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PETROLEUM RELATED GEOCHEMICAL SIGNATURES AND REGIONAL GROUNDWATER FLOW, CHAUVIN AREA, EAST-CENTRAL ALBERTA

by

Stephen Holysh

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled

PETROLEUM RELATED GEOCHEMICAL SIGNATURES AND REGIONAL
GROUNDWATER FLOW, CHAUVIN AREA, EAST-CENTRAL ALBERTA

submitted by Stephen Holysh in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in GEOLOGY

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ABSTRACT

A field-based research project was carried out in east-central Alberta to study the possible role of regional groundwater flow in the generation of geochemical signatures related to petroleum deposits, with a view of applications to exploration. To this end, a regional hydrogeological investigation, a detailed study of water chemistry and a soil-gas study were conducted.

Analysis of pore fluid pressures shows groundwater to move on a regional scale downward from surface to the Mannville sands. Within the entire Mannville Group, but concentrated in the cleaner lower sands, water flows laterally towards the northeast. Underpressuring of these sands suggests recharge, and that subsequent migration is to the near-surface subcrop of the Paleozoic unconformity in northern Saskatchewan.

The study of shallow water chemistry does not appear to be an effective geochemical exploration tool in this recharge area in particular, and in recharge areas in general. However relatively young, shallow groundwaters have been found to contain anomalous water chemistries, specifically with respect to those halogens which can be related to petroleum deposits. Water chemistry surveys may therefore be more successful in regional discharge areas.

Fundamental differences appear to exist in the composition of the hydrocarbon gases detected over local groundwater recharge and

discharge areas. The soil-gas survey suggests that the vertical migration paths of highly soluble gases, such as benzene, may be deflected away from local recharge areas by groundwater flow. These hydrocarbons would then reach the surface laterally offset from the oil pool of their origin. Should further studies prove this to be the case, geochemical exploration for petroleum deposits will be improved if subsurface water flow is considered.

ACKNOWLEDGEMENT

I would like to extend my sincere thanks to Dr. József Tóth for providing me with the opportunity to study petroleum hydrogeology at the University of Alberta. For his inspiration for this project, his steadfast dedication and enthusiasm, his guidance and the many hours of discussion, all of which are reflected in this thesis, I am extremely grateful.

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A final thanks to my committee members who provided guidance and useful criticisms.

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1. INTRODUCTION

Geochemical exploration for hydrocarbons has evolved from its inception in the 1930's into a somewhat nebulous science often viewed with skepticism in the petroleum industry. Geochemical exploration techniques are based on the theory of vertical migration, which assumes that many hydrocarbon reservoirs leak hydrocarbon gases which subsequently migrate vertically upward to the surface, regardless of subsurface conditions. Although biological degradation of hydrocarbons, or alteration to the physical characteristics of rock and surface soils above the hydrocarbon deposit may influence the shape of the resulting soil geochemical anomaly, detection of hydrocarbon gases or gas related geochemical anomalies at the surface is assumed to take place directly above an oil accumulation (Figure 1.1A).

Over the years, several authors have noted the absence of investigations assessing the role of lateral and vertical groundwater flow on the migration paths of ascending hydrocarbon gases, and on the final shape and position of soil-gas anomalies (Hitchon, 1974; Hunt, 1979; Duchscherer, 1981; Philp and Crisp, 1982). Despite these observations no detailed studies have been carried out to investigate this phenomenon since it was brought to light by Pirson in 1946.

A lack of rigorous scientific scrutiny into the fundamentals of geochemical techniques, i.e., timing, rates, pathways and mechanisms of hydrocarbon gas migration from reservoirs to the surface, has also been noted. This has resulted from a general lack of interest in these fundamentals by individuals and by corporations involved in geochemical

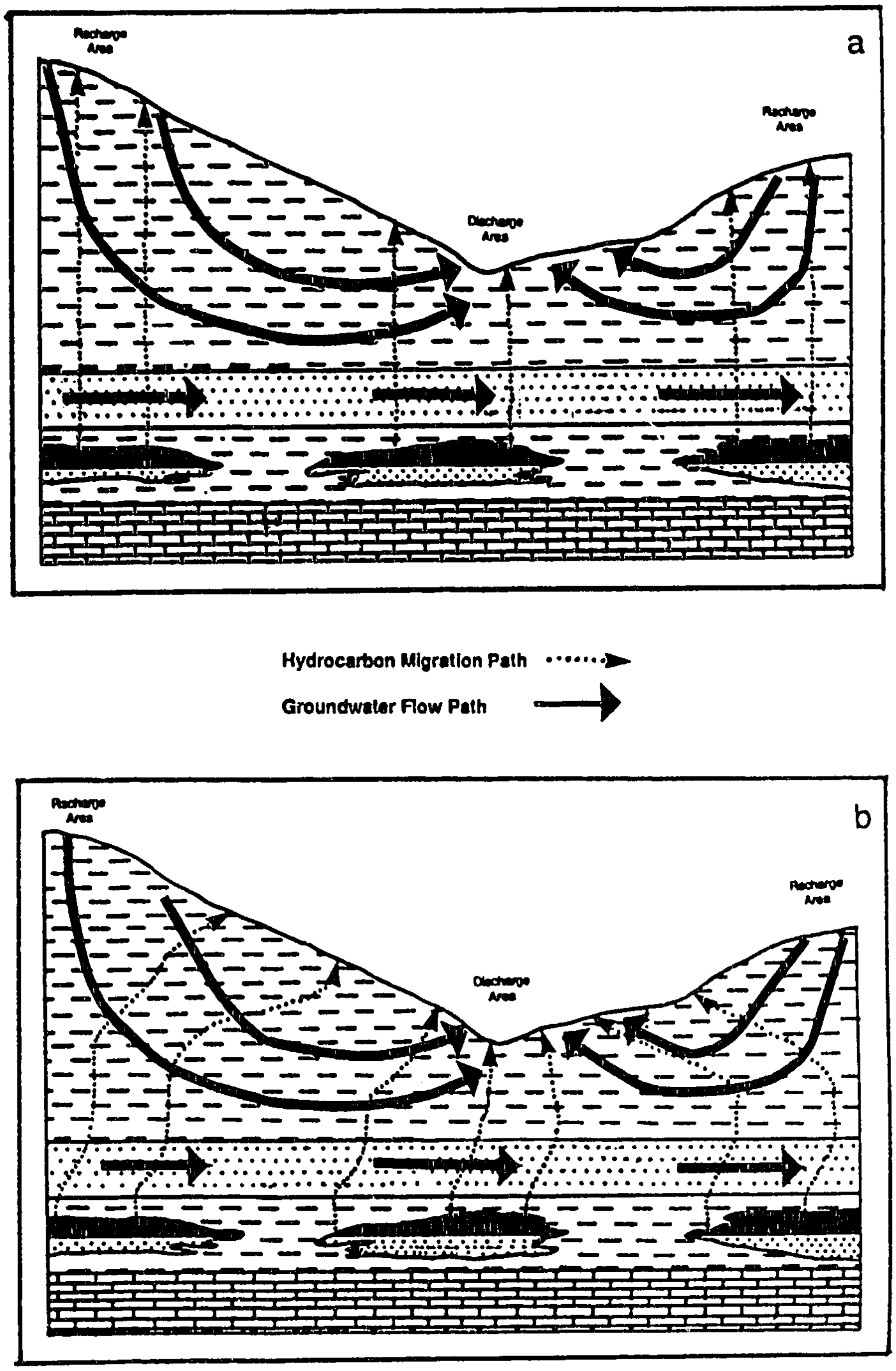


Figure 1.1 Schematic illustration showing:

a) the migration of hydrocarbon gases from oil reservoirs to the surface with groundwater having no effect on the migration path, and

b) the migration of hydrocarbons from the same reservoirs to the surface with groundwater influencing the migration path.

exploration. Numerous papers include statements of a nature similar to MacElvain's (1963)

> "the exact mechanics of such vertical gas movement are a matter of relative unimportance".

More recently, Duchscherer (1981) has stated that:

> "the most important practical requirements of a prospecting tool is that it be successful in locating petroleum accumulations. Any technique that will do this consistently . . . . will be accepted whether or not the underlying theory is completely understood."

Despite his use of the term "consistently", Duchscherer adds in the same paper that:

> "geochemical methods used in exploring for hydrocarbons locate only those petroleum accumulations that give a geochemical anomaly."

This neglect and poor understanding of the fundamentals has led to numerous unsuccessful geochemical surveys, and as a result, the science of geochemical exploration for petroleum has earned a somewhat unfavourable reputation. Price (1986) has, however, suggested that misleading conclusions are too often based on oversimplified assumptions, and that more work is necessary to determine the basic principles upon which geochemical exploration is founded. Despite the situation outlined above, there has recently been a resurgence in petroleum geochemical exploration with millions of dollars spent annually on applying an increasing number of near surface exploration techniques.

The intent of this study is to examine the ability of flowing groundwater to suppress, or to shift ascending hydrocarbon gases and petroleum associated brines so that surface geochemical anomalies would be absent or located laterally offset from their source reservoirs (Figure 1.1B). The influence of groundwater flow on shallow geochemical signatures was examined through regional and local groundwater flow investigations, a detailed study of water chemistry, and a soil gas survey.

The regional flow of groundwater in east-central Alberta and general relationships between water chemistry, geology, and local flow systems in the area were also examined. First, the physiographic setting, geology and both local and regional groundwater flow systems are presented. The water chemistry and the soil-gas survey results are then discussed in light of the geological and hydrogeological characteristics of the area.

1.1 Study Area

The Chauvin area is located in the plains region of east-central Alberta, approximately 48 km east of Wainwright on the Saskatchewan border, (Figure 1.2). The regional flow system was determined for the larger, Lloydminster-Wainwright area shown in Figure 1.2, but geochemical sampling was confined to the immediate Chauvin area.

Topographic elevations in the Chauvin study area range from less than 610 m above mean sea level (amsl) in low lying wet regions to over 760 m amsl in the hills just south of Killarney Lake (Figure 1.3). The region is covered by a glacial till unit that gives the land a gently undulating topography. Dominant physiographic features in the area include a topographically high ridge running north-south through Rg. 2, high hills in

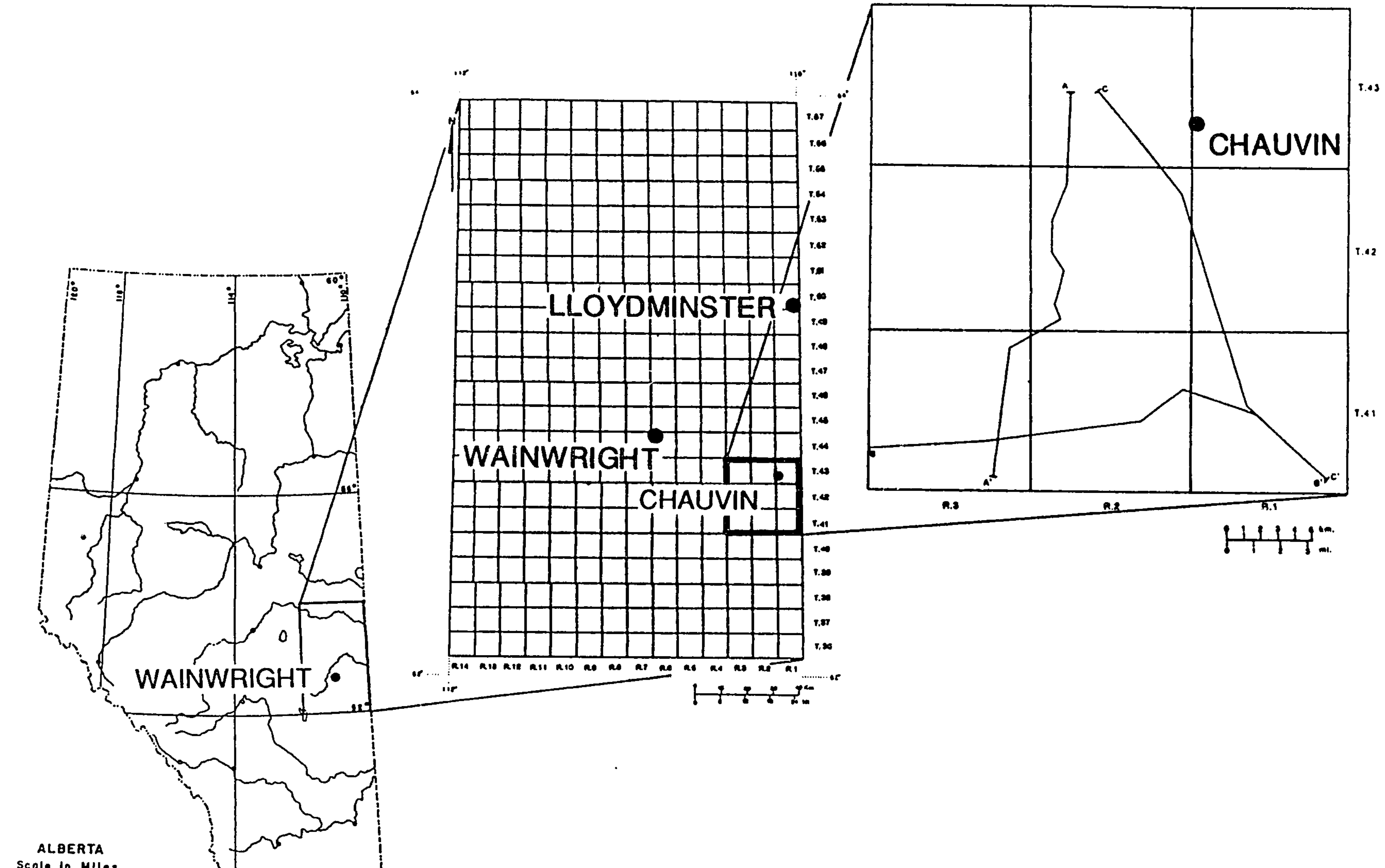


Figure 1.2 Location map.

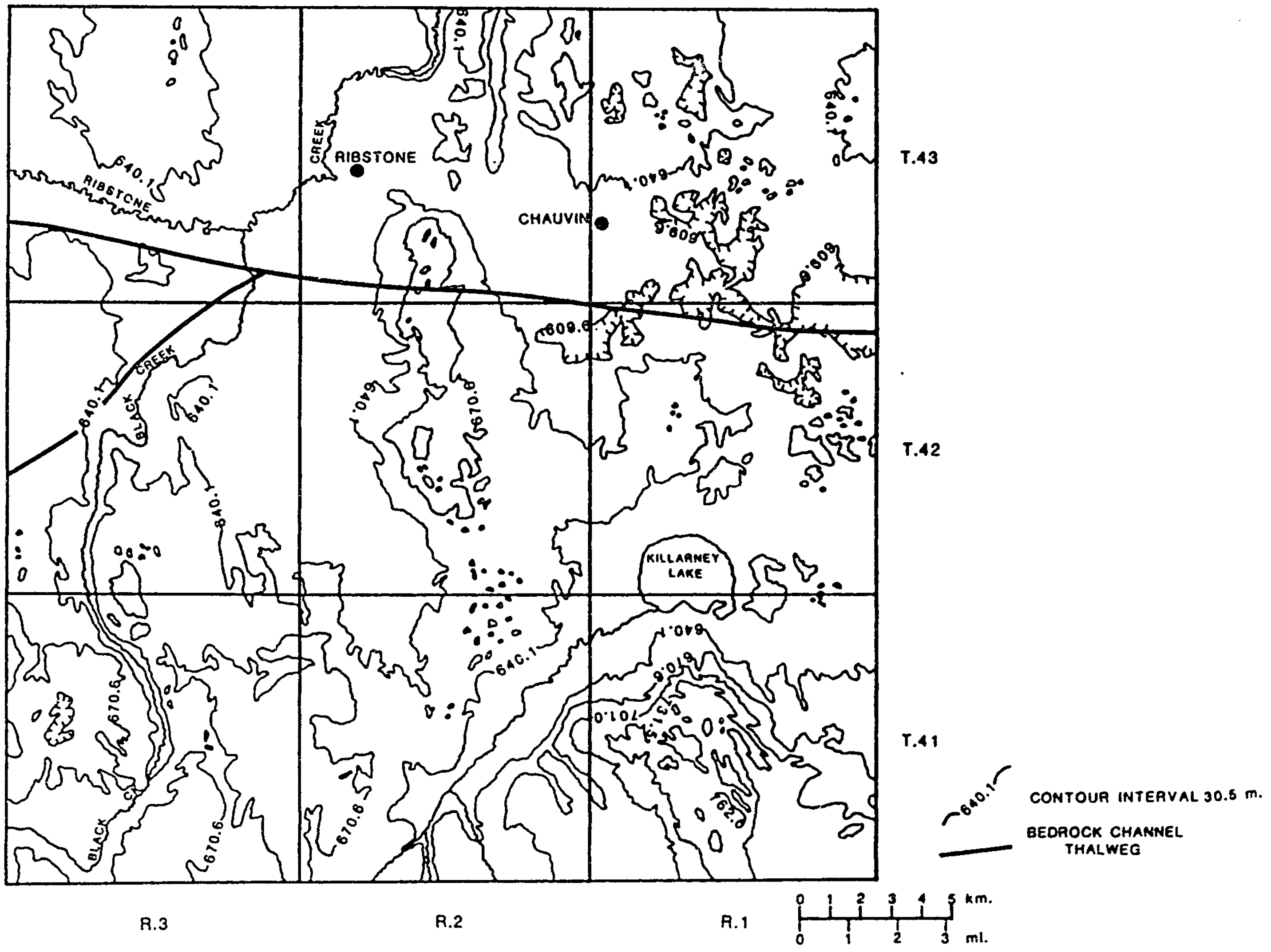


Figure 1.3 Topography of Chauvin area.

Twp.41, Rg.1, and a low lying wet region in Twp. 43, Rg. 1 just south-east of Chauvin.

The hummocky nature of the till results in numerous closed depressions throughout the area in which rainwaters accumulate. The eastern half of the study area is poorly drained with no creeks or rivers draining eastward from the area into Saskatchewan. A consequence of this poor drainage is the variable shore lines displayed by most water bodies. Drainage in the west part of the area is somewhat improved with waters draining northeast via Black Creek into Ribstone Creek which empties into the Battle River, 13 km (8 mi) to the north.

The climate of east-central Alberta is described as humid-continental (LeBreton, 1963) with temperatures ranging from about 32° C in the summer to -30° C in winter. Long winters are followed by short springs during which precipitation can fall as either rain or snow. Summers are moderately warm and dry, although frosts can occur as late as June or as early as September. Fall is mild to cool, and frosts are common.

Oil pools within the area are situated beneath both local recharge and discharge areas of groundwater. Based on literature reports (Christopher, 1980), the area was believed to be a regional discharge region and appeared ideal for a hydrogeological petroleum geochemical study. It was thus expected that, with oil pools located below different local hydrological regimes, the effect of shallow local flow systems on the geochemical surface expressions of the reservoirs could be examined. The Chauvin area was also selected based on the coincidence of mapped chloride anomalies in shallow groundwaters (Hackbarth, 1975), with bedrock channels and deep Mannville oil pools. Initial investigations revealed the area to be a regional recharge region with water moving downward from the land surface. The water chemistry survey was therefore not as effective as was first hoped.

2. GEOLOGY

2.1 Surficial Geology

Surficial sediments and glacial geology of the Wainwright area have been studied by Bayrock (1967). The area was glaciated by the Keewatin ice sheet of Pleistocene age with the nature of surficial sediments suggesting large scale downwasting and stagnation of the glacier and minor fluctuations of the ice front. Over most of the area, the bedrock is directly overlain by till which in turn is locally overlain by glacio-fluvial or glacio-lacustrine sediment.

Local topographic relief is related to the nature of the surficial deposits. Hummocky moraine till is associated with topographically higher elevations and has a rolling or hilly nature. Ground moraine till, although less abundant, is also associated with topographic highs and has a level to undulating nature. Lower elevations are usually covered by flat outwash or glacio-lacustrine deposits.

The high hills in the southeast part of the study area are interpreted as ice thrust ridges by Kupsch (1962). Such ridges are produced where drainage from the margin of a glacier is blocked, resulting in a porewater pressure build-up. The effective stress of the underlying sediment is lowered below that of the ice, which is frozen to the sediment, and large blocks or slices of sediment are lifted into the ice (Christiansen and Whitaker, 1976).

The outwash sand comprising fine to medium grained sand with scattered pebbles, is interpreted to be deltaic in origin. Glacio-lacustrine sediments were laid down in proglacial lakes with coarser materials found more proximal to the ice margin. Kame deposits, associated with stagnating ice, are dominantly medium grained sand with pockets of gravel and till.

Composition of the surficial sediments is variable. The average composition of the till, according to Bayrock (1967), is 50% sand, 30% silt, and 20% clay. The mineralogy of the glacial drift was also examined by Wallick (1981), who determined that quartz, dolomite, plagioclase, calcite, kaolinite, illite, montmorillonite, gypsum, mirabillite and tremolite were present. Dolomite, while absent in the bedrock, is the dominant carbonate mineral in the till. The drift is largely quartz and plagioclase in composition, these being residual minerals of earlier glacio-fluvial erosion of the Belly River Formation.

Drift thickness over the area varies from about 20 m in lower topographic elevations to about 125 m under the hill in Twp. 41, Rg. 1. Thick till accumulations are also found in the bedrock channels shown in Figure 1.3. The hummocky moraine is the thickest drift unit, usually over 20 m in thickness.

2.2 Bedrock Geology

2.2.1 General Overview

The Chauvin region is underlain by the Late Cretaceous Belly River Formation (Figure 2.1). The formation dips gently to the southwest and consists of a series of thin, alternating, fine to medium grained bentonitic sandstones, siltstones, shales, carbonaceous shales, and coal seams (LeBreton, 1963). In the Chauvin area the Belly River can be differentiated into alternating marine shale and continental sandstone sequences. The

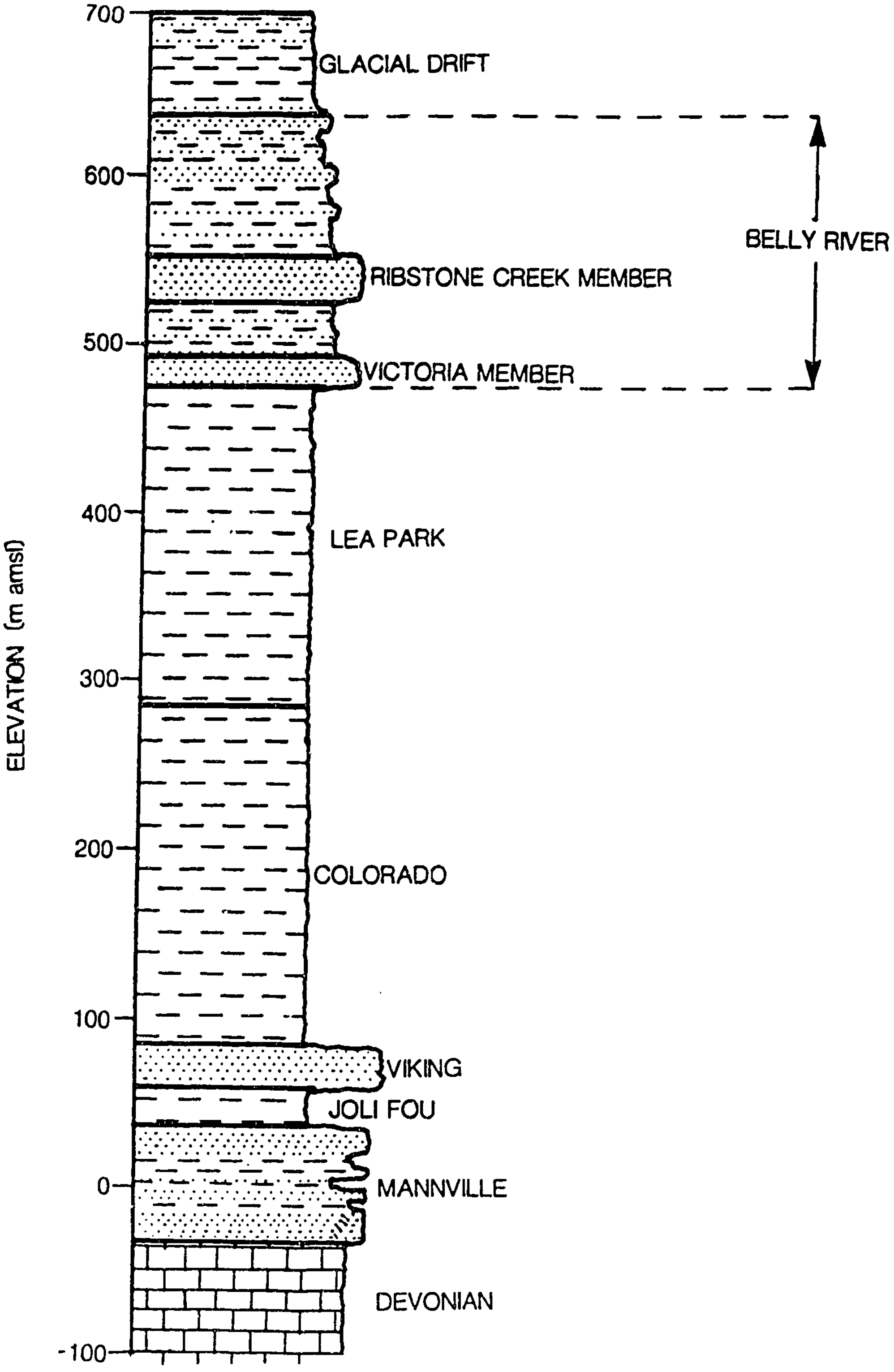


Figure 2.1 Schematic stratigraphic column showing formation compositions and average thicknesses.

near-shore nature of the Belly River aquifers is suggested by numerous coal seams and dirty bentonitic sands that are limited in lateral extent.

A mineralogical analysis of the Belly River Formation in east-central Alberta revealed that forty percent by weight of the total rock consists of clay minerals, largely smectite or swelling clays (Wallick, 1981). The remainder of the rock consists of quartz, plagioclase and minor quantities of K-feldspar. Carbonates ranging in concentration from 0 to 11% were found dominantly as calcite and siderite authigenic cements. The principal primary minerals in the bedrock are: volcanic glass and plagioclase crystals of oligoclase-andesine composition, quartz, K-feldspar, biotite, and organic compounds containing H,C,S, and N which are associated with coal and clay-shale. Secondary minerals or alteration products of the above include: calcite, siderite, pyrite, montmorillonite, illite, kaolinite, chlorite, and cristobalite.

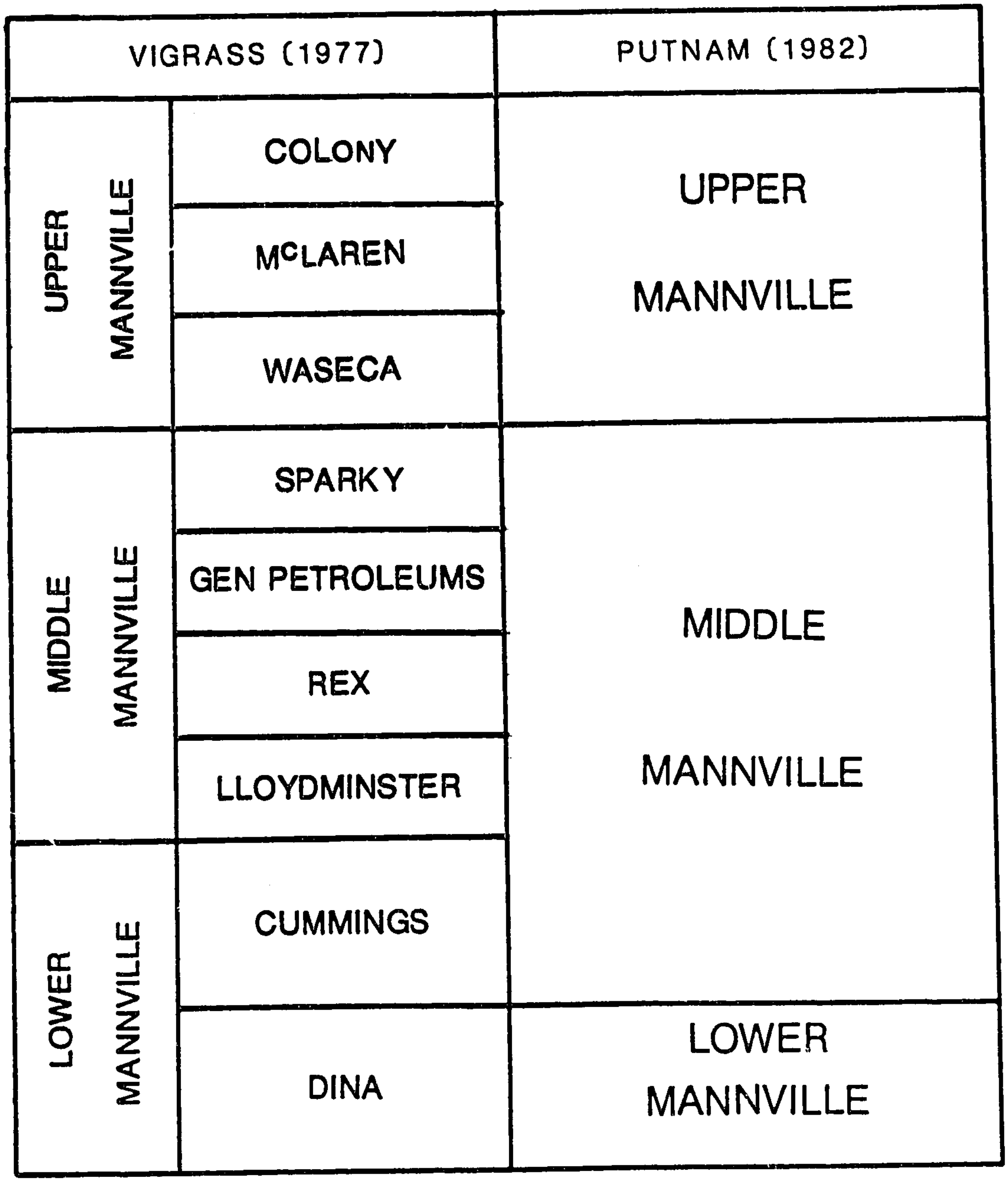
Two major near-shore sandstone units are found beneath the Chauvin region. These are the Ribstone Creek Sandstone and the Victoria Sandstone (Figure 2.1). Both units average about 30 m in thickness and have similar lithologies. The Ribstone Creek Sandstone consists of a series of interbedded sandstones, silty sandstones, and siltstones, with grain sizes ranging from fine to medium sand. Carbonate cementation in the sand ranges from poor to complete. Underlying the Ribstone Creek sand by about 30 m is the Victoria Sandstone. Whereas the Ribstone Creek Sandstone is used both by farmers for domestic water and by the oil industry for industrial purposes, the Victoria Sandstone is not used for ground water purposes in the Chauvin area and does not appear to be a water-producing aquifer in the whole region. The water quality is assumed, based on the water chemistry study, to be poor, probably brackish to saline in nature.

Beneath the Belly River Formation lies the Lea Park Formation (Figure 2.1), a dominantly shale unit with local dirty sandstone beds or lenses. This shale is approximately 200 m thick and is underlain by about 200 m of bentonitic Colorado Shale. Both shale units were deposited in a broad, slowly subsiding epeiric sea. Beneath the Colorado Formation is the gas-producing, marine, Viking Sandstone. This unit averages 20 to 30 m in the study area. The Joli Fou shale, situated beneath the Viking Formation, is a relatively thin (25 to 40 m), extensive dark grey marine shale. The Mannville sands lie below the Joli Fou shale, and extend about 150 m to the Paleozoic unconformity (Figure 2.1).

2.2.2 Mannville Sedimentology

The Mannville Group is a complex assemblage of sandstones, siltstones, shales and coals of both marine and continental origin. The lack of chronostratigraphic units, and common drastic lateral facies changes, has made the development of a rigourous stratigraphic framework difficult. Informally, the Mannville has been divided into the lower, middle and upper subgroups. Subsequently it has been divided into nine members: the Colony, McLaren, Waseca, Sparky, General Petroleums (G.P.), Rex, Lloydminster, Cummings, and Dina (Vigrass, 1977). Putnam (1982) classifies the Colony, McLaren, and Waseca Formations as upper Mannville, the Dina as lower Mannville, and the remaining formations as middle Mannville (Figure 2.2). In this study the Cummings and Dina members were considered to constitute the lower Mannville.

Early Mannville sedimentation was influenced by the paleotopography



VIGRASS (1977)		PUTNAM (1982)
UPPER MANNVILLE	COLONY	UPPER MANNVILLE
	McLAREN	
	WASECA	
MIDDLE MANNVILLE	SPARKY	MIDDLE MANNVILLE
	GEN PETROLEUMS	
	REX	
	LLOYDMINSTER	
LOWER MANNVILLE	CUMMINGS	
	DINA	LOWER MANNVILLE

Figure 2.2 Mannville stratigraphy.

and structure on the Paleozoic unconformity surface. Extensive erosion before the onset of Mannville deposition is indicated by 150 m of relief found on this surface (Orr et al., 1977). The position of northwest trending ridges on the unconformity surface appears to interrupt the lateral continuity of Mannville sands until Sparky time when these ridges finally became buried.

The emergence of land that accompanied the unconformity resulted in karstification of the upper Devonian units (Tóth, 1978) and the deposition of the nonmarine, dominantly fluvial clastic Dina sands. These sand bodies are tabular in nature, having accumulated in local lows of the eroded Paleozoic rocks.

The Cummings, Lloydminster, Rex, G.P., and Sparky Formations were deposited in marine to near shore marine environments. Their cyclic nature reflects transgressive/regressive phases of the Boreal and Gulfian early Cretaceous seas. The sand bodies in this interval are dominantly sheet sandstones formed by the seaward progradation of beach facies sands. Sand accreted onto beaches by longshore drift and by landward directed wave action, resulting in extensive sand bodies 6 to 9 metres in thickness and, in some cases, traceable over tens of kilometres. With rapid changes in sea level, the focus of sand deposition moved landward or seaward so that sheet sands in this interval are not always laterally extensive but may be separated by low permeability lagoonal or deeper water sediments (Putnam, 1982). In addition to lateral facies changes, the sheet sands are commonly broken by thick ribbon-shaped sand and shale deposits up to 40 m thick and several hundred metres across. These ribbons can be estuarine channels, tidal inlet channels, tidal creek channels or distributary type channels

(Putnam, 1982). Each sand body has to be studied individually for a depositional environment interpretation.

The upper Mannville (Colony, McLaren, Waseca Formations) is dominated both by sheet sandstones and ribbon-like sand bodies. Ribbon sand bodies are more abundant than in the middle Mannville and sheet sandstones are not as regionally continuous. A pronounced north or north-west trend to the ribbon sands has been observed. The sands were deposited in a continental-fluvial environment with deltaic and tidal influences.

2.3 Petroleum Geology

Petroleum in the Lloydminster heavy oil region is found throughout the Lower Cretaceous Mannville Group sands. The Mannville sands in the Chauvin area are found approximately 650 m below surface, and dip south-west at about 2m/km (Dunning et al., 1980). Four different oil fields are located in the study area, namely: the Hayter, David, Chauvin North, and Chauvin fields (Figure 2.3).

On a regional scale, trapping of oil in the Lloydminster heavy oil belt has been attributed to the dissolution of the underlying Devonian Prairie Evaporite Formation (Putnam,1982) which has resulted in a draping of the overlying sediment and consequent oil trapping in these folded units. However, numerous local stratigraphic petroleum traps have been found in the region. Oil is often trapped in sandstones that onlap lower permeability Devonian strata, in sheet sands that abut updip against shale-filled channels, and in sands that laterally pinch out into more shale-rich facies. The ribbon or channel sand deposits also contain stratigraphically trapped oil.

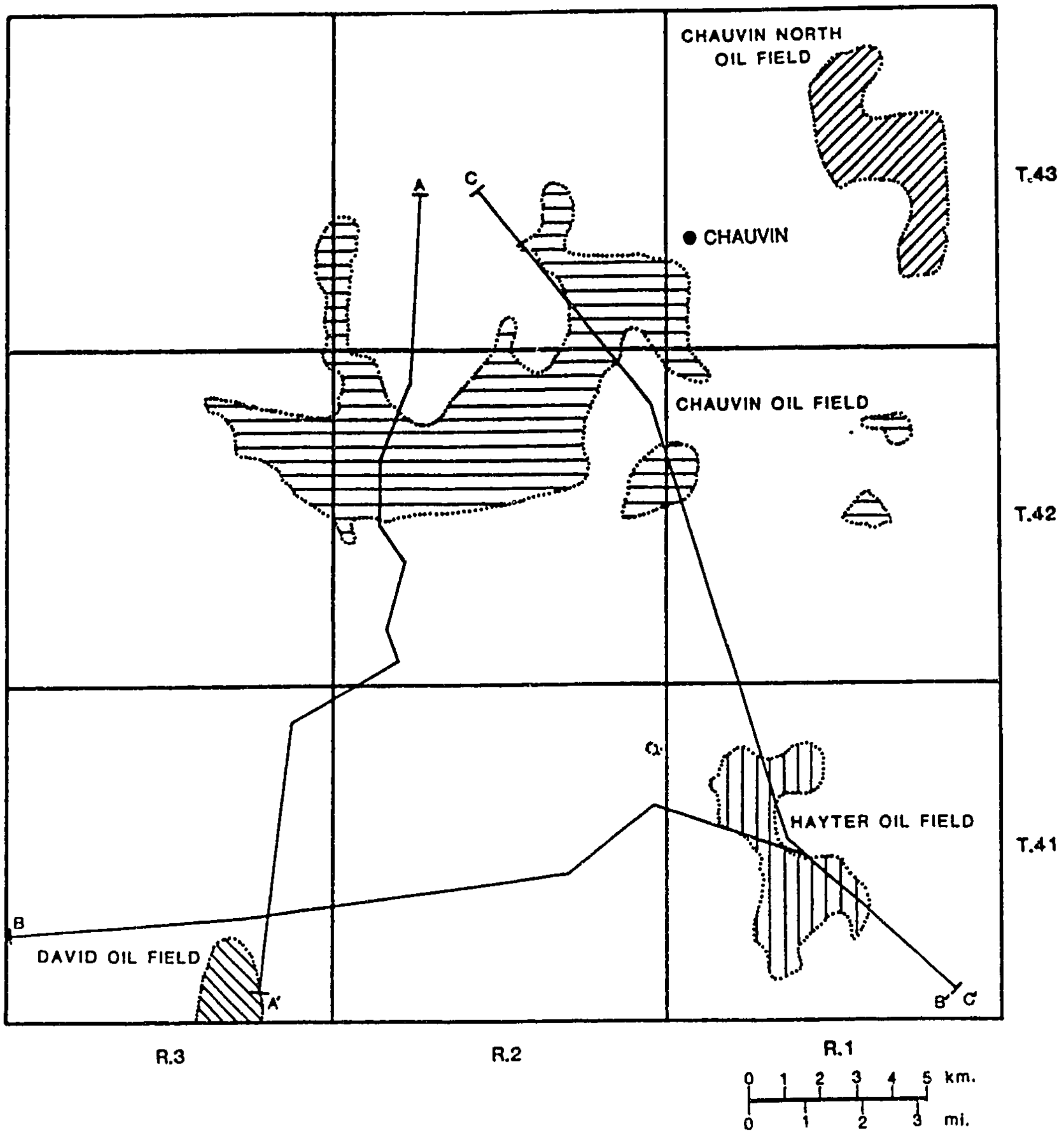


Figure 2.3 Oil field location map.

Structural traps are less common and are dominantly structural highs resulting from differential compaction of sediment over thick ribbon sands. Recently, attention has turned to the role of faulting in petroleum trapping (E. Klovan, pers. comm., 1986). Photolineaments on aerial photographs may indicate deep seated faults that exert a control on petroleum accumulation. These faults, observed in the Lloydminster area by Mollard (1985), have largely been overlooked by oil companies in the area.

