Renewable Resources and Saskatchewan Research Council. Interpretive Report No. 1, 52 p.

Christiansen, E.A., Acton, D.F., Long, R.J., Meneley, W.A., and Sauer, E.K., 1977. Fort Qu'Appelle Geolog, The valleys - past and present. The Saskatchewan Museum of Natural History, Saskatchewan Culture and Youth. Interpretive Report No. 2, 83 p.

Environment Canada, 1968-1978. Monthly record, meteorological observations in western Canada. Atmospheric Environment Service, Ontario.

Maathuis, H., 1981. Hatfield Valley Aquifer System in Saskatchewan. Saskatchewan Research Council, Geology Division. Report prepared for Saskatchewan Environment, 43 p.

Maathuis, H. and Schreiner, B.T., 1982. Hatfield Valley Aquifer System in the Wynyard Region, Saskatchewan. Saskatchewan Research Council, Geology Division. Report prepared for Saskatchewan Environment, 61 p.

Maathuis, H. (in progress). Nitrate concentrations in deep aquifers in Saskatchewan. Saskatchewan Research Council, Geology Division.

Meneley, W.A., 1972. Groundwater resources in Saskatchewan, in Water Supply for the Saskatchewan - Nelson Basin, Appendix 7, Section F, Saskatchewan - Nelson Basin report, Ottawa. pp. 673-723.

McNeely, R.N., Neimanir, V.P., and Dwyer, L., 1979. Water quality source book. A guide to water quality parameters. Inland Water Directorate, Water Quality Branch, Ottawa, Canada, 89 p.

Prest, V.K., 1970. Quarternary geology of Canada, _in_ Economic Geology, Douglas, R.J.W. (Ed.), Geological Survey of Canada. Report No. 1, Queen's Printer for Canada, Ottawa, pp. 677-764.

Saskatchewan Environment, 1980. Municipal drinking water quality objectives. Saskatchewan Environment, Water Pollution Control Branch, Regina, 8 p.

Schreiner, B.T. and Maathuis, H., 1982. Groundwater studies in the Melville area, Saskatchewan. Saskatchewan Research Council, Geology Division. Report prepared for Saskatchewan Environment, 77 p.

Whitaker, S.H., and Christiansen, E.A., 1972. The Empress Group in southern Saskatchewan. Canadian Journal of Earth Sciences, Volume 9, No. 4, pp. 353-360.

APPENDIX A

MAPS, CROSS-SECTIONS AND LOG INDEX

2 plastics.

water quality bar explanation.

2 plastics

log index.

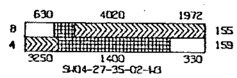
Draft 1
Version 1
Aug. 9/72

SASKATCHEWAN RESEARCH COUNCIL

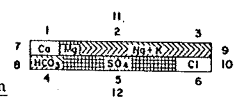
Water Quality Bar Diagram

Compiled by: J.H. Dyck, C.T. McKenzie, W.A. Meneley

Example:



Key:



Explanation

Bar graph of major ions based on percentage of total milligram equivalents per liter, modified from Lekahena and Smoor (1970). Examples above were computer plotted (McKenzie, 1972).

Key:
1. Total hardness, *milligrams per liter as* $CaCO_3$.
2. Specific conductivity, *micromhos/cm @ 25°C.*
3. Year of analysis.
4. Total ionic concentration, *milligrams per liter.* Computed by summation of the constituents determined without correcting for the reduction of bicarbonate to carbonate (Hem, 1970).
5. Sulphate concentration, *milligrams per liter.*
6. Chloride concentration, *milligrams per liter.*
7. Potassium concentration, *milligrams per liter.*
8. Iron concentration, *milligrams per liter.*
9. Top of the inlet section of the well, *feet below surface.* When the letter "S" appears in this field it denotes a surface water sample.
10. Bottom of the inlet section of the well, *feet below surface.*
11. Name of testhole, well, or sample location.
12. Land location of testhole, well or sample location.

Missing data (i) 'asterisk' (i.e.*) for "key-variables" 1 to 8.
(ii) 'blank' for "key-variables" 9 to 12.

▦ Diagonal slash indicates grouped ions (i.e. Ca + Mg are reported together as total hardness).

Selected References

Hem, J.D., 1970. Study and interpretation of the chemical characteristics of natural water: 2nd Edition. U.S. Geol. Survey water supply paper 1473, 363 p.

Lekahena, E.G., and Smoor, P.B., 1970. Grondwaterkaart van Nederland, Blad 49 Oost Bergen op Zoom and Blad 50 West Breda. Dienst Grondwaterverkenning TNO, Delft.

McKenzie, C.T., 1972. Personal communication August 1, Saskatchewan Research Council, report in preparation.

Cross Section Log Index

Testholes drilled under the program are marked with an *

1. Cox STH #1	600S/1560 W NE 14-63-27-W3
2. Cox STH #5	2100N/820 W SE 26-63-26-W3
3. SRC Pierce Lake	SE11-29-63-25-W3
4. Banff Aquit Pierceland #107	520S/1900W NEC 28-63-25-W3
*5. SRC Pierce Lake 81-1	SW11-25-63-25-W3
6. Banff Aquit Pierceland #138	1900E/2000N SWC-30-63-24-W3
7. Cox STH #8	2340S/500E NW24-63-24-W3
8. GDA Beacon Hill	4-29-63-23-W3
*9. SRC Johnston Lake 81	NW16-22-63-23-W3
10. SRC Waterhen River No. 1	SE11-14-63-22-W3
11. Trend STH #37	200N/2540E SW28-62-21-W3
*12. SRC Golden Ridge 81	SW12-23-62-21-W3
13. Trend STH #30	2180N/1650E SW14-62-20-W3
*14. SRC Dorintosh 81-1	SE1-3-62-19-W3
*15. SRC Dorintosh 81-3	SE3-10-62-18-W3
16. Imperial Barnes #1-33	1-33-61-17-W3
*17. SRC Meadow Lake 81-2	SW15-14-61-17-W3
18. Seaboard Meadow Lake #1	13-21-61-15-W3
*19. SRC Saint Cyr Lake	SE7-17-61-14-W3
20. Banff Aquit Emberville #101	550N/ SEC4-62-27-W3
21. Banff Aquit Pritchard #7	660E/680S NWC11-62-27-W3
22. Banff Aquit Pritchard #6	200E/1640N SWC33-62-26-W3
23. Banff Aquit Emberville #134	1400W/1200N SEC27-62-26-W3
*24. SRC Pierceland 81-4	SW3-25-62-26-W3