Putnam (1982) has observed a relationship between oil distribution and quality, and the groundwater hydrology of the reservoirs. The thick ribbon sands in the upper and middle Mannville and the regionally extensive lower Mannville sands have largely been flushed of oil. Where these sands do contain oil, it is heavier and more viscous than oil in the thinner sheet sands. Oils in the area have a wide range in API gravities, from 10 to 25 degrees (Orr et al, 1977). Putnam (1982) proposed that groundwaters are channelled through these thicker continuous sands while the more isolated, thin sheet sands are bypassed, leaving oils in these sands unaffected. Drill stem test (DST) data in the area are too widely scattered to observe and verify this possibility. The fact that waters from the upper Mannville channel sands are often fresh (total dissolved solids (TDS) levels as low as 3000 ppm) indicates that waters are quickly descending from the surface, possibly through the faults mentioned above.

3. HYDROGEOLOGY

3.1 Groundwater Flow

Groundwater moves in response to energy gradients. The direction of water flow is towards regions of low fluid potential, i.e., low mechanical energy per unit mass of fluid, from areas where this potential is high. The energy at any point in a porous medium is described as the amount of work required to transport a fluid from an arbitrary chosen datum (usually sea level) and state to the position and state of the point in question. This work has three components; i) to raise the water from an elevation $z = 0$ to an elevation z, ii) to accelerate the fluid from velocity $v = 0$ to a velocity v, and iii) to raise the pressure from $p = p_o$ to a pressure p. Simplifying these components comprising the fluid potential results in the following expression

$$\Phi = hg \qquad (3.1)$$

where Φ is the fluid potential, g is the acceleration due to gravity, and h is the hydraulic head, which takes into account the elevation head (the elevation of the point in question) and the pressure head (Figure 3.1) through the following equation

$$h = z + {}^{p}/_{\rho g} \qquad (3.2)$$

where z is the elevation of the point in question, p is the pressure at the

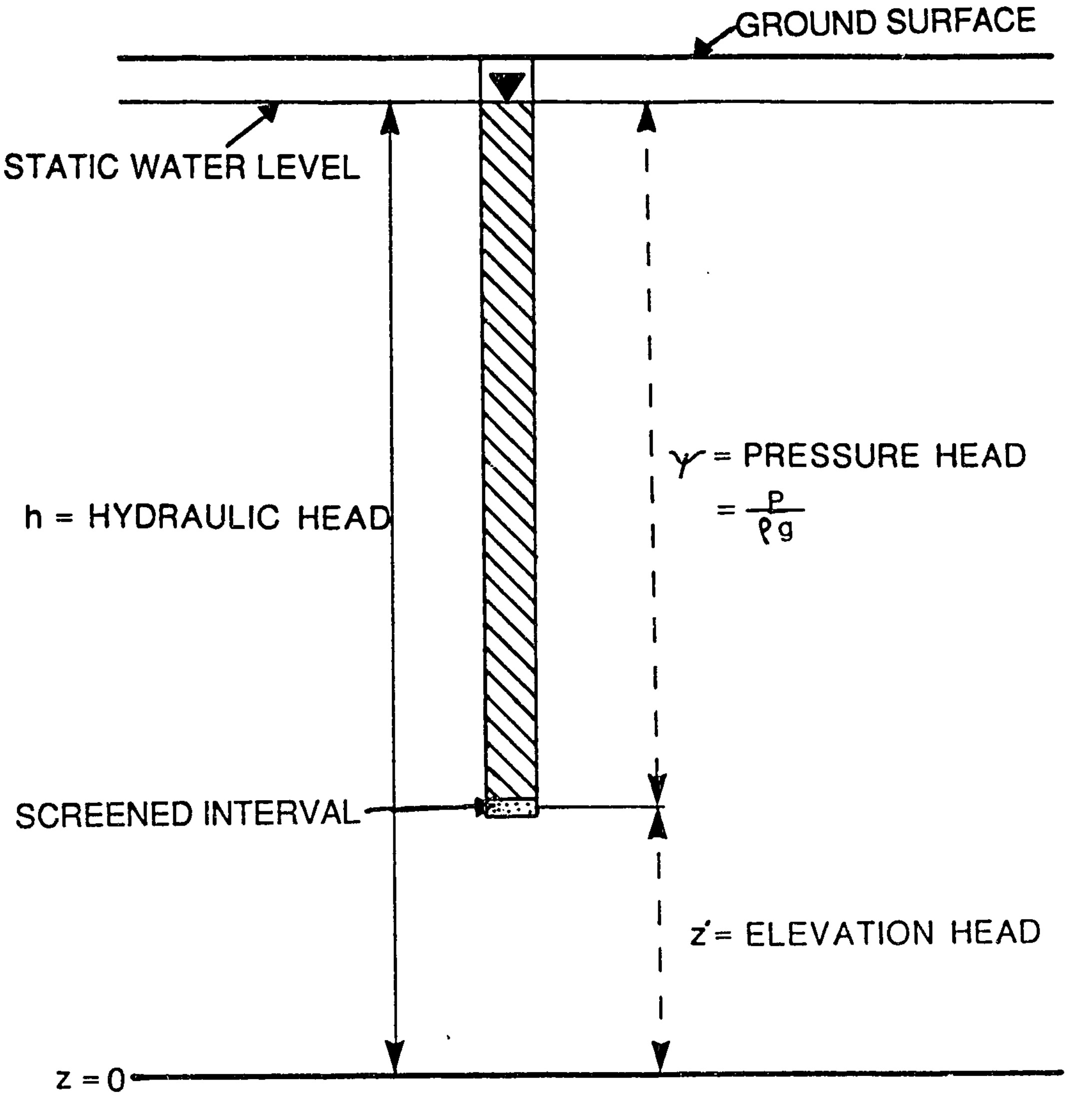


Figure 3.1 Relationship of hydraulic head to pressure and elevation.

point in question, ρ is the density of the fluid, and g is the acceleration due to gravity.

The hydraulic head is therefore a measure of the fluid potential. Hydraulic head is a physical quantity that can be measured at any point in a porous medium, and groundwater flow always takes place from regions of high head to regions of low head. Equation 3.2 can also be used to calculate the hydraulic head at any given point provided the fluid density and the pressure at the point in question are known. A detailed analysis of the fundamentals of fluid flow is available in Freeze and Cherry, (1979).

3.2 Surface Hydrogeological Features

Numerous surface morphological features originate as a direct result of discharging groundwaters (Tóth 1971). Several features indicative of groundwater discharge, including saline soils, surface marshes and lakes, halophytic and phreatophytic vegetation, and flowing wells were found in Chauvin discharge areas.

Upon evaporation of discharging water at or near the land surface, mineral salts dissolved in the water precipitate and accumulate to form saline soils. Salts are most often sodium sulfate or sodium chloride in composition, but can also consist of chlorides and sulfates of magnesium and calcium. Salt accumulations require an evapotranspiration rate that exceeds the groundwater discharge rate, sufficient soluble material in subsurface strata through which the water travels, and low rainfall levels so that accumulating salts are not washed away. Associated with saline soils are halophytes, i.e., salt tolerant plant species. Red samphire is the most noticeable halophyte found in the study area. Its presence indicates saline soil conditions, which might be due to groundwater discharge even where surface salts are not visible.

Where discharge exceeds evapotranspiration, surface lakes and marshes may develop. Distinctions between surface water accumulations resulting from groundwater discharge and those resulting from ponded surface water are discussed by Tóth (1971). Associated with surface water accumulations are phreatophytes, plants that thrive under wet conditions. Willow, foxtail barley, and bulrushes are examples of phreatophytes found in Chauvin discharge areas.

Where the hydraulic head is above the elevation of the land surface, artesian conditions exist. These conditions result in flowing wells and indicate an increase in hydraulic head with depth, a fundamental characteristic of discharge areas. Figure 3.2 shows the location of surface hydrogeological features indicative of discharging groundwater in the Chauvin area.

3.3 Flow Systems

In a unit basin (Figure 3.3a), groundwater moves from topographic highs or recharge areas, to topographic lows or discharge areas. A recharge area is defined as that part of a drainage basin in which the net groundwater flow is directed downwards away from the water table, whereas the discharge region is that part of the basin in which the net flow of groundwater is directed upwards towards the water table. In between these two areas, water flows laterally through the midline area of a basin.

Tóth (1963) has suggested that flow systems can be divided into local, intermediate, and regional levels as illustrated in Figure 3.3b. Where local

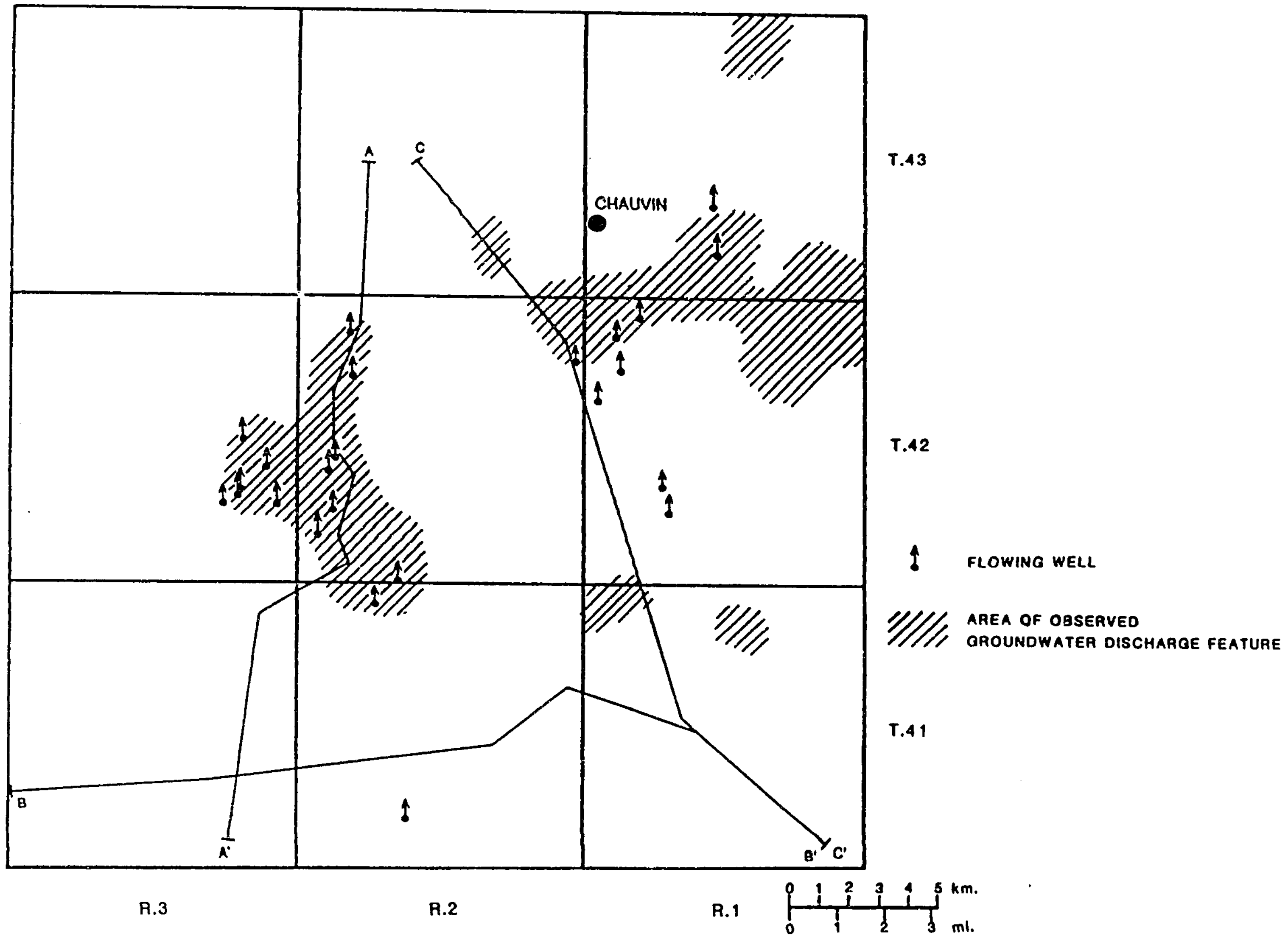


Figure 3.2 Surface discharge features.

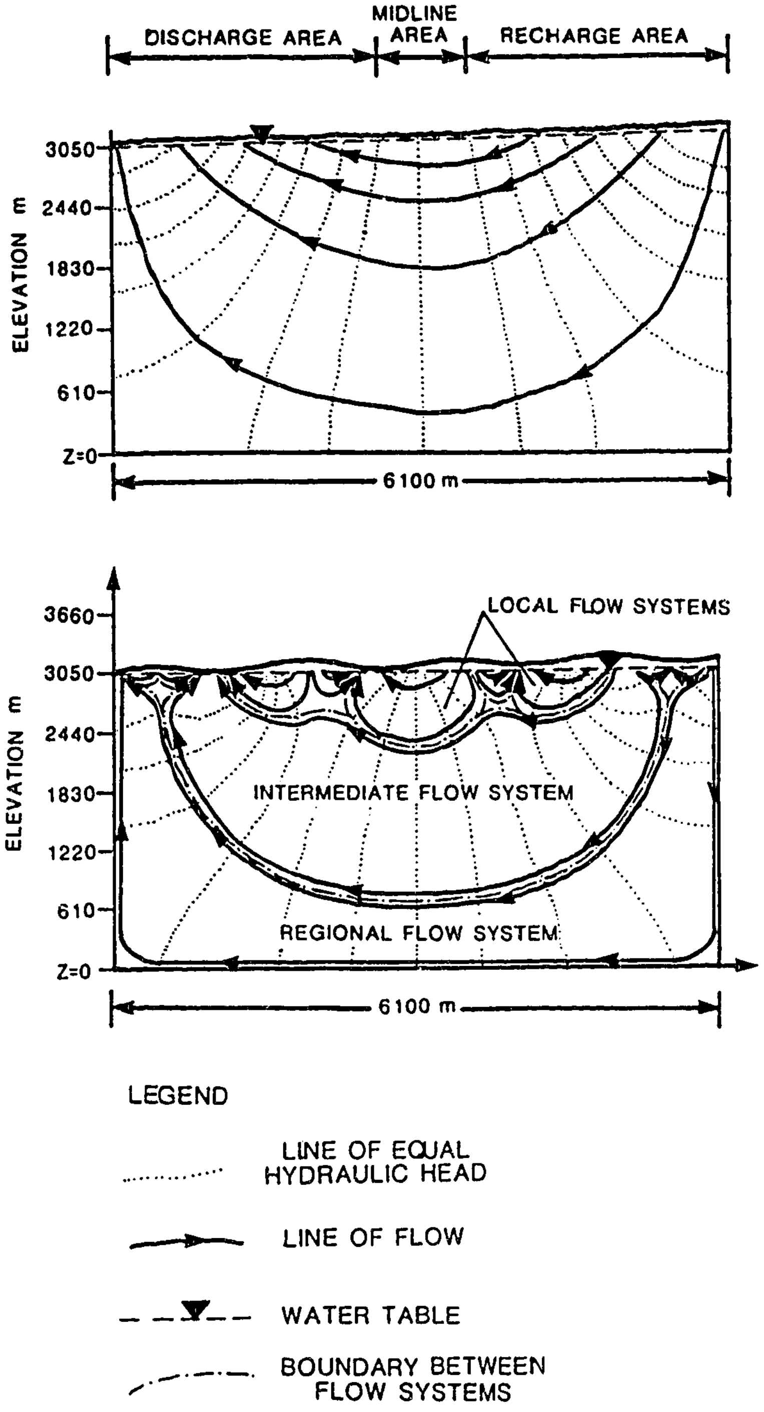


Figure 3.3 a) Flow through a unit basin.
b) Flow through a topographically complex basin.
(Modified From Tóth 1980)

relief is negligible, local systems may not develop, and only regional and intermediate systems will be found. In areas with a pronounced local relief, regional systems may not develop. The terms are not specific, and allow a conceptualization of the nature of ground water flow.

3.4 Regional Hydraulics

3.4.1 Potentiometric Surface Maps

A contoured plot of water-level elevations or hydraulic heads for wells tapping a confined aquifer is referred to as a potentiometric surface map. In calculating hydraulic head values, the density of the fluid is commonly taken as that of fresh water. These plots indicate fluid movement directions within an aquifer with flow occurring from areas of high hydraulic head to areas of low hydraulic head.

Such maps are valid strictly where the fluid density is constant, where no vertical flow components exist, and where the aquifer is approximately horizontal. In most instances, especially in areally extensive studies, these criteria are not met. Density differences, however, are often insufficient to invalidate general conclusions (Tóth, 1978). Potentiometric surface maps constructed for vertically separated aquifers may also permit a qualitative interpretation of vertical flow directions.

Detailed potentiometric surface maps in the vicinity of Chauvin were constructed for the glacial drift and the shallow bedrock. On a more regional scale, a series of four potentiometric surface maps were constructed for different elevation levels in the Mannville sands.

3.4.1.1 Shallow Potentiometric Surface Maps

Potentiometric surface maps were constructed for the glacial drift and shallow bedrock using the water well driller's reports obtained from the Ground Water Resources Information Service of Alberta Environment. These reports indicate well depth and water level in a completed well. The accuracy of the reports is variable and often the exact location of a well or the elevation of a well is not stated. In these cases the well was positioned at the owner's residence if known, or failing that, was placed in the centre of the specified 5 x 5 km area, and assigned the area's average topographic elevation. A summary of these records is found in Appendix A.

Similar patterns of groundwater flow are shown by both the glacial drift and the shallow bedrock potentiometric surface maps (Figure 3.4 and 3.5). The flow systems are controlled by present topography, with groundwater moving from uplands to lowlands. From the topographic map (Figure 1.3), it is apparent that highs of about 640 m or greater are sufficient to generate recharge areas. Of importance is the fact that over the entire region, the head measurements in the shallow bedrock are generally lower than those in the overlying drift, indicating a downward component of groundwater flow on a more regional scale.

3.4.1.2 Regional Potentiometric Surface Maps, Mannville Fm.

Regional potentiometric surface maps for the Mannville Formation (Figures 3.6 through 3.9) were constructed using (DST) data from the files of the Canadian Institute of Formation Evaluation (CIFE). Stabilized reservoir pressures were determined from Horner plots constructed from the DST data. The procedure is described by Horner (1951). CIFE

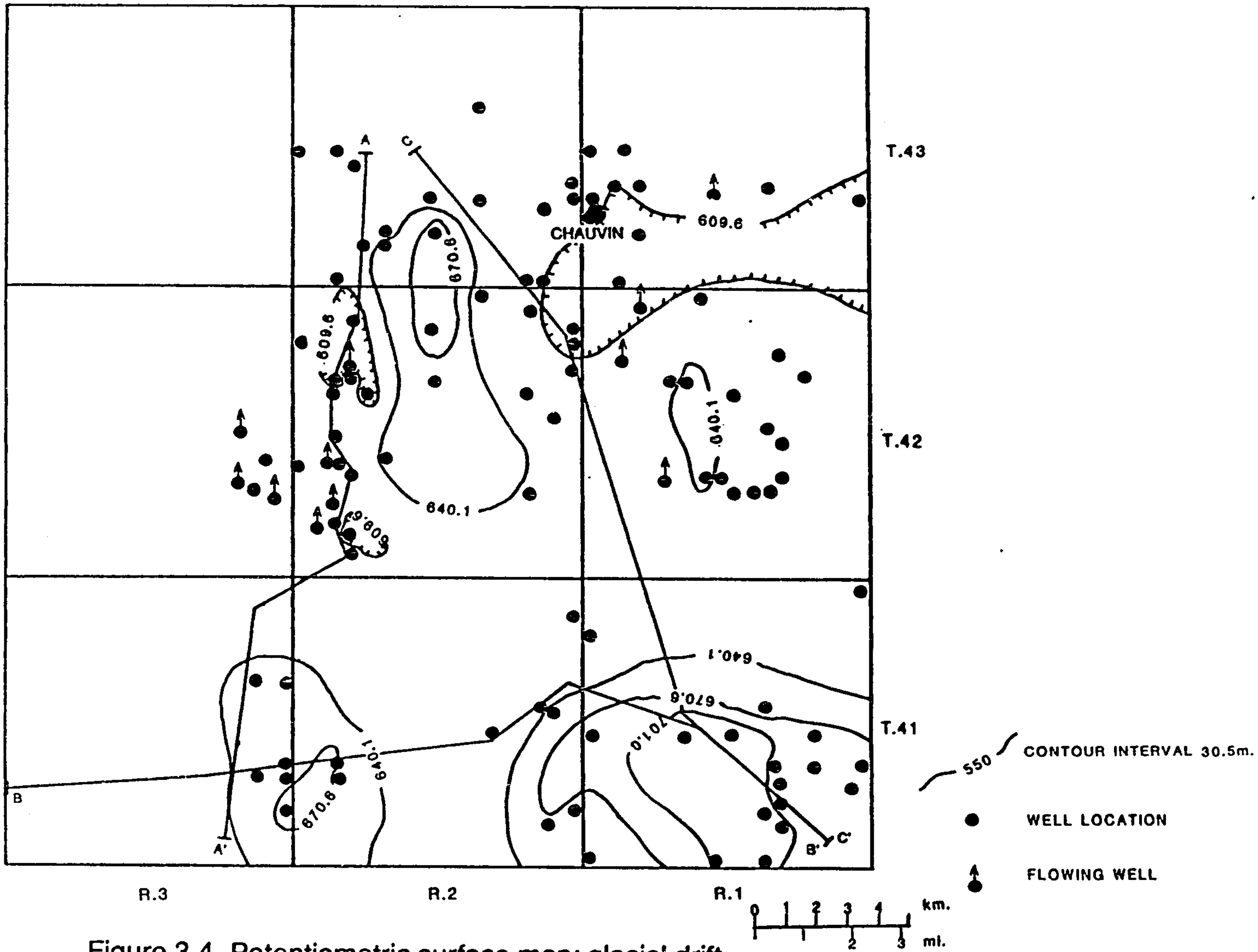


Figure 3.4 Potentiometric surface map; glacial drift.

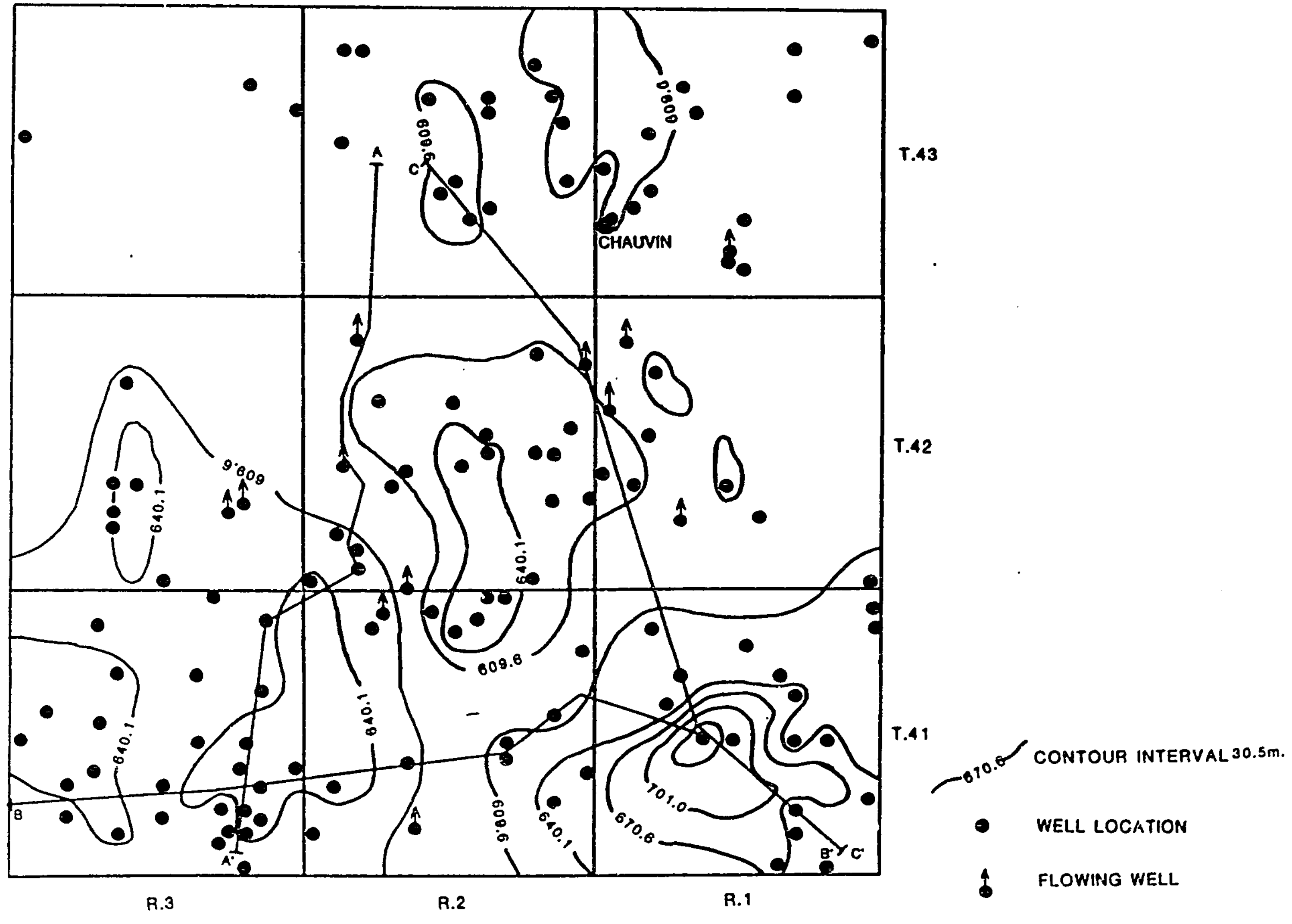


Figure 3.5 Potentiometric surface map; shallow bedrock.

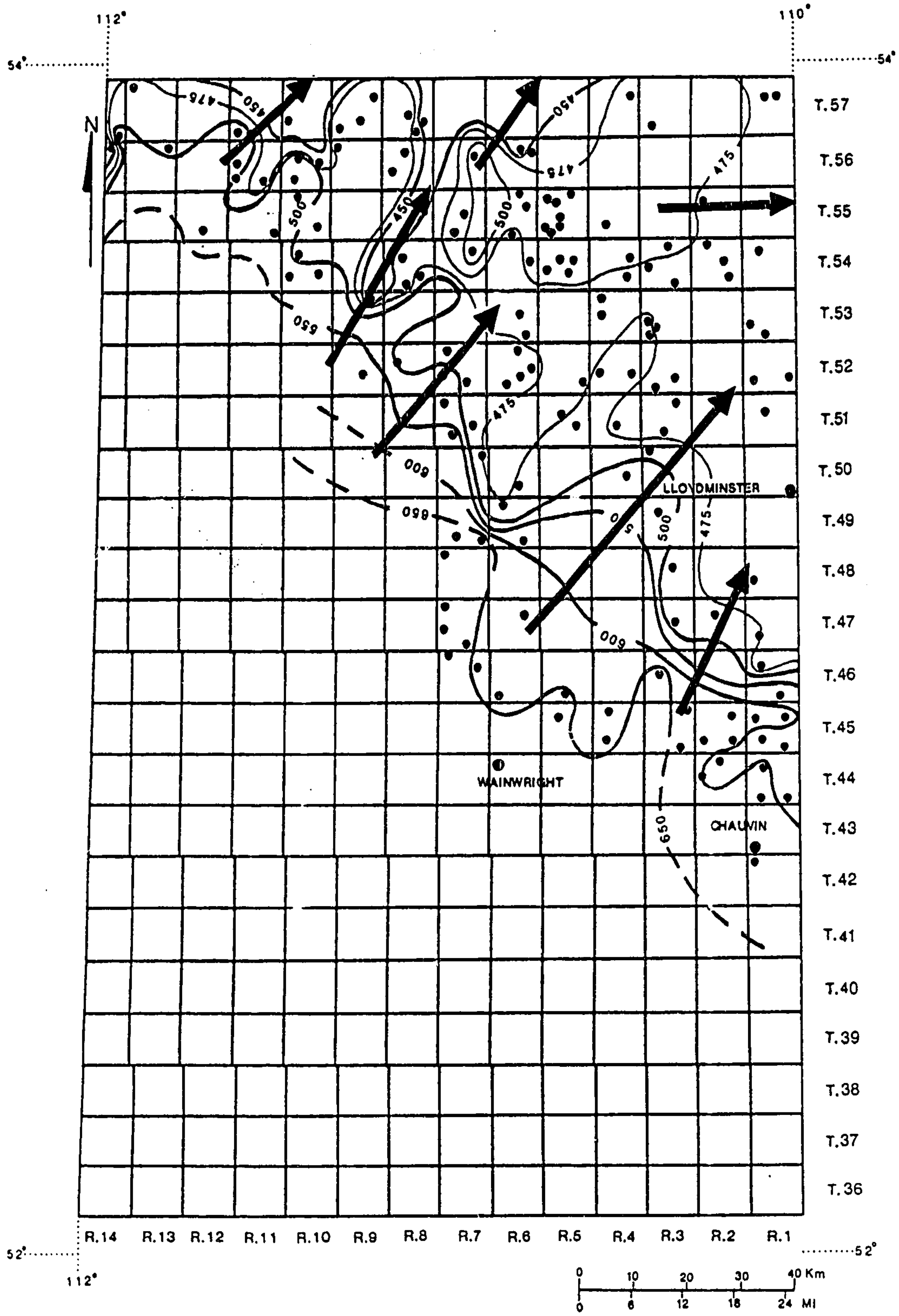


Figure 3.6 Potentiometric surface map: +200 to +100 m (amsl).

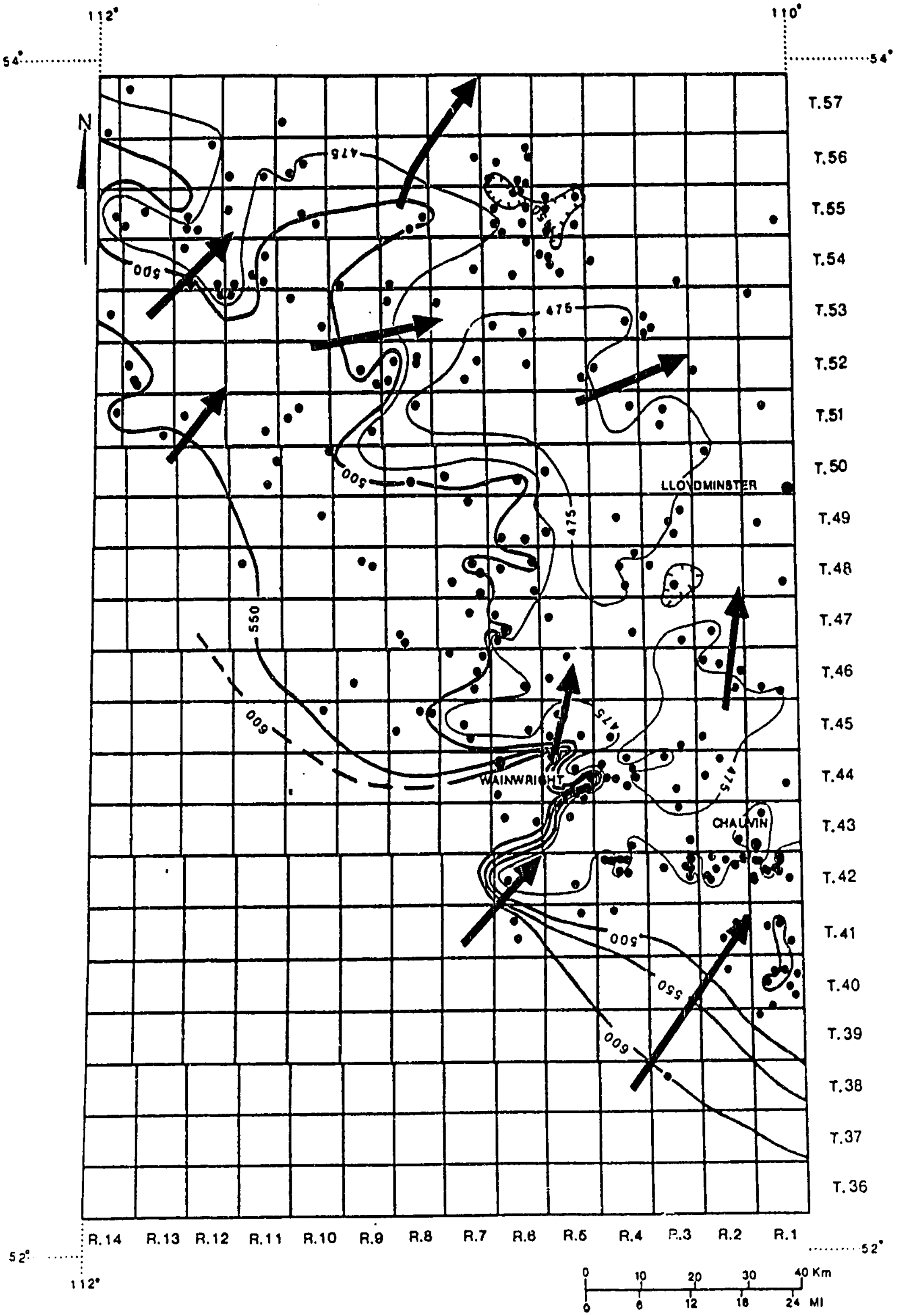


Figure 3.7 Potentiometric surface map: +100 to 0 m (amsl).

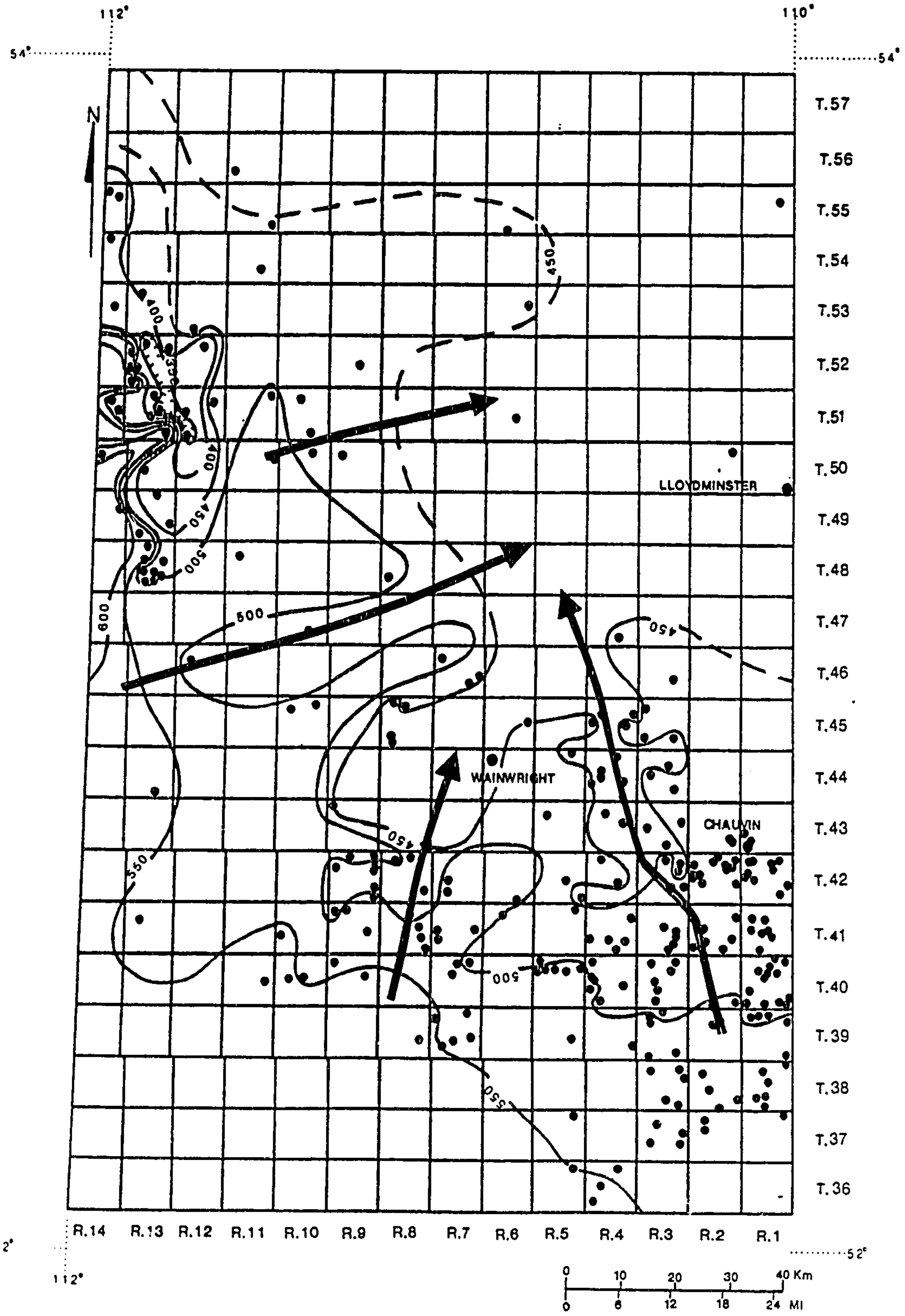


Figure 3.8 Potentiometric surface map: 0 to -100 m (amsl).

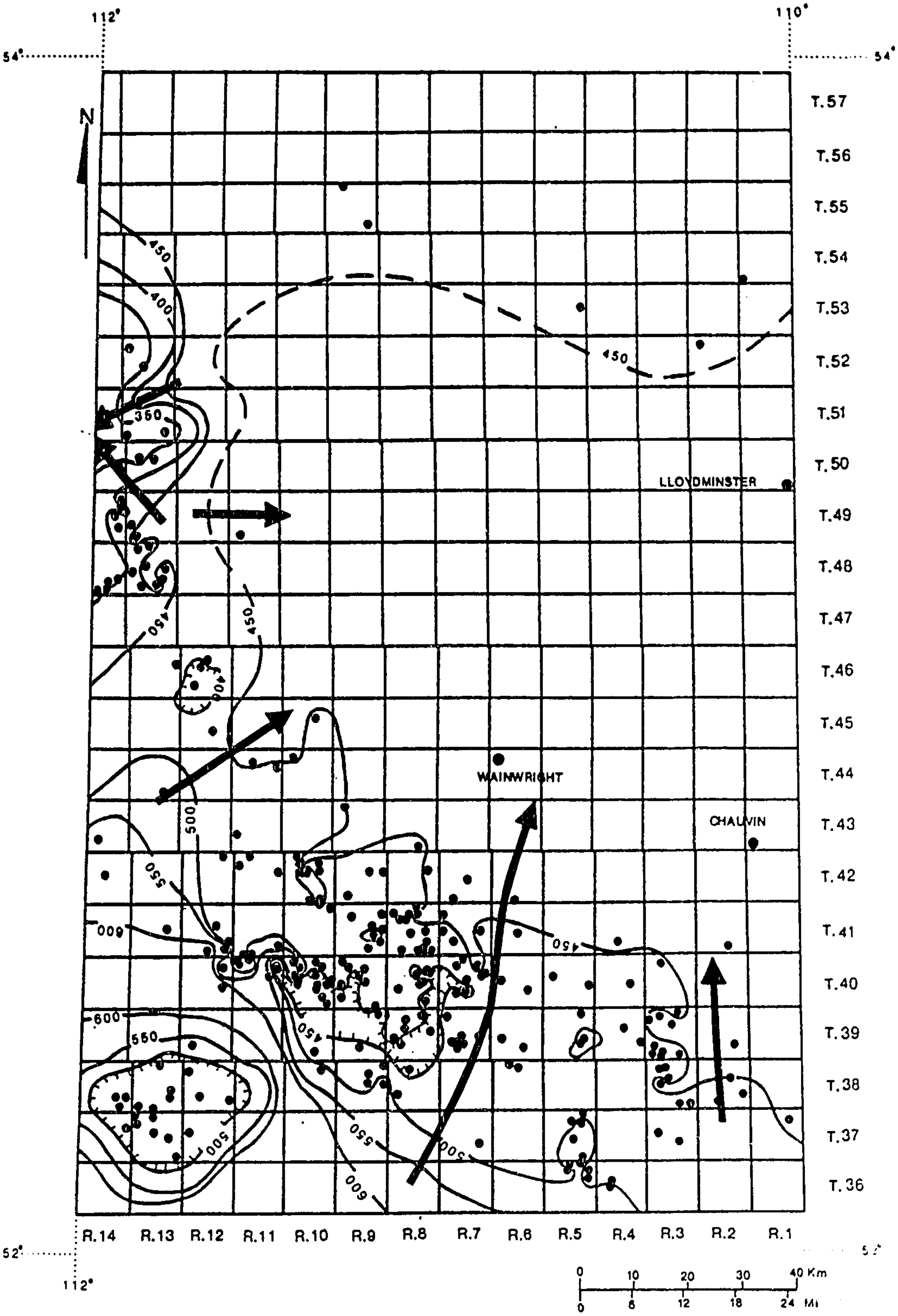


Figure 3.9 Potentiometric surface map: -100 to -200 m (amsl).

categorizes the tests, based on quality, into A, B, C, D, E, F, G, and P classes, A being of the best quality. Over 1500 top quality (A, B, and C) analyses were used in this study. These pressures were further screened for production influences by comparing the DST date to that of the original production date in the area, and by comparing the obtained pressure to the initial pool pressures given by the ERCB (1986). Pressures deemed to be affected by production were not used in the construction of potentiometric surface maps. A list of unscreened data appears in Appendix B.