25.	Banff Aquit Emberville #133	2720E/2480S NWC24-62-26-W3
26.	FFIB P. Angemeier	NE9-17-62-25-W3
27.	Banff Oil Lepine Lake	450 N/20 E NEC15-62-25-W3
28.	Banff Aquit Emberville #118	660 S/1900 E NWC18-62-24-W3
*29.	SRC Beacon Hill	SW4-15-62-24-W3
30.	Banff Aquit Emberville #161	2000W/2240S NEC11-62-24-W3
31.	FFIB Ed Hoffer	SE6-12-63-24-W3
32.	FFIB G. Hempel	NW13-11-62-23-W3
33.	Banff Aquit Makwa #160	80N/20E SWC13-62-23-W3
34.	FFIB K. Schamber	SW3-13-62-23-W3
*35.	SRC Goodsoil 81-2	SW4-27-62-22-W3
36.	FFIB H. Lange	5-26-62-22-W3
37.	Trend STH #18	1990N/1910E SW30-62-21-W3
38.	Utex Can M.L.-4	5S/40W NEC16-60-27-W3
39.	Utex Can M.L.-4	84W/36S NEC14-60-27-W3
40.	Banff Aquit Makwa #13	2040N/250W SEC13-60-27-W3
41.	Banff Aquit Makwa #180	1980S/640E NWC9-60-26-W3
42.	FFIB E. Mihalceon	CE7-10-60-26-W3
*43.	SRC Mudie Lake 81-2	SE8-14-60-26-W3
44.	Banff Aquit Makwa 143	1670W/1790S NEC35-60-25-W3
45.	Banff Aquit Makwa 127	2350N/1800E SWC6-61-24-W3
46.	Banff Aquit Makwa 150	800S/800E E1/4 29-60-24-W3
47.	Western Decalta ST 7	2484S/1828W NEC18-60-23-W3
48.	Banff Aquit Makwa 39	700W/650N SEC15-60-23-W3
49.	Western Decalta ST 5	1910N/914E SWC6-60-22-W3
*50.	SRC Makwa Lake 81-1	NE 1-28-59-22-W3

51. Trend STH 28	2205S/1537E NW6-60-21-W3
52. Trend STH 32	440S/70W NE16-60-21-W3
53. Trend STH 27	1860W/1360S NE22-60-21-W3
54. FFIB P. Schiele	CSE23-60-21-W3
*55. SRC Loon River 81-3	SE9-6-61-20-W3
*56. SRC Rapid View 81-2	SE8-31-60-19-W3
*57. SRC Makwa River 81	NW12-35-60-19-W3
58. FFIB L. Temple	NE2-2-61-19-W3
*59. SRC Four Corners 81	SW5-3-61-18-W3
*60. SRC Meadow Lake 81-1	NE1-28-60-17-W3
61. Highwood Dev. STH #3	260E/4N NEC32-59-16-W3
62. EPD Meadow Lake	SW2-60-16-W3
63. EPD Meadow Lake	10-34-59-15-W3
*64. SRC Matchee 81	SE9-32-59-14-W3
65. Banff Aquit Peck Lake 71	1500W/1300S NEC8-58-26-W3
66. Banff Aquit Peck 22	1950W/1950S NEC20-58-26-W3
67. Banff Aquit STH 329	660N/660W SE1-59-26-W3
*68. SRC Mudie Lake 81-1	NE4-24-59-26-W3
*69. SRC Pierceland 81-1	SW1-1-61-26-W3
*70. SRC Pierceland 81-2	NW5-18-61-25-W3
71. Banff Aquit Emberville no. 88	660N/1980E SWC25-61-26-W3
*72. SRC Pierceland 81-3	SW12-36-61-26-W3
73. EPD Pierceland	SW16e-62-26-W3
74. EPD Pierceland	NW16-2-62-26-W3
75. EPD Pierceland	SW1-11-62-26-W3
76. Banff Aquit Emberville 256	2400N/50E SW12-62-26-W3

77. Banff Aquit Emberville 100	600S/600E NWC25-62-26-W3
78. Banff Aquit Emberville 135	1520W/75S NEC35-62-26-W3
*79. SRC Northern Pine	NE16-7-63-25-W3
80. Gen.Am. STH #1	13-29-63-25-W3
81. Gen. Am. STH #2	9-2-64-26-W3
82. Banff Cold Lake #1	21773S/9691E NEC33-64-26-W3
83. IOL Cold Lake East #1	6-23-64-26-W3
84. Banff Oil Cold Lake #4	1346N/4982E NEC33-64-26-W3
85. Banff Oil Cold Lake #12	19092N/566E NEC33-64-26-W3
86. Banff Oil Cold Lake #14	26758N/4127E NEC33-64-26-W3
87. IOL Martineau East	8-3-66-26-W3
88. Banff Aquit Makwa 186	200N/300E SW32-59-24-W3
89. Banff Aquit Makwa 35	2300N/240E SWC18-60-24-W3
90. Banff Aquit Makwa 84	2000S/270E NWC7-61-24-W3
91. Banff Aquit Makwa 130	660S/660E NWC18-61-24-W3
92. Banff Aquit Makwa 111	650S/650E NWC19-61-24-W3
93. Banff Aquit Makwa 123	1500S/2400E NWC31-61-24-W3
94. Banff Lepine Lake C-22	42E/1171N NEC24-62-25-W3
95. FFIB Big Indian Head Res.	C36-62-25-W3
96. Banff Lepine Lake D-23	1420E/4S NEC2-63-25-W3
97. Banff Lepine Lake I-28	180E/120S NEC23-63-25-W3
98. Banff Aquit Pierceland 157	270E/2580S NWC1-64-25-W3
99. Banff Aquit STH 299	707S/2060E NE18-64-24-W3
100. Banff Aquit STH 303	1730S/650W NE29-64-24-W3
101. Banff Aquit Tatukose Lake 175	650W/700S NEC4-65-24-W3