The regional potentiometric surface maps were constructed for horizontal, 100 m thick intervals through the Mannville sands. Due to the regional dip, and the limited thickness of the Mannville strata, these horizontal sections do not intersect the Mannville over the entire region. The lack of data in the northeast and southwest parts of the maps, results from the intersection of the horizontal slice with the Mannville. The strike of the Mannville sands is, therefore, roughly indicated by the northeast trending contour lines. The higher hydraulic head values to the west in Figure 3.8 and to the southwest in the Figures 3.6, 3.7 and 3.9 are from the overlying Viking Formation. The steep contours between the Viking and the Mannville Group indicate a large pressure change through the Joli Fou Shales. The potentiometric low in the south-west corner of Figure 3.9 results because data in this area are from both the Viking and Mannville Formations. Those values greater than 550 m are from the Viking Formation, whereas the lower values further south are from the Mannville Formation (Figure 3.10).

The main purpose of these maps was to place the Chauvin area hydrogeologically into a regional setting i.e., to see if the Chauvin area was

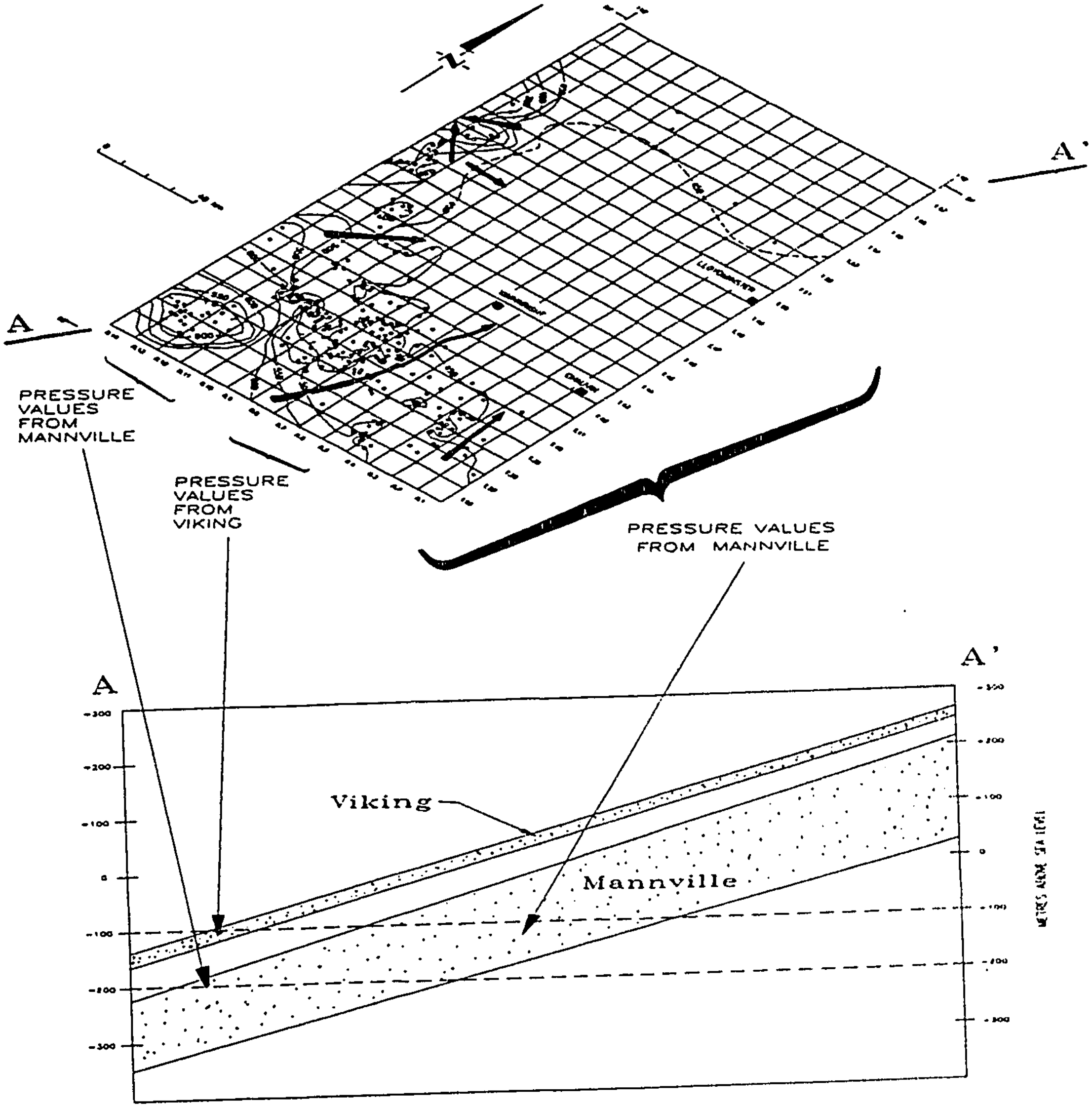


Figure 3.10 Schematic cross-section showing origin of potentiometric low in southwest part of figure 3.9

a regional recharge or discharge area. The maps are therefore discussed in general terms. The four maps show similar trends with water flowing from high heads in the southwest towards lower heads in the northeast. The hydraulic head values in the Mannville also show a decrease with depth throughout the region as seen in areas that are covered by more than one regional potentiometric surface map. In such areas, the head values in the lower section are less than those in the upper section. This suggests vertically downward water movement to the lower Mannville, Dina sands. Water subsequently moves laterally in a north-eastward direction. Local perturbations in the regional potentiometric field are present in all four maps and most likely result from sedimentological variations, (Rakhit, 1987), in the Mannville strata.

3.4.2 Pressure-Depth Diagrams

Pressure-depth diagrams were constructed in areas with DST data available in formations above and below the Mannville Group. Data for these plots were taken from areas covering nine townships (29 km^2) (Figure 3.11). The pressure-depth diagrams for the two areas in the south-west part of the region were combined because of the limited data outside of the Mannville Group and the proximity of the two areas. The plot centred on Twp. 50, Rg. 13 was constructed to examine the potentiometric low in this area.

Hydrostatic pressures are calculated for a hydraulically continuous, unconfined rock body saturated with a static fluid, by the following expression

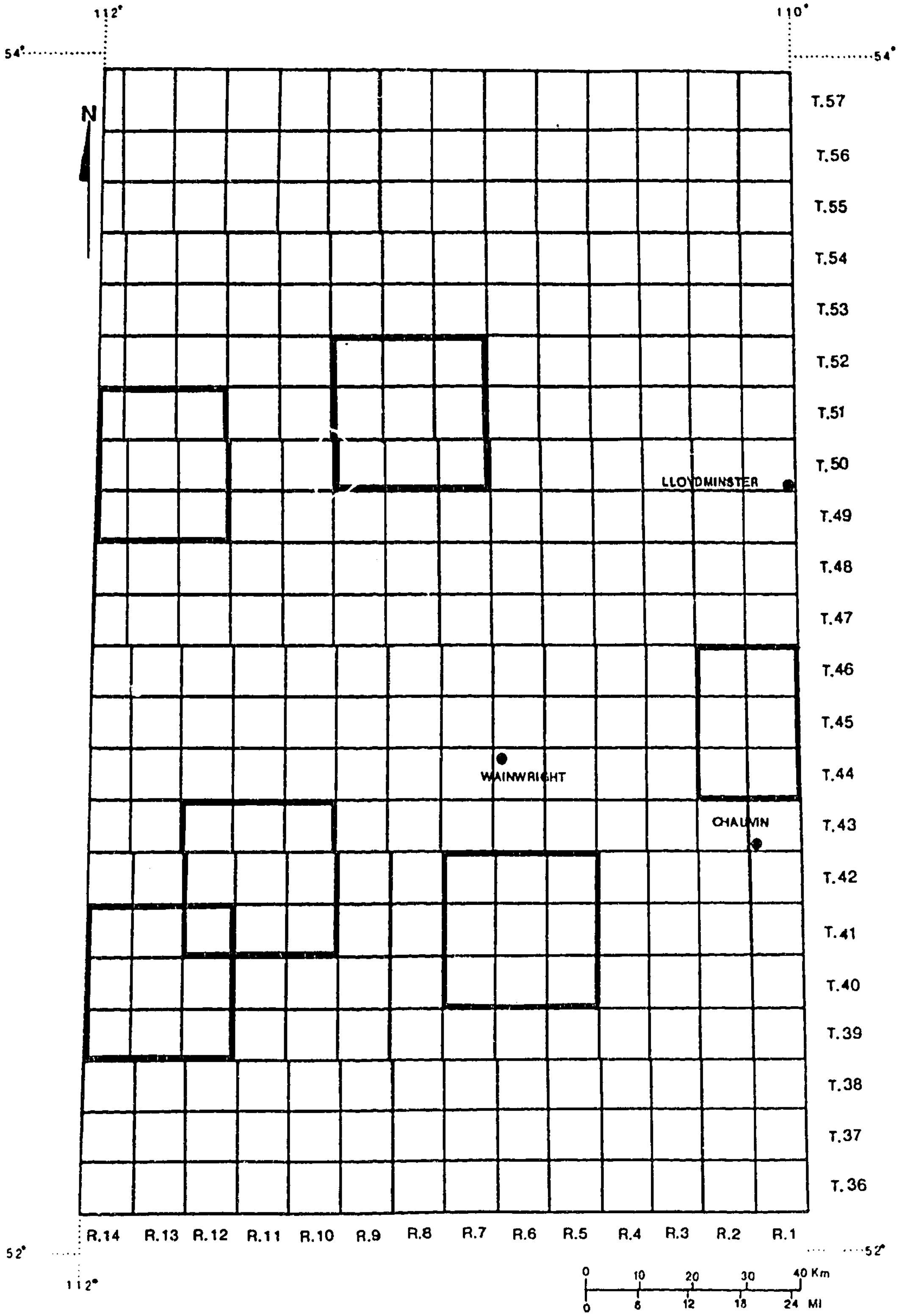


Figure 3.11 Areas for which pressure-depth plots were constructed.

$$p = \rho g d \qquad (3.3)$$

where p is pore pressure, ρ is density of the fluid, g is acceleration due to gravity, and d is depth. At a given depth, an observed pressure that deviates from the hydrostatic pressure calculated by the above expression is termed subhydrostatic if it is less than the hydrostatic value, and termed superhydrostatic if it is greater than the hydrostatic value.

Pressure-depth diagrams readily reveal whether pore fluids in a formation are overpressured, underpressured, or hydrostatically i.e. normally, pressured, and whether flow between or within aquifers has an upward or downward component. The slope of a pressure-depth curve is $\Delta p/\Delta d$, the rate of change in pressure with depth. In a hydrostatic situation where there is no fluid movement, the fluid potential at every point must be equal. Consequently, the rate of downward increase in pressure head must be exactly compensated by that of the downward decrease in elevation head. In areas of downward groundwater flow the fluid potential decreases with depth so that the rate of the downward increase in pressure head must be lower than that of the downward decrease in elevation head. This results in a lower pressure gradient than for the hydrostatic case, and the resulting slope of the pressure-depth curve will be less than the slope of the hydrostatic curve. Conversely, in areas of upward flow, the pressure gradient will be greater than for the hydrostatic case, and the resulting slope of the pressure- depth curve will be greater than that of the hydrostatic curve (Tóth, 1978, 1979; Orr and Kreitler, 1985; Belitz and Bredehoeft, 1988).

The pressure-depth diagrams (Figure 3.12a-f) show similar

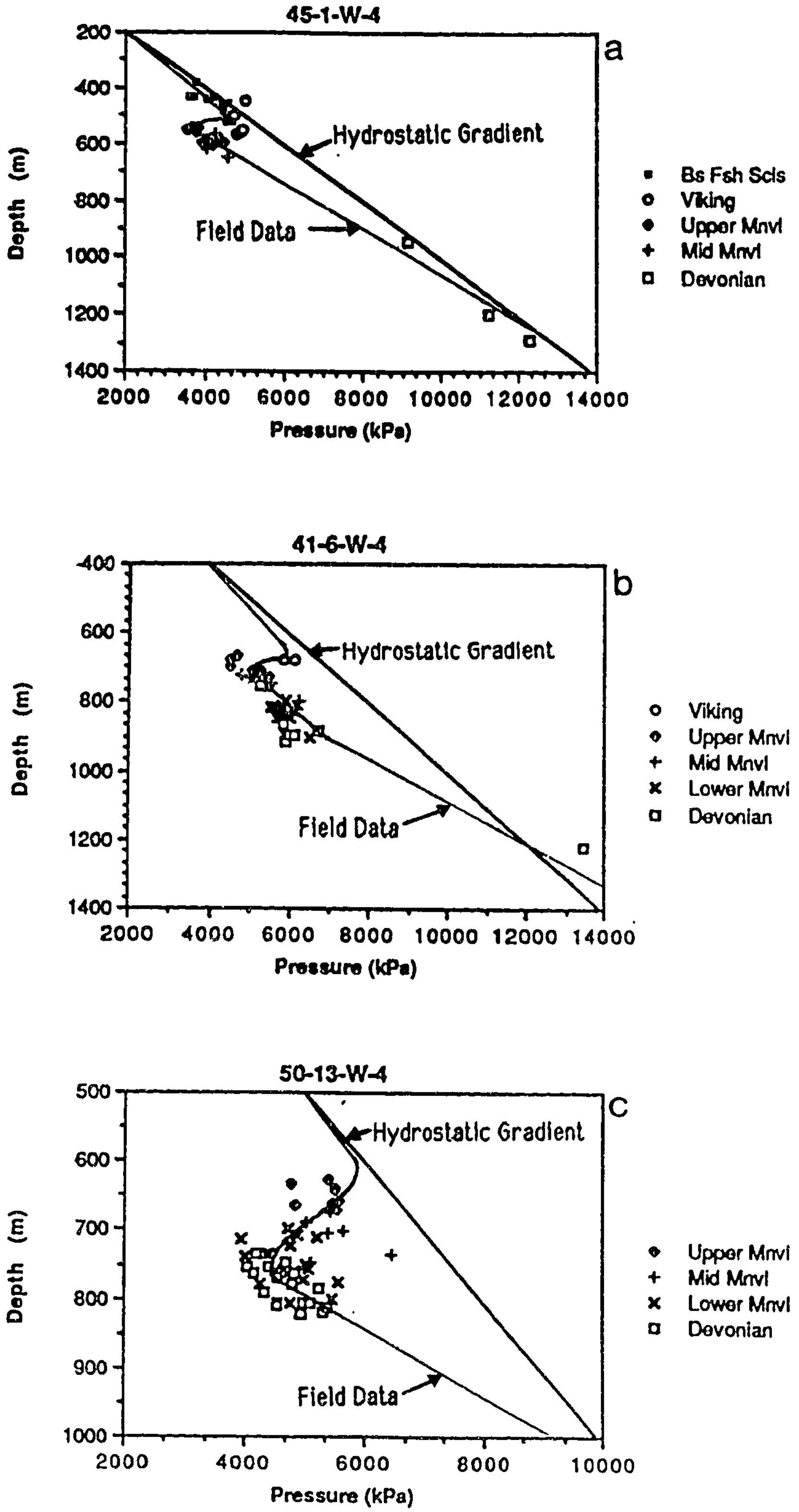


Figure 3.12 Pressure-depth plots.

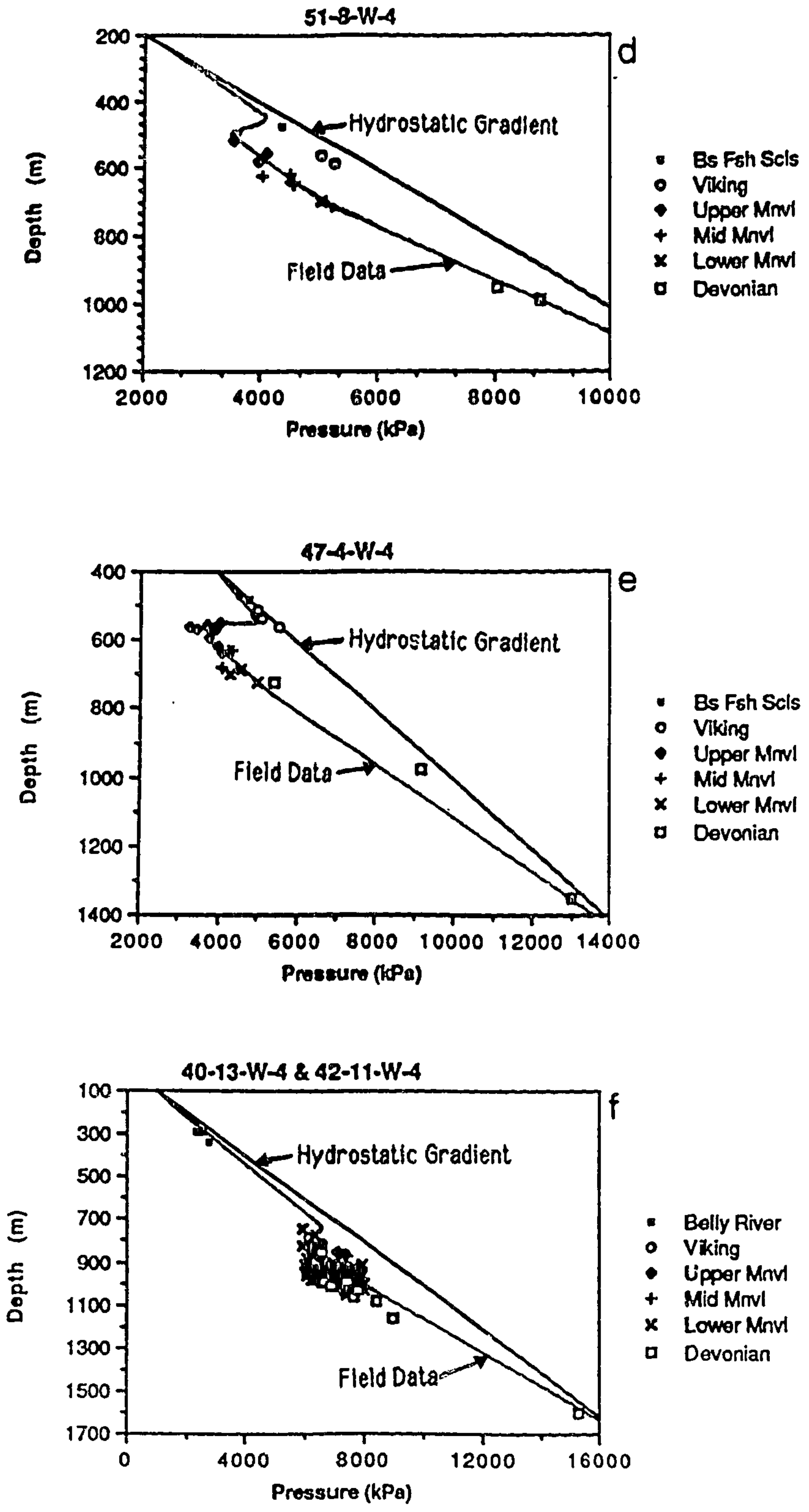


Figure 3.12 (cont.) Pressure-depth plots.

relationships to those conceptualized by Tóth and Corbet (1986) for underpressured units in southern Alberta. A characteristic curve can be drawn through the data in all cases. Formations above the Mannville Group, namely the Belly River, the Base of Fish Scales Zone, and the Viking, are pressured at near hydrostatic levels, whereas the entire Mannville Group is pressured at a considerably lower level. The areas covered by individual curves are sufficiently large that, due to topography and the dip of the strata, some Viking data points lie at depths greater than or equal to Mannville data points. For this reason, the curves drawn through the field data sometimes show two points at the same depth having different pressure values.

There is a general trend, most noticeable in Figure 3.12d, towards underpressuring in the Viking Formation. The slope of the pressure-depth curve for the upper portion of the graphs is slightly less than the slope of the hydrostatic curve, suggesting a downward component of flow in these units. A large pressure change occurs through the Joli Fou shales. This is indicated where the field data curves turn sharply to the left between those values in the Viking Formation and those in the Mannville Formation. This was also evidenced in the potentiometric surface diagrams. A variety of mechanisms have been invoked to explain the causes of underpressured units.

In the San Juan Basin, Berry (1960) has attributed underpressuring to reverse chemical osmosis across semipermeable membranes. Rather than ions diffusing from more saline to fresher aquifers, fresh waters are allowed to pass through the low permeability membrane to more saline formations. If recharge into the fresher aquifers proceeds at a slower rate than diffusion of water out of the aquifers, underpressuring of the less saline formation can result.

In pre-Pennsylvanian formations in the Appalachian region (Russell, 1972), and in southern Alberta (Tóth and Corbett, 1986), elastic rebound has been invoked to cause subnormal pressures. In this case, preglacial and glacial erosion have removed extensive surface material. Under the subsequent lower-stress regime, subsurface shales expand in volume and attract waters from adjacent sediments, leaving them underpressured.

In regions of downward flow where there is a net downward loss in fluid potential, the observed pressures will be somewhat less than hydrostatic (Tóth, 1978). Belitz and Bredehoeft (1988), however, suggest that vertical flow will not result in significant deviations from hydrostatic pressures. They attribute subhydrostatic pressures in the Denver basin to the fact that waters are draining from subsurface aquifers at a faster rate than the aquifers are being recharged. If hydraulic communication between an aquifer and its recharge area is much weaker than hydraulic communication with its discharge area, then water will leave the aquifer at a faster rate than its rate of recharge, resulting in underpressuring.

If underpressuring in the Mannville had resulted from erosional rebound of the Lea Park and Colorado shales, then the Viking formation, situated closer to the base of the Colorado shales (Figure 3.13, 3.14, 3.15), should also be similarly or more highly underpressured than the Mannville. However, the pressure-depth plots clearly show the Viking sandstone, and the Base of Fish Scales zone, to be pressured at near hydrostatic levels, much greater than the Mannville Formation. Chemical osmosis can also be ruled out as a cause of Mannville underpressuring. The only semipermeable membrane proximal to the Mannville is the overlying Joli Fou shale. Formation waters above these shales in the Viking formation have salinities similar to the Mannville waters, and osmosis of fresh water would be negligible. Downward flowing groundwaters result in a gradual deviation to subhydrostatic pressures with depth. The sharp drop in pressures across the Joli Fou shale suggests that downward flowing groundwater is also unlikely to be the sole cause of the low Mannville pressures.

The situation in east-central Alberta appears similar to that in the Denver basin as discussed by Belitz and Bredehoeft (1988). Recharge to the Mannville is through the Lea Park and Colorado shales, two extensive low permeability units. Discharge from the Mannville, however, is to the near surface, through the highly permeable lower Mannville sands and the karstified upper Devonian carbonates. The Paleozoic unconformity is suggested to act as a drainage conduit for water in the Red Earth region of Alberta (Tóth, 1978). The high conductivity of the clean lower Mannville sands, combined with the karstified Upper Devonian carbonates, also seems to allow water in east-central Alberta to flow readily along this boundary to the unconformity subcrop approximately 300 kilometres to the north-east in Northern Saskatchewan.

The pressure-depth diagrams also suggest that the underpressuring of the Mannville is causing upward vertical migration of groundwaters from the Devonian. Despite limited Devonian data, the slope of the curves connecting the lower Mannville data points to those in the Devonian, is greater than the hydrostatic curve in all cases, indicating upward flow. Further examination of this possibility would require more DST data below the Mannville in the area.

Pore fluid pressures may be indicating permeability variations within the Mannville Formation. Figure 3.12c shows, contrary to the other pressure-depth plots, that the lower Mannville and the upper Devonian strata are underpressured to a greater extent than the upper and middle Mannville units. This would result where the hydraulic resistance between the lower two units and the discharge area is less than that between the upper units and the discharge area. Hydraulic communication is controlled by permeability. Enhanced cementation or a higher shale fraction in the upper and middle Mannville strata along the western part of the study area would result in a lower permeability for these units, and in turn a lower hydraulic communication. Groundwater would be directed downward through these sands to the more permeable lower units. Core studies would be needed to further pursue this issue.

3.5 Groundwater Flow in East-Central Alberta

Through the examination of potentiometric surface maps and pressure-depth diagrams, subsurface pore fluid pressure analysis has revealed the regional groundwater flow pattern in east-central Alberta. This flow pattern, partly illustrated in the hydrogeologic cross-sections (Figures 3-13 to 3-15), may also have influenced petroleum entrapment in the area.

Shallow subsurface potentiometric surface maps (Figure 3.4, 3.5) and the hydrogeologic sections (Figure 3.13, 3.14, 3.15) indicate downward movement of groundwater on a regional scale from surface. This is supported by the pressure-depth diagrams (Figure 3.12) which display curves with slopes less than the hydrostatic curve for strata above the

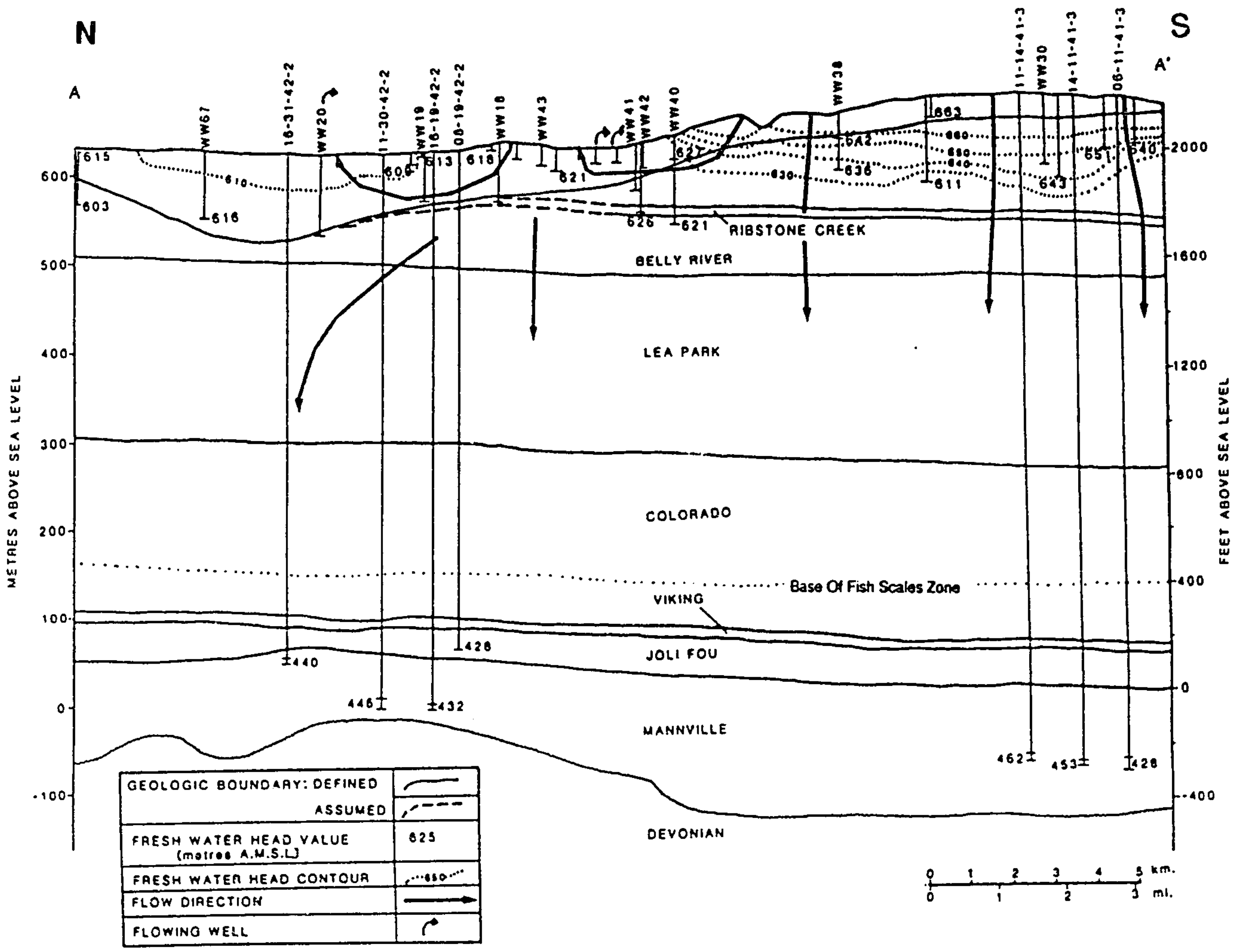


Figure 3.13 Hydrogeologic cross-section A-A'

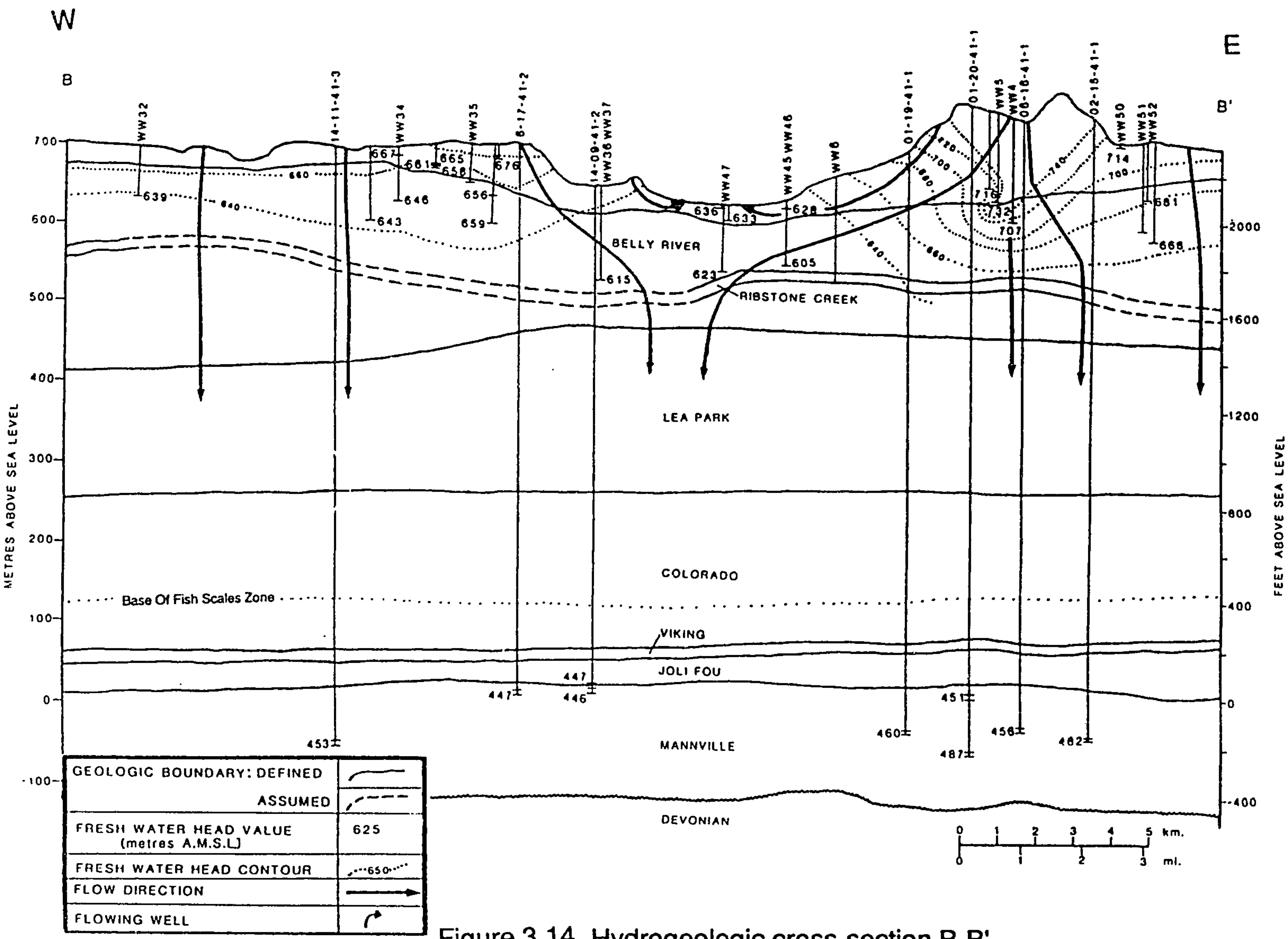


Figure 3.14 Hydrogeologic cross-section B-B'

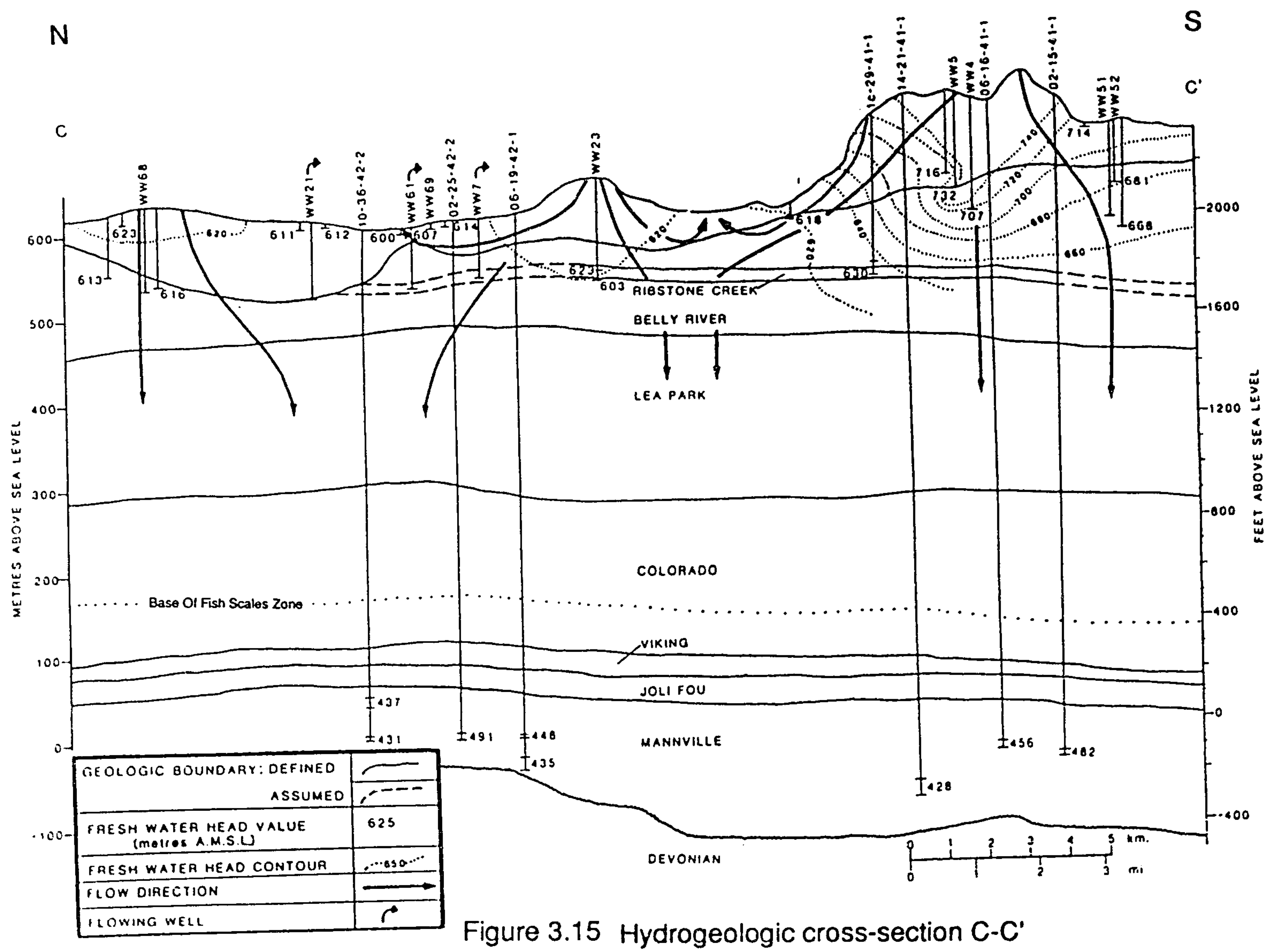


Figure 3.15 Hydrogeologic cross-section C-C'

Mannville. Potentiometric surface maps within the Mannville Formation reveal that flow is generally downward to the lower Mannville sands with subsequent lateral migration in a north-easterly direction. The underpressuring of the entire Mannville Group, however, suggests a north-eastward lateral component of flow throughout the unit. The Paleozoic unconformity appears to be draining waters to the subcrop of the unconformity in northern Saskatchewan. Pressure-depth diagrams may also suggest that in the western part of the study area the upper and middle Mannville strata are less permeable than the lower Mannville and upper Devonian units and that lateral flow in this area is concentrated in these latter units.

The hydraulic theory of petroleum migration (Tóth, 1980) suggests that hydrocarbons are transported with formation fluids into regions of relative energy minima. Quasi-stagnant, low energy regions occur with a sudden decrease in pore pressure, with sudden changes in flow direction, where fluids cross permeability barriers, or where opposing flow systems meet.

This study suggests that in east-central Alberta, two opposing flow systems meet in the Mannville Formation. Waters flowing downward from the surface meet waters that are moving upward from the Devonian strata. Water flow is then redirected laterally to the northeast. The concentration of hydrocarbons in the Mannville may result, at least partly, from a "hydraulic" trap acting in the Mannville sands.

4. WATER CHEMISTRY STUDY

Chemical surveys of formation waters related to petroleum exploration have largely been confined to studies conducted in the Soviet Union. These studies focus primarily on deep brines, where brines in non-producing regions are compared to brines in productive areas. Similar water chemistries are indicative of favourable regions or strata for further study.

Kartsev et al., (1959) summarized techniques and examples of early Russian hydrochemical studies. Hydrochemical indicators of petroleum were divided into direct and indirect categories. Direct indicators are derived directly from petroleum accumulations, and include the presence of dissolved bitumens, primarily napthenic acids, phenols, and quantities of iodine and ammonia in excess of 5 mg/l and 100 mg/l respectively. Indirect indicators of petroleum are salts and ions that are connected with crude oil or with favourable conditions for the presence of oil. They include reduced compounds of sulfur, the absence of sulfates, both of which indicate the reduction of sulfate in the presence of organic matter, sodium bicarbonate, which may form from the oxidation of hydrocarbons in certain instances, and calcium chloride, and bromide, both of which indicate semi-stagnant flow conditions and therefore favourable regions for petroleum accumulations.

Russian studies have also examined surface or shallow subsurface waters as potential aids to both oil exploration and geologic structure delineation. Deep formation waters can influence the chemical composition of shallow groundwaters by advecting upward to mix with shallow waters, or through vertical ion diffusion (Kartsev et al., 1959). Two necessary conditions for upward water movement are an increase in hydraulic head with depth, and sufficient hydraulic communication between deeper and shallower aquifers. Hydraulic communication can be enhanced by faults or fracture networks. Diffusion will take place towards the surface since, as a rule, deeper waters are more concentrated in ions and salts. In both cases the salinity of the shallow waters will increase.

4.1 Chauvin Water Study

Christopher's (1980) potentiometric surface map of Saskatchewan (Figure 4.1), shows a potentiometric low in the area adjoining the Chauvin region of Alberta. Christopher suggests that deep Mannville brines are moving upwards to the near surface in the North Saskatchewan River valley, where the bottom of the bedrock channel is lower than the hydraulic head values of the Mannville waters. The localized coincidence of solonetzic soils, artesian wells, and oil pools, suggests that shallow waters in the Chauvin area might be influenced by upward moving deep brines.

A water chemistry survey was conducted to look for indications of petroleum associated brines in shallow groundwaters, and to examine the position of these brine-indicators with respect to local flow systems. Relationships between geology, local flow systems, and shallow water chemistry in the Chauvin area were investigated to better evaluate possible indications of deeper brines in shallow waters.

4.1.1 Sampling Procedure

Seventy-seven shallow-well water-samples were collected from farms in the area along with thirty-two deep Mannville brines from oil wells, deep

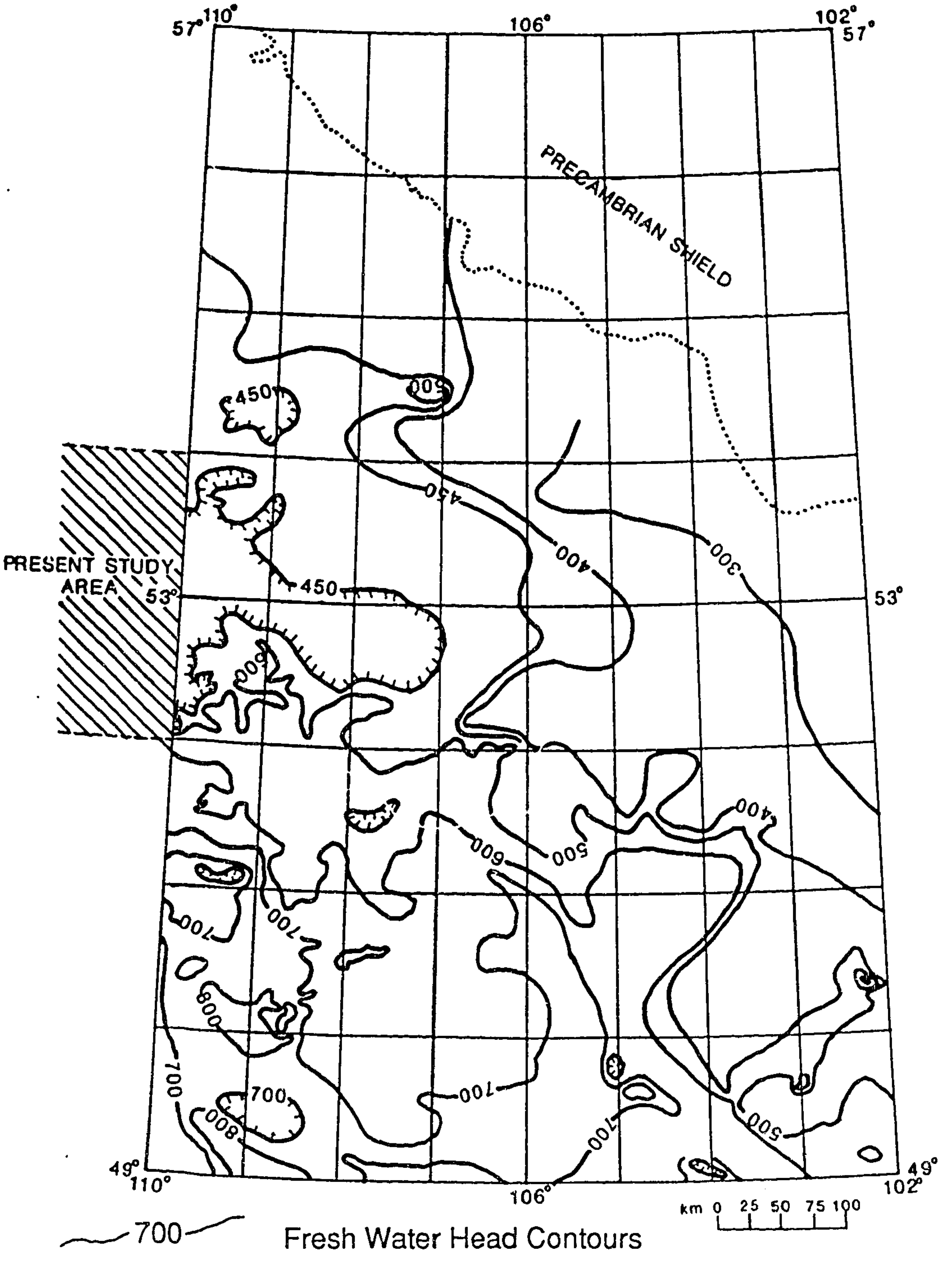


Figure 4.1 Potentiometric surface map of the Mannville Formation in Saskatchewan. (Modified From Christopher 1980)

water supply wells or deep water injection wells. Oil companies in the area have a re-injection program whereby water that is separated from the oil is treated with chemicals to enhance further oil production, and then re-injected to the producing formations. This ensures the maintenance of high pressures in these formations. Data obtained from the analyses of the injection waters (Appendix D) indicated that chemicals added to the waters have a negligible effect on the standard ion chemistries of the formation waters. Consistent water chemistries were found in all sampled Mannville waters, including those located away from injection wells. The quantity of chemicals added to injection waters is minimal when compared to the total amount of formation water being re-injected.

Prior to collection, sample containers were thoroughly rinsed, soaked in a 2% HCl solution, and then flushed five times with distilled water. Immediately prior to the collection of a sample the containers were rinsed twice with the water being sampled.

Three replicate samples were taken. An untreated one litre sample was sent to Western Industrial Laboratories, Edmonton, for standard ion analysis, a 500 ml sample was taken for Br^- and I^- analysis by nuclear activation by Nuclear Activation Services, Hamilton, as well as for oxygen and hydrogen stable isotope analysis by Dr. Muehlenbachs and the author at the University of Alberta, Edmonton. A 250 ml sample was obtained to be analyzed for trace metals by Dr. Horlick at the University of Alberta. This latter sample was filtered and treated with 10 ml of 50% HNO_3 to prevent metals from precipitating out of solution or from adsorbing to the walls of the container or to clay particles in the sample.

4.2 Standard Ions

The water chemistries of the shallow water wells (Appendix D) were plotted on Stiff diagrams, where the concentrations of ions in solution are plotted in terms of their chemical equivalence. These diagrams provide a quick visual comparison of waters and allow a classification based on graphical shapes. Based on these diagrams the shallow water samples were divided into six distinct groups. Stiff diagrams for representative waters from the six groups are shown in Figure 4.2. The six water types were also plotted on a Durov diagram (Figure 4.3) which shows hydrochemical types and also shows some of the processes involved in water evolution. Waters plotting in the following fields of the Durov diagram have the following characteristics (Lloyd and Heathcote, 1985):

1. - HCO_3^- and Ca^{2+} dominant
   - frequently indicates recharging waters in limestone, sandstone, and many other aquifers

2. - HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
   - when Mg^{2+} is dominant or Ca^{2+} and Mg^{2+} are important, waters associated with dolomites are frequently indicated
   - when Ca^{2+} and Na^+ are important, partial cation exchange may be indicated

3. - HCO_3^- and Na^+ dominant
   - normally indicates ion-exchanged waters

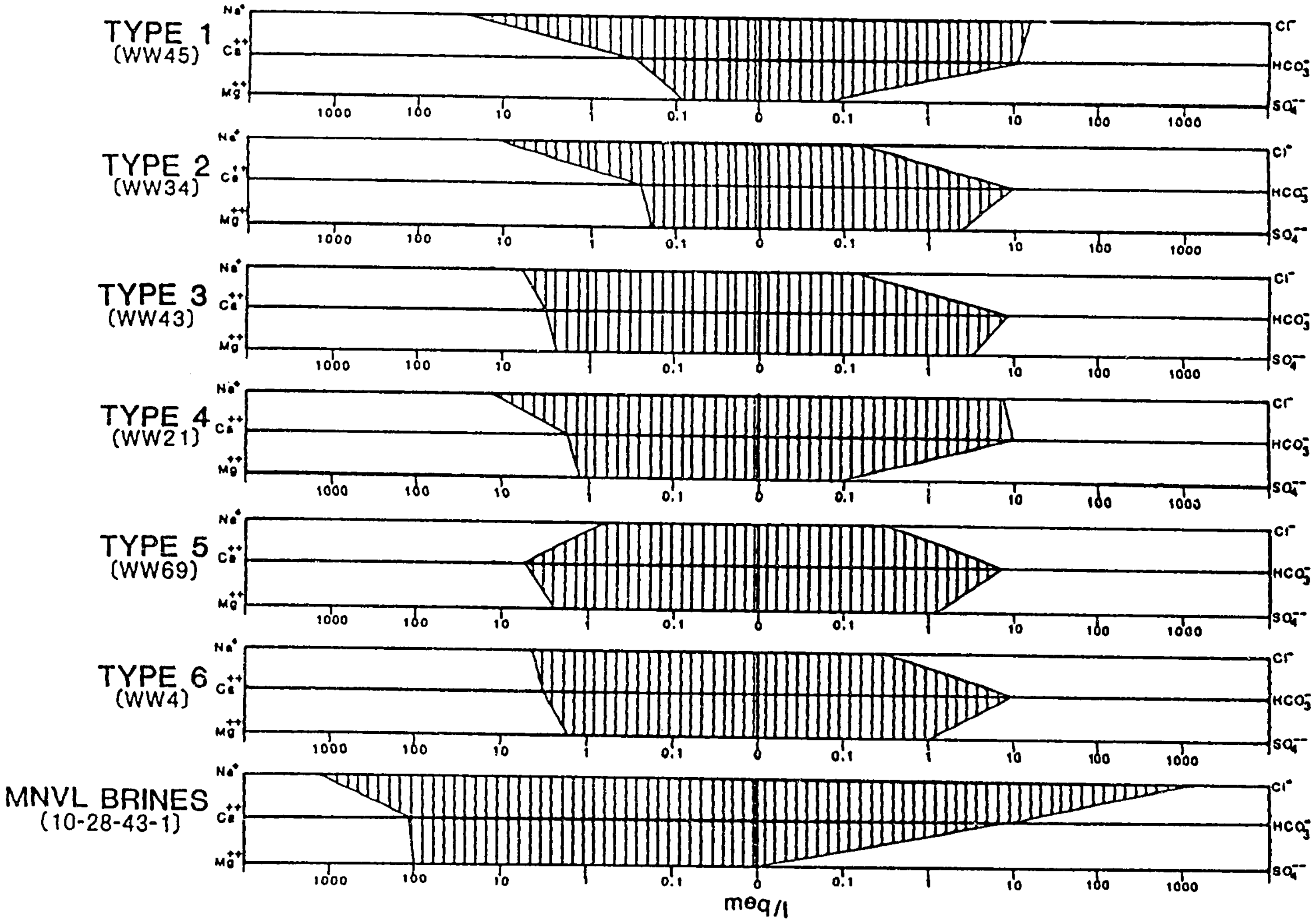


Figure 4.2 Representative Stiff diagrams for the different water types.

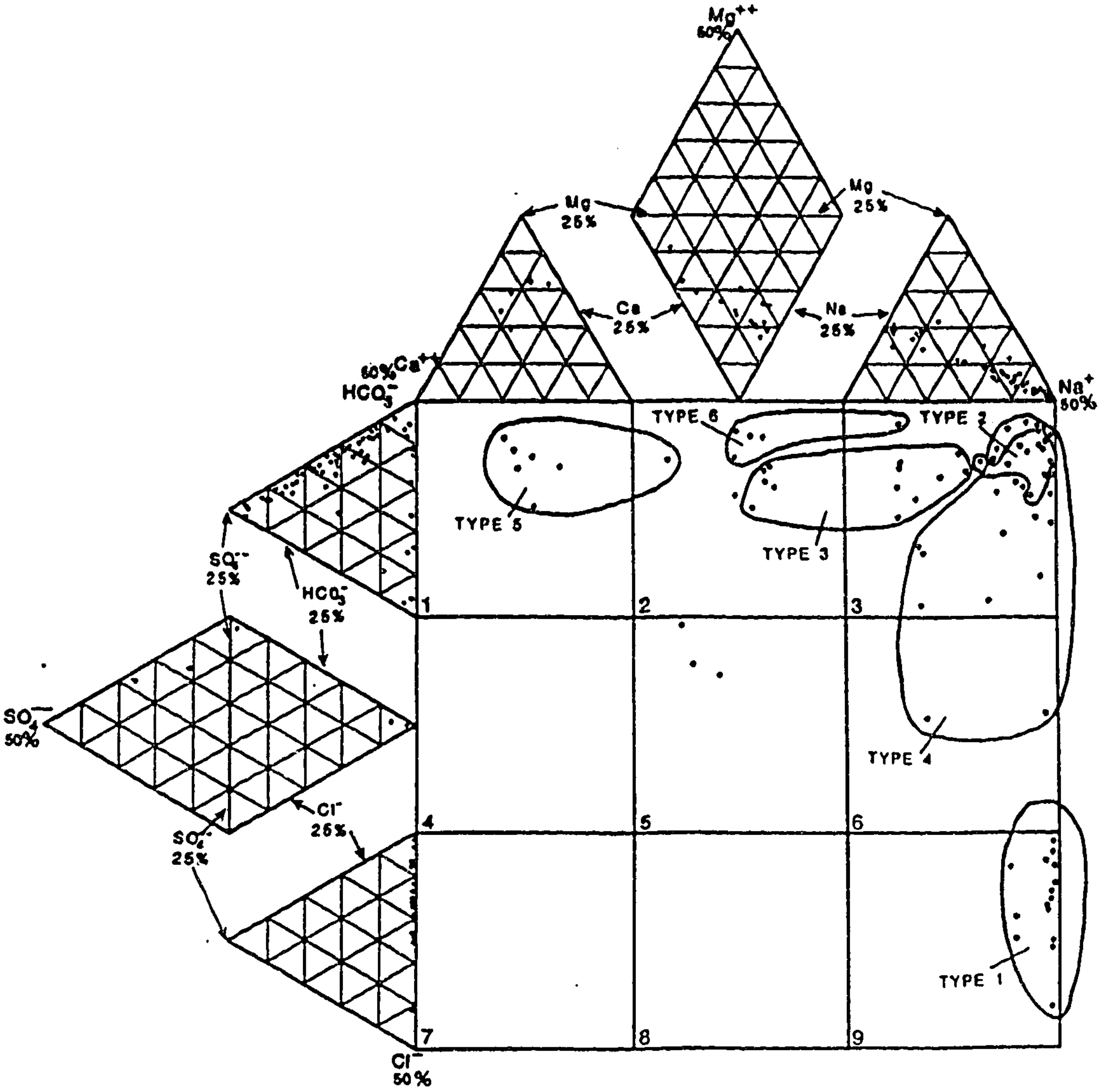


Figure 4.3 Durov diagram of shallow water samples.

- the generation of CO_2 at depth can produce HCO_3^- where Na^+ is dominant under certain circumstances

4. - SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant
   - Ca^{2+} and SO_4^{2-} dominant frequently indicates a recharge water in lavas and gypsiferous deposits
   - may indicate a water exhibiting simple dissolution or mixing

5. - No dominant anion or cation
   - indicates waters exhibiting simple dissolution or mixing

6. - SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant
   - not frequently encountered and indicates probable mixing

7. - Cl^- and Ca^{2+} dominant
   - rare and may indicate cement pollution
   - may also indicate reverse ion exchange of Na^+ - Cl^- waters.

8. - Cl^- dominant and no dominant cation
   - indicates that the groundwaters may be related to reverse ion exchange of Na^+ - Cl^- waters

9. - Cl^- and Na^+ dominant
   - frequently indicates end-point waters

The locations of the sampled shallow waters are shown in Figure 4.4 while Figure 4.5 shows the locations of the sampled Mannville brines. Table 4.1 summarizes the six shallow water types. Several of the shallow water samples did not fit into one of the six groups and were not classified. These waters likely result from a mixing of other waters in the area. The chemical characteristics and general geographic positions of the six water types are as follows:

Type 1

These waters were generally found in the southern part of the study area. On the Durov diagram, they plot in the area indicating end point waters, having sodium as the dominant cation and chloride as the dominant anion. Calcium was always found in greater concentrations than magnesium, but both cations are found in negligible concentrations. Sulfate was also found to be insignificant, whereas bicarbonate was a more important ion. This group of waters had the highest TDS values of all the shallow ground waters sampled.

When observed in relation to topography, the waters were noted to occur over both topographic highs and lows. These waters were all produced from the Ribstone Creek sandstone.

Type 2

These waters were, for the most part, confined to the southwest corner of the study area. The Stiff diagrams show these waters to have a cation composition similar to Type 1 waters (Figure 4.2), with sodium dominant, and calcium and magnesium relatively insignificant. Calcium is always

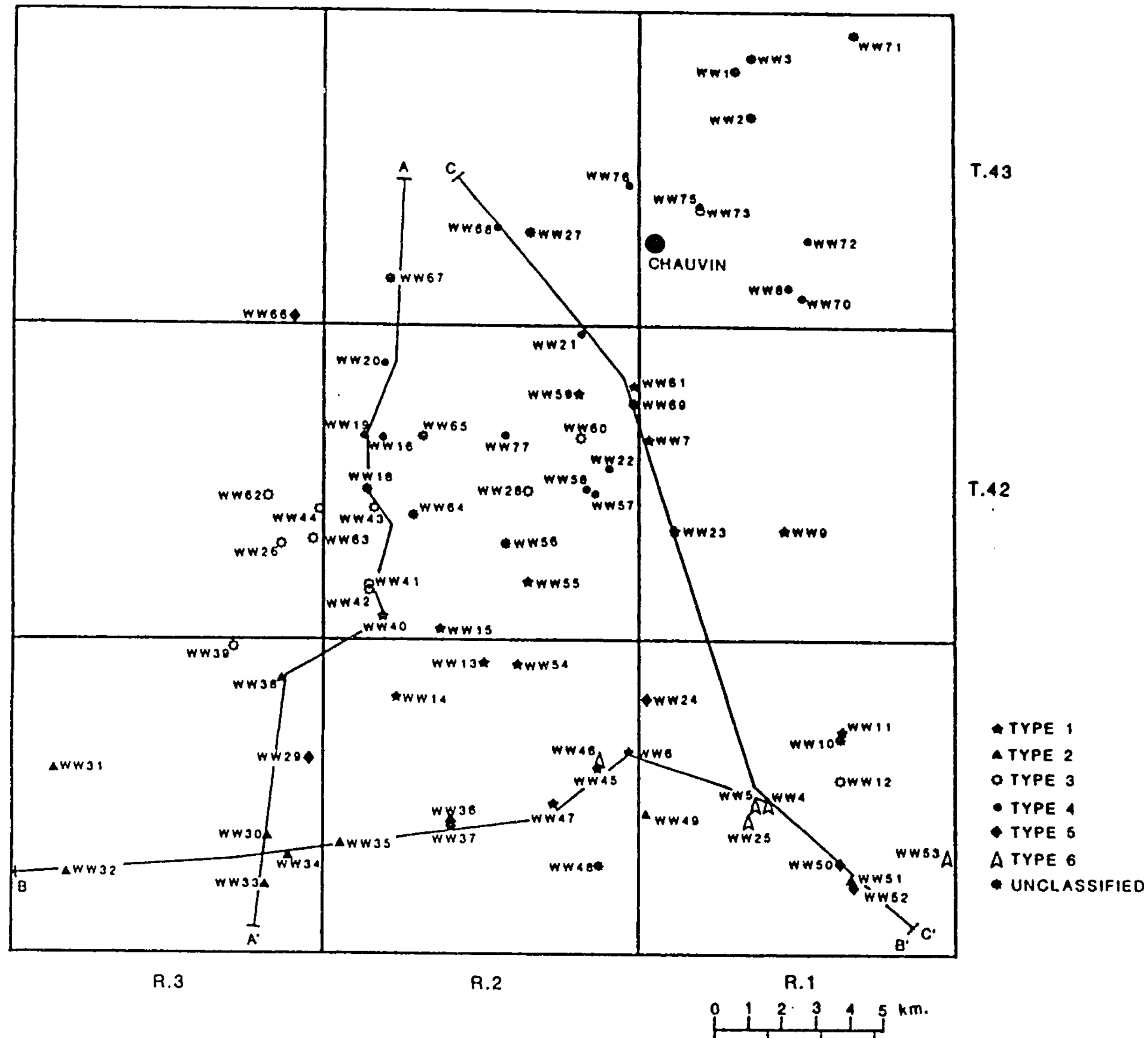


Figure 4.4 Water sample locations; shallow wells.

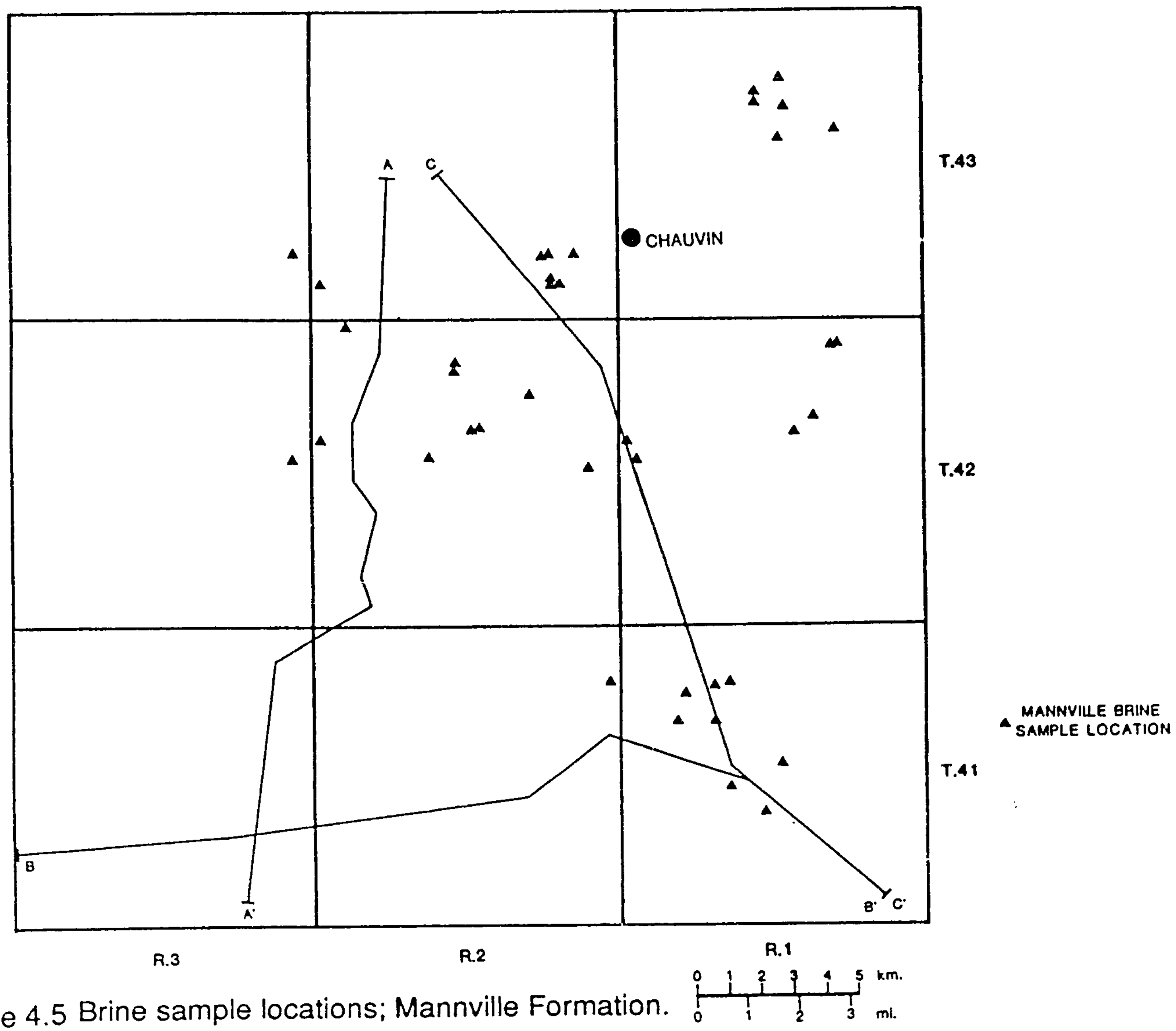


Figure 4.5 Brine sample locations; Mannville Formation.

Table 4.1
Water Type Summary

Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Unclassified
WW 6	WW 30	WW 12	WW 8	WW 24	WW 4	WW 1
WW 7	WW 31	WW 26	WW 16	WW 29	WW 5	WW 2
WW 9	WW 32	WW 28	WW 17	WW 36	WW 25	WW 3
WW 11	WW 33	WW 39	WW 19	WW 50	WW 46	WW 10
WW 13	WW 34	WW 41	WW 20	WW 52	WW 53	WW 18
WW 14	WW 35	WW 42	WW 21	WW 66		WW 27
WW 15	WW 38	WW 43	WW 22	WW 69		WW 48
WW 23	WW 49	WW 44	WW 57			WW 56
WW 37	WW 51	WW 60	WW 58			WW 64
WW 40		WW 62	WW 68			WW 65
WW 45		WW 63	WW 70			WW 67
WW 47		WW 73	WW 72			WW 71
WW 54		WW 74	WW 75			
WW 55			WW 76			
WW 59			WW 77			
WW 61						

found in greater concentrations than magnesium. The dominant anion is bicarbonate. Sulfate is found in greater concentrations than chloride, although both anions are relatively insignificant. On the Durov diagram these waters are classified as cation exchanged; calcium and magnesium in the waters having exchanged for sodium on clay or organic material in the sediment.

Type 2 waters are associated with topographically high regions, and are produced from the Belly River Formation above the Ribstone Creek Sandstone.

Type 3

Most of these waters are found in the west-central region of the study area. Sodium is again the dominant cation, but calcium and magnesium are more important than in the first two water types. Calcium is more abundant than magnesium. The anion composition is similar to Type 2 waters, with bicarbonate dominant, and chloride being negligible. Sulfate is found in slightly greater concentrations than in the Type 2 waters. These waters, like those in the previous group, are classified as ion exchanged by the Durov diagram.

The waters are generally associated with topographically lower areas, and are produced either from the Belly River Formation above the Ribstone Creek Sand, or from the shallow glacial drift.

Type 4

Type 4 waters are chemically more diverse and, more geographically spread out than the other groups. They spread from the mid-central to the north-east part of the region. Sodium, as in water Types 2 and 3, is the dominant cation. Calcium and magnesium are generally found in negligible concentrations, but can be important in some of these waters. Bicarbonate is again the dominant anion, but as with Type 1 waters, chloride is more abundant than sulfate. Sulfate is usually found in insignificant quantities. The Durov diagram shows these waters to be cation exchanged, similar to Type 2 and 3 waters. Waters plotting towards the bottom of area #3 on the diagram have higher concentrations of sulfate, whereas the horizontal spread in the data shows the variation in the cation composition.

Most of these wells produce water close to where the Ribstone Creek Sandstone is truncated by the east-west trending bedrock channel (Figure 3.13 and 3.15). Poor data quality and quantity regarding the bedrock surface negates the determination of a more accurate production zone for these waters. In the case of samples WW 22, WW 57, and WW 58 which do not lie as close to the bedrock channel, production appears to be either from the Ribstone Creek Sandstone, or from slightly above this zone.

Type 5

These waters are distributed throughout the study area. This group is the only one in which sodium is not the dominant cation. In this case calcium is dominant, and magnesium is usually found in greater concentrations than sodium. Bicarbonate is the dominant anion, with chloride being negligible. The Durov diagram suggests that these are recharge waters.

The wells are not confined to topographic highs or lows, and except for the case of sample WW 52, they all produce from the glacial drift, at depths shallower than 5 metres. WW 52 produces from the bedrock above the Ribstone Creek Sandstone.

Type 6

This small group of waters is restricted to the southeast corner of the study area. Usually sodium is the dominant cation, but in all cases calcium, magnesium, and sodium are found nearly in equal amounts. As in the case of Type 3 and 5 waters, bicarbonate is the dominant anion, with chloride being negligible. The waters are very similar to Type 5 waters except for an increase in the sodium content. These waters plot in the field of partial ion exchange on the Durov diagram.

The wells are found in the topographically high region in the south-east and produce water from the Belly River Formation above the Ribstone Creek Sandstone.

Mannville Brines

Sodium is the dominant cation in the Mannville brines with calcium and magnesium usually being found in equal concentrations. The anions are dominated by chloride with bicarbonate being the second most important anion. Sulfate is found in negligible concentrations, usually less than 5 mg/l. These waters show a large variation in TDS, with concentrations ranging from 54 000 to 106 000 mg/l.

4.3 Halogen Chemistry

Bromide and iodide concentrations were determined by neutron activation analysis for all of the sampled waters. Chloride was determined as part of the major ion analysis.

High concentrations of bromide and iodide have been found in many subsurface brines, and in particular, those associated with oil fields, (Collins et al., 1967; Collins, 1969).

Iodine has an atomic weight of 127 and is the heaviest and rarest of the stable halogens found in nature. In many common soils and rocks, iodine occurs in a predominantly water soluble state (Lloyd et al., 1982). In sediment, however, iodide is strongly incorporated and mechanisms to solubilize the iodide must be in operation (Collins, 1969). Reported concentrations of iodide in sedimentary rocks are somewhat variable. Whereas Lloyd et al. (1982) report values in sandstones of 0.1 to 1 ppm, Collins (1975) reports a value of 1.7 ppm. Concentrations in shales or argillaceous rocks are reported to range from 2.2 ppm (Collins, 1975) to an order of magnitude greater than that for sandstones (Lloyd et al., 1982). Sea water contains concentrations of only 0.05mg/l (White, 1957) whereas petroleum associated brines contain an average of 10 mg/l. Values for brines have been reported as high as 1400 mg/l (Collins, 1975).

Bromine has an atomic weight of 80. Chemically it behaves similarly to chlorine, not forming its own minerals as sea water evaporates, but rather replacing chlorine in solid phases. Replacement is controlled by the mineral composition rather than by the concentration of bromine in the brine. With each phase of crystallization, more bromine is left in in solution than is entrained in the solid phase, leaving the solution bromine enriched.

Average concentrations of bromine are listed by Collins (1975). Shales contain 4 ppm, sandstones 1 ppm, and carbonates 6 ppm. Sea water contains 65 mg/l, whereas petroleum associated brines contain from 50 to 6000 mg/l.

The enrichment of both iodide and bromide in oil field related brines has been attributed to the concentration of these elements by marine organisms (Collins et al., 1967; Chave, 1960). Seaweeds have been found to concentrate iodide to 8,000 ppm and bromide to 6,800 ppm, while some corals have concentrations ranging up to 69,200 ppm and 19,800 ppm for iodide and bromide respectively (Collins, 1969). These organisms eventually become part of the sediment and bromide and iodide are solubilized during anaerobic decomposition (Lloyd et al., 1982).

4.3.1 Halogen Distribution

Figure 4.6 shows the average concentrations of bromide and iodide in the sampled waters, in sea water, and in organic material. The Ribstone Creek waters (Type 1) contain anomalously high concentrations of bromide, iodide and chloride relative to other shallow groundwaters sampled. Type 4 waters also show relatively high values for these elements and are thought to contain some proportion of the Ribstone Creek waters due to mixing. The remaining shallow waters all have negligible quantities of bromide, iodide and chloride. These values are suspected background levels.

Bromide and iodide concentrations of natural brines and waters are affected by several processes including mixing, diffusion, mineral dissolution and precipitation, membrane filtration and organic matter dissolution. Ratios involving the three halogens have been found to reveal evolutionary histories of groundwaters most effectively. Morton (1986), in a brine contamination study of shallow subsurface and surface waters in the

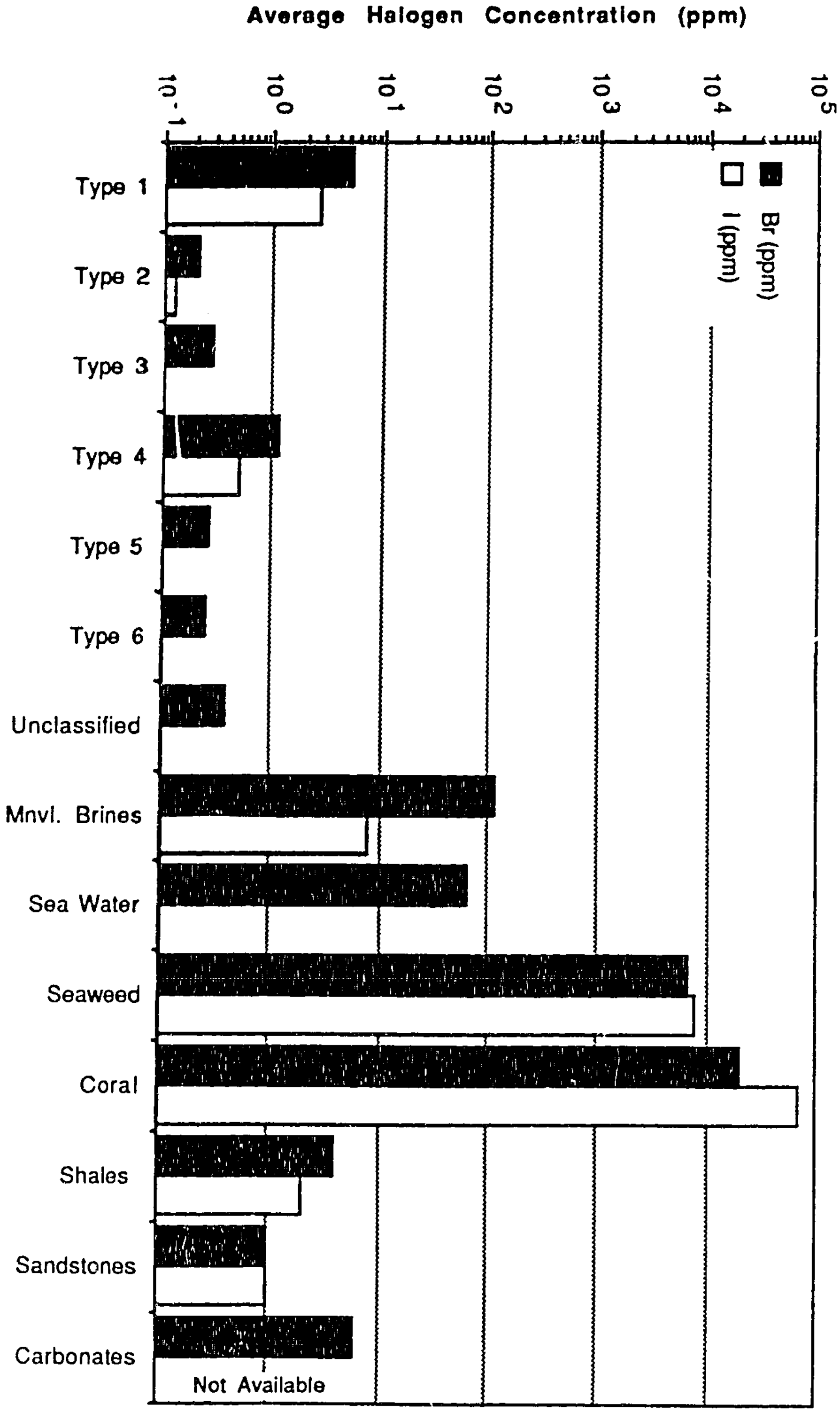


Figure 4.6 Distribution of bromide and iodide in natural environment and in sampled waters.

Vamoosa-Ada aquifer in Oklahoma, looked at several of these ratios. Brine contamination in his study was not the result of natural upward flow of deeper brines, as originally suspected in the Chauvin area, but was due to contamination from oil production, through irresponsible brine disposal methods, and faulty well casings.

Morton used ratios of sodium, chloride, bromide and lithium to detect brine contamination in shallow waters. In the present study iodide was used instead of lithium, due to the greater reliability of the iodide data, and to the fact that lithium data were unavailable for the sampled Mannville brines.

In Figure 4.7 the sodium/bromide ratios were plotted against the bromide concentrations. The sodium/bromide values are relatively widely scattered until a value of 2 to 3 mg/l bromide is reached. This result is similar to that obtained by Morton, who concluded that a level of 2 mg/l bromide was an effective index for determining brine contamination. Using this cut off value, all the Ribstone Creek waters (Type 1) lie in, or border on, the field indicating brine contamination. The term brine contamination refers to a water that shows characteristics similar to those of the Mannville brines, possibly due to natural mixing or to an evolution of meteoric waters towards a brine composition. Type 5 waters are fairly distinctive in the lower left corner of the graph. These waters have not travelled through the sediment to any great extent and therefore have much lower concentrations of all ions than the other waters. The low sodium concentrations result in the waters plotting separate from the other shallow waters. The Mannville brines are also shown on the graph. The three brines with low bromide concentrations are not readily attributable to

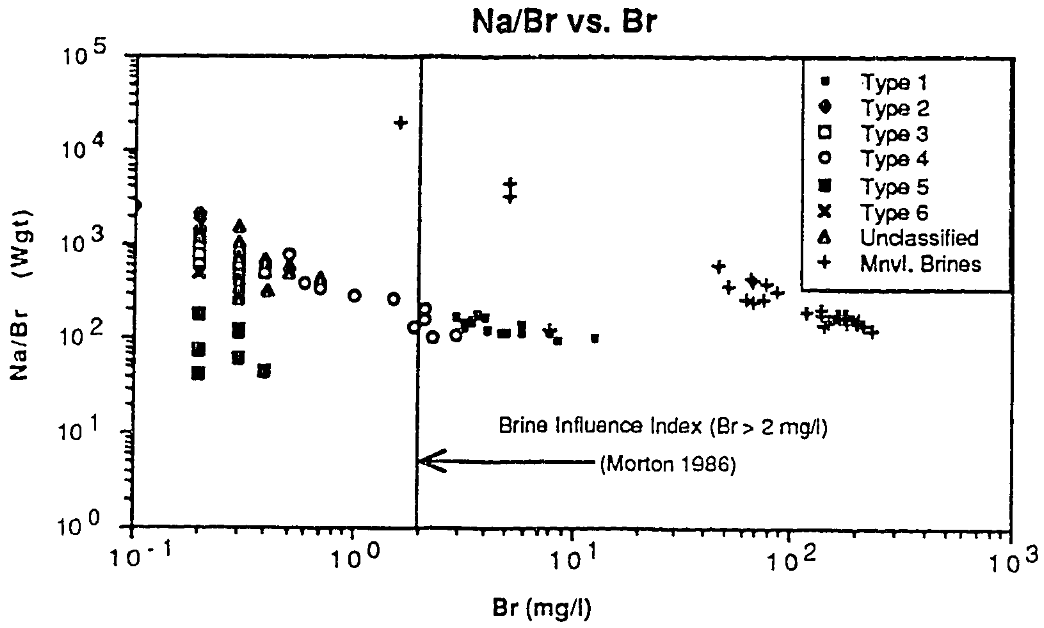


Figure 4.7 Na/Br vs. Br.

any geological phenomenon, and may result from measuring errors.

Figures 4.8a, 4.8b and 4.8c showing the sodium/chloride ratios versus the chloride, bromide and iodide concentrations, all display similar trends. The left sides of the graphs show widespread sodium/chloride values that start to level off as the waters approach a Mannville brine composition at a sodium/chloride value of about 0.75. The sodium/chloride ratios of the Ribstone Creek sandstone waters (Type 1) are similar to those values for the Mannville brines. The curves do not level off completely, and choosing a brine contamination value is difficult. Brine contamination cut-off values for chloride, bromide and iodide are taken as 400 mg/l, 3 mg/l, and 2 mg/l respectively. In all three instances, the value chosen isolates most of the Ribstone Creek waters into the brine influenced field.