102. Sask. Pow. Corp. STH 1-26-59	1-26-59-23-W3
103. Banff Aquit Makwa #77	660N/2000E SWC33-60-27-W3
104. Banff Aquit Makwa #159	1980N/1980E SEC9-61-23-W3
105. Banff Aquit Makwa #163	2040S/600W NEC17-61-23-W3
106. Banff Aquit Makwa #82	220S/420W NEC20-61-23-W3
*107. SRC Goodsoil 81-1	SW4-4-62-23-W3
108. FFIB J. Eberharler	NW5-14-62-23-W3
109. EPD Goodsoil	3-26-62-23-W3
*110. SRC Lac des Iles	NE14-33-62-23-W3
111. Banff Aquit Makwa 191	650S/670E NW34-63-23-W3
112. Banff Aquit STH 301	1784N/1982W SE8-64-23-W3
113. Banff Aquit Tatukose Lake	1900N/680E SW34-64-23-W3
114. SRC Loon Lake	SE11-18-58-21-W3
115. Westen Decalta S.T.-23	2170N/2560E SW26-58-22-W3
*116. SRC Makwa Lake 81-2	SE9-17-59-22-W3
*117. SRC Watson Lake 81	SW13-16-60-22-W3
*118. SRC Beaver River 81-1	SE1-4-61-22-W3
*119. SRC Flat Valley 81	SE4-15-61-22-W3
120. EPD Flat Valley	SW13-27-61-22-W3
121. SRC Golden Ridge	SW4-3-62-22-W3
122. SRC Peerless	NW5-10-62-22-W3
123. FFIB G. Sahowich	SW4-22-62-22-W3
124. EPD Goodsoil	5-34-62-22-W3
125. Trend STH #8	1420N/1900E SW11-63-22-W3
126. SRC Waterhen River No. 2	SW6-14-63-22-W3

127. Banff Aquit Makwa 46	200N/800W SE31-63-22-W3
128. Banff Aquit Tatukose Lake 194	1900S/450W NW16-64-22-W3
129. Banff Aquit Tatukose Lake 196	660N/660E SW4-65-22-W3
130. EPD South Makwa	4-15-58-20-W3
*131. SRC Loon River 81-1	SW2-4-60-20-W3
*132. SRC Loon River 81-2	NE16-18-60-20-W3
133. SRC Beaver River No. 2	NE16-18-61-20-W3
134. SRC Beaver River No. 1	SE10-30-61-20-W3
135. Trend STH 19	1970S/2050W NE10-62-21-W3
136. DTRR Mistohay Lake	SE16-14-63-21-W3
*137. SRC Mistohay Lake 81-1	SW14-24-63-21-W3
138. Pac. Petr. Barpel Mistohay L.	12-34-63-21-W3
139. Trend STH 6	2050N/2154E SE4-65-21-W3
*140. SRC Rapid View 81-1	NE16-7-60-19-W3
141. FFIB S. Dyck	SW4-26-60-19-W3
142. FFIB A. Penner	NW13-26-60-19-W3
*143. SRC Dorintosh 81-2	NE16-22-62-19-W3
144. DTRR Kimball Lake	NW16-32-62-19-W3
145. Highwood STH #1	40S/45W NEC12-58-17-W3
146. FFIB T Yaddal	SW4-24-58-17-W3
147. NUCO Meadow Lake 1-26	1-26-58-17-W3
148. EPD Meadow Lake	13-4-59-17-W3
149. EPD Meadow Lake	1-22-59-17-W3
150. SRC Meadow Lake	SE16-27-59-17-W3
151. FFIB O. Kwasnuik	SW4-13-60-18-W3
152. SRC Bridge Creek	SW2-27-60-18-W3

153. FFIB E. Peters	SE1-4-61-18-W3
154. FFIB B. Blatz	NW13-11-61-18-W3
155. EPD Dorintosh	10-14-61-18-W3
156. SRC Barnes Crossing	SW4-26-61-18-W3
157. FFIB R. Ens	16-9-62-18-W3
158. DTRR Dorintosh	SW5-34-62-18-W3
159. DTRR Waterhen River	NW16-33-62-18-W3
160. DTRR Waterhen River	SE9-63-18-W3
161. SRC Jeanette Lake	NW-7-64-17-W3
162. Highwood STH 9	8S/6W NEC11-58-16-W3
163. FFIB F.P. Prudot	NW36-58-16-W3
164. Highwood STH 2	35N/30W NEC35-58-16-W3
*165. SRC Cabana 81	SW4-12-59-16-W3
166. Highwood STH 27	1175N/1025W N1/4 11-59-16-W3
167. Highwood STH 28	425S/41E NE27-59-16-W3
168. FFIB D. L'Heureux	SW13-11-60-16-W3
169. FFIB M. Paramzchuk	SW4-23-60-16-W3
170. Highwood Sth 15	75W/10S NEC19-58-14-W3
171. Highwood STH 6	170S/40E NEC36-58-15-W3
172. Highwood STH 16	30N E1/4 12-59-15-W3
173. Highwood STH 14	80E/12S SEC17-59-14-W3
174. FFIB E. Campbell	NW4-18-60-14-W3
175. FFIB W. Ehle	SW12-33-60-14-W3
176. Seaboard Meadow Lake #7	12-31-61-14-W3

APPENDIX B

WATER QUALITY GUIDELINES

MUNICIPAL DRINKING WATER QUALITY OBJECTIVES (SASKATCHEWAN ENVIRONMENT, 1980)

1. Bacteriological

(i) Total Coliforms	At least 90 per cent of the samples in any consecutive 30-day period should be negative for total coliform organisms and no one sample should contain more than 10 total coliform organisms per 100 ml. Properly operated municipal waterworks should be free of coliform bacteria.
(ii) Fecal Coliforms	None of the coliform organisms detected should be fecal coliforms.
(iii) Nuisance Biological Organisms	Biological organisms in concentrations which may produce objectionable colour, taste, odour and turbidity, or which may release toxic metabolites, or which may harbour pathogens are undesirable in drinking water and should be kept below such concentrations as to prevent any undesirable effects.