Similarly shaped curves, but with lower sodium/chloride values, were obtained by Morton who attributed them to varying degrees of mixing between fresh waters and brines. In these figures the higher concentration values, including those of Type 1 and Type 4 waters, also appear to be the result of mixing. The initial decrease in the sodium/chloride ratios as the Cl, Br, and I concentrations increase is most likely due to the addition of chloride as the waters move through the subsurface, and is not attributable to the mixing of fresh and saline waters. Initially sodium is rapidly added to waters by cation exchange as they enter the ground, and the Na/Cl ratio rises. This is suggested by the positions of the water types on the Durov diagram. Chloride is added to the waters at a slower rate and the Na/Cl ratio starts to fall only when cation exchange drops off relative to chloride enrichment.

On the iodide plot, the Ribstone Creek waters are positioned much

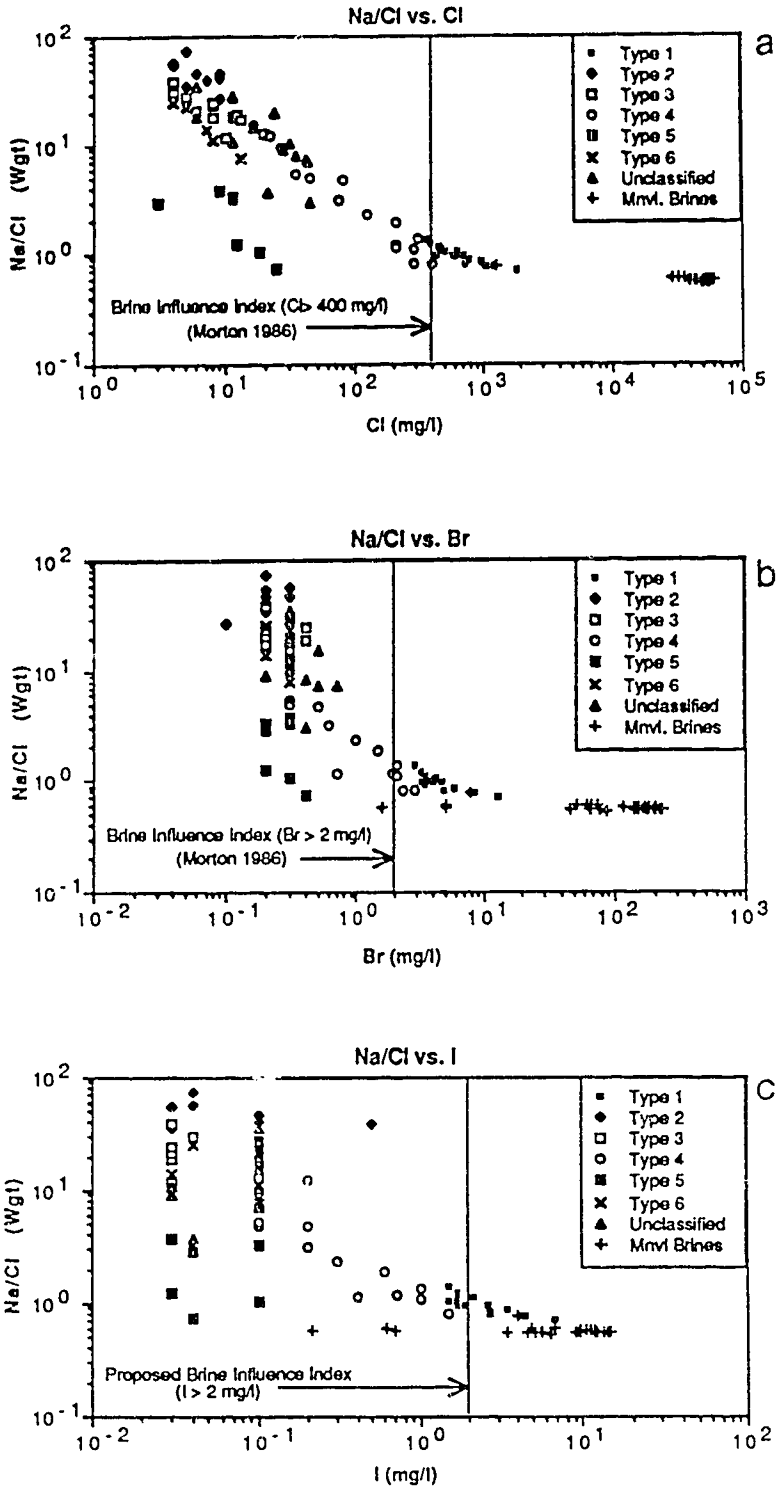


Figure 4.8 a) Na/Cl vs. Cl.
b) Na/Cl vs. Br.
c) Na/Cl vs. I.

closer to the Mannville brines than in the bromide plot. If conservative mixing between brines and fresh waters were occurring, the Mannville waters should be positioned similary in both plots with respect to the shallow waters. This suggests that mixing is not taking place or that some process is occurring either to enrich shallow waters in iodide or to deplete deeper waters in bromide as they move up to the surface. The three anomalous brines from Figure 4.7 also contain anomalously low values of iodide, but not of chloride. Type 5 waters are again a distinctive group plotting in the lower left corner of the graphs. The one brine sample that plots in amongst the Ribstone Creek waters is water from Oakwood Petroleum's water supply well that produces from the Ribstone Creek Sandstone.

The bromide/chloride ratios in the cases of Figures 4.9a, 4.9b and 4.9c are relatively widely scattered to the left hand sides of these graphs, but level off as the chloride, bromide and iodide levels increase. The brine cut off values, where the curves level out, could be picked at lower values than for the Na/Cl curves, and would still isolate the Ribstone Creek waters (Type 1) into the brine influenced field. The bromide/chloride ratios for the brines are somewhat lower than the values for the Ribstone Creek waters.

The previous figures, based on Morton's (1986) work, suggest that a mixing process between deep Mannville brines and shallow meteoric waters may be taking place in the Ribstone Creek Sandstone. If this is the case, then, on graphs with linear coordinates, conservative mixing trends will plot as straight lines (Hanor, 1987). Figures 4.10a, 4.10b, and 4.10c show that on each linear plot involving the halogens, the shallow waters have a

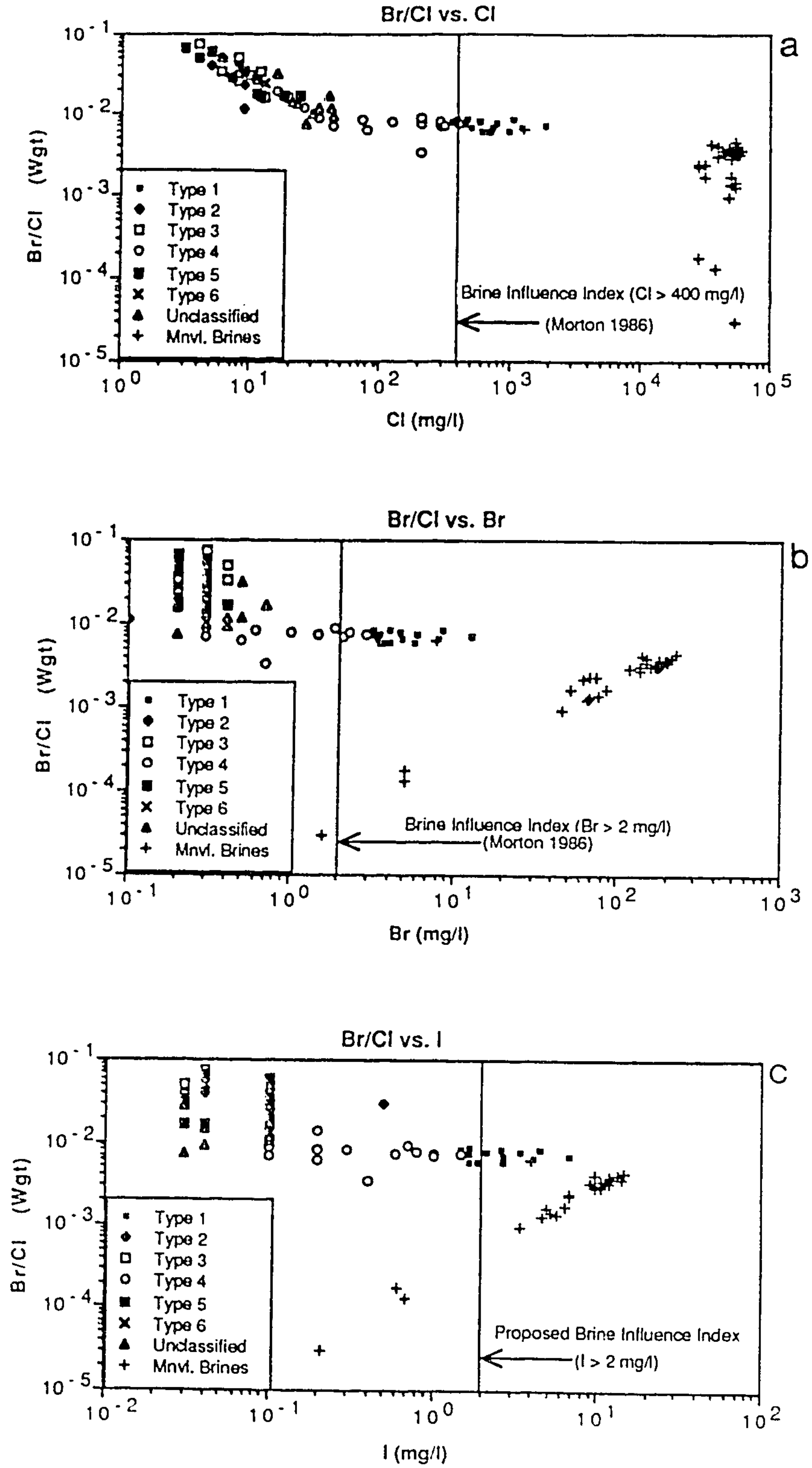


Figure 4.9 a) Br/Cl vs. Cl.
b) Br/Cl vs. Br.
c) Br/Cl vs. I.

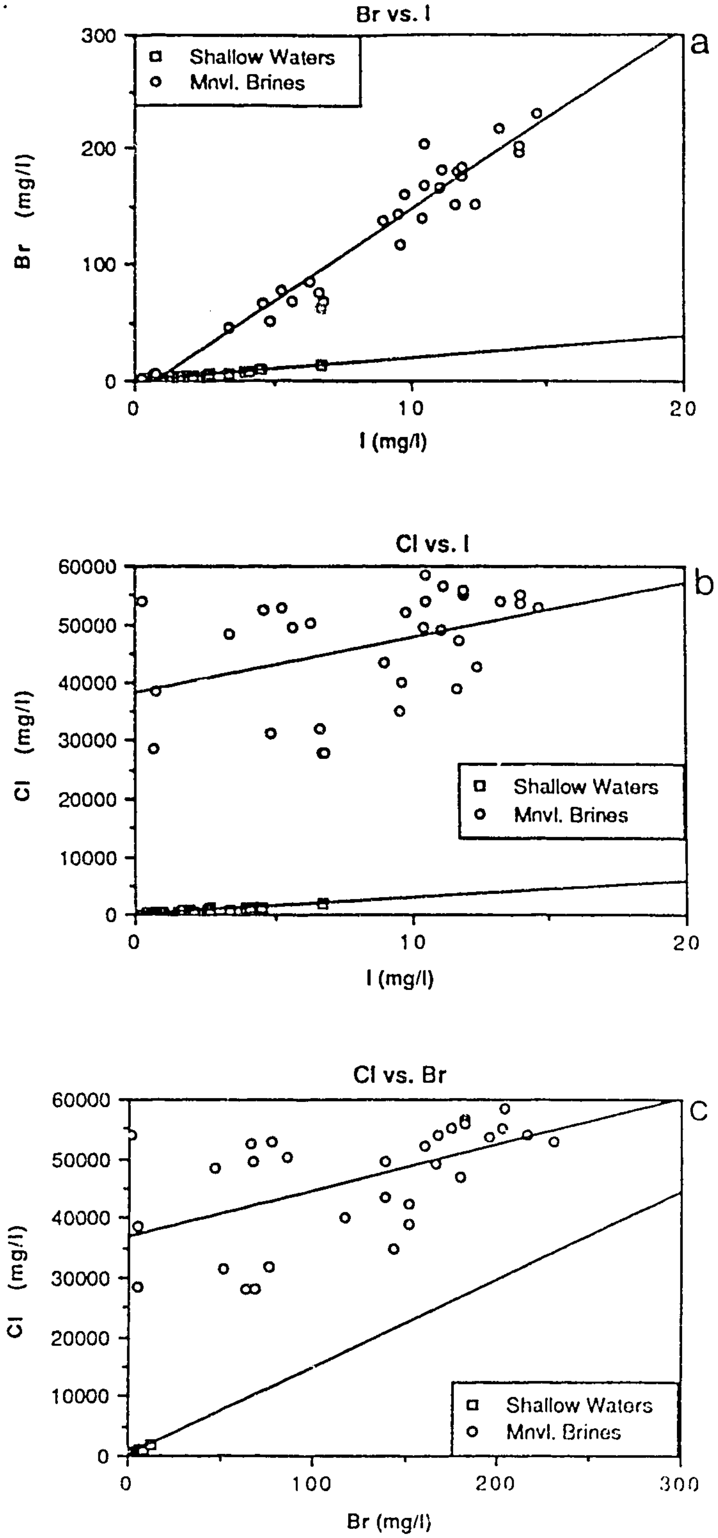


Figure 4.10 a) Br vs. I.
b) Cl vs. I.
c) Cl vs. Br.

linear trend which is different from the Mannville brines. This suggests that mixing of two end member waters is not taking place, and that the elevated halogen values of the Ribstone Creek waters must be explained by a process other than present day physical mixing.

The similarities in halogen composition between the Mannville brines and the shallow waters from the Ribstone Creek sandstone may indicate that processes similar to those which have influenced Mannville brine chemistry are presently working in the shallow subsurface environment to alter the water chemistries of infiltrating meteoric waters.

4.4 Trace Elements

High concentrations of some trace elements have been found in several petroleum associated brines (Collins, 1975). Upward movement of deep subsurface brines to the near surface might be indicated if high concentrations of trace elements found in Mannville brines were also detected in shallow waters. The sampled Mannville brines and shallow waters were analyzed for Ba, Co, Cu, Ni, U, V, Li, B, Sr, and Zn by induced coupled plasma mass spectrometry and atomic emmission spectrometry.

Technical difficulties prevented measurement of trace elements in the Mannville brines. With concentrations remaining unknown for the brines, attention could not be focussed on a particular element in the shallow waters. The analytical method was also not particularly effective for determining V, Ni, and Cu concentrations in many shallow samples due to interference with high Cl, Fe, Ca, and S levels. The results were examined with reference to the six water types determined earlier and are shown in Figure 4.11. Distinct trends were not obvious and the concentrations of all

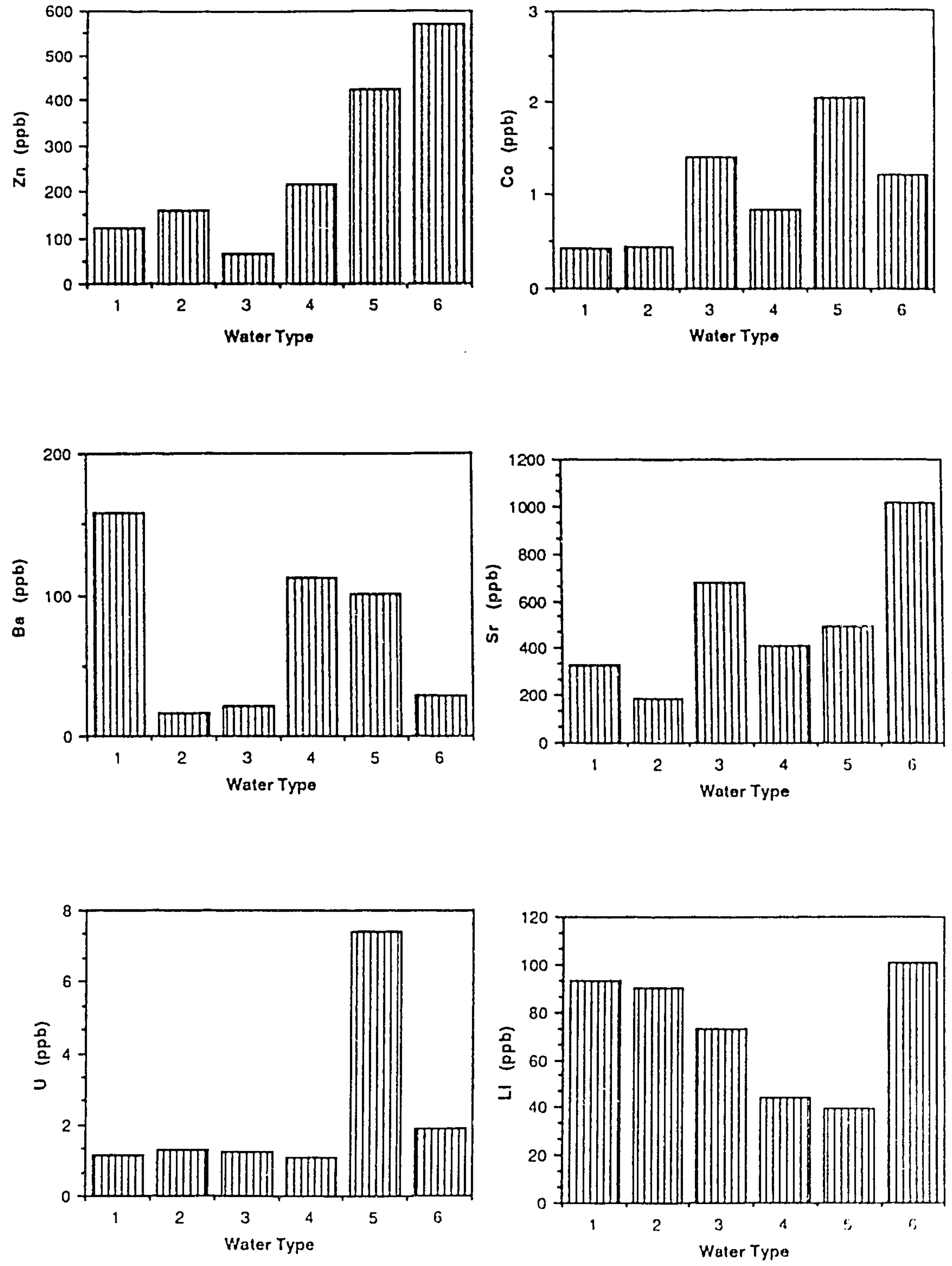


Figure 4.11 Trace metal distribution.

elements determined were close to suspected background levels in most samples. Large variations within individual water type populations were also common. The low trace metal concentrations found in the shallow waters indicate that either deeper waters are not moving upward, or if they are, they do not contain high concentrations of these elements. The behaviour of these elements in shallow oxygen rich waters will differ from their behaviour in deeper reducing environments, so that even if mineralized waters were rising from below these elements may precipitate from solution en route. Further chemical study of trace element behaviour would be necessary to determine the effectiveness of future surveys.

4.5 Stable Isotopes

The stable isotopes of oxygen and hydrogen are powerful tools in hydrogeological investigations. Their conservative behaviour in all surface waters and modern low temperature groundwaters, is useful to trace sources and evolution of waters in the hydrologic cycle. In the subsurface, the degree of interaction between water and the rock or sediment matrix can also be examined using these ratios. Applications of stable isotopes to hydrogeological studies are presented by Fontes (1986).

Stable isotope abundances are reported as delta (∂) values in units of per mil (o/oo) relative to a standard (standard mean ocean water (SMOW) for oxygen and hydrogen) such that

$$\partial A = \frac{R_A - R_{STND}}{R_{STND}} \cdot 1000 \qquad 4.1$$

where R_A and R_{STND} are the ratios of the heavy isotope to the light isotope in the sample and in the standard respectively. A water sample with a $\partial\,^{18}O$ value of -10 has an absolute $^{18}O/^{16}O$ ratio that is 1% (10 o/oo) lower than that of SMOW.

The relative isotopic homogeneity of the oceans with respect to oxygen and hydrogen, makes them suitable as a reference standard. As water evaporates from ocean basins, lighter isotopes are preferentially incorporated into the atmosphere and the ratio of heavy to light isotopes is less than that of the oceans. When the air masses move inland, heavy isotopes precipitate preferentially before lighter isotopes. Subsequent rainfalls farther inland become more depleted in heavy isotopes. This rain out effect is enhanced by high altitudes and cooler climates. The greater the distance inland, and the higher the latitude, the more depleted in heavy isotopes is the meteoric precipitation. Craig (1961) has shown a systematic worldwide relationship between ∂ D and $\partial\,^{18}O$ that has become known as the meteoric waterline.

Variations in the isotopic composition of meteoric waters entering the groundwater system can arise from seasonal differences in precipitation, temporal climatic shifts, and from evaporation of waters before infiltration into the ground.

With an increase in the depth, temperature, and residence time in a sedimentary basin, other mechanisms become important in influencing the isotopic composition of waters. Exchange with minerals and dissolved compounds, membrane filtration, mixing, and hydration reactions affect the isotopic composition of brines (Fontes 1986). The oxygen isotope ratio is affected through exchange with silicates, and more importantly, carbonates.

The resulting $^{18}O/^{16}O$ ratio will depend on the original $\partial\,^{18}O$ value of the unexchanged water, the $\partial\,^{18}O$ value of the solid with which equilibration takes place (+ 22.3 $^{o}/oo$ average for carbonates in the Alberta basin (Clayton et al., 1966)), and the extent and temperature of equilibration. The hydrogen isotope ratio can be affected by exchange with petroleum hydrocarbons, H_2S gas, water of hydration in sedimentary minerals (gypsum and clays), or by exchange with hydroxyl ions in clays. Most sedimentary basins show small shifts in D/H ratios indicating that these effects are small, probably due to the much greater mass of hydrogen in pore fluids than in the rock matrix of a basin.

4.5.1 Stable Isotope Results

The stable isotope results are shown in Figure 4.12. The shallow waters plot in an elongate grouping offset from the meteoric water line. This small offset is largely the result of evaporation subsequent to precipitation, but may be partly caused by water-rock interactions. The spread of the shallow water data can be attributed to seasonal variations in precipitation or to more long term climatic changes depending on the ages of the waters. The trend of this group parallels the meteoric water line indicating a meteoric origin for the shallow waters.

There is therefore no isotopic evidence to suggest that the Ribstone Creek waters have resulted from mixing. Had the trend of this group deviated from the meteoric water line towards the Mannville brines, a mixing of meteoric waters with brines would have been indicated for the Ribstone Creek waters which are the isotopically heaviest shallow waters, plotting at the top of the shallow water group (Type 1). The heavier

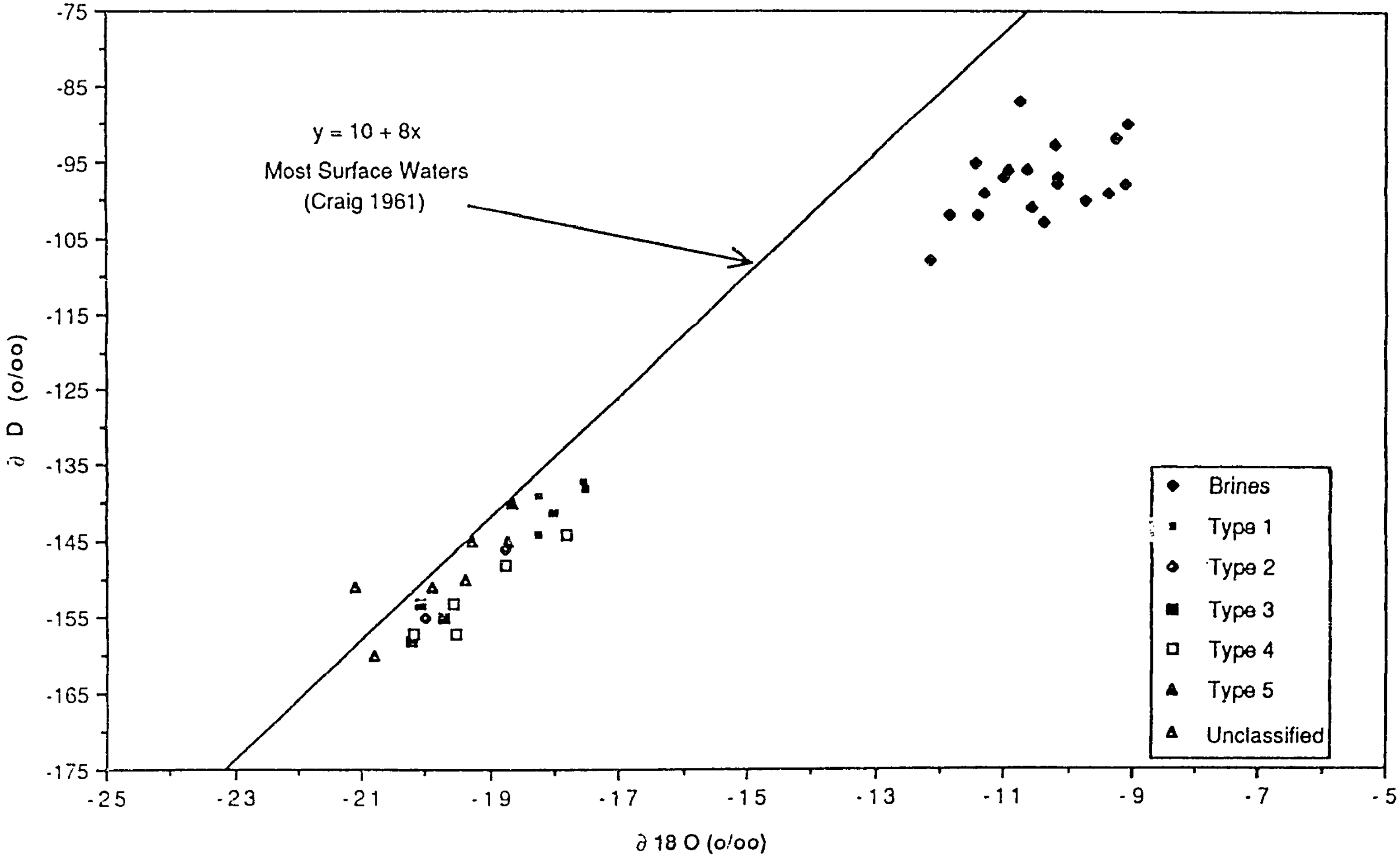


Figure 4.12 Stable isotope composition.

isotopic composition of the Ribstone Creek waters might indicate that precipitation of these waters occurred during the warming period about 4500 years ago, after the last glaciation.

The Mannville brines have shifted considerably from the meteoric water line. This suggests a greater extent of isotopic exchange has taken place in these brines, shifting both oxygen and hydrogen towards a heavier isotopic composition. Figure 4.13 shows data from Hitchon and Friedman (1969) for various brines in the Western Canada Sedimentary basin. The Mannville brines sampled for this study plot close to the data of Hitchon indicating a regular isotopic evolution for the sampled waters.

4.5.2 ^{14}C Age Dates

To further investigate the possibility for mixing of brines with shallow waters in the Ribstone Creek sandstone, samples were taken for ^{14}C analysis to obtain the age of this water.

^{14}C, the radioactive isotope of carbon, is continuously produced in the earth's atmosphere through nuclear reactions between secondary cosmic ray neutrons, and nitrogen nuclei:

$$^{14}N + n \rightarrow {}^{14}C + p \qquad (4.2)$$

The ^{14}C atoms oxidize to form $^{14}CO_2$ molecules which mix with non-radioactive CO_2 in the atmosphere, and through a series of exchange and assimilation reactions, enter the biosphere and hydrosphere. Through time, the ^{14}C decays at a certain rate. By measuring the remaining ^{14}C in a carbonaceous material, its age can be determined.

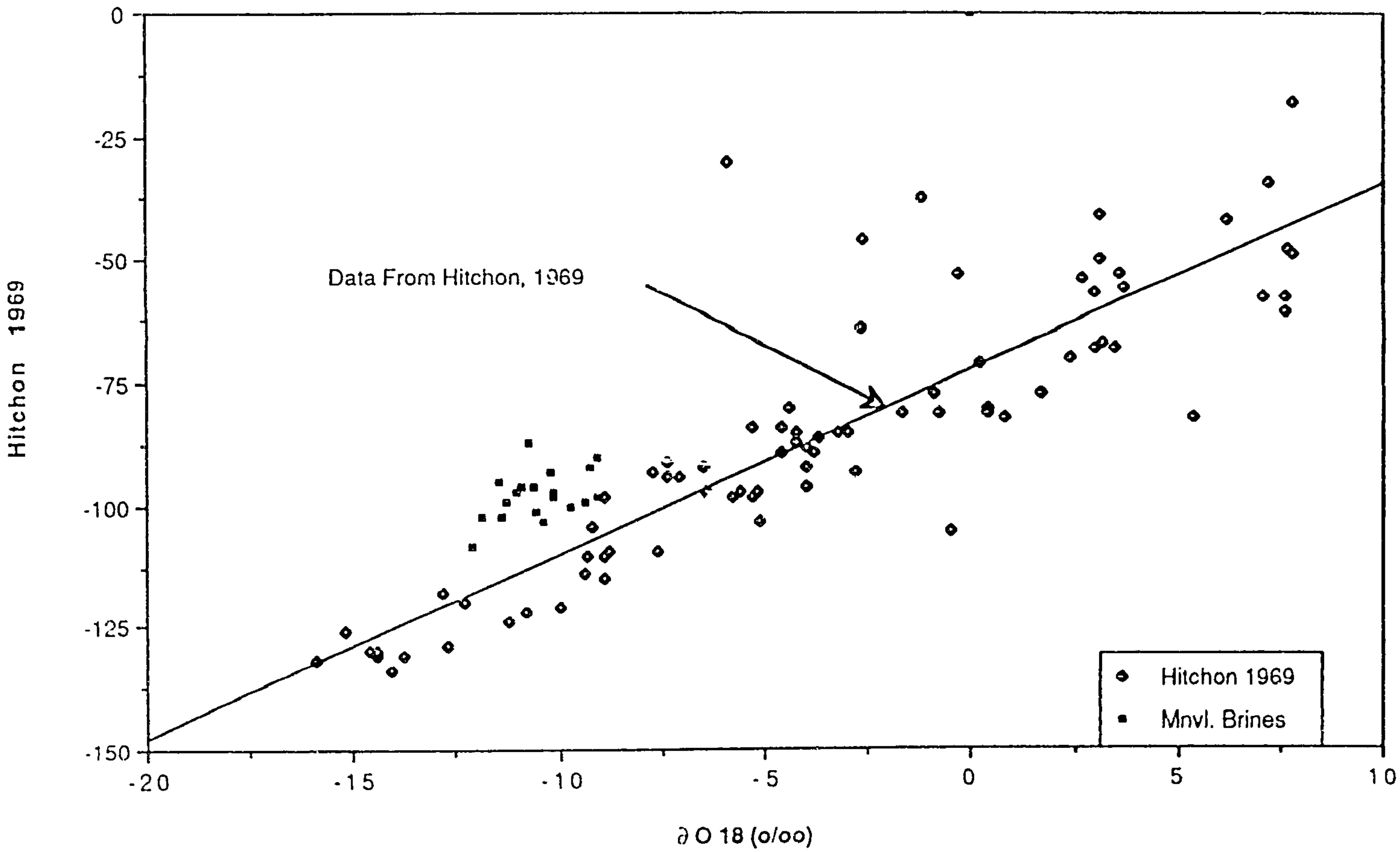


Figure 4.13 Isotopic composition of sampled Mannville waters compared to values obtained by Hitchon (1969) for the Western Canadian Sedimentary Basin.

Dissolved carbon bearing species were precipitated from six 50 litre water samples by the addition of barium chloride and sodium hydroxide to the waters. Procedures to prevent atmospheric contamination as outlined by Geyh and Wagner (1979) were followed. Two of the sampled waters were from the Mannville sands while the remaining four were from the Ribstone Creek Sandstone. In order to account for the various sources of carbon in a groundwater system, and the varying ^{14}C activities associated with these carbon sources, the raw age dates determined by the laboratory must be corrected.

Sources of carbon in groundwater are reviewed by Mook (1986). Possible carbon sources that can alter the original ^{14}C content of waters in the Chauvin area include:

1) In the saturated zone, the oxidation of organic material will add carbon to the water.
2) Sulfate reduction in the absence of free oxygen will also add organic carbon to the system in the saturated zone.
3) Dissolution of carbonate cements and carbonate rocks in the saturated zone.
4) Carbon exchange with soil carbonates or limestone can dilute the live ^{14}C content of the dissolved bicarbonate.

In the radioactive decay law:

$$A_o = Ae^{-\lambda t} \tag{4.3}$$

A_o and A are the original and measured specific radioactivities of the material respectively, t is the age, and λ is the decay constant, where $\lambda = \ln 2/t_{1/2}$ ($t_{1/2}$ being the half life, 5730 +/- 40 years in the case of ^{14}C).

Correction equations found in the literature attempt to correct for Ao, the original specific radioactivity of the water. Unlike organic material where Ao is taken to be equal to the ^{14}C activity of the atmosphere, Ao must be adjusted in the case of groundwaters to account for the carbon altering processes mentioned above. Ao is, therefore, not just the ^{14}C activity of the groundwater as it enters the saturated zone.

Fontes and Garnier (1979) have reviewed possible correction equations found in the literature. These equations use either the carbonate chemistry of the water system, the ^{13}C isotope chemistry or a combination of the two to obtain corrected Ao values. Table 4.2 shows the raw ages for the waters along with several corrected ages. The Ingerson-Pearson equation uses the ^{13}C value for the sampled water to correct the age using the equation

$$A_o = \frac{\partial_t - \partial_c}{\partial_g - \partial_c}(A_g - A_c) + A_c \qquad (4.4)$$

where ∂_t, ∂_g, and ∂_c are the stable isotope compositions of the total dissolved carbon, the soil CO_2, and the solid carbonate respectively, and A_g and A_c are the ^{14}C activity of the soil CO_2 and solid carbonate. This equation simplifies to

$$A_o = (\partial_t/-25) \times 100 \text{ pmc (percent modern carbon)} \qquad (4.5)$$

when practical values of $\partial_g = -25$ ‰, $\partial_c = 0$ ‰ and $A_c = 0\%$ are substituted into the above. In both the Fontes-Garnier (1979) paper and in a study by Kimball (1984) the ages obtained from the Ingerson-Pearson equation closely correspond to those obtained from the Fontes-Garnier equation. The ages obtained from the Ingerson-Pearson equation are taken to be the most accurate of the ones in Table 4.2 and are assumed to be the actual ages of the waters.

4.6 Interpretation of Shallow Water Chemistry Data

The interpretation of the chemistry of shallow groundwater requires a knowledge of the sediment or rock mineralogy through which the water travels, and of the chemical processes affecting the water along its path.

Beneath the Chauvin area, the Belly River Formation consists of a number of distinct alternating continental sandstone and marine shale members. At the time of the bedrock aquifer deposition, the water contained within the sediment was fresh to brackish in nature. With subsequent uplift and erosion, these connate waters have been slowly flushed from the system by fresh meteoric water recharge. LeBreton (1963) suggests that this recharge has flushed connate waters from the system to depths of only 100 to 150 metres in east-central Alberta.

The change in the chemistry of a water with depth or distance along a flow path can best be explained through one or more of the following reactions, worked out by previous authors and summarized as follows (Wallick, 1981) :

(a) Reaction of carbonic acid with limestone and/or dolomite in the glacial till, leaving Ca^{2+}, Mg^{2+}, and HCO_3^- in solution:
$H_2CO_3 + CaCO_3 \rightleftharpoons Ca^{2+} + 2HCO_3^-$

Table 4.2

14C Age Dating Results

Water Sample	∂13C	Original 14C Date	Freeze & Cherry Equation (1979) t=-8270 ln(A/Ao)+8270 ln Q Q = .85	Ingerson-Pearson Equation Ao = (∂13t/-25)*100	Vegreville Isotope Lab Equation Age Corr. = (C13 + 25)*16
WW 6	-7.0	>40190	>38846	>10523	>39902
WW 7	-18.1	37600	36256	2670	37490
1c-29-41-1	-5.0	>40020	>38676	>13305	>39700
10-20-41-1	-3.5	>40750	>39406	>16253	>40406
7-28-43-1*	-8.5	>40500	>39156	>8918	>40236
11-26-42-2*	-1.3	34730	33386	24440	34351

$2H_2CO_3 + CaMg(CO_3)_2 \rightleftharpoons Ca^{2+} + Mg^{2+} + 4HCO_3^-$

(b) Oxidation of pyrite in the presence of calcite, under alternate wet-dry conditions:

$FeS_{2(s)} + 7/2O_2 + H_2O \longrightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$

$Fe^{2+} + 1/4O_2 + H^+ \longrightarrow Fe^{3+} + 1/2H_2O$

$Fe^{3+} + 3H_2O \longrightarrow Fe(OH)_{3(s)} + 3H^+$

$H^+ + CaCO_3 \longrightarrow Ca^{2+} + HCO_3^-$

$Ca^{2+} + SO_4^{2-} \longrightarrow CaSO_{4(s)}$

(c) Dissolution of gypsum to produce Ca^{2+} and SO_4^{2-}:

$CaSO_4 + 2H_2O \longrightarrow Ca^{2+} + SO_4^{2-} + 2H_2O$

(d) Loss of Ca^{2+} and Mg^{2+} and gain of Na^+ by cation exchange with Na-rich smectite clays.

(e) Once the partial pressure of oxygen decreases to a level sufficiently low for bacterial sulfate reduction to occur, loss of sulfate and gain of CO^2 take place in the presence of *Desulfovibrio desulfuricans* bacteria: $SO_4^{2-} + 2CH_2O \longrightarrow HS^- + HCO_3^- + H_2CO_3$ where CH_2O represents organic matter (HS^- maybe removed from solution through reactions with ferrous iron to form FeS and then pyrite, FeS_2).

(f) Addition of Cl- through ionic diffusion from deeper more saline formation waters or through dissolution of halite.

In addition to these processes, Chebotarev (1955) in studying over 10 000 water chemistry analyses, noted an anion evolution along a flow path as follows:

$$HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$$

4.7 Interpretation of Chemistry in Terms of Flow Systems

Type 1

Interpretation of the origin and evolution of the Ribstone Creek waters is complicated. The water chemistry and isotopic work suggest that physical mixing of fresh waters with Mannville brines is not taking place in the Ribstone Creek Sandstone. The nature of the regional flow system, with waters moving downward from the surface, also negates the likelyhood of Mannville brines rising up to the near surface.

One possible origin for these waters is the dilution of ancient brackish waters trapped with the Ribstone Creek sediment at the time of deposition about 75 million years ago. LeBreton (1963) attributes shallow saline groundwaters to extremely limited movement of waters since uplift and erosion. However with the Ribstone Creek Sandstone being so close to the surface and active groundwater flow systems, at least since the retreat of the last glaciers, it is unlikely that ancient waters would still remain in this unit. If the ^{14}C age date of 2670 years obtained for sample WW7 is accepted, then the waters in the sandstone are much younger than Cretaceous, or even late Tertiary, age. The iodide concentration in the Ribstone Creek is approximately 50 times greater than that of sea water indicating that processes other than simple sea water dilution have acted on these waters. The possibility of waters being connate, therefore, appears to be remote.

Derivation of these waters from simple chemical evolution of infiltrating fresh meteoric waters is also unlikely. Waters sampled only 20 metres above the Ribstone Creek unit (e.g. WW41 (Figure 3.13)) show very different water chemistries, with negligible concentrations of chloride, bromide and iodide. No source of halogens is available in the bedrock above the Ribstone Creek Sandstone so that any component of the waters descending from the area around WW41 would remain fresh.