2. Physical

Water should not contain impurities that would be offensive to the sense of sight, taste or smell.

Parameter	Maximum
Colour	15 units
Temperature	15°C
Turbidity	5 units

3. Chemical — General

Constituent	Maximum Desirable (Concentration in mg/L)
Alkalinity (as $CaCO_3$)	500*
Chloride	250
Copper	1.0
Fluoride	1.5
Iron	0.3
Hardness (as $CaCO_3$)	800*
Magnesium	200*
(Magnesium and Sodium) plus Sulphate	1,000*
Manganese	0.05
Methylene Blue Active Substances	0.5*
Phenolics	0.002
Sodium	300*
Sulphate	500
Sulphide as H_2S	0.05
Total Dissolved Solids (sum of dissolved ions)	1,500*
Zinc	5.0

The pH range of the water should not fall outside the range of 7.0 to 9.5*

4. Chemical-Health and Toxicity Related

Constituent	Maximum Acceptable (Concentration in mg/L)
Arsenic	0.05
Barium	1.0
Boron	5.0
Cadmium	0.005
Chromium	0.05
Cyanide (free)	0.2
Lead	0.05
Mercury	0.001
Nitrates as NO_3	40*
Nitrilotriacetic Acid	0.05
Nitrites as N	1.0
Polychlorinated Biphenyls [Note (a)]	0.003*
Selenium	0.01
Silver	0.05
Total Trihalomethanes [Note (b)]	0.35
Uranium	0.02

Note:

(a) Polychlorinated Biphenyls (PCBs) should not be detectable in drinking water (i.e., less than 0.00002 mg/L). The above level of 0.003 mg/L is intended for short-term situations and should not continue for more than six to eight months in a given supply.

(b) The maximum total trihalomethane (i.e., comprised of chloroform, bromodichloromethane, chlorodibromomethane, and bromoform) concentration of 0.35 mg/L applies to actual concentrations, as determined by the purge equivalent, gas sparge or similar method acceptable to the department.

5. Biocides

Constituent	Maximum Acceptable (Concentration in mg/L)
Aldrin & Dieldrin	0.0007
Carbaryl	0.07
Chlordane (total isomers)	0.007
DDT (total isomers)	0.03
Diazinon	0.014
Endrin	0.0002
Heptachlor & Heptachlor Epoxide	0.003
Lindane	0.004
Methoxychlor	0.1
Methyl Parathion	0.007
Parathion	0.035
Toxaphene	0.005
2, 4-D	0.1
2, 4, 5-TP	0.01
Total of individual biocides	0.1

6. Radioactivity

Radionuclide [Notes (d,e,f)]	Maximum Desirable (Concentration in Bq/L) [Note (c)]
Cesium — 137	5
Iodine — 131	1
Radium — 226	0.1
Strontium — 90	1
Tritium	4,000

Note:

(c) One Becquerel (Bq)/L corresponds to approximately 27 Picocuries (pCi)/L.

(d) The objectives for the radiological characteristics of water are based on dose — response relationships as recommended by the ICRP in publication 26 and reviewed in the 1978 Guidelines for Canadian Drinking Water Quality.

(e) Where the concentration exceeds the value in the maximum desirable column, the acceptablility would have to be considered by the department.

(f) Other radionuclides not specified herein should not exceed concentrations as established by the department. Reference will be made to one per cent of the ICRP recommended annual occupational dose equivalent limit for 50 years of continuous exposure in the case of short-term maximum acceptable concentrations and to 0.1 per cent of this dose equivalent limit in the case of long-term acceptable concentrations.

SASKATCHEWAN DEPARTMENT OF THE ENVIRONMENT
Water Quality Division

CHEMICAL WATER QUALITY GUIDELINES

FOR

PRIVATE WATER SUPPLIES

Constituent	Range of Concentrations				Refer To Note No.
	Satisfactory Quality	Poor Quality	Not Recommended For Consumption	Unsuitable For Use	
TOTAL DISSOLVED SOLIDS, mg/l	100-1500	1500-3000	3000-4000	over 4000	a
TOTAL HARDNESS, mg/l as $CaCO_3$	50- 500	500-1000	1000-2000	over 2000	b
TOTAL ALKALINITY, mg/l as $CaCO_3$	50- 500	500-1000	1000-1500	over 1500	
CHLORIDE, mg/l	up to 250	250- 500	500-1000	over 1000	
SODIUM, mg/l	up to 300	300- 500	500-1000	over 1000	c
SULPHATE, mg/l	up to 400	400- 800	800-1200	over 1200	d
NITRATE, mg/l	up to 40	40- 300	over 300		e
IRON, mg/l	up to 0.3	0.3-1.0			f
MANGANESE, mg/l	up to 0.05	0.05-0.5			f
pH, units	7.0-9.5	6-7 and 9.5-10		less than 5.5 more than 10.5	

NOTES:

(a) Total dissolved solids (dissolved mineral salts) are picked up by the water in passing through or over the earth. They can only be removed by demineralizing units. A water softener will not reduce the total dissolved solids.

(b) Hardness of water relates to the difficulty of producing a lather with soap. "Hard waters" waste soap and cause bathtub ring, hard-to-remove scale in boilers, kettles, or electric irons. Waters with more than 200 mg/l of hardness are generally considered "hard." Hardness can be reduced by use of a water softener. To determine the hardness in grains per gallon, divide the value in mg/l by 14.3

(c) Persons on a sodium restricted (salt-free) diet should consult their physician with respect to the suitability of water used for consumptive purposes.