A third possible mechanism that could have contributed to the evolution of these waters is diffusion. Movement of ions from deeper, more saline formation waters to the near surface by diffusion has been used by Hendry and Schwartz (1988) to explain water chemistry patterns in the Milk River aquifer in southern Alberta. This process would be opposite to reverse osmosis where ions are retained in the more saline waters.

Diffusion is the process whereby individual molecules move through a gas, liquid, or solid medium under the influence of a concentration gradient. As long as a concentration gradient is maintained diffusion will continue. For diffusion to be considered an effective transport mechanism, it has to be dominant over advective transport. Hendry and Schwartz (1988) note that in units with hydraulic conductivities less than 10^{-8} m/s, diffusion will become important. In the Colorado shales which have a hydraulic conductivity in the order of 10^{-10} to 10^{-11} m/s, diffusion can possibly dominate over advection.

The mass of a diffusing ion passing through a given cross section per unit time is proportional to the concentration gradient. This expression is known as Fick's first law and is written

$$F = -D \, dC/dx \qquad (4.6)$$

where F is the mass of solute per unit area per unit time, D is the diffusion coefficient, C is the solute concentration, and dC/dx is the concentration gradient.

The solution to the combination of Fick's law with the continuity equation yields the relation (Freeze and Cherry, 1979)

$$C_i(x,t) = C_o \operatorname{erfc} (x/2\ D^{*}t) \qquad (4.7)$$

where C_i would be the concentration of species i in the Ribstone Creek Sandstone, C_o would be the concentration of species i in the Mannville brines, x is the distance separating the two units, D^* is the effective diffusion coefficient, and t is the time over which diffusion has taken place. This solution assumes that the hydraulic gradients in the strata are negligible, the solute concentration in the higher concentration unit remains constant with time, and the initial concentration of species i in the lower concentration unit is zero. This equation was solved (Appendix C) to obtain estimates of t, the time necessary for diffusion to increase the chloride concentration in the Ribstone Creek Sandstone from 0 to 700 mg/l assuming the average chloride concentration of the Mannville brines to be 50 000 mg/l. Diffusion was assumed to take place from the Mannville rather than from deeper Devonian units.

Difficulties arise in trying to choose an appropriate value for D^*, the effective diffusion coefficient. Since no experimentally derived values are available for strata in the Chauvin area, a value based on literature reports was selected. Ranganathan and Hanor (1987) calculate a value using the relation

$$D^* = D\phi^n \qquad (4.8)$$

where D is the diffusion coefficient in free solution, σ is the porosity of the sediment, and n is a value related to the tortuosity of the paths between mineral grains, equal to 4 in the case of shales. Using this expression with a porosity value of 10%, yields an effective diffusion coefficient of 1.5 10^{-13} m^2/s. Hendry and Schwartz (1988) have used a value of 6 10^{-12} m^2/s, but note that values as high as 3 10^{-10} m^2/s have been used in other studies involving clay tills. This large range of reported values results in time values ranging from a reasonable 3.6 million years to an impossible 7.2 billion years, for 700 mg/l of chloride to accumulate in the Ribstone Creek Sandstone through diffusion. The lower D^* values are probably closer to the real values, and diffusion is, therefore, unlikely to have accounted for the chemistries of these waters. This can not be accurately determined unless more reliable diffusion coefficients are found.

Only trace amounts of halogens are found above the Ribstone Creek Sandstone suggesting diffusion is not the dominant process controlling the chemistry of these waters. Unless they are being flushed from the system by more active shallow flow systems, halogens are expected in greater concentrations than presently found in groundwaters above the Ribstone Creek unit.

Membrane filtration appears to be the most suitable mechanism to explain the salinity in the Ribstone Creek sandstone. As waters are driven under the influence of a head gradient across a shale unit, the solute movement is restricted relative to water movement. This results when cations are adsorbed onto negatively charged clay mineral surfaces. Subsequent cations are then repelled by the positively charged membrane, and in order to maintain electrical neutrality, anions also become restricted. Large effective stresses are necessary before clays act as effective semi-permeable membranes (Lloyd and Heathcote 1985). Shallow groundwaters, therefore, are generally not subject to membrane filtration. Schwartz (1974), however, has stated that in fresh water systems, clays do not have to be greatly stressed to act as effective membranes. He suggests that residual glacial stresses are sufficient for certain glacial tills to act as membranes.

The Lea Park shale beneath the Belly River Formation may, therefore, act as a semipermeable membrane (Figure 3.13, 3.14, 3.15). In this scenario, as waters descend to the Mannville Formation under the prevailing head conditions, ions accumulate adjacent to the Lea Park shale in the lower Belly River Formation. Over time, the Ribstone Creek sandstone becomes more brackish. This is presently the situation in the Chauvin area. The low calcium concentrations, one of the ions most affected by membrane filtration, in the Ribstone Creek can be explained if cation exchange is taking place in the Belly River Formation. This is strongly suspected from the chemistries of other shallow waters, and also explains the high sodium levels within the Ribstone Creek unit. Sulfate is also strongly affected by membrane filtration, but sulfate reduction could account for the low concentrations in the sandstone. Chloride, bromide and iodide are not involved in subsequent reactions but are conservative and remain in solution. They will, therefore, be the most noticeable ions to accumulate under membrane filtration processes.

Membrane filtration has also been found to affect ^{18}O molecules (Clayton et al., 1966). The extent of this effect is uncertain, and the shift in the position of the shallow water composition from the meteoric water line in Figure 4.13 may, in fact, be partly a result of this membrane process.

Type 2

Type 2 (Figure 4.2, 4.3, 4.4) waters are produced from wells situated on topographically high areas. The hydraulic head data in Figure 3.13 indicate downward water movement in the area of these wells (WW30, WW38). This high is, therefore, interpreted as a local recharge area, and the waters as recharge waters.

Water chemistry supports this interpretation. Type 2 waters, with bicarbonate and sulfate as the dominant anions, are found towards the beginning of the Chebotarev sequence indicating their recharge nature. The occurrence of bicarbonate and sodium as the dominant ions is attributed to the combined effect of carbonate dissolution and cation exchange (processes (a) and (d) above). Removal of calcium from solution through ion exchange may be important in that it allows water to remain undersaturated with respect to calcite and dissolution of carbonate to continue. The sulfate content of the waters probably results from the oxidation of pyrite, from dissolution of gypsum in the sediment, or both mechanisms.

The dominance of sodium over calcium suggests that optimum conditions for cation exchange are present in the shallow subsurface environment. Such conditions occur in dirty sands with a significant clay content, where water is able to move relatively freely through the ground, but sufficient clay concentrations are still available as exchange sites. Organic rich surface soils may also enhance cation exchange with humus acting as exchange sites.

Type 3

Type 3 waters (Figure 4.2, 4.3, 4.4), as noted earlier, are produced in areas of low topographic elevation. Figure 3.13 shows a decrease in hydraulic head from wells in the southwest to wells producing these waters (WW41, WW42, WW43). A component of these waters will, therefore, be derived from flow in this direction. A second component of these waters is derived from waters that have recharged in the north-south trending central ridge running through Rg. 2. Artesian conditions, and surface salt accumulations suggest a local discharge region.

Water chemistry can again be used to support these conclusions. Bicarbonate and sulfate are still the dominant anions suggesting that discharge is only of local waters that have not travelled great distances through the subsurface. These anions would have accumulated through similar processes to those discussed for the above waters, namely carbonate dissolution and pyrite oxidation or gypsum dissolution for bicarbonate and sulfate respectively. Two processes may account for the increased importance of calcium and magnesium in Type 3 waters. Reverse ion exchange may have shaped the cation composition, or these waters may be made up dominantly of recharge waters from the central ridge, that have not undergone cation exchange to the same degree as Type 2 waters. In both instances calcium and magnesium would be found in greater concentrations. Hem (1985) notes that if sodium constitutes considerably more than 50% of the cations, then calcium and magnesium will be removed from clay exchange sites into solution, replaced by sodium. The possibility for reverse cation exchange exists since sodium comprises about 90% of the total cations in Type 2 waters. As Type 2 waters flow north under the prevailing hydraulic gradient, sodium may come out of solution in exchange for calcium and magnesium.

These waters are found within a considerable depth range (6 to 106 metres) indicating that the chemistry of these waters is not strongly altered as they approach the surface.

Type 4

Type 4 waters are similar to those of Type 1, in that they are not unique to either recharge or discharge areas. Figures 3.13 and 3.15 show that these wells (WW19, WW20, WW21, WW68) produce from the bedrock/drift contact where the Ribstone Creek Sandstone is truncated by the east-west trending bedrock channel. The waters are not particularly recharge or discharge, but are interpreted as a mixture of Type 1 waters and fresher waters from the coarse sands in the lower part of the bedrock channel.

The water chemistry appears to be similar to that expected from a dilution of Ribstone Creek waters (Figure 4.2, 4.3). Chloride, although still a major anion, is no longer dominant. The high concentrations of chloride reflect an older age for these waters. Sulfate, as is the case in Type 1 waters, is negligible, suggesting that these waters may be affected by sulfate reduction. The cations are dominated by sodium, but calcium and magnesium are more important than in Type 1 waters. Bromide and iodide are found in concentrations higher than background level, but not quite as high as in the Ribstone Creek waters.

Type 5

These waters are not confined to a particular geographic region, or to a particular elevation (Figure 4.2). The waters are produced from very shallow wells, usually about 5 metres in depth. Figures 3.14 and 3.15 show three of these wells (WW50, WW52, WW69), located both in recharge and discharge areas. The Durov diagram identifies these as recharge waters. The waters are interpreted to have been minimally altered since precipitation, having travelled insignificant distances through the ground. Those wells located in discharge areas have waters that have not yet mixed with rising discharge waters.

The water chemistry is consistent with a shallow, slightly evolved water. Bicarbonate is the dominant anion indicating water in the first stage of the Chebotarev sequence. Chloride is negligible and the minor sulfate content probably originated from dissolution of gypsum or from the oxidation of pyrite in the drift. The cations are dominated by calcium, with sodium being negligible. The high calcium and magnesium contents arise from the dissolution of dolomite and/or calcite in the till. The resulting calcium and magnesium ions have not been exchanged for sodium, as is the case in all the other sampled waters. Bromide and iodide concentrations are only found at background levels.

Type 6

These waters are found in the topographically high southeast corner of the study region (Figure 4.2). The cross sections in Figures 3.13 and 3.14 show hydraulic head data indicating downward flow in this area (WW4, WW5). The waters are interpreted as recharge waters that have evolved to a degree somewhere between waters of Type 2 and Type 5.

Anions are dominated by bicarbonate, with sulfate found in lower concentrations than in Type 2 and 5 waters. Chloride is negligible. The cations are present nearly in equal concentrations, although sodium is usually found in the greatest concentrations. These waters are found at greater depths than those of Type 2, and yet they are not as chemically evolved, even though near surface sediments in the two areas are similar.

This can be explained by the local geology. As outlined earlier, the hill in Twp. 41, Rg. 1 formed as a result of glacial ice thrusting. This deformation results in fractured, near surface material that may channel water quickly to depths. This water would not be in contact with the sediment long enough for cation exchange or pyrite oxidation to take place. Exchange sites along such fractures would be rapidly saturated with sodium, and any pyrite or gypsum would have reacted with earlier passing waters. This can explain the lower sulfate and sodium concentrations than those found in Type 2 waters.

Mannville Brines

The chemistry of the Mannville brines suggests that they are deep subsurface waters that have evolved from a marine origin to their present composition (Ostroff, 1967). The low sulfate concentrations result from strong sulfate reduction in these waters. The large variation in the TDS content of the Mannville waters may result from localized dilution due to infiltration of meteoric waters from the surface. Meteoric waters could reach the Mannville strata through those faults mentioned earlier. The uniformity of the Mannville brines with respect to the relative proportions of the standard ions, suggests that waters reaching the Mannville from above, do not have an effect on the standard ion proportions of the brines. The isotopic results suggest that these waters are typical of the Alberta Basin and are too old for ^{14}C-age dating techniques.

5. SOIL-GAS GEOCHEMICAL SURVEY

Prospecting for oil and gas through shallow soil gas surveys was first suggested by V. A. Sokolov in 1929. He proved the theoretical possibility for the diffusion of gases from hydrocarbon accumulations to the surface, and in 1930, he experimentally found higher concentrations of hydrocarbon gases in the soil air above oil pools. Gas surveys directly detect hydrocarbon gases in the soil air or adsorbed on soil particles, and now constitute the most common method of shallow geochemical surveys. The basic premise for geochemical surveys is that seals of oil and gas traps are not totally impermeable, and allow the escape of hydrocarbons, which migrate towards the surface where detection is possible.

More recently, surface geochemical surveys have expanded to include the detection of more indirect surface chemical phenomena arising from migrating hydrocarbon gases. These surveys assume that vertically migrating hydrocarbons alter the physical characteristics of rock and soil particles through which they have travelled. Detectable phenomena include reductive leaching of metals from near surface sediment, near surface cementation patterns, alteration of soil microbiology, and anomalous distributions of helium and radon in the soil atmosphere. Magnetic, electrotelluric and radiometric surveys have all been employed by the geochemical industry to detect these indicators.

5.1 Migration of Gases

The exact migration mechanism of hydrocarbon gases from oil reservoirs to the near surface is not clearly understood. Four mechanisms have been proposed to account for this migration; effusion (Kartsev et al., 1959), diffusion (Pirson, 1946; Kartsev et al., 1959; Duchscherer, 1981), vertical transport by deep basin brines (Pirson, 1969; Jones, 1984), and the vertical migration of natural gas microbubbles (MacElvain, 1969; Price, 1986).

Price (1986), in a detailed review of petroleum surface geochemical exploration, presents arguments against the first three transport mechanisms, and proposes the vertical migration of natural gas microbubbles as the only transport mechanism in agreement with the observed data.

Effusion, by definition meaning to pour forth, is discounted as a viable transport mechanism of hydrocarbon gases to the surface since microseepage by effusion should result in surface anomalies with hydrocarbon concentrations much higher than are presently found. The very meaning of effusion is contradictory to microseepage and seems to appear in the literature synonymous to advection. Effusion should also transport higher molecular weight hydrocarbons to the surface. Kartsev et al. (1959), however, envisaged effusion as a minor part in the migration history of gases. They proposed that as dissolved gases rose to the surface by diffusion, there would come a point at which the hydrostatic pressure was sufficiently low for these gases to exsolve out of solution. Existing as a free phase, the gases would migrate under a pressure gradient toward the surface by effusion. They also suggest that the lack of high molecular weight hydrocarbons reaching the surface is due to sorption of these compounds on mineral surfaces along the path of migration. They note that heavier hydrocarbons are sorbed more readily than are lighter hydrocarbons, and are found in higher concentrations closer to oil reservoirs.

Vertical transport to the surface by deep basin brines is an acceptable method of transporting hydrocarbon gases to the surface only in situations where brines are moving vertically upward to the surface. Brines, as is the case in the Chauvin region, are simply not always moving vertically upwards in areas of oil pools, and this transport mechanism can therefore not explain hydrocarbon migration in all cases. This is, however, not because, as Price (1986) incorrectly states, significant vertical fluid flow through shales is impossible (Toth, 1980, 1984).

A number of arguments have been put forth against diffusion, whereby migration takes place under a concentration gradient, as the transport mechanism (Hunt, 1979; Price, 1986). These include:

1) Diffusion, being a spherically dispersive process with no enhanced vertical component, is unable to account for the sharp outlines of most soil hydrocarbon gas anomalies. Diffusion would expand and dilute gas two feet laterally for each foot of vertical ascent (MacElvain, 1969), so that on approaching an oil field, a gradual increase in the concentrations of soil hydrocarbons would be expected; 2) Diffusion does not account for the halo type soil gas anomalies that are commonly found over oil pools;

3) Diffusion does not account for the lack of higher molecular weight hydrocarbons reaching the surface; 4) Diffusion has been found to be too slow a process to account for many of the discovered geochemical anomalies over deep oil accumulations. An unreferenced Soviet study found that the gas content of a sand, located 300 metres above a gas storage reservoir, increased over 10 time its original value only several months after gas emplacement in the reservoir (Hunt, 1979).

Despite these negative arguments, it appears that diffusion, the migration of natural gas microbubbles, or both mechanisms are the most viable in transporting subsurface hydrocarbons to surface. Little work has been done to determine conditions under which gas microbubbles can exist and under what conditions such bubbles would dissolve into formation fluids. Gas bubble formation and migration under atmospheric conditions is discussed by MacElvain (1969). Experimental results are also needed to assess the rates of hydrocarbon gas diffusion in the subsurface more accurately. Times necessary for light hydrocarbon gases to diffuse to the surface from oil reservoirs at various depths with various subsurface conditions have been calculated mathematically (Saraf, 1970; Smith et al., 1971). A three metre thick aquifer, half-way between the surface and a 1740 metre deep reservoir, with a lateral groundwater flow velocity of one metre per year can laterally shift vertically diffusing gases 190 kilometres (Smith et al., 1971). Price (1986) uses this observation to argue against diffusion as the transport mechanism of gases to the surface. However, different values for ambiguous parameters such as the coefficients of diffusion and adsorption, the microbial degradation, or the fracture intensity, alters these calculated values. With gases diffusing through water-filled pores, along surfaces of mineral particles, partially through crystal lattices and in extreme cases through large open faults and fractures at rates similar to those in pure water, diffusion coefficients are difficult to determine without experimental results as a guide. The values determined by Smith et al and Saraf, none-the-less, may indicate that diffusion is not the dominant transport mechanism of hydrocarbon gases to the surface.

Most successful studies indicate that soil gas anomalies are found directly to overlie oil and gas reservoirs, so that although the possibility for lateral gas migration by groundwater flow is logical, it is not borne out by observation (MacElvain, 1963). This argument, however, only pertains to successful geochemical studies, where groundwater has had no influence on hydrocarbon migration paths. Unsuccessful studies are not discussed by MacElvain and the role of groundwater flow on hydrocarbon migration in these instances is conveniently overlooked. It has been put forward that vertical migration may take place primarily through the film of adsorbed water on mineral grains rather than through free flowing waters in the subsurface (MacElvain, 1963).

Halo type anomalies often detected in geochemical surveys, likely result from biological oxidation of hydrocarbons to produce CO_2 and organic acids (Price, 1986). Ideal conditions for the growth of hydrocarbon consuming bacteria are found directly over oil reservoirs, associated with the greatest quantities of hydrocarbons. Towards the edges of a rising gas plume, concentrations of hydrocarbons are insufficient to support these organisms. As a result, hydrocarbons are found at the surface in a ring around the perimeter of an oil pool since gases directly over the pool are destroyed by biological activity. This would be the case regardless of the transport mechanism. If diffusion was dominant, then the sharp outer boundaries of the halo soil gas anomalies must also be explained. Microbial action may play a role in this phenomenon. There may exist certain microorganisms that can tolerate and oxidize only small hydrocarbon concentrations. When amounts increase above a critical level, hydrocarbons become toxic and the population cannot survive. In this scenario, there would exist a region, between those organisms which require hydrocarbons for survival and those organisms for which hydrocarbons are toxic, where diffusing hydrocarbons would reach the surface unaltered by biological activity.

Despite being an extremely important process in modifying or destroying migrating soil hydrocarbon anomalies, the extent and nature of the interaction of microbes with migrating hydrocarbon gases has been largely overlooked in geochemical studies. Not only will biological activity affect final concentrations of hydrocarbon gases reaching the surface, but, due to climatic factors, these concentrations can vary seasonally. Davis (1969) presents a summary of microbiological techniques and implications for shallow petroleum exploration. Benzene and toluene, two higher molecular weight hydrocarbons, are those least affected by microbial action (Hitchon, 1974).

The differing solubilities of hydrocarbons in water may also alter migrating hydrocarbon plumes. Heavier hydrocarbons, most notably benzene and toluene, are more soluble in groundwaters. These hydrocarbons dissolve more readily into subsurface waters and exsolve out of these waters later than lighter compounds. Lateral groundwater flow may, therefore, affect these compounds to a greater extent than lighter hydrocarbons.

Migration of hydrocarbon gases in the subsurface can take place through a number of pathways. In zones of major tectonic disturbances, gases will migrate preferentially through faults. Initial seeps after such disturbances can be quite intense, but as material precipitates in these passage-ways through time, the gas flux will diminish. Tectonic fissures or fractures are found in many rocks and again provide preferential pathways for migrating gases. Fractures are less extensive than faults so that large fracture zones or networks are required for preferential migration of gases to the surface. Where faults or fractures are not developed, hydrocarbon gases will migrate through the pore systems of saturated rock units.

5.2 Chauvin Gas Survey

Hydrocarbons escaping from a reservoir are generally assumed to migrate vertically to the surface regardless of the subsurface hydraulics or geology. Several authors have alluded to the possibility for groundwater flow laterally to shift vertically migrating hydrocarbon gases. Hitchon (1974), Duchscherer (1981), and Philp and Crisp (1982) have all suggested that more study be given to the overall effect of lateral and vertical groundwater flow on the concentration, positioning, and shaping of soil gas anomalies.

When soil gas anomalies are absent over an oil reservoir, attention rarely, if ever, turns to groundwater flow and its potential to divert rising hydrocarbon gas plumes. The lack of observations linking the lateral migration of vertically rising hydrocarbons to groundwater flow has resulted in the fact that this phenomenon is perpetually ignored. Pirson's (1946) appears to be the only study that has detected a correlation between shallow groundwater flow systems and soil gas anomalies. In over five years of conducting ethane emanation studies, Pirson found that areas of artificially high gas emanations were present over regions of groundwater discharge, whereas artificially low emanations were located over topographic highs or recharge areas. Pirson attributed these results to the collection of gases in percolating meteoric groundwaters and the subsequent release of these gases in drainage areas.

The geochemical soil gas survey in the Chauvin area was designed so that any effect of shallow groundwater flow on vertically migrating hydrocarbons would be observed. The Chauvin area has numerous oil pools located over topographic highs, determined to be local recharge zones and over topographic lows, determined to be local discharge zones. Figure 5.1 shows the soil gas sampling locations with respect to the oil fields and the dominant recharge and discharge areas. As a working hypothesis, it was assumed that oil fields located beneath the recharge areas of local flow systems, would display either a weakened geochemical signature or no signature at all. This would result from downward flowing groundwaters dispersing upward moving hydrocarbon gases or laterally shifting these gases from the recharge zone. Over discharge areas the upward flow of groundwater coincides with the upward migration of hydrocarbon gases and strong geochemical signitures would be expected.

Three major survey lines were selected to traverse the study region, two running north-south and one running east west (Figure 5.1). The lines were jogged as necessary to remain along side of the roads in the area, but the original intent of the survey was not changed. 250 soil-gas samplers were placed into the ground along these lines at quarter mile spacings in late September, 1987 and were retrieved six weeks later in early November.

5.3 Selection of Survey Method

Shallow geochemical surveys attempt to detect hydrocarbon gases present in one of three different modes, namely as: free gases in soil pores,

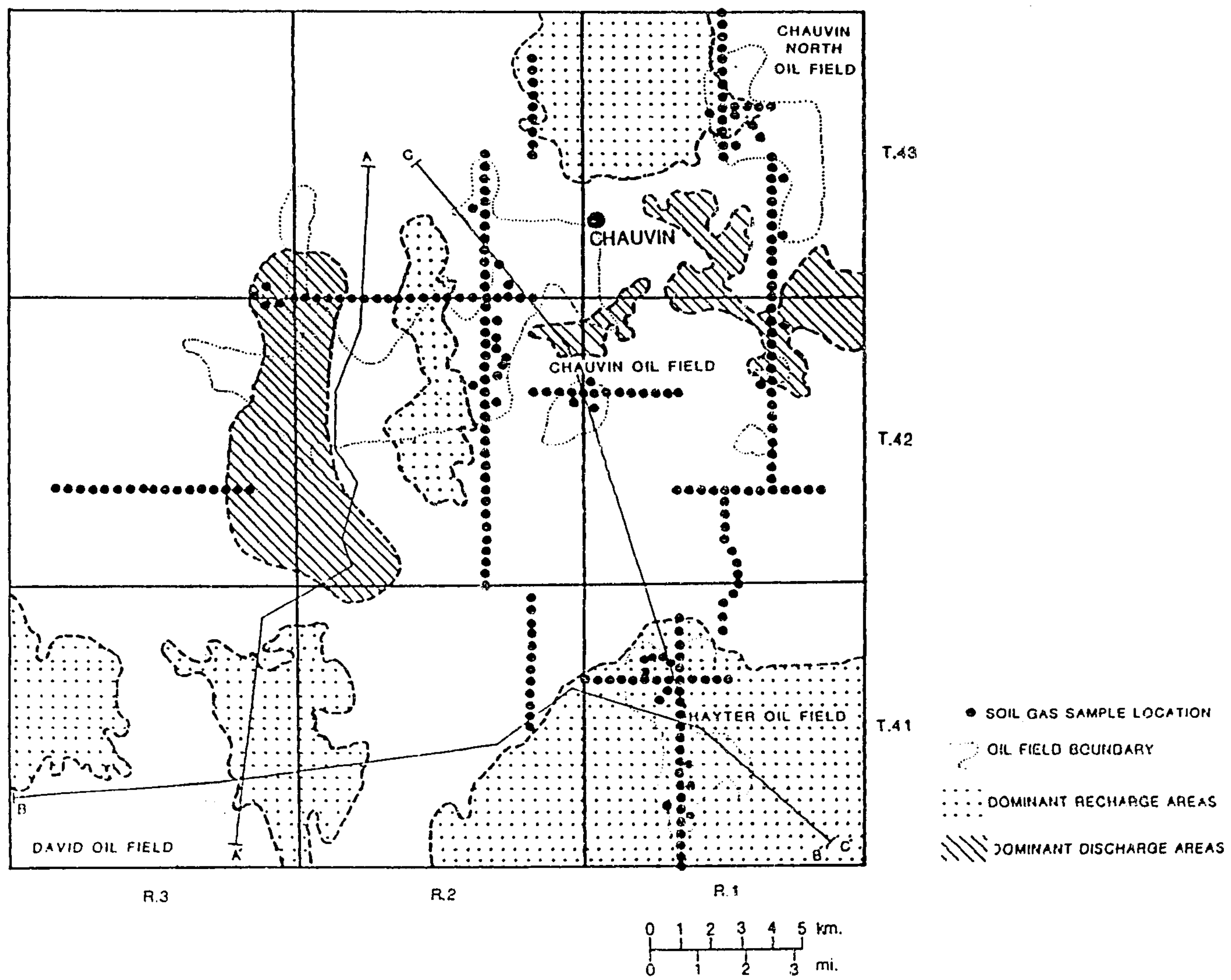


Figure 5.1 Soil-gas sampling locations.

dissolved gases in groundwaters, and adsorbed gases on soil particles.

The latter type was deemed inappropriate for the Chauvin region in light of the results obtained by McRossan et al. (1972). They concluded after a geochemical survey of the Caroline, Alberta area, that with the varying carbonate content of surface tills in Alberta, adsorbed hydrocarbon gases were released in different quantities upon acid treatment. Soil samples with high carbonate contents would dissolve to a greater extent thus releasing greater quantities of hydrocarbon gases than those samples with lower carbonate contents. No correlation with subsurface petroleum accumulations was possible, even after the data were adjusted for carbonate content.

Whereas dissolved hydrocarbon gas studies have been limited in number and confined to deep brine or Russian studies, pore gas studies are carried out frequently in North America by a variety of geochemical firms. It was decided that a soil pore-gas survey was most appropriate for this study and Petrex, a Denver based company was selected to assist with the program. Time integrative soil gas procedures, such as that of Petrex, have been criticized because of the intense biological activity occurring in the uppermost soil horizons, and because they have not been sufficiently tested for existing problems to be discovered (Price, 1986). However, compounds of higher molecular weight were found by Horovitz (1972) not to be produced biogenically in the shallow subsurface, and it was decided, therefore that the Petrex method could be applied.

5.3.1 The Petrex Method

The Petrex soil gas method involves a time integrative sampling procedure that eliminates short term fluctuations in the near surface environment. An open ended test tube is placed into the ground to collect volatilizing hydrocarbons, about 20-30 cm below the ground surface. Within the test tube is a collector, a ferromagnetic, currie point wire coated with activated charcoal (Figure 5.2). The samplers are left in the ground for several weeks before they are removed, sealed, and sent to the laboratory for analysis. There, the hydrocarbon compounds are desorbed from the wire, ionized, separated according to mass and counted by a computerized mass spectrometer. A spectral "fingerprint" is obtained for each sample (Figure 5.3) and includes hydrocarbons ranging in mass from 15 to 240. This mass range includes the alkanes, the alkyl aromatics and the cycloalkanes. A general overview of the method is given by Klusman et al. (1986).

In areas of proven oil production, Petrex requests a set of "training samples" which are collected over known oil pools throughout the study area. The spectral fingerprints for this set are evaluated by a multivariate factor analysis aimed at explaining relationships among several difficult-to-interpret, correlated variables in terms of a few conceptually meaningful, relatively independent factors. In the case of a Petrex study, the variables are the different hydrocarbon gases detected in the samples, e.g., benzene, methane, etc.. The factor analysis procedure identifies different groups of gases that are consistently correlated with each other in the training set. These groupings are referred to as factors. Each factor determined is relatively independent of all other factors, so that a particular gas will usually not be found in more than one factor. From the training sample analysis, a factor indicative of the presence of oil is

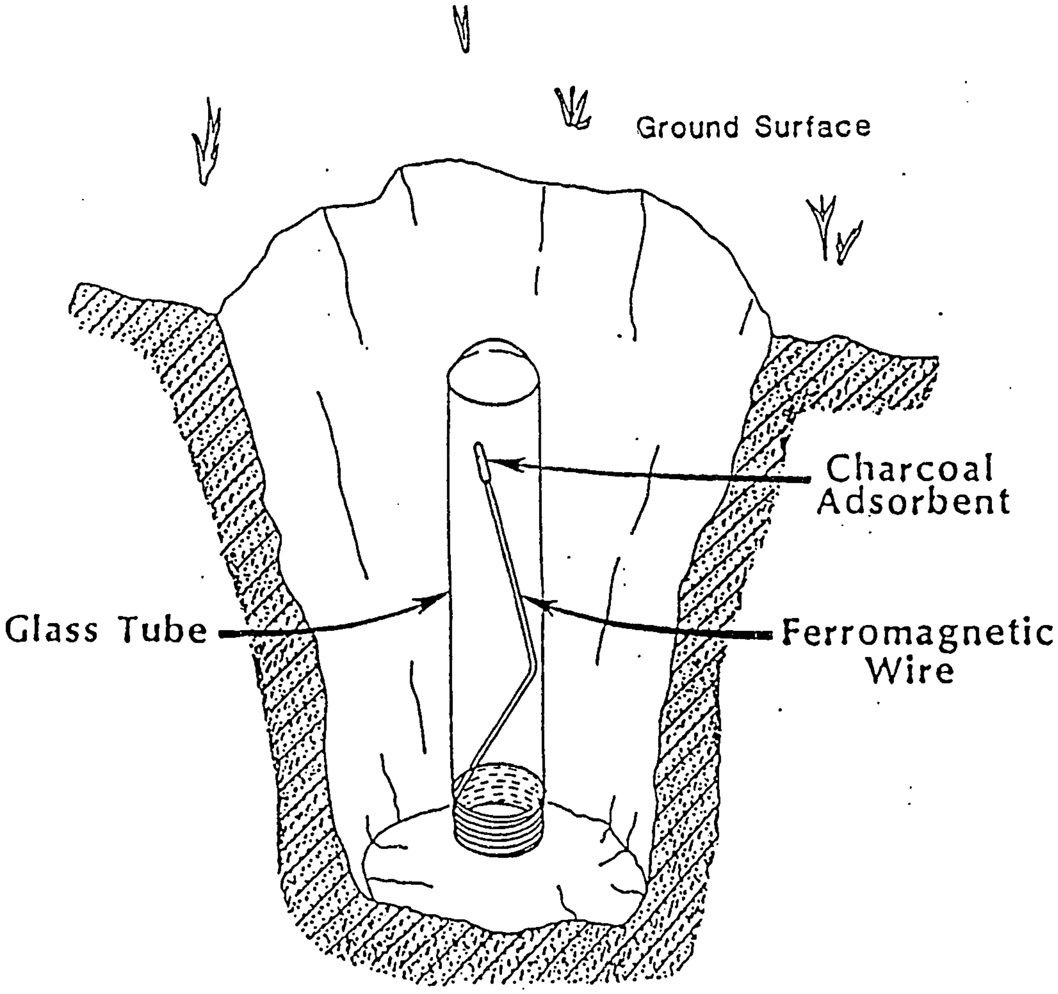


Figure 5.2 Method of soil-gas sampling.
(Modified From Petrex 1985)

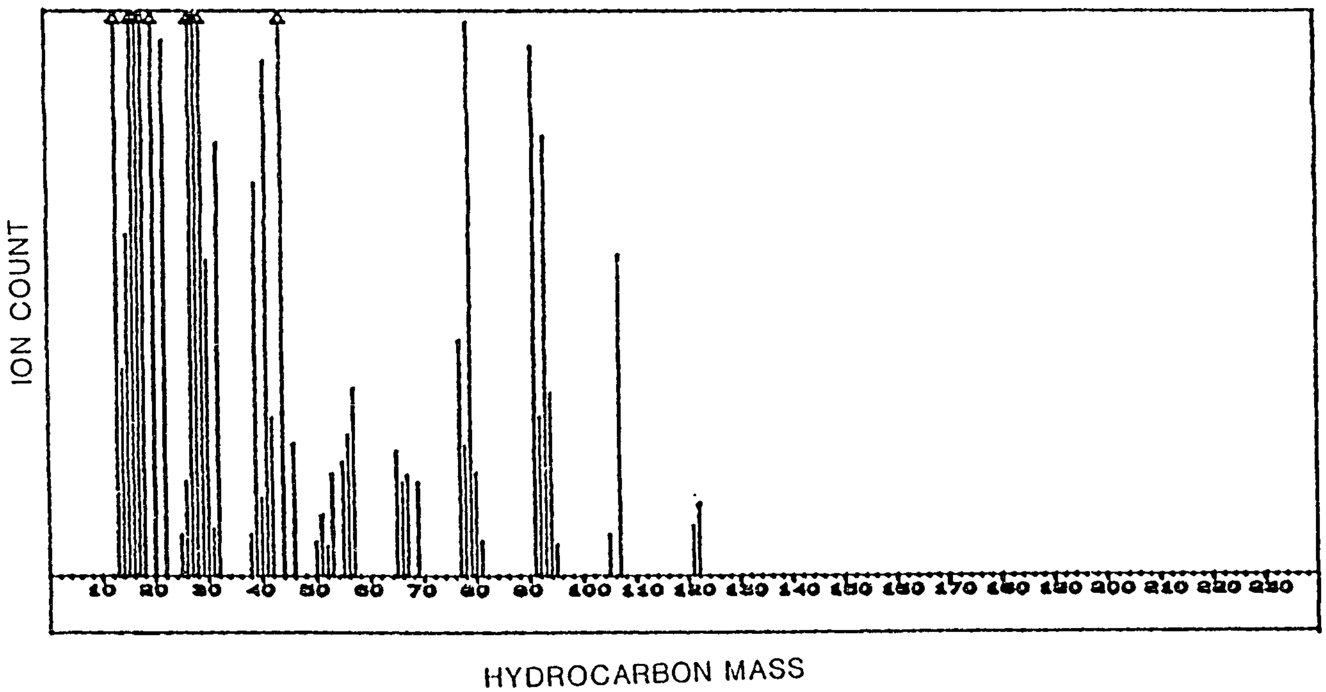


Figure 5.3 Example of Petrex "fingerprint" analysis of one soil-gas sample.

determined. This factor is then used to obtain an oil signature for the entire study area. In the Chauvin study, Petrex indicated that benzene and toluene were two important gases constituting the oil factor.

All of the samples, including the training set itself, are then analyzed with respect to that factor indicating oil. Those samples showing a strong correlation to the oil indicative factor, that is, those samples containing the gases deemed to indicate the presence of oil are given a high factor score value indicating their similarity to the training set. A factor score is a weighted sum of the values (standardized) of the variables (gases) comprising the oil factor.

5.4 Analysis of Results

The map in Figure 5.4 shows the factor score values obtained from Petrex. The highest, most consistent values are found in the discharge area along the line running north-south through the Chauvin oil field in Rg. 2. High values are also found over the major recharge area in Twp. 41, Rg.1 over the Hayter oil field. These high values, however, are more sporadic than in the above area.

Subsequent to the conduction of the survey, a possible fundamental problem was found in the Petrex method. The collection of a reference training set assumes, that over the entire area studied, subsurface oil accumulations will result in similar oil spectral signatures at the surface. This assumption holds valid only in regions that are relatively homogeneous, where gases migrate through rock strata with similar adsorptive properties, are subjected to similar biological degradation, and experience similar hydrological conditions. The composition of oil

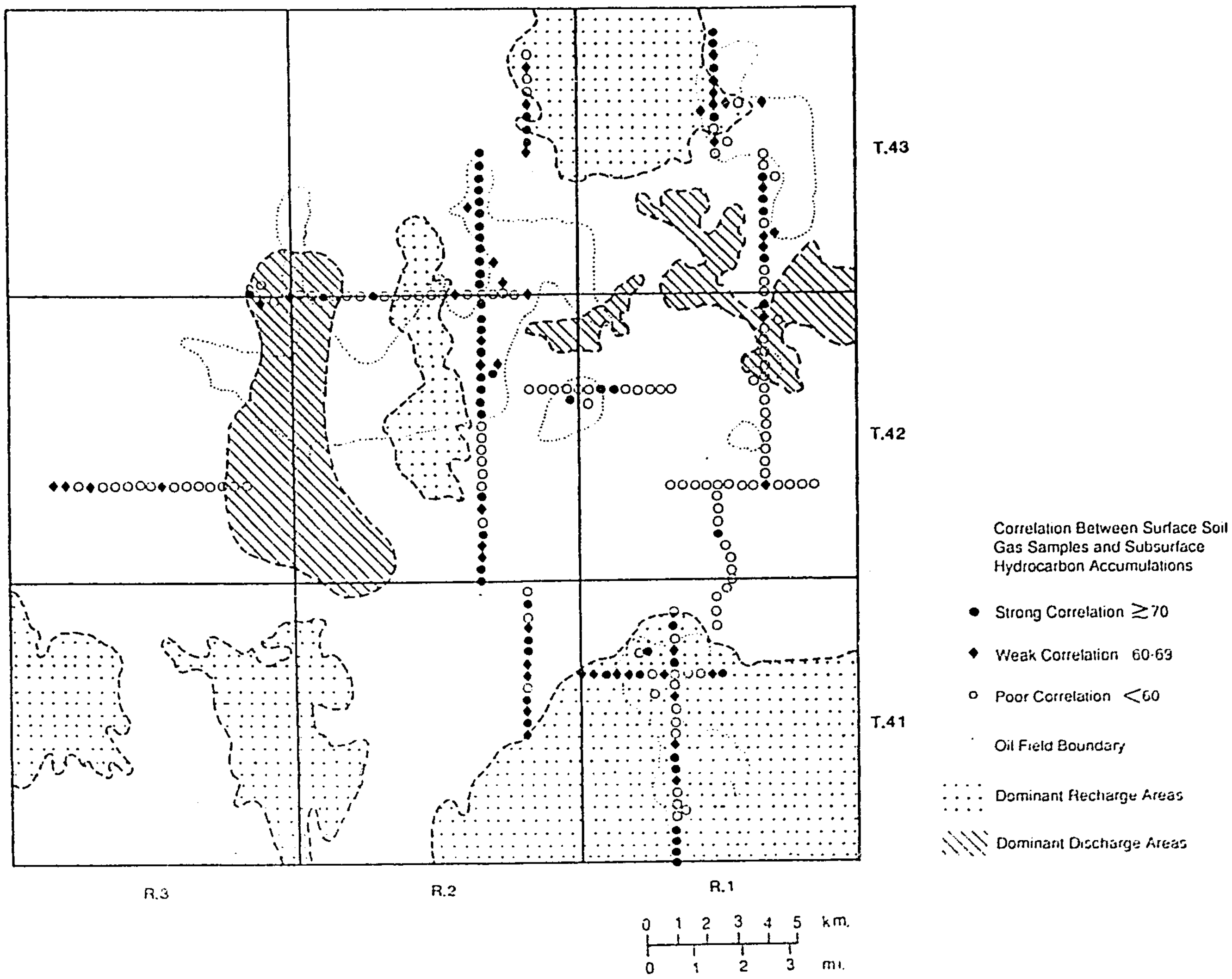


Figure 5.4 Factor scores map.

accumulations throughout the study area is also assumed to be uniform. Should the spectral signatures for individual members of the training set vary as a result of any of the above mentioned conditions, then the oil signature or factor determined by the analysis will be a statistical combination of oil signatures in areas with different conditions.