(d) Due to laxative effects, sulphate in excess of 400 mg/l is regarded as unsuitable for infant feeding.

(e) Nitrate in excess of 40 mg/l is considered UNSAFE for consumption by infants up to 6 months of age.

(f) Iron and manganese cause yellowing or browning of water. Amounts above 0.5 mg/l may result in staining of laundry and plumbing. Domestic units for removal are available. Iron in excess of 7 mg/l may not be practical to remove.

(g) Livestock. Livestock, depending on species, may tolerate water quality slightly above the limits suggested under "not recommended for consumption." However, if a "poor quality" water is to be used for intensive livestock or poultry production, consult the Provincial Veterinary Laboratory or your veterinarian.

(h) Irrigation. In general, water of "poor quality" for drinking is unsuitable for irrigation of fine-textured clay lands that have low permeability. Such water may occasionally be used on sand or loam soils that are more permeable. Waters with high sodium and alkalinity contents may cause problems, especially if they greatly exceed the total hardness. For specific information on the suitability of water for irrigation consult the Soils Department, University of Saskatchewan, Saskatoon.

(i) Bacteriological Safety. This can only be assessed for a completed water supply by submitting a sample in a special sterile bottle obtainable from your district public health inspector or the Provincial Laboratory.

$$\text{Adjusted SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}[9.4 - p(K_2' - K_c') - p(\text{Ca} + \text{Mg}) - p\text{Alk}]$$

Values of $p(K_2' - K_c')$, $p(Ca + Mg)$, and pAlk for calculation of the adjusted SAR with Eq. (10.1)

Concentration Ca + Mg + Na, meq/l	$p(K_2' - K_c')$	Concentration Ca + Mg, meq/l	p(Ca + Mg)	Concentration CO_3 + HCO_3, meq/l	pAlk
0.5	2.11	0.05	4.60	0.05	4.30
0.7	2.12	0.10	4.30	0.10	4.00
0.9	2.13	0.15	4.12	0.15	3.82
1.2	2.14	0.2	4.00	0.20	3.70
1.6	2.15	0.25	3.90	0.25	3.60
1.9	2.16	0.32	3.80	0.31	3.51
2.4	2.17	0.39	3.70	0.40	3.40
2.8	2.18	0.50	3.60	0.50	3.30
3.3	2.19	0.63	3.50	0.63	3.20
3.9	2.20	0.79	3.40	0.79	3.10
4.5	2.21	1.00	3.30	0.99	3.00
5.1	2.22	1.25	3.20	1.25	2.90
5.8	2.23	1.58	3.10	1.57	2.80
6.6	2.24	1.98	3.00	1.98	2.70
7.4	2.25	2.49	2.90	2.49	2.60
8.3	2.26	3.14	2.80	3.13	2.50
9.2	2.27	3.90	2.70	4.0	2.40
11	2.28	4.97	2.60	5.0	2.30
13	2.30	6.30	2.50	6.3	2.20
15	2.32	7.90	2.40	7.9	2.10
18	2.34	10.00	2.30	9.9	2.00
22	2.36	12.50	2.20	12.5	1.90
25	2.38	15.80	2.10	15.7	1.80
29	2.40	19.80	2.00	19.8	1.70
34	2.42				
39	2.44				
45	2.46				
51	2.48				
59	2.50				
67	2.52				
76	2.54				

Source: From Ayers, 1975; National Academy of Sciences and National Academy of Engineering, 1972; and references therein.

Guidelines for interpretation of water quality for irrigation

Problems and quality parameters	No problems	Increasing problems	Severe problems
Salinity effects on crop yield:			
Total dissolved-solids concentration (mg/l)	< 480	480–1 920	> 1 920
Deflocculation of clay and reduction in K and infiltration rate:			
Total dissolved-solids concentration (mg/l)	> 320	< 320	< 128
Adjusted sodium adsorption ratio (SAR)	< 6	6–9	> 9
Specific ion toxicity:			
Boron (mg/l)	< 0.5	0.5–2	2–10
Sodium (as adjusted SAR) if water is absorbed by roots only	< 3	3–9	> 9
Sodium (mg/l) if water is also absorbed by leaves	< 69	> 69	
Chloride (mg/l) if water is absorbed by roots only	< 142	142–355	> 355
Chloride (mg/l) if water is also absorbed by leaves	< 106	> 106	
Quality effects:			
Nitrogen in mg/l (excess N may delay harvest time and adversely affect yield or quality of sugar beets, grapes, citrus, avocados, apricots, etc.)	< 5	5–30	> 30
Bicarbonate as HCO_3 in mg/l (when water is applied with sprinklers, bicarbonate may cause white carbonate deposits on fruits and leaves)	< 90	90–520	> 520

Source: From Ayers, 1975.

Suitability of Groundwaters for Irrigation

The suitability of a water for irrigation depends upon; 1) the salinity hazard, which is related to the electrical conductivity of the water, 2) the sodium hazard, which is a relative measure of sodium to calcium and magnesium in the water, 3) the hydraulic conductivity of the soil and drainage, and 4) the bicarbonate content.

The following classifications are taken from Richards (1954)*.

Salinity hazard classification:

Class C1: low salinity water, up to 250 μS conductivity, can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop.

Class C2: medium salinity water, conductivity between 250 and 750 μS, can be used if a moderate amount of leaching occurs.

Class C3: high salinity water, conductivity between 750 and 2250 μS, cannot be used on soils with restricted drainage.

Class C4: very high salinity, conductivity greater than 2250 μS, can be used only where soils have high hydraulic conductivities and good drainage. Must be applied in excess to provide considerable leaching and only very salt-tolerant crops should be used.