Petrex presently isolates oil signatures found above oil pools from those signatures over oil pools which are associated with faults. Although both types of samples indicate the presence of subsurface oil, the gases migrating up through a fault have been subjected to conditions different from those experienced by gases that have migrated straight up through the rock strata. Different hydrocarbon gases reach the surface in each case resulting in differing spectral fingerprints, which are not combined by Petrex to obtain an oil signature over an entire region. Hydrology may not have as dramatic an effect as faulting or biological degradation on gas composition and migration to the surface, but its possible influence has been altogether ignored.

The hydrological effect on migrating hydrocarbon gases can be examined in the Chauvin area if the oil composition, the subsurface geology and the biological degradation are taken to be uniform. Petrex however, analyzed 14 oil samples from the study region in its laboratory. The spectral fingerprints from this analysis show two different oils in the area. The oils produced from the lower Mannville Dina sands and from the upper Mannville Colony sands are different from the oils produced from the middle Mannville sands. Representative fingerprints for these different oils are shown in Figure 5.5. Both types of oil show similar spectral peaks, but these peaks are suppressed, especially in the higher mass ranges for the

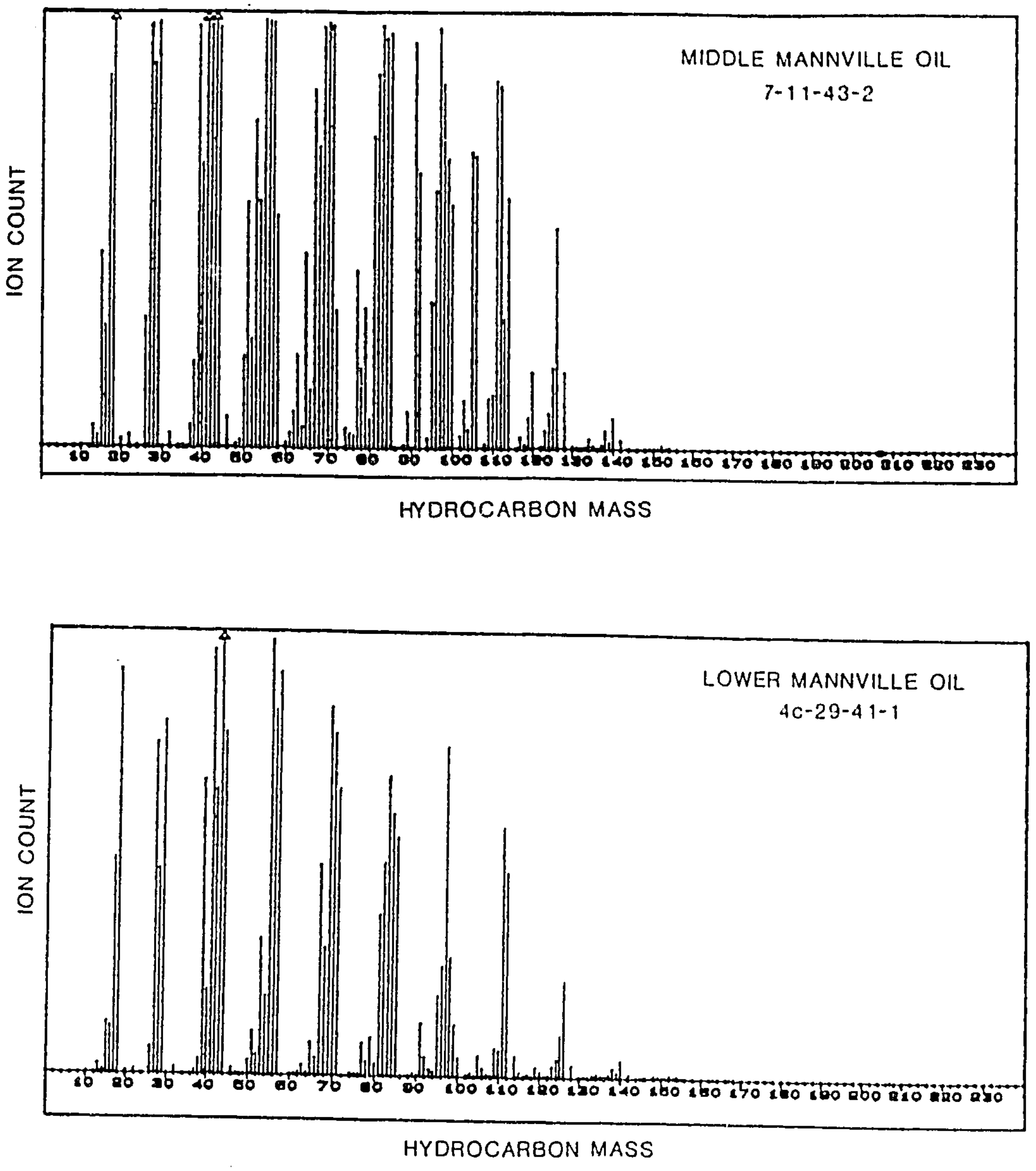


Figure 5.5 Petrex "fingerprints" for the two different oils in the Chauvin area.

Colony/Dina oils. The benzene peak (mass 76) is low in both cases, but somewhat lower for the Colony/Dina oils, whereas the toluene peak (mass 92) is much stronger in the middle Mannville oils. A peak at mass 113 is noticeably missing from the Colony/Dina oils.

The Petrex survey traversed four relatively productive oil areas, all of which produce from the middle Mannville sands. The Hayter oil field also produces from the lower Mannville Dina sands, and is situated beneath a major local groundwater recharge area (Figure 5.1). The Chauvin North oil field stretches from a local recharge to a local discharge area, however the survey in the area crossed mainly through the recharge area. Two areas of the Chauvin oil field, both situated over local discharge areas were surveyed for soil gas.

The Hayter oil field is the only one of these four areas that produces both types of oils. The complex nature of the Mannville sedimentology prevents an accurate delineation of individual oil pools without a detailed sedimentological investigation. If it is assumed that hydrocarbon gases migrating up from the Dina sands are mixed and incorporated with the overlying Sparky and Lloydminster oils before further migration from these units to the surface takes place, then the resultant spectral fingerprints obtained at the land surface in this area should largely be a result of middle Mannville oils as is the case in the other three areas. Should the Dina oil pools be situated so that upward migrating gases bypass middle Mannville oil pools, then the resulting spectral fingerprints obtained at surface should be similar with respect to benzene and depressed with respect to toluene.

The total ion counts for benzene and toluene are shown in Figure 5.6. One of the first observations noted is the high variability in the data.

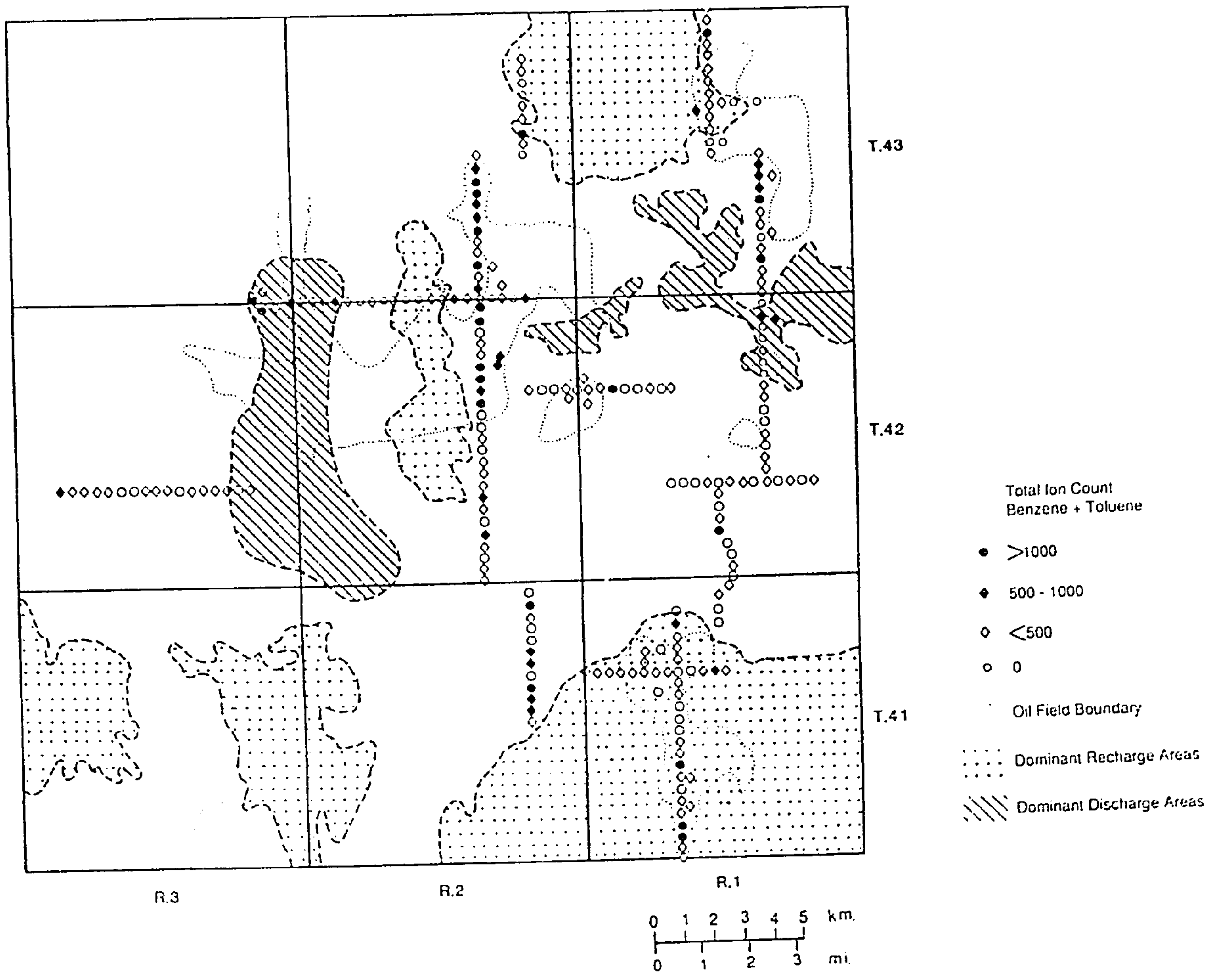


Figure 5.6 Total ion count map, benzene plus toluene.

Although Petrex does not supply an error analysis, some of the variability can undoubtedly be attributed to contamination and measurement errors. Contamination would include variability in the manufacturing and subsequent treatment of the charcoal collector wires, and possible field contamination from human activities such as oil spills from tractors etc.. Natural variation in hydrocarbon gas emanations may be caused by heterogeneities in the shallow subsurface soil and till, resulting in preferential gas migration towards or away from certain localized areas. Small scale climatic factors such as vegetation cover, or surface drainage may also naturally affect the near surface gas flux.

Over the Chauvin North and Hayter oil fields, a noticeable decrease in the toluene and benzene concentrations is observed. Higher, more consistent values are obtained over the Chauvin oil field. While several samples over the Hayter and Chauvin North oil fields contained neither benzene nor toluene it was also observed that many samples in these areas contained no benzene and only low concentrations of toluene. Over the Chauvin oil field, few toluene bearing samples record no benzene. It appears that some mechanism is acting to suppress both the toluene and the benzene flux in local groundwater recharge areas. Toluene, however, is not as strongly affected as benzene. With the solubility of benzene being approximately twice that of toluene (North, 1985), it is possible that downward flowing groundwater in both the Hayter field and the Chauvin North field removes the benzene from these areas. Toluene, being less soluble, would be more likely to migrate to the surface in recharge areas. Adding support to this theory is the fact that high benzene values were recorded in the oil poor discharge area just west of the Hayter field. If the assumption that microbiological conditions are uniform over the entire study area is correct, then these benzene values are unlikely to be part of a halo anomaly resulting from microbial activity, since no halo anomalies are observed over pools in the Chauvin oil field. In the Chauvin field, upward moving groundwaters allow the benzene as well as the toluene to reach the surface. The low values in the area between Rgs.1 and 2 may be a result of some of the mechanisms mentioned above. More samples in this area are necessary to establish the relative benzene and toluene fluxes. The fact that toluene values are distributed relatively uniformly over the area, and that benzene concentrations are lower over the Hayter oil field, suggests that gases emanating from the Hayter field are similar in composition to those gases from the other three areas, and are, therefore, not derived from oil from the Dina sands for their composition.

Between recharge and discharge areas, there is significant variation in the flux of two of the most important gases that determine the presence of oil according to Petrex. Further investigation may show that recharge and discharge areas have fundamentally different gas emanations which, on one hand, result in different Petrex spectral fingerprints but, both of which indicate the presence of subsurface oil on the other. If this were found to be the case, training sets would have to be taken separately for different hydrological regimes.

6. SUMMARY AND CONCLUSIONS

The possible role of groundwater flow in the generation of geochemical signatures related to petroleum deposits has been investigated. Two geochemical parameters, namely shallow water chemistry and soil gas, were examined for evidence of deep petroleum accumulations. Water chemistry investigations involved the determination of the standard ion, halogen, trace element and isotopic composition of the sampled waters. The soil gas survey detected hydrocarbon gases in the shallow subsurface. In addition, regional and local flow systems were characterized.

Shallow flow systems were found to be controlled by local topography, with water moving from highlands to lowlands. Extensive soil salinization in the Chauvin area has been attributed to the discharge of water from these local systems. On a regional scale, the hydraulic head decreases with depth and waters move downward from the land surface to the underpressured, lower Cretaceous Mannville sands. Subsequent lateral movement in these sands is to the north-east, most likely to the subcrop of the Paleozoic unconformity in northern Saskatchewan. The underpressuring of the Mannville Formation gives a characteristic curve to pressure-depth diagrams in the area, and results from poor hydraulic communication between the Mannville strata and the recharge area, relative to the hydraulic communication between the Mannville strata and the discharge area. Recharging waters flow through the Colorado and Lea Park shales to the Mannville at a lower rate than waters discharging from the Mannville, leaving the unit underpressured.

Underpressuring in the Mannville sands also appears to influence the underlying Devonian strata. Waters in these latter units flow upward to the Mannville. The meeting of two opposing flow systems in the Mannville sands creates semi-stagnant zones (Tóth, 1980) and is believed to have contributed, along with stratigraphy, to the accumulation of hydrocarbons in the unit.

Chemical and isotopic compositions of all shallow waters, except those from the Ribstone Creek sandstone, can be explained by simple chemical reactions in the near-surface environment as waters flow from recharge to discharge areas. Cation exchange is the dominant process affecting most of these shallow waters.

The anomalously high TDS, Na^+, Cl^-, Br^-, and I^- concentrations detected in the Ribstone Creek waters must be explained other than by present-day physical mixing, since brines are not moving from depth to the shallow subsurface. Chemical and isotopic analysis of deep and shallow waters also suggest that the Ribstone Creek waters do not result from a mixing of brines with shallow waters.

Two viable mechanisms, diffusion and membrane filtration, have been hypothesized to account for the chemistry of the Ribstone Creek waters. Diffusion of ions, against the prevailing hydraulic gradient, from deep brines to the shallow subsurface may account for the anomalous ion concentrations in these waters. Diffusion coefficients are, however, difficult to estimate and a more detailed examination of this mechanism requires experimentally derived data.

The mechanism that best explains the chemistry of the Ribstone Creek waters is membrane filtration. With the Lea Park shales acting as the filtering membrane, ionic concentrations increase in the lower Belly River Formation. The halogens, being conservative in nature, show the most noticeable increase in concentration.

The similarities between Mannville brines and shallow Ribstone Creek waters might indicate that processes affecting brines in the Alberta basin are presently working at shallow depths on infiltrating meteoric waters. Waters of recent meteoric origin, therefore, chemically evolve with respect to the halogens, towards a brine composition relatively early in their subsurface history. The similarities in waters may also indicate that membrane filtration, the mechanism thought to be influencing shallow water chemistry, is one mechanism affecting deeper waters in the basin.

The soil gas survey detected thermogenically produced, high molecular weight hydrocarbons at surface. The gases migrate to the surface either by molecular diffusion or by migration as gas microbubbles. Factor analysis of the data showed that gases indicative of subsurface oil accumulations were, for the most part, located above oil reservoirs throughout the study area. When ion counts for the individual gases were plotted, however, it appeared that samples collected over recharge areas were deficient in benzene and toluene, two of the gases deemed by Petrex to indicate subsurface oil. It is believed that this is attributable to downward moving waters carrying dissolved benzene and toluene away from recharge areas. Benzene, being more soluble in water is affected to a greater extent than toluene. Whereas benzene was absent in recharge associated samples, it was abundant in discharge areas, even in some areas not known to contain large quantities of oil.

This study was successful in characterizing local and regional flow systems, in interpreting shallow water chemistry patterns and in detecting differences in soil hydrocarbon gas composition in differing hydrodynamic regions.

Similar studies conducted in other areas may help corroborate some of the ideas presented in this paper. With respect to the regional flow system, further investigation north of the present study area may help to resolve the apparent conflict between the potentiometric surface maps constructed for this study, on the one hand, and by Christopher (1980), on the other. It may be that the regional discharge area indicated by Christopher is located further north than the boundaries of this study.

With respect to water chemistry, the detection of anomalous halogen concentrations in relatively shallow groundwaters should be pursued. If the halogens in the Chauvin area are indeed a result of membrane filtration, then future petroleum related water geochemical surveys may be hindered, at least in areas in areas of downward flowing groundwaters. If, however, these halogens have diffused from deep oil field brines to the shallow subsurface, then water chemistry studies may have strong applications in the geochemical exploration industry. Similar studies in other areas may help to resolve the origin of halogens in shallow Alberta groundwaters. Investigations into the behaviour of trace metals under shallow oxygen rich and deep reducing conditions should be undertaken before further trace metal studies are carried out.

The soil gas survey was successful in detecting different soil hydrocarbon gas compositions over local recharge areas and over local discharge areas although large fluctuations in the data make conclusions regarding the gas distribution difficult. The soil gas survey also located, to varying degrees of success, the oil fields in the Chauvin area. Similar soil gas surveys in the future should focus on the variability in benzene concentrations, specifically with respect to differing hydrogeologic regimes. Studies in other geographic locations may reveal that hydrocarbons other than benzene and toluene are also affected by groundwater flow. Further work may enable Petrex to refine their exploration procedure and improve the effectiveness of determining oil pool locations.

This study identifies a large gap in the current understanding of hydrocarbon gas migration to the shallow subsurface. Groundwater flow is an aspect of geochemical exploration that has been largely ignored by industry. Further basic research into the fundamentals of geochemical petroleum exploration methods will improve the capability of the oil industry to explore for hydrocarbons.

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APPENDIX A

SHALLOW WATER-WELL RECORDS (SUMMARY)

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
SE-01-42-1	DILBERRY LK. PROV. PK.	625.05	10.67		
SE-01-42-1	DILBERRY LK. PROV. PK.	625.05	24.39		
SE-01-42-1	DILBERRY LK. PROV. PK.	625.05	42.69		
SE-02-41-1	J.ROCKWOOD	695.17	71.65	51.83	643.34
NW-02-41-1	F. REAVY	725.66	10.67	6.10	719.56
13-02-41-1	BRIAN HAGER	718.04	134.16	73.18	644.86
SE-03-41-1	S.E. HAGER	731.76	19.21	13.72	718.04
SE-03-41-1	HAGER, E.E	731.76	104.28	54.88	676.88
SE-04-41-1	JOHN BLUME	708.89	9.15	7.93	700.97
NE-04-41-1	C. MCNALLY	754.63	82.32	2.13	752.49
NW-05-41-1	RAY AMBLER	678.40	0.00		
SW-06-41-1	H. GILLESPIE	676.88	20.12	16.46	660.41
SE-10-41-1	J.HAGER	705.84	4.57	3.35	702.49
NE-10-41-1	BERNIE HAGER	716.52	3.66	2.74	713.77
SW-11-41-1	F. HAGER	724.14	97.57		
SW-11-41-1	D.HAGER	701.27	112.81	33.54	667.73
SW-11-41-1	GRAHAM HAGER	701.27	114.34	34.76	666.51
NW-11-41-1	JAMES C. PAINTER	693.65	5.79	3.66	689.99
NW-12-41-1	W.C. LEVITT	701.27	27.44	9.15	692.12
10-12-41-1	NORMAN LEVITT	672.30	64.64	7.93	664.38
SE-13-41-1	E.J. SKINNER	678.40	9.76	3.66	674.74
SW-14-41-1	JOE SKINNER	695.17	25.92	18.29	676.88
NW-14-41-1	E.HASSEL	667.73	51.83	36.59	631.14
NE-14-41-1	EVERETT SKINNER	676.88	73.79	19.51	657.36
NE-14-41-1	EVERETT SKINNER	676.88	3.66	1.22	675.66
NE-14-41-1	E. SKINNER	685.42	74.70	67.08	618.34
NW-15-41-1	J. MALLONGH	710.42	3.66	2.13	708.28
08-16-41-1	KANATA EXPL. LTD.	762.25	226.24	140.25	622.00
13-16-41-1	SKINNER BROTHERS	762.25	106.11	45.74	716.52
14A-16-41-1	SKINNER BROS.	747.01	109.15	14.64	732.37
15-16-41-1	PILGUARD & SKINNER	747.01	136.60	39.64	707.37

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
NE-16-41-1	MIKE SKINNER	747.01	128.06		
16B-16-41-1	JOHN SKINNER	747.01	129.58	39.64	707.37
NW-18-41-1	E.CIGGS	695.17	20.73	10.06	685.11
NW-18-41-1	R.CIGGS	695.17	82.32		
SE-22-41-1	A. J. SKINNER	663.16	1.83	1.83	661.33
NW-23-41-1	J.MERRIMAN	652.49	10.67	10.06	642.42
2D-27-41-1	RICK HAGAR	640.29	92.08	16.46	623.83
13-27-41-1	ORVAL HAGER	620.47	7.62	3.05	617.42
NW-27-41-1	CALVIN FERRIER	620.47	3.05	2.74	617.73
NW-27-41-1	GIRL GUIDE CAMP	620.47	3.35	3.05	617.42
1-29-41-1	JOFFRE RESOURCES	731.76	174.77	99.47	632.29
1-29-41-1	JOFFRE RESOURCES	734.81	173.84	106.11	628.70
NW-30-41-1	SKINNER, DOUG	617.42	6.10	6.10	611.32
NW-30-41-1	VERN SKINNER	617.42	6.10		
NW-30-41-1	VERNON SKINNER	617.42	6.10		
NW-30-41-1	A. SKINNER	617.42	4.57		
NW-30-41-1	W. SKINNER	617.42	4.88	3.66	613.76
NW-30-41-1	F.L. MISENER	623.52	3.66	2.74	620.78
SW-32-41-1	E.COTE	622.00	14.03	4.27	617.73
08-36-41-1	DILBERRY LK. PROV. PK.	625.05	22.26	7.93	617.12
SW-36-41-1	DILBERRY LK. PROV. PK.	625.05	30.19	4.23	620.82
SW-36-41-1	DILBERRY LK. PROV. PK.	625.05	74.70		
NE-36-41-1	DILBERRY LK. PROV. PK	625.05	8.54	4.88	620.17
NE-36-41-1	DILBERRY LK. PROV. PK.	625.05	8.54	4.88	620.17
NE-36-41-1	DILBERRY LK. PROV. PK.	625.05	7.62	4.57	620.47
01-01-41-2	GRANT HAGER	0.00	74.70	22.87	
SE-01-41-2	GRANT HAGER	0.00	77.75	33.54	
NW-01-41-2	H. NICHOLS	673.83	6.10	4.27	669.56
NW-06-41-2		664.68	54.88	30.49	634.19
NE-07-41-2	J.P.HANNA	688.46	19.51	16.46	672.00
NE-07-41-2	E. HANNA	688.46	103.67	29.27	659.19

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
NE-07-41-2	E.HANNA	688.46	34.15	29.27	659.19
NE-07-41-2	E. HANNA	688.46	67.38	32.01	656.45
SE-12-41-2	G.WHITE	676.88	25.92	16.77	660.11
12-12-41-2	A.RISELY	676.88	62.50	21.34	655.54
NW-14-41-2	R. BEATTY	637.24	3.66	1.52	635.72
11-14-41-2	GLENN BEATTY	638.77	99.70	15.85	622.91
14-14-41-2	GLENN BEATTY	637.24	32.01	3.96	633.28
SW-16-41-2	RICHARD E. AUSTIN	640.29	4.57		
05-16-41-2	R.E. AUSTIN	637.24	116.78	22.09	615.15
SE-18-41-2	R. YOUNGHAUS	673.22	9.15	2.44	670.78
05-24-41-2	GRANT GIGGS	632.67	82.32	27.44	605.23
05-24-41-2	R.G.GIGGS	632.67	5.49	4.27	628.40
05-24-41-2	R.G.GIGGS	646.39	3.66	2.44	643.95
NE-24-41-2	W.WATSON	647.91	91.47		
SE-27-41-2	H.READ	640.29	24.39	Flowing	
SE-30-41-2	DOERR,I.	676.27	7.93	4.27	672.00
SE-32-41-2	L.MCMANN	636.33	88.42	6.10	630.23
NE-32-41-2	FEARO	622.61	117.39	Flowing	
09-33-41-2	MCMANN BROS.	650.96	71.35	9.15	641.81
SW-34-41-2	O.MCMANN	657.06	18.29	9.15	647.91
10-34-41-2	RAY MCMANN	663.16	132.63	43.91	619.25
NE-34-41-2	S.MCMANN	664.66	148.49	105.80	558.88
13-35-41-2	RICHARD GRAMLUCH	670.78	41.16	5.98	664.80
SE-02-41-3	S.W. SWANSON	670.78	79.27	64.03	606.75
SE-02-41-3	SID HOGG	670.78	67.08		
16-02-41-3	N. WAGNER	658.58	41.77	18.29	640.29
NW-04-41-3	SIMPSON	646.39	14.03	5.18	641.20
SE-05-41-3	R. TRIPP	647.91	6.10		
04-08-41-3	LARRY NELSON	655.54	57.63	23.78	631.75
SW-08-41-3	A.G. NELSON	664.68	21.34	12.20	652.49
SW-08-41-3	A.G.NELSON	652.49	56.41	13.72	638.77

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
NW-08-41-3	RIBSTONE HUTTERITES	660.11	33.54	6.10	654.01
SW-10-41-3	WRIGHT	677.18	48.78	42.69	634.50
NW-10-41-3	PICK	639.07	4.27	3.05	636.02
08-11-41-3	DON AUSTIN	675.35	49.39	25.00	650.35
08-11-41-3	DON AUSTIN	675.35	64.94	24.39	650.96
SE-12-41-3	E. RICHARDS	680.84	18.29	5.49	675.35
SW-12-41-3	W. CANNING	661.63	62.81	4.57	657.06
NW-12-41-3	O. FELDCAMP	671.08	7.01	4.27	666.82
13-12-41-3	BILL SULLIVAN	678.40	72.57	32.32	646.08
NW-12-41-3	J.L. DEIF	678.40	30.49		
NE-12-41-3	W. RETZLOFF	674.74	15.25	9.15	665.60
01-13-41-3	JOHN M. KRAFT	675.35	0.00		
01-13-41-3	JOHN M. KRAFT	675.35	0.00		
01-13-41-3	JOHN KRAFT	675.35	75.62	30.49	644.86
01-13-41-3	JOHN KRAFT	675.35	75.62	27.44	647.91
01-13-41-3	JOHN KRAFT	675.35	72.87	33.54	641.81
01-13-41-3	JOHN KRAFT	675.35	70.13	42.69	632.67
01-13-41-3	JOHN KRAFT	675.35	76.23	60.98	614.37
01-13-41-3	JOHN KRAFT	675.35	18.29	13.72	661.63
01-14-41-3	W.SULLIVAN	676.88	98.18	33.54	643.34
NE-14-41-3	F.M. HAWKIN	679.93	115.86	9.15	670.78
NE-15-41-3	ROYDEN	643.64	14.33	11.89	631.75
SE-17-41-1	MALLARD	748.83	65.86	30.49	718.34
13-18-41-3	ALF SYMINGTON	701.27	76.53	50.31	650.96
13-18-41-3	SYMINGTON	701.27	77.75	48.78	652.49
08-19-41-3	CARL VARTY	670.78	60.07	25.92	644.86
SE-20-41-3	STURGESS	678.40	73.18	30.49	647.91
NW-24-41-3	KRAFT	679.93	103.67	68.60	611.32
NE-24-41-3	J. KRAFT	676.88	24.39	23.17	653.71
15-24-41-3	FRED KRAFT	676.88	25.31	18.60	658.28
SE-27-41-3	MCRAE	661.94	35.06	34.45	627.48

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
SW-28-41-3	FULLER	690.90	87.51	27.44	663.46
SE-32-41-3	GOLDEN	632.97	9.15	4.57	628.40
13-35-41-3	T.L. HAWKINS & SONS	647.91	48.78	12.20	635.72
13-35-41-3	T. HAWKEN	647.91	54.88	12.20	635.72
13-35-41-3	T.D. HAWKEN	647.91	38.11	30.49	617.42
13-35-41-3	T.L. HAWKINS & SONS	647.91	41.16	13.42	634.50
13-35-41-3	T.L. HAWKINS & SONS	647.91	53.97	28.05	619.86
04-36-41-3	E. LAWRENCE	657.06	64.64	27.44	629.62
04-36-41-3	E.S. LAWRENCE	657.06	27.44	15.25	641.81
04-36-41-3	EARL LAWRENCE	657.06	64.64	21.34	635.72
16-16-41-1	SIMON SKINNER	747.01	0.00		
01-36-41-1	DILBERRY LK. PROV. PK.	625.05	27.14	11.59	613.46
02-27-41-1	RICK HAGAR	640.29	15.25	3.96	636.33
10-20-41-1	RENNAISSANCE BATTERY	747.01	221.97	133.24	613.76
10-20-41-1	RENAISSANCE BATTERY	747.01	186.60	125.01	622.00
16-12-41-1	NORMAN LEVITT	672.30	54.88		
02-27-41-1	RICK HAGER	640.29	15.25		
02-27-41-1	RICK HAGER	640.29	4.57		
02-03-41-1	ERNEST HAGER	0.00	15.85	3.05	
SE-03-41-1	WAYNE HAGER	0.00	12.20		
SE-03-41-1	WAYNE HAGER	0.00	11.89	4.57	
05-11-41-1	MADGE B. HAGER	693.65	112.20		
05-11-41-1	GRAHAM HAGER	693.65	50.00	12.81	680.84
01-14-41-1	LORN MAULD	704.32	52.44	7.01	697.31
16-16-41-1	SKINNER BROS.	747.01	115.86		
NE-36-41-1	DILBERRY LK. PROV. PK.	625.05	0.00		
15-36-41-1	GEORGE MURRAY	625.05	6.40		
16-16-41-1	MARTIN PILGUARD	747.01	108.24	43.30	703.71
NE-25-41-2	G. GIERCKE	617.42	47.87	30.49	586.93
01-13-41-2	HELEN BERZE	669.26	24.39	6.10	663.16
09-33-41-2	DON MCMANN	658.58	137.21		

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
13-35-41-2	RICHARD GRAMLUCH	670.78	41.16	5.95	664.83
SE-02-41-2	T.D. DENIS	0.00	64.03		
16-24-41-2	WAYNE WATSON	647.91	97.57		
14-14-41-2	GLENN BEATTY	637.24	91.47		
16-34-41-2	HARRY NICKEL	670.78	28.05	5.79	664.99
12-02-41-2	MERLE TAYLOR	0.00	57.32	3.66	
NW-02-41-2	JOHN ALMBERG	0.00	54.88		
SE-08-41-2	KIETH READ	647.91	53.36	Flowing	
1(2)-13-41-3	JOHN M. KRAFT	669.26	16.77	10.67	658.58
01-14-41-3	JOHN SULLIVAN	676.88	82.93		
13-18-41-3	ALFRED J. SYMINGTON	701.27	110.07	56.41	644.86
15-02-41-3	DOME PETROLEUM	658.58	176.54	10.85	647.74
15-02-41-3	DOME PETROLEUM	658.58	177.76	10.95	647.63
13-35-41-3	T.L. HAWKINS	647.91	41.16	13.42	634.50
15-02-41-3	DOME PETROLEUM	658.58	129.58	28.05	630.53
NW-24-41-3	CARL VARTY	678.40	27.44	15.25	663.16
06-11-41-3	DOME PETROLEUM	678.40	201.54	60.07	618.34
01-13-41-3	JOHN L. KRAFT	675.35	18.29		
SE-02-41-3	CAMERON PERRY	0.00	0.00		
13-35-41-3	T.L. HAWKEN	647.91	40.86	13.42	634.50
15-02-41-3	DOME PETROLEUM	658.58	53.66		
04-04-41-3	BARRY TRIPP	0.00	18.29	2.44	
04-04-41-3	DAVID TRIPP	0.00	13.72	5.49	
01-05-41-3	ROBERT TRIPP	0.00	27.44	2.13	
08-19-41-3	CARL VARTY	670.78	64.03	24.39	646.39
SW-04-41-3	BARRIE TRIPP	0.00	13.72		
02-01-42-1	DILBERRY LK. PROV. PK.	0.00	25.31	18.29	
02-01-42-1	ALBERTA ENVIRONMENT	635.72	20.43	1.83	633.89
02-01-42-1	ALBERTA ENVIRONMENT	0.00	21.34	2.44	
KILLARNEY LK.		0.00	0.00		
09-08-42-1	W. SIMPLE	618.95	67.38	Flowing	

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
SW-10-42-1	KIWANIS CLUB WASKASOO	626.57	35.06		
NW-10-42-1	DAVE MASON	626.57	3.96	1.22	625.35
NW-10-42-1	DAVE MASON	626.57	5.18	3.96	622.61
11-10-42-1	WAYNE SKINNER	620.47	40.25	16.77	603.70
NW-10-42-1	MELVIN SKINNER	628.09	73.18		
N-10-42-1	C.D. MCLEAN	631.14	29.58	7.62	623.52
NE-10-42-1	BEACH	626.57	5.18	4.57	622.00
SW-14-42-1	SALT LK. GIRL GUIDE CAMP	625.05	4.27	3.05	622.00
NW-14-42-1	A.GLOVER	631.14	7.32	4.88	626.26
01-16-42-1	DONALD SKINNER	640.29	5.49	3.66	636.63
01-16-42-1	DONALD SKINNER	640.29	5.18		
01-16-42-1	DONALD SKINNER	640.29	91.17	26.22	614.07
02-16-42-1	G.SKINNER	648.83	4.27	3.35	645.47
01-18-42-1	J.SIMPLE	657.97	117.39	54.88	603.09
05-18-42-1	S. CHAPMAN	645.78	97.57	21.34	624.44
SE-22-42-1	E.CYR	632.67	6.10	3.66	629.01
SW-20-42-1	G.BOYER	653.40	91.47	45.74	607.67
NW-22-42-1	COULOMB	617.42	3.05	2.44	614.98
07-26-42-1	CLIFFORD CARLSON	617.42	10.06	6.10	611.32
07-26-42-1	CLIFFORD CARLSON	617.42	13.42	7.32	610.10
NW-26-42-1	R. NICHVELS	614.37	4.27	2.74	611.63
SW-28-42-1	G.COLLETT	647.91	5.18	3.35	644.56
SE-29-42-1	RIDER	668.04	91.47	30.49	637.55
05-29-42-1	W.SIMPLE	644.86	133.24	29.88	614.98
NW-30-42-1	W.W. TESSIER	608.28	72.57		
NE-30-42-1	G. CHAPMAN	625.05	57.63	Flowing	
NW-32-42-1	C. MCNALLY	615.90	79.88	Flowing	
14-33-42-1	J. MACINTOSH	618.95	34.76	5.79	613.15
NW-33-42-1	J.E. MCNALLY	615.29	7.32	0.91	614.37
NE-35-42-1	ADAMS	614.37	2.13	1.22	613.15
09-04-43-1	C. MCNALLY	612.85	82.32	2.13	610.71

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
01-17-42-1	SHOT HOLE	639.99	13.72	Flowing	
13-19-42-1	WALTER CHAPMAN	615.90	70.13	Flowing	
07-31-42-1	ROLAND LAROUCHI	612.85	72.57	Flowing	
01-18-42-1	KEVIN HALDENBY	657.06	105.19	33.54	623.52
05-18-42-1	MEL HALDENBY	646.39	91.47	15.25	631.14
01-02-42-2	E.B. LANG	642.12	4.27	3.35	638.77
SW-04-42-2	MCMANN	622.61	114.34	Flowing	
05-05-42-2	T. OLSON	632.67	25.61	5.49	627.18
NW-05-42-2	J. MCMANN	618.95	20.73	14.64	604.31
NW-05-42-2	J.VARTY	625.05	76.23		
NW-05-42-2	LAURIE OLSON	632.67	36.59	3.66	629.01
SW-06-42-2	J. VARTY	654.93	24.39	12.81	642.12
01-07-42-2	J. CLIFFORD	628.09	9.15	6.10	622.00
08-07-42-2	SHOT HOLE	622.67	19.21	Flowing	
07-07-42-2	SHOT HOLE	625.05	18.59	Flowing	
01-07-42-2	LIAL CLIFFORD	628.09	77.44	1.52	626.57
16-07-42-2	SHOT HOLE	624.83	19.82	Flowing	
09-07-42-2	SHOT HOLE	622.97	19.82	Flowing	
16-07-42-2	SHOT HOLE	623.40	19.82	Flowing	
NE-11-42-2	G. ALLEN	645.78	7.32	5.79	639.99
NW-12-42-2	ROBERT SIMARD	647.91	73.18	25.92	622.00
NE-12-42-2	H. YOUNG	658.58	106.72	32.01	626.57
13-13-42-2	ROBERT ARMOUR	654.01	108.24	25.92	628.09
NW-13-42-2	R. RAMON	649.44	109.76	24.39	625.05
16-15-42-2	B. FORSTER	663.16	71.96	9.15	654.01
11-15-42-2	ROBERT FORSTER	678.40	68.91	8.84	669.56
16-15-42-2	R. FORSTER	663.16	60.98		
05-16-42-2	J.A. PETERSON	666.21	118.91	43.30	622.91
08-17-42-2	E. PETERSON	666.21	48.17	16.62	649.59
04-17-42-2	MONCRIEFF	623.52	23.66	1.83	621.69
01-18-42-2	SHOT HOLE	623.49	19.82	Flowing	