Sodium hazard:

Sodium, when present in irrigation water in excess of calcium and magnesium, may reduce the hydraulic conductivity and cause hardening of the soil by replacement of calcium and magnesium by sodium ions on the soil clays. The sodium absorption ratio (SAR) is an estimate of the extent of replacement.

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}} \qquad \text{(concentration in epm)}$$

Sodium hazard classification:

Class S1: low sodium water, SAR 0-10, can be used for irrigation on almost all soils with little danger of sodium exchange.

Class S2: medium sodium water, SAR 10-18, will present appreciable sodium hazard in fine textured soils having high cation-exchange-capability, especially under low leading conditions.

---

* Richards, LA. 1954. Diagnosis and improvement of saline and alkaline soils. U.S. Dept. of Agric. Handbook No. 60. U.S. Gov. Printing Office, Washington, D.C. 160 p.

Class S3: high sodium water, SAR 18-26, may produce harmful levels of exchangeable sodium in most soils and will require good drainage, high leaching and organic matter additions.

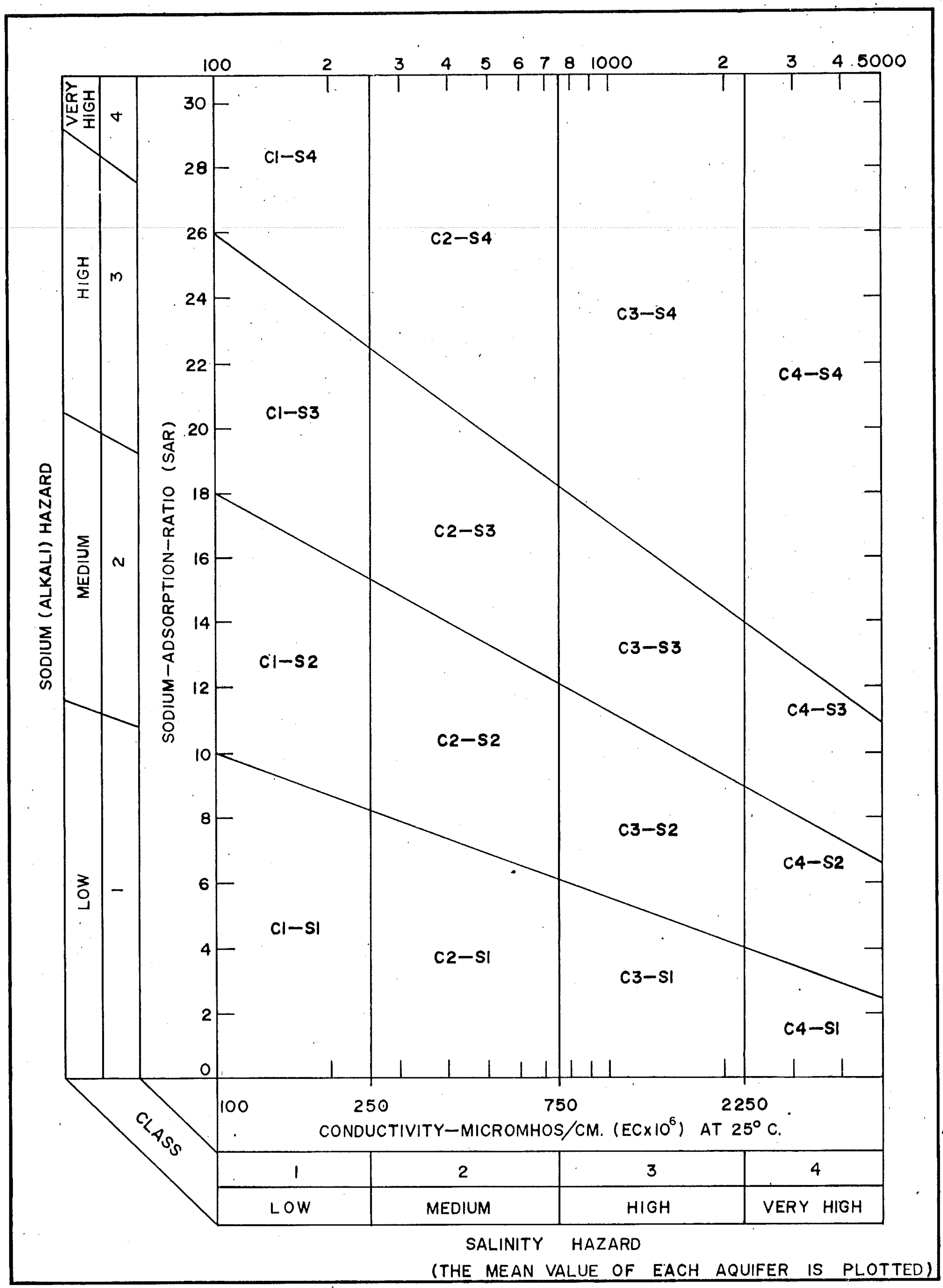
Class S4: very high sodium hazard, SAR greater than 26, in generally unsatisfactory for irrigation except under special circumstances.

Bicarbonate content: residual sodium carbonate

When much bicarbonate is present in the water, Ca^{++} and Ma^{++} tend to precipitate as carbonates if evapotranspiration causes the soil solution to become more concentrated. The relative concentration of sodium increases and, as a result, absorption of sodium to the soil complex is likely to increase. The equation expressing the residual sosium carbonate reads:

$$\text{residual } Na_2CO_3 = (CO_3^{=} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

where the concentration is expressed in milliequivalents per litre. When the residual sodium carbonate exceeds the 2.5 value, water is not suitable for irrigation. Waters with values between 1.25 and 2.5 are marginal, and those having a value less than 1.25 are probably safe.



SODIUM (ALKALI) HAZARD
VERY HIGH
HIGH
MEDIUM
LOW
4
3
2
1
SODIUM-ADSORPTION-RATIO (SAR)
C1-S4
C1-S3
C1-S2
C1-S1
C2-S4
C2-S3
C2-S2
C2-S1
C3-S4
C3-S3
C3-S2
C3-S1
C4-S4
C4-S3
C4-S2
C4-S1
100
250
750
2250
5000
CONDUCTIVITY-MICROMHOS/CM. (ECx10^6) AT 25° C.
CLASS
1
2
3
4
LOW
MEDIUM
HIGH
VERY HIGH
SALINITY HAZARD
(THE MEAN VALUE OF EACH AQUIFER IS PLOTTED)

APPENDIX C

GRAIN-SIZE DATA AND HYDRAULIC CONDUCTIVITIES

Grain-size data and hydraulic conductivity

Testhole name Land location	Depth ft.	D^1_{10} mm	K^2 cm/s	K^3 m/day
SRC Matchee 81	280	0.21	4.4×10^{-2}	38
SE9-32-59-14-W3	295	0.15	2.25×10^{-2}	19
	350	0.195	3.8×10^{-2}	33
	390	0.152	2.3×10^{-2}	20
	410	0.16	2.56×10^{-2}	22
SRC Meadow Lake 81-1	140	0.30	9.0×10^{-2}	78
NE1-28-60-17-W3	160	0.254	6.45×10^{-2}	56
	180	0.22	4.84×10^{-2}	42
	210	0.235	5.52×10^{-2}	48
	230	0.150	2.25×10^{-2}	19
SRC Four Corners 81	220	0.20	4.0×10^{-2}	35
SW5-61-18-W3	240	0.22	4.84×10^{-2}	42
	260	0.19	3.61×10^{-2}	31
	280	0.13	1.69×10^{-2}	15
SRC Dorintosh 81-3	140	0.18	3.24×10^{-2}	28
SE3-10-62-18-W3	160	0.243	5.9×10^{-2}	51
	180	0.30	9.0×10^{-2}	78
	200	0.27	7.29×10^{-2}	63
	220	0.24	5.76×10^{-2}	50

Grain-size data and hydraulic conductivity

Testhole name Land location	Depth ft.	D_{10}[1] mm	K[2] cm/s	K[3] m/day
SRC Dorintosh 81-1	280	0.24	5.76×10^{-2}	50
SE1-3-62-19-W3	310	0.213	4.54×10^{-2}	39
	350	0.235	5.52×10^{-2}	48
SRC Golden Ridge 81	240	0.20	4.0×10^{-2}	35
SW12-23-62-21-W3	260	0.225	5.06×10^{-2}	44
	280	0.23	5.29×10^{-2}	46
	300	0.24	5.76×10^{-2}	50
	320	0.195	3.8×10^{-2}	33
	340	0.185	3.42×10^{-2}	30
SRC Johnston Lake 8	220	0.150	2.25×10^{-2}	19
NW16-22-63-23-W3	240	0.137	1.88×10^{-2}	16
	260	0.17	2.89×10^{-2}	25
	280	0.19	3.61×10^{-2}	31
	300	0.31	9.61×10^{-2}	83
	320	0.19	3.61×10^{-2}	31

Notes: 1 The D_{10} was taken from grain-size gradation curves as determined by sieve analysis using 1/2 Q sieves. It is the grain-size diameter at which 10% of the soil particles are finer and 90% are coarse.

2 $K = 1.0 (D_{10})^2$ D_{10} in millimeters, K in cm/s

3 K (m/day) = 864 K (cm/s)

APPENDIX D

DISCUSSION OF TERMINOLOGY AND LIST OF CONVERSIONS

APPENDIX D

DISCUSSION OF TERMINOLOGY

An Aquifer: is a zone in which a well can be constructed which will yield water at a sufficient rate for the need intended (Meneley, 1972).

A Semi-confining Layer: is a layer which has a low, though measurable, hydraulic conductivity and in which the horizontal flow component can be neglected (Kruseman and de Ridder, 1970).

An Aquifer System: includes one or more aquifers and related semi-confining layers, which functions as one geohydrologic unit under development conditions (Meneley, 1972).

A "Confining" Layer: is a layer in which the hydraulic resistance to vertical flow is so large that for all practical purposes the layer can be considered as impervious.

A Semi-confined Aquifer: or leaky aquifer, is a completely saturated aquifer that is bounded above by a semi-confining layer and below by a layer that is either confining or semi-confining (Kruseman and de Ridder, 1970).

Hydraulic Resistance (c): also called reciprocal leakage coefficient or resistance against vertical flow, is the ratio of the saturated thickness m^1 of the semi-confining layer to the vertical hydraulic conductivity K_v^1 of this layer. (Kruseman and de Ridder, 1970).

The Net Groundwater Yield: is the additional amount of water resource available that is derived by increasing the average rate of groundwater recharge by groundwater development (Meneley, 1972).

The Sustained Yield: of an aquifer is the amount of groundwater which can be withdrawn continuously without lowering water levels to critical stages or causing undesirable changes in water quality (Walton, 1970). Meneley (1972) considered the sustained yield as the sum of the net groundwater yield and the amount of water which becomes available as result of a decrease in groundwater discharge which inevitably must occur as a result of groundwater development and which cannot be credited as a net increase.

List of Conversion

1 U.S. gallon (gal) = 3.785 litres

1 Imperial gallon (I gal) = 4.546 litres

1 gal = 0.8327 I gal

1 I gal = 1.2011 gal

1 gal/day x ft^2 = 4.07 x 10^{-2} m/day

1 I gal/day x ft^2 = 4.89 x 10^{-2} m/day

1 m/day = 24.57 gal/day x ft^2

= 20.45 I gal/day x ft^2

1 I gal/day x ft = 1.24 x 10^{-2} m^2/day

1 I gal/day x ft = 1.49 x 10^{-2} m^2/day

1 m^2/day = 80.65 gal/day x ft

= 67.11 I gal/day x ft

1I gal/min = 5.45 m^3/day

1 gal/min = 6.55 m^3/day

1 m^3/day = 0.18 gal/min

= 0.15 I gal/min

1 acre-feet = 1234 m^3

1 mile = 1609 m = 1.609 km

1 km = 0.62 mile

1 $mile^2$ = 2.59 km^2

1 km^2 = 0.39 $mile^2$

Piezometer SRC Matchee 81: SE9-32-59-14-W3

Casing: 275 feet, black steel, diameter 2 inches

Screen: stainless steel, slot 10, diameter 2 inches

Screen bottom at approximately 276 feet below ground surface

Flowing testhole SRC Mudie Lake 81-2: SE8-14-60-26-W3

July 16, 1982: Testhole was drilled to a depth of 160 feet. Coarse sand and gravel was encountered at depth of 90-108 feet. Prior to E-logging hole started to flow at an estimated rate of 5 Igpm. Specific gravity of mud at time flow started was approximately 1.065. This suggests that the hydraulic head was about 7 feet above ground level. Mud specific gravity was increased to 2.20 to cease flow and to allow for E-logging. Hole was cemented off with three sacks of cement, mixed with one gal. of bentonite and 40 Igal. of water. Cement mixture was pumped into the hole and flow ceased. Site checked on July 16, 1982 and no flow was observed.

Water samples were taken from wells 100 m south of site. These wells were completed in same zone and water level was near or above ground level.

"HATFIELD VALLEY" AQUIFER SYSTEM IN THE WATERHEN RIVER AREA (73K), SASKATCHEWAN.

Volume II

(Appendices E and F)

H. Maathuis
B.T. Schreiner
Geology Division
Saskatchewan Research Council

Prepared for Saskatchewan Environment under the Canada-Saskatchewan Interim Subsidiary Agreement on Water Development for Regional Economic Expansion and Drought Proofing

June, 1982

SRC Publication No. G-744-7-C-82

TABLE OF CONTENTS

A P P E N D I X   E

TESTHOLE LOGS, PIEZOMETER COMPLETION AND FLOWING TESTHOLE DATA

A P P E N D I X F

WATER QUALITY DATA

Original

Johnston Lake Piezometer

Bottom of washdown valve to bottom of screen	0.41 ft.
Bottom of washdown valve to bottom of screen slots	0.63 ft.
Bottom of washdown valve to top of screen slots	3.45 ft.
Bottom of washdown valve to top of screen	3.66 ft.
Bottom of washdown valve to top of reducing bushing	3.80 ft.
Bottom of washdown valve to bottom of coupling	23.56 ft.
Bottom of washdown valve to top of coupling	23.77 ft.

Second length

Bottom of pipe to bottom of coupling	19.87 ft.
Bottom of pipe to top of coupling	20.08 ft.

Third length

Bottom of pipe to bottom of coupling	19.87 ft.
Bottom of pipe to top of coupling	20.08 ft.

Fourth length

Bottom of pipe to bottom of coupling	19.88 ft.
Bottom of pipe to top of coupling	20.09 ft.

Fifth length

Bottom of pipe to bottom of coupling	19.88 ft.
Bottom of pipe to top of coupling	20.09 ft.

Sixth length

Bottom of pipe to bottom of coupling	19.87 ft.
Bottom of pipe to top of coupling	20.08 ft.

Seventh length

Bottom of pipe to bottom of coupling	19.87 ft.
Bottom of pipe to top of coupling	20.08 ft.

Eighth length

Bottom of pipe to bottom of coupling	19.87 ft.
Bottom of pipe to top of coupling	20.08 ft.

Nineth length

Bottom of pipe to bottom of coupling	19.86 ft.
Bottom of pipe to top of coupling	20.07 ft.

Tenth length

Bottom of pipe to bottom of coupling	19.87 ft.
Bottom of pipe to top of coupling	20.08 ft.

Eleventh length

Bottom of pipe to bottom of coupling	19.88 ft.
Bottom of pipe to top of coupling	20.09 ft.
Bottom of pipe to top of coupling	22.91 ft.
Bottom of pipe to bottom of top plug	23.13 ft.
Bottom of pipe to top of top plug	23.34 ft.

Total length 226.65 ft.
Piezometer above ground 2.65 ft.
Bottom of piezometer 224.00 feet below ground surface.

Piezometer was put in same hole. No sand pack was used. After pumping piezometer, sand appeared to have collapsed. Three quarter pail of bentonite pellets was put in and annular filled with cuttings and sand.

August 6, 1981 - water level 9.19 metres (30.15 ft.) below top of piezometer.

Flowing Testhole SRC Meadow Lake 81-1: NE1-28-60-17-W3

August 22, 1981: Testhole drilled to depth of 300 feet. During E-logging hole started to flow at low rate. Specific gravity of mud at time of E-logging was approximately 1.05. Additional gel was mixed, specific gravity approximately 1.21, and pumped into testhole. Flow ceased and crew retired for the day.

August 23, 1981: At 02:00 hrs the condition of the hole was checked and appeared to flow heavily. Driller was informed about the situation and conditions were assessed. Hydraulic head appeared to be low and flow high, but excellent drainage conditions existed. Therefore, it was decided to leave the hole flowing until sufficient cement and calcium chloride could be obtained. A batch of 15 sacks of cement and 1 gal. $CaCl_2$ was mixed and pumped in the hole. Flow stopped at 11:00 hrs but cement plug did not hold and flow restarted at 13:00 hrs. Additional cement was brought in and 30 sacks were mixed with 2 gal. $CaCl_2$ and 125 I gal. of water. With 80 feet of dril stem in the hole cement (appr. 225 I gal., specific gravity 1.84) was pumped into the hole and flow ceased at 15:00 hrs. No cement return was obtained. Remainder of hole was filled with cuttings, mixed with cement. Site abandoned at 20:00 hrs. Inspection of site during subsequent days indicated plugging was successful.

Miscellaneous Data: Flow was estimated by driller to be in the order of 100 IGPM. With 60 feet of drill stem in the hole and 20 on the drilling rig, the hydraulic head was measured to be $\pm$ 5 feet above groundlevel. Based on estimated topographic elevation of 1545 ft ASL (top map 25' C.I.) the hydraulic head is $\pm$ 1550 ft. ASL.