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
SW-18-42-2	W. DALLY	631.14	6.10	5.18	625.96
05-18-42-2		631.14	28.66	Flowing	
09-18-42-2	SHOT HOLE	624.65	15.25	Flowing	
09-18-42-2	SHOT HOLE	624.25	19.82	Flowing	
16-18-42-2	KEN MORRISON	626.57	64.94	Flowing	
16-18-42-2	LESLIE MORRISON	626.57	0.00		
16-18-42-2	KEN MORRISON	626.57	19.82		
16-18-42-2	L. MORRISON	626.57	9.15	8.54	618.03
SE-19-42-2	MILES JOHNSTON	625.05	0.00		
SE-19-42-2	DOUGLAS JOHNSTON	625.05	48.17		
16-19-42-2	CLIFFORD	617.42	9.15		
16-19-42-2	A. CLIFFORD	617.42	5.79	4.57	612.85
14-20-42-2	HERB GUTTERINK	647.91	60.07	41.16	606.75
15-20-42-2	CLARE DALLYN	647.91	0.00		
15-20-42-2	FRANCES DALLYN	647.91	0.00		
15-20-42-2	C. DALLYN	647.91	102.45	14.33	633.58
01-22-42-2	J. FURLOTTE	661.94	73.18	30.49	631.45
13-22-42-2	A. BEERWALD	679.93	143.91		
15-23-42-2	A. HOULE	642.12	12.81	9.76	632.36
16-23-42-2	GERALD BELANGER	635.72	31.40	12.96	622.76
16-23-42-2	GERALD BELANGER	635.72	42.69		
06-24-42-2	L. CAYFORD	639.68	4.88	3.66	636.02
06-24-42-2	WAYNE SKINNER	639.68	92.99	25.92	613.76
06-24-42-2	W. SKINNER	639.68	96.35	12.20	627.48
08-25-42-2	E. CHAPMAN	612.24	6.10	4.88	607.36
16-25-42-2	ROLAND LAROUCHE	605.23	71.65	Flowing	
16-25-42-2	ROLAND LAROUCHE	605.23	71.65	Flowing	
16-25-42-2	ROLAND LAROUCHE	605.23	71.65	Flowing	
16-25-42-2	E. LAROUCHE	605.23	5.49	4.88	600.35
11-26-42-2	BP RESOURCES	649.44	617.73	204.28	445.15
NE-26-42-2	T. ARMOUR	632.97	89.34	12.20	620.78

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
NE-26-42-2	MILDRED ARMOUR	631.14	99.09	12.20	618.95
01-28-42-2	R. LEBLANC	678.40	12.20	10.37	668.04
16-28-42-2	J.H. HIGGINSON	680.54	144.83	76.23	604.31
04-29-42-2	W. CLIFFORD	629.01	25.00	4.57	624.44
04-29-42-2	W. CLIFFORD	629.01	50.00	Flowing	
01-30-42-2	E. DOBSON	617.42	12.81	7.93	609.50
13-30-42-2	R. MORRISON	618.95	7.62	4.57	614.37
05-32-42-2	E. DALLYN	615.90	0.00		
05-32-42-2	C. DALLYN	615.90	12.20	9.15	606.75
01-33-42-2	CLEMENT CITO	686.03	38.42	8.23	677.79
09-33-42-2	MCMANN BROS.	658.58	117.08	31.71	626.87
16-34-42-2	T. LEBLANC	653.10	114.64	30.49	622.61
16-35-42-2	J. MCMANN	611.32	111.90		
09-35-42-2	J.B. GIRARD	615.90	6.40	3.96	611.93
S-36-42-2	RENE LAROUCHE	612.24	74.70	Flowing	
08-25-42-2	GEORGE CHAPMAN	667.73	7.93	3.05	664.68
14-10-42-2	GLENN R. MCMANN	679.93	4.27		
13-22-42-2	TRIAD OIL	679.93	143.30	56.20	623.73
01-17-42-2	ANDY MCMANN	615.90	86.29	16.16	599.74
05-32-42-2	ROBERT SHARP	612.24	91.47	Flowing	
08-25-42-2	GEORGE CHAPMAN	649.44	6.10		
15-12-42-2	ROBERT BEATTY	605.23	91.47		
01-36-42-2	CLARENCE JEFFERY	632.67	32.62	5.18	627.48
12-05-42-2	LARRY OLSON	654.01	98.79	8.54	645.47
16-14-42-2	ROGER MEPHAM	664.68	101.23	32.32	632.36
04-03-42-3	CLARENCE ANDERSON	644.86	47.26	33.54	611.32
05-09-42-3	HUTTERITES	644.86	6.71	4.57	640.29
13-09-42-3	HUTTERITES	644.86	10.98	4.57	640.29
13-09-42-3	HUTTERITES	644.86	39.64	9.15	635.72
13-09-42-3	HUTTERITES	644.86	36.59	18.29	626.57
13-09-42-3	HUTTERITES	644.86	24.39		

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
12-09-42-3	HUTTERITES	644.86	103.67	5.18	639.68
SE-10-42-3		644.86	100.62		
09-10-42-3		646.39	34.15		
14-11-42-3	W. ANDERSON	632.67	18.29	Flowing	
11-15-42-3	SPRING	#VALUE!	#VALUE!		
13-12-42-3	H. MORRISON	625.05	11.59	9.15	615.90
15-12-42-3	MERVIN MCCLUSKEY	626.57	24.39	Flowing	
11-13-42-3	SHOT HOLE	623.86	19.21	Flowing	
11-13-42-3	SHOT HOLE	623.52	19.21	Flowing	
01-14-42-3	M. MCCLUSKEY	625.65	26.22	Flowing	
01-14-42-3	SHOT HOLE	625.65	19.21	Flowing	
02-16-42-3	R. MCLESKIE	652.49	8.54	4.57	647.91
02-16-42-3	WILFRED BOOMHOWER	652.49	13.72	5.49	647.00
02-16-42-3	CHANNON	652.49	18.29		
02-16-42-3	W. BOOMHOWER	652.49	6.10	4.27	648.22
07-22-42-3	J. PICHARD	635.72	51.22		
01-23-42-3	SHOT HOLE	618.95	18.59	Flowing	
01-23-42-3	SHOT HOLE	618.95	18.59	Flowing	
09-23-42-3		618.95	14.94	Flowing	
09-23-42-3		618.95	20.43	Flowing	
09-23-42-3		618.95	21.34		
02-27-42-3	MRS. A. REINHART	641.81	0.00		
03-28-42-3	J. REINHART	635.72	106.72	1.83	633.89
13-09-42-3	HUTTERITES	644.86	27.44		
13-09-42-3	HUTTERITES	644.86	33.54	6.71	638.16
09-14-42-3	MONCRIEFF	622.00	21.04	Flowing	
12-03-43-1	H. SCOTT	609.80	87.51	3.35	606.45
12-03-43-1	H.D. DALLYN	609.80	89.34	4.27	605.53
12-03-43-1	H.D. DALLYN	609.80	83.24		
09-04-43-1	VERNON MCNALLY	609.80	79.27		
09-04-43-1	VERNON MCNALLY	609.80	81.71		

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
09-04-43-1	VERN MCNALLY	609.80	67.08		
SW-06-43-1	A. SHULTZE	612.85	23.48	14.64	598.21
SW-07-43-1	STANLEY GRIMBLE	625.05	0.00	Flowing	
13-07-43-1	K.A. SAKER	628.09	10.67	2.13	625.96
13-07-43-1	TOWN TEST WELL	628.09	0.00		
NW-07-43-1	H.E. HARPER	628.09	0.00		
11-07-43-1	VILLAGE OF CHAUVIN	628.09	75.31	16.77	611.32
NW-07-43-1	VILLAGE OF CHAUVIN	628.09	0.00		
NW-07-43-1	VILLAGE OF CHAUVIN	628.09	0.00		
NE-07-43-1		628.09	76.23	35.37	592.73
NE-07-43-1	VILLAGE OF CHAUVIN	628.09	76.23	33.23	594.86
TOWN		628.09	33.54		
TOWN		628.09	30.49		
12-10-43-1	FRED STONE	628.09	86.29	2.59	625.50
16-12-43-1		611.32	14.64	7.93	603.40
01-15-43-1	W. BAYNKAM	632.67	10.98	10.06	622.61
SE-16-43-1	R.H. FOLKINS	625.05	45.74	Flowing	
SE-17-43-1	RICHARD PEGG	621.69	0.00	Flowing	
04-17-43-1	RICHARD PEGG	632.67	85.37	36.59	596.08
04-17-43-1	RICHARD PEGG	632.67	57.02	19.36	613.31
04-17-43-1	W. ROBINSON	632.67	80.19	23.78	608.89
NW-17-43-1	W. ROBINSON	655.54	0.00		
02-18-43-1	R. FOLKINS	625.05	0.00		
02-18-43-1	ROGER FOLKINS	625.05	21.34	15.25	609.80
12-18-43-1	DICK NICHOLSON	649.44	107.32	47.26	602.18
NW-18-43-1	M. CAHILL	656.14	16.77	15.85	640.29
NE-18-43-1	JENNY FOLKINS	647.91	45.74	22.87	625.05
05-20-43-1	TURCOTTE	663.16	100.62	51.53	611.63
05-20-43-1	TURCOTTE	663.16	100.62	51.83	611.32
05-20-43-1	GORDON DOUNEY	663.16	83.24	67.99	595.16
13-21-43-1	RENE COURCHESNE	629.62	0.00		

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
13-21-43-1	E.COARCHESNE	629.62	126.53	38.11	591.51
SW-26-43-1	R.COURCHESNE	620.47	54.88	23.78	596.69
13-21-43-1	K.BENGSTON	629.62	54.88		
05-28-43-1	RIO PRADO CHAUVIN	628.09	697.00	198.19	429.91
13-28-43-1	DENNIS BENOIT	640.29	54.88		
08-29-43-1	DENNIS BENOIT	644.86	73.79	45.74	599.13
08-29-43-1	DENNIS BENOIT	644.86	73.18	57.93	586.93
04-31-43-1	DOUG PERRY	663.16	99.09		
04-31-43-1	E. PERRY	661.63	96.04		
04-31-43-1	D. PERRY	661.63	76.23		
SE-32-43-1	L.TURCOTTE	640.29	6.71		
04-35-43-1	MARC BENOIT	618.95	50.00	17.99	600.96
08-36-43-1	JOHN BEIRSCH	638.77	75.31	46.04	592.73
01-36-43-1	J. BEIRSCH	638.77	76.23		
16-36-43-3	PETE OLSON	0.00	43.60	17.50	
NE-36-43-1	J.MAYR	614.07	11.28	8.23	605.84
TOWN	CHAUVIN VILLAGE	628.09	64.03		
TOWN	CHAUVIN VILLAGE	628.09	30.49		
TOWN	CHAUVIN VILLAGE	628.09	30.49		
01-36-43-1	RICHARD COTE	638.77	75.01		
NE-04-43-1	VERNON MCNALLY	609.80	#VALUE!	Flowing	
05-20-43-1	BENOIT & TURCOTTE	663.16	103.06	51.83	611.32
SE-19-43-1	RON MORRISON	657.06	60.98		
05-20-43-1	RICHARD TURCOTTE	663.16	103.67		
12-07-43-1	SHELL CANADA	628.09	18.52	15.70	612.39
12-07-43-1	SHELL CANADA	628.09	26.83	15.70	612.39
12-07-43-1	SHELL CANADA	628.09	14.33	15.70	612.39
12-07-43-1	SHELL CANADA	628.09	12.20	15.70	612.39
12-07-43-1	SHELL CANADA	628.09	15.85	15.70	612.39
12-07-43-1	SHELL CANADA	628.09	19.21	15.70	612.39
04-08-43-1	RICHARD PEGG	618.95	26.53	15.85	603.09

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
SW-01-43-2	F. POIVIER	616.51	7.32	6.71	609.80
NE-02-43-2	MARSOLIAS	618.95	9.15	7.93	611.02
04-03-43-2	ALTA. ENVIRONMENT	678.40	140.25		
NE-31-43-2		0.00	0.00		
14-05-43-2	R.C. TIZZIRD	615.90	4.57	3.96	611.93
16-05-43-2	C. DALLYN	646.39	77.14		646.39
16-05-43-2	D.M. BRADLU	646.39	#VALUE!		
16-05-43-2	C.DALLYN	646.39	0.00		
SE-06-43-2	VIC DALLYN	616.51	6.10	5.18	611.32
NE-07-43-2		622.00	0.00		
NE-07-43-2	G.B. DIAMOND	622.00	76.23	7.62	614.37
SE-08-43-2	ALF POLLARD	643.34	60.98	6.10	637.24
SE-09-43-2	E.COTE	623.52	8.54	4.88	618.64
16-09-43-2	R. MILLS	632.67	13.11	9.15	623.52
11-10-43-2	COTE, L.	632.67	88.12	16.46	616.20
16-10-43-2	ALBERT DELEMONT	617.42	67.69		
16-10-43-2	ALBERT DELEMONT	617.42	28.05	4.57	612.85
16-10-43-2	R. DELEMONT	617.42	76.23	8.23	609.19
NE-10-43-2	T.COTE	628.70	6.71	3.96	624.74
NE-12-43-2	RICHARD COBOURNE	628.09	18.60	8.23	619.86
NE-12-43-2	GOEDE	625.05	10.37	7.62	617.42
01-13-43-2	PERKINS	628.09	83.85		
01-13-43-2	C. PERKINS	628.09	33.84	17.07	611.02
06-13-43-2		634.19	85.37	21.65	612.54
08-15-43-2	A. SIMARD	628.09	83.85		
05-15-43-2	DENNIS SIMARD	628.09	83.85	14.64	613.46
01-16-43-2	J. REINHART	632.67	81.41	19.51	613.15
SW-17-43-2	T. RADCHENKO	618.95	5.49		
12-17-43-2	G.M. JOHNSON	618.95	4.27	3.66	615.29
12-17-43-2	J.A. BAKER	618.95	6.10		
12-17-43-2	RIBSTONE SCHOOL	618.95	30.49		

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
12-17-43-2	L.C. WHITE	618.95	0.00		
12-17-43-2	L.C. WHITE	618.95	0.00		
12-17-43-2	ALTA. WHEAT POOL	618.95	64.64	18.29	600.65
11-17-43-2	RIBSTONE VILLAGE	618.95	66.47	13.72	605.23
12-17-43-2	M. OLIVER	619.25	4.27		
NW-18-43-2	W.E. CLIFFORD	618.95	5.49	4.88	614.07
NE-18-43-2	O. YOUNG	617.12	4.88	3.66	613.46
01-19-43-2	R.W. MORRISON	614.37	60.98	12.20	602.18
01-19-43-2	R. MORRISON	614.37	62.20	13.72	600.65
16-22-43-2	L.PARE	634.19	29.88	19.21	614.98
16-22-43-2	L. PARE	634.19	85.07	30.49	603.70
11-24-43-2	HOWARD ALLEN	647.91	93.91	38.72	609.19
11-24-43-2	DAN ALLEN	647.91	87.51	35.37	612.54
11-24-43-2	H. ALLEN	647.91	97.57		
11-24-43-2	A. HOWARD	647.91	85.37	30.49	617.42
NE-26-43-2	SPORRAN	644.86	91.47	18.29	626.57
01-27-43-2	RICHARD PRAY	634.19	83.24	26.83	607.36
01-27-43-2	RICHARD PRAY	634.19	0.00		
02-28-43-2	JOE SCHMIDT	640.29	55.49	9.76	630.53
01-31-43-2	D. BOWERS	628.09	67.08	22.26	605.84
04-32-43-2	W.H. BUSTON	628.09	70.13	26.83	601.26
04-32-43-2	S. WIBBER	628.09	0.00		
NW-36-43-2	T. WILLIAMS	0.00	13.72	13.11	
SW-08-43-2	A. SEIM	649.44	0.00		
04-28-43-2	D. SCHMIDT	617.42	57.93		
14-10-43-2	CLEMENT COTE	625.05	91.47		
14-10-43-2	CLEMENT COTE	625.05	91.47		
04-25-43-2	B. MCARTHUR	641.81	0.00		
12-17-43-2	RAY BUCK	618.95	9.76		
04-25-43-2	MURRAY MCARTHUR	641.81	89.03	37.20	604.62
SW-17-43-2	WAYNE BUCK	618.95	4.88		

Well Location	Well Owner	Surface Elevation (m.)	Depth of Well (m.)	Depth to Water in Completed Well (m.)	Hydraulic Head (m.)
SW-17-43-2	L. RADCHENKO	618.95	5.49		
01-31-43-2	DUANE BOWERS	628.09	67.08		
09-32-43-2	KARLA WHITE	0.00	48.78		
12-12-43-2	BENOIT	628.09	17.38	9.63	618.46
04-19-43-3	BIDER	628.09	64.33	6.40	621.69
04-19-43-3	R. GROVES	628.09	73.18		
16-24-43-3	FRED BURTON	634.19	72.57	26.53	607.67
08-26-43-3	RALPH PERKINS	635.72	73.18	6.71	629.01
SW-25-43-3	G. DEBNEY	629.62	0.00		
01-36-43-3	GERALD WHITE	628.09	70.13		
01-36-43-3	WAYNE BUCK	628.09	0.00		

APPENDIX B

CIFE DRILL STEM TEST DATA

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
10-03-036-01-W-4	688.85	B	BLQZ	824.75	829.06	-135.91	-140.21	6204.12	495.02
10-03-036-01-W-4	720.39	B	BLQZ	823.78	829.51	-103.38	-109.12	6141.38	520.42
08-07-036-04-W-4	775.69	B	CLNY	839.27	851.00	-63.58	-75.32	6472.34	590.99
06-17-036-04-W-4	718.81	A	BLQZ	878.29	884.01	-159.49	-165.20	6196.54	469.96
03-20-036-04-W-4	691.80	C	CLNY	765.24	775.01	-73.43	-83.21	6319.27	566.50
03-20-036-04-W-4	691.80	B	CLNY	755.24	759.99	-63.43	-68.18	6146.89	561.43
03-20-036-04-W-4	691.80	C	SPRK	819.27	829.00	-127.46	-137.19	6586.10	539.73
03-20-036-04-W-4	691.80	A	CLNY	755.24	759.99	-63.43	-68.18	6291.00	576.13
06-34-036-04-W-4	668.49	B	SPRK	759.26	764.01	-90.77	-95.52	5883.50	507.21
11-25-036-05-W-4	680.31	B	CMGS	837.77	841.49	-157.46	-161.18	6067.60	459.82
09-33-036-05-W-4	758.01	A	BLQZ	930.80	936.01	-172.79	-178.00	6210.33	458.31
09-33-036-05-W-4	758.01	B	CMGS	917.29	920.50	-159.28	-162.49	6104.14	461.99
14-34-036-05-W-4	724.39	C	SPRK	837.29	842.01	-112.90	-117.62	6492.33	547.22
07-35-036-05-W-4	695.00	B	CMGS	845.79	850.00	-150.79	-154.99	5920.74	451.27
07-35-036-05-W-4	695.00	A	CLNY	753.26	759.99	-58.25	-64.98	5997.96	550.42
16-35-036-05-W-4	685.01	C	SPRK	800.27	804.00	-115.26	-118.99	6374.43	533.32
03-36-036-05-W-4	675.89	B	CMGS	830.76	836.01	-154.87	-160.11	5743.54	428.59
05-36-036-05-W-4	680.10	C	CMGS	833.78	838.99	-153.68	-158.89	5003.70	354.30
05-36-036-05-W-4	680.10	B	CMGS	832.29	837.01	-152.19	-156.91	5590.47	415.91
02-18-036-10-W-4	782.70	B	BLQZ	1023.34	1028.00	-240.64	-245.30	5542.20	322.56
02-18-036-10-W-4	782.70	B	BLQZ	1018.34	1033.00	-235.64	-250.30	5533.24	321.65
11-08-036-12-W-4	820.49	C	BLQZ	1089.35	1097.49	-268.86	-277.00	8610.48	605.69
10-18-036-12-W-4	826.01	C	DTRL	1079.65	1090.57	-253.64	-264.57	8535.32	611.85
07-29-036-12-W-4	822.35	B	GLCC	1074.16	1098.80	-251.81	-276.45	8083.70	560.73
10-12-036-13-W-4	814.91	C	DTRL	1105.35	1114.01	-290.44	-299.10	8314.68	553.67
06-24-036-13-W-4	827.84	A	DTRL	1085.44	1090.27	-257.61	-262.43	8218.84	578.64
10-33-036-13-W-4	825.70	C	DTRL	1071.36	1081.00	-245.65	-255.30	7698.96	535.13
10-20-036-14-W-4	817.47	B	DTRL	1090.93	1107.34	-273.46	-289.86	8299.51	565.23
10-34-036-14-W-4	824.79	C	SPRK	1068.34	1080.00	-243.55	-255.21	7596.91	525.82
10-34-036-14-W-4	824.79	C	SPRK	1049.34	1061.01	-224.56	-236.22	7692.75	554.59
06-27-036-15-W-4	819.61	B	BNFF	1084.53	1109.47	-264.92	-289.86	7842.37	522.85
06-19-037-01-W-4	715.98	B	LDUC	957.39	962.56	-241.41	-246.58	7168.73	487.51
03-35-037-01-W-4	651.21	C	CMGS	767.25	770.99	-116.05	-119.79	5544.96	447.90
10-35-037-01-W-4	654.59	A	WSEC	687.21	691.99	-32.63	-37.40	5334.66	509.34

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
10-29-037-02-W-4	674.10	A	CLNY	706.24	715.00	-32.14	-40.90	5526.34	527.39
02-32-037-02-W-4	688.21	C	MCRN	720.72	722.50	-32.51	-34.29	5601.50	538.18
06-13-037-03-W-4	721.49	B	CLNY	755.24	763.01	-33.75	-41.51	5640.80	537.96
09-15-037-03-W-4	697.99	A	CMGS	828.78	837.01	-130.79	-139.02	5777.32	454.62
10-17-037-03-W-4	670.56	A	CLNY	710.23	723.99	-39.67	-53.43	5647.01	529.67
05-20-037-03-W-4	681.01	B	DINA	840.27	845.00	-159.26	-163.98	6046.23	455.34
08-24-037-03-W-4	757.70	C	SPRK	839.73	843.99	-82.02	-86.29	6088.97	537.17
06-28-037-03-W-4	736.00	C	REX	828.26	833.99	-92.26	-97.99	6013.82	518.53
06-28-037-03-W-4	736.00	A	SPRK	804.27	815.00	-68.26	-79.00	5643.56	502.24
06-28-037-03-W-4	736.00	A	CLNY	777.25	784.01	-41.25	-48.01	5617.36	528.57
04-01-037-05-W-4	683.70	C	SPRK	795.27	805.01	-111.57	-121.31	6286.86	525.07
10-15-037-05-W-4	705.79	C	BLQZ	877.29	889.01	-171.49	-183.22	6759.17	512.36
10-15-037-05-W-4	705.79	C	GLCC	855.27	867.00	-149.48	-161.21	6288.24	486.31
10-26-037-05-W-4	690.43	C	CLNY	795.27	805.01	-104.84	-114.57	6386.15	541.94
12-27-037-05-W-4	702.99	B	BLQZ	880.28	889.01	-177.29	-186.02	6409.59	472.39
11-35-037-05-W-4	700.80	B	BLQZ	868.29	872.00	-167.50	-171.21	6092.42	452.32
11-35-037-05-W-4	700.80	B	MCRN	763.26	767.00	-62.46	-66.20	5931.08	540.88
16-10-037-07-W-4	764.23	B	CMGS	957.33	961.00	-193.10	-196.78	6547.49	473.17
10-01-037-11-W-4	766.57	B	GLCC	995.19	1006.45	-228.62	-239.88	8107.14	593.01
15-16-037-11-W-4	754.01	C	BLQZ	986.81	1026.99	-232.79	-272.98	8320.89	596.18
11-19-037-12-W-4	791.57	B	GLCC	1041.84	1052.17	-250.28	-260.60	8229.18	584.27
11-19-037-12-W-4	791.57	B	CLNY	961.96	972.31	-170.39	-180.75	6392.35	476.71
11-01-037-13-W-4	833.20	C	CLNY	1004.34	1009.99	-171.14	-176.78	6339.95	472.97
11-03-037-13-W-4	830.79	C	DTRL	1075.35	1101.00	-244.56	-270.21	6204.81	375.76
11-07-037-13-W-4	823.57	B	BLQZ	1040.93	1051.56	-217.36	-227.99	8325.02	626.82
16-14-037-13-W-4	827.81	B	CLNY	1008.82	1012.52	-181.02	-184.71	6386.15	468.79
06-16-037-13-W-4	840.79	A	SPRK	1050.35	1055.00	-209.56	-214.21	8258.14	630.78
10-21-037-13-W-4	848.56	B	DTRL	1064.10	1069.85	-215.54	-221.28	8155.41	613.77
10-21-037-13-W-4	848.56	C	CLNY	1013.49	1019.25	-164.92	-170.69	6228.94	467.80
07-24-037-13-W-4	799.70	C	BLQZ	1047.33	1064.00	-247.63	-264.29	7722.40	532.04
11-27-037-13-W-4	821.01	B	BLQZ	1017.33	1045.01	-196.32	-224.00	8140.93	620.55
07-29-037-13-W-4	840.94	C	BLQZ	1048.86	1068.32	-207.91	-227.38	8156.79	614.68
10-30-037-13-W-4	836.98	C	CLNY	1010.74	1018.03	-173.76	-181.05	6397.18	475.37
10-30-037-13-W-4	836.98	B	CLNY	1009.22	1021.08	-172.24	-184.10	6331.68	467.92

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
11-31-037-13-W-4	830.88	C	CLNY	1013.79	1022.60	-182.91	-191.72	6421.31	467.92
11-33-037-13-W-4	829.06	C	CLNY	987.88	1004.32	-158.82	-175.26	6470.27	493.19
11-36-037-13-W-4	774.50	B	BLQZ	1027.51	1077.47	-253.02	-302.97	7911.32	529.28
11-36-037-13-W-4	774.50	C	BLQZ	1015.32	1025.65	-240.82	-251.16	8037.50	574.17
11-01-037-14-W-4	822.05	B	BLQZ	1054.95	1063.75	-232.91	-241.71	8261.59	605.71
07-10-037-14-W-4	828.11	C	BLQZ	1045.35	1072.99	-217.24	-244.88	7998.20	585.09
15-11-037-14-W-4	824.30	B	SPRK	1030.35	1040.01	-206.05	-215.71	7823.07	587.39
06-24-037-14-W-4	820.09	B	BLQZ	1035.35	1050.01	-215.25	-229.91	7831.34	576.53
07-25-037-14-W-4	823.57	C	BLQZ	1064.71	1070.46	-241.14	-246.89	8120.24	584.58
07-25-037-14-W-4	823.57	C	CLNY	993.97	999.74	-170.40	-176.17	6245.49	464.01
11-28-037-14-W-4	834.39	B	OCDZ	1099.35	1103.01	-264.96	-268.62	5666.31	311.41
10-04-038-01-W-4	697.99	B	CLNY	711.64	719.94	-13.64	-21.95	5307.77	523.81
07-08-038-01-W-4	696.77	A	CLNY	713.77	717.19	-17.00	-20.42	5440.16	536.41
10-09-038-01-W-4	712.32	C	SPRK	747.61	752.25	.30	-39.93	5275.36	500.69
10-21-038-01-W-4	714.91	A	MCRN	728.25	741.00	13.35	-26.09	5156.77	506.48
13-28-038-01-W-4	696.50	C	CLNY	704.23	716.01	-7.73	-19.51	5038.87	500.55
14-36-038-01-W-4	676.99	A	CLNY	685.23	694.00	-8.24	-17.01	5031.97	500.84
04-03-038-02-W-4	681.23	C	CLNY	716.24	725.00	-35.01	-43.77	5434.64	515.16
10-04-038-02-W-4	680.01	C	BLQZ	812.56	815.34	-132.55	-135.33	6144.13	493.01
10-04-038-02-W-4	680.01	C	REX	777.50	783.34	-97.49	-103.33	6455.79	558.35
07-12-038-02-W-4	699.39	A	CMGS	805.27	815.00	-105.88	-115.61	5718.02	472.73
07-12-038-02-W-4	699.39	B	MCRN	724.23	734.99	-24.83	-35.60	5397.41	520.54
06-16-038-02-W-4	702.90	C	SPRK	771.24	784.01	-68.35	-81.11	5871.78	524.44
09-22-038-02-W-4	679.70	A	LDMR	796.25	800.01	-116.54	-120.30	5560.13	448.94
11-29-038-02-W-4	698.30	B	MCRN	762.25	767.49	-63.95	-69.19	5584.26	503.25
11-29-038-02-W-4	698.30	B	CLNY	712.55	726.95	-14.25	-28.65	5138.15	502.85
06-01-038-03-W-4	686.71	B	BLQZ	803.41	807.72	-116.70	-121.01	5851.10	478.20
08-02-038-03-W-4	715.06	A	LDMR	812.25	815.49	-97.19	-100.43	5753.19	488.25
08-03-038-03-W-4	688.09	C	DINA	815.27	819.00	-127.19	-130.91	5954.52	478.56
04-10-038-03-W-4	676.69	A	SPRK	745.24	757.00	-68.55	-80.31	5552.54	492.15
10-20-038-03-W-4	678.79	C	GLCC	798.84	807.72	-120.05	-128.93	5600.81	447.02
07-25-038-03-W-4	673.39	B	MCRN	692.12	697.99	-18.73	-24.60	5181.59	507.07
12-28-038-03-W-4	674.00	B	LDMR	793.26	796.99	-119.25	-122.99	5783.53	469.04
16-29-038-03-W-4	764.71	B	LDMR	793.26	798.00	-28.55	-33.28	5014.73	480.79

Well Location	K.B.	Cife	Tested	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure	Hydraulic Head
	(m)	Quality Code	Formation	From (m)	To (m)	From (m)	To (m)	(kPa)	(m)
16-29-038-03-W-4	764.71	B	CLNY	702.22	709.00	62.50	55.72	5303.63	600.29
06-32-038-03-W-4	674.31	B	CMGS	795.27	800.01	-120.96	-125.70	5653.21	453.53
08-32-038-03-W-4	671.20	B	LDMR	784.26	788.00	-113.06	-116.80	5674.59	464.11
05-36-038-03-W-4	681.90	A	CLNY	703.22	712.01	-21.32	-30.11	5287.09	513.78
16-32-038-06-W-4	692.20	C	DINA	857.29	867.00	-165.09	-174.80	6139.31	456.52
07-33-038-06-W-4	708.39	C	SPRK	857.38	860.76	-148.99	-152.37	6081.39	469.87
07-33-038-06-W-4	708.39	A	SPRK	857.38	860.76	-148.99	-152.37	6099.32	471.70
04-17-038-08-W-4	698.60	B	GLCC	891.28	903.00	-192.68	-204.40	6588.86	473.79
08-33-038-08-W-4	719.33	B	BLQZ	907.38	908.61	-188.05	-189.28	6205.50	444.55
10-04-038-09-W-4	967.31	B	VKNG	831.28	851.00	136.03	116.31	5883.50	726.53
09-14-038-09-W-4	721.71	A	BLQZ	930.31	934.00	-208.61	-212.29	6473.03	450.06
06-20-038-09-W-4	755.90	C	BLQZ	976.90	983.89	-221.00	-227.99	6703.32	459.52
06-22-038-09-W-4	767.09	C	SPRK	925.31	939.49	-158.22	-172.39	6434.41	491.27
07-24-038-09-W-4	739.69	B	GLCC	895.80	905.99	-156.11	-166.30	6863.28	539.13
07-24-038-09-W-4	739.69	C	GLCC	907.29	932.99	-167.60	-193.30	7456.94	580.46
07-27-038-09-W-4	757.21	B	CMGS	935.31	940.00	-178.10	-182.79	6601.27	493.16
10-32-038-09-W-4	742.49	A	BLQZ	945.19	998.22	-202.70	-255.73	6353.74	419.13
10-36-038-09-W-4	752.61	C	SPRK	879.64	894.59	-127.02	-141.98	6755.72	554.86
10-36-038-09-W-4	752.61	C	GLCC	925.68	934.21	-173.06	-181.60	6264.80	461.93
10-24-038-10-W-4	784.31	B	GLCC	997.33	1009.01	-213.02	-224.70	7024.63	497.94
04-35-038-10-W-4	770.50	A	GLCC	962.33	971.49	-191.82	-200.99	7136.33	531.79
10-11-038-11-W-4	737.01	A	SPRK	917.14	922.63	-180.13	-185.62	7691.37	601.96
06-34-038-11-W-4	739.69	B	GLCC	942.14	954.33	-202.45	-214.64	7453.50	552.01
11-04-038-12-W-4	779.68	C	BLQZ	1029.95	1037.54	-250.27	-257.86	7723.09	534.00
12-05-038-12-W-4	780.01	C	BLQZ	1035.84	1053.51	-255.82	-273.50	7401.09	490.55
12-05-038-12-W-4	780.01	B	OCDZ	1017.85	1035.50	-237.83	-255.48	7950.62	564.63
10-06-038-12-W-4	768.40	B	GLCC	993.06	1031.14	-224.66	-262.74	7506.59	522.28
11-08-038-12-W-4	782.12	B	CLNY	943.67	949.45	-161.55	-167.34	6213.77	469.62
11-11-038-12-W-4	748.28	C	ELRL	1025.07	1037.54	-276.79	-289.26	7475.56	479.79
03-12-038-12-W-4	736.61	C	CLNY	885.28	905.01	-148.67	-168.40	6228.94	477.07
06-14-038-12-W-4	741.91	C	SPRK	975.31	979.99	-233.40	-238.08	7874.09	567.74
06-14-038-12-W-4	741.91	B	GLCC	1005.32	1009.99	-263.40	-268.07	7445.91	494.05
10-16-038-12-W-4	754.08	B	GLCC	983.61	986.94	-229.53	-232.87	7960.28	581.07
10-29-038-12-W-4	727.59	B	VKNG	832.38	865.63	-104.79	-138.04	5378.10	427.37

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
11-30-038-12-W-4	736.70	A	GLCC	967.33	987.49	-230.62	-250.79	7899.60	565.37
11-30-038-12-W-4	736.70	B	VKNG	849.27	866.00	-112.57	-129.30	5893.16	480.41
06-04-038-13-W-4	808.33	B	CLNY	963.48	975.36	-155.15	-167.03	6191.71	470.71
06-04-038-13-W-4	808.33	B	BLQZ	1039.71	1063.45	-231.38	-255.12	8122.31	585.56
07-06-038-13-W-4	834.85	C	CLNY	1006.17	1013.76	-171.32	-178.92	6120.69	449.44
07-09-038-13-W-4	783.49	B	CLNY	949.82	961.49	-166.34	-178.00	5423.61	381.26
11-11-038-13-W-4	763.22	A	CLNY	931.77	943.66	-168.56	-180.44	6295.14	467.86
06-13-038-13-W-4	748.10	C	GLCC	983.33	994.99	-235.23	-246.89	8077.49	583.17
07-14-038-13-W-4	755.60	B	CLNY	914.70	941.83	-159.10	-186.23	6351.67	475.46
07-15-038-13-W-4	761.39	B	GLCC	993.97	1036.93	-232.58	-275.54	8025.78	564.90
07-16-038-13-W-4	766.27	B	BLQZ	983.91	1035.71	-217.65	-269.44	8445.00	618.19
07-16-038-13-W-4	766.27	B	BLQZ	1008.61	1014.37	-242.34	-248.11	8001.65	571.27
10-17-038-13-W-4	777.85	C	SPRK	987.88	1005.84	-210.03	-227.99	7850.65	582.08
06-21-038-13-W-4	774.19	C	GLCC	1018.98	1028.40	-244.78	-254.20	8197.47	586.98
10-23-038-13-W-4	736.31	B	SPRK	940.80	950.00	-204.49	-213.70	7563.82	562.72
10-24-038-13-W-4	747.98	A	BLQZ	983.00	996.70	-235.02	-248.72	8282.96	603.33
06-25-038-13-W-4	744.02	B	BLQZ	982.69	993.04	-238.68	-249.02	8191.26	591.99
10-26-038-13-W-4	726.95	C	GLCC	949.76	966.22	-222.82	-239.27	8096.11	595.09
10-34-038-13-W-4	737.01	C	CLNY	901.28	911.96	-164.28	-174.96	6430.97	486.60
06-35-038-13-W-4	736.40	B	GLCC	984.22	991.21	-247.82	-254.81	7026.01	465.62
07-36-038-13-W-4	734.26	B	SPRK	937.57	944.27	-203.30	-210.01	7805.83	589.86
11-02-038-14-W-4	817.29	C	OCDZ	1072.36	1077.99	-255.07	-260.70	6442.00	399.46
11-02-038-14-W-4	817.29	B	SPRK	1042.33	1047.99	-225.04	-230.70	4100.46	190.54
11-02-038-14-W-4	817.29	B	CLNY	990.32	995.99	-173.02	-178.70	6216.53	458.48
11-03-038-14-W-4	815.04	B	SPRK	1048.25	1059.18	-233.21	-244.14	7702.40	547.28
11-04-038-14-W-4	829.67	A	SPRK	1062.88	1067.71	-233.22	-238.05	7632.77	543.22
10-08-038-14-W-4	845.52	C	SPRK	1068.06	1082.04	-222.55	-236.52	6361.33	419.58
07-10-038-14-W-4	815.95	B	SPRK	1050.08	1056.44	-234.13	-240.49	6083.46	383.45
07-11-038-14-W-4	834.30	A	SPRK	1066.36	1071.01	-232.06	-236.71	4536.91	228.57
07-11-038-14-W-4	834.30	C	SPRK	1060.35	1065.00	-226.05	-230.70	7775.49	565.04
07-11-038-14-W-4	834.30	B	CLNY	1011.32	1015.99	-177.02	-181.69	6136.55	446.82
06-12-038-14-W-4	832.71	B	GLCC	1083.61	1098.50	-250.90	-265.79	6978.43	453.74
06-12-038-14-W-4	832.71	B	SPRK	1058.00	1072.90	-225.29	-240.18	5335.35	311.69
06-12-038-14-W-4	832.71	A	CLNY	1006.17	1021.08	-173.46	-188.37	6248.25	456.67

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
10-28-038-14-W-4	777.85	B	GLCC	1076.30	1089.66	-298.45	-311.81	8060.26	517.35
07-29-038-14-W-4	783.03	B	BLQZ	1100.99	1103.38	-317.96	-320.34	7587.95	455.13
07-29-038-14-W-4	783.03	B	BLQZ	1095.51	1100.33	-312.47	-317.30	7702.40	471.07
07-29-038-14-W-4	783.03	B	GLCC	1080.87	1085.70	-297.84	-302.67	8049.22	521.10
06-34-038-14-W-4	775.41	B	GLCC	1068.98	1078.99	-293.57	-303.58	8080.25	525.94
06-34-038-14-W-4	775.41	B	GLCC	1063.49	1073.51	-288.08	-298.09	7803.07	503.14
10-01-039-01-W-4	672.69	A	SPRK	714.23	722.99	-41.53	-50.29	5218.83	486.62
10-01-039-01-W-4	672.69	C	MCRN	688.22	696.99	-15.53	-24.29	5078.17	498.27
13-25-039-01-W-4	684.00	C	LDMR	751.24	756.00	-67.24	-71.99	5600.12	501.82
10-31-039-01-W-4	703.51	A	MCRN	700.23	709.00	3.28	-5.49	4467.27	454.74
10-31-039-01-W-4	703.51	A	CLNY	689.23	697.99	14.28	5.52	4685.84	488.05
10-32-039-01-W-4	680.01	A	SPRK	687.24	690.68	-7.24	-10.67	4976.81	498.89
10-32-039-01-W-4	680.01	B	SPRK	681.76	685.19	-1.75	-5.18	4915.45	498.11
09-33-039-01-W-4	678.48	B	CMGS	765.91	770.84	-87.42	-92.35	5400.85	461.22
09-33-039-01-W-4	678.48	A	SPRK	719.26	723.60	-40.77	-45.11	5071.96	474.60
07-11-039-02-W-4	664.52	C	GLCC	773.84	777.24	-109.31	-112.72	5460.84	446.22
11-27-039-02-W-4	702.29	C	SPRK	757.68	765.66	-55.39	-63.37	5850.41	537.60
01-28-039-02-W-4	691.90	C	MCRN	718.22	726.00	-26.33	-34.11	5223.65	502.81
14-02-039-03-W-4	677.91	B	MCRN	694.23	707.99	-16.32	-30.08	5228.48	510.32
06-03-039-03-W-4	674.31	B	CMGS	790.27	794.00	-115.96	-119.69	5802.83	474.30
03-05-039-03-W-4	673.49	A	LDMR	788.26	794.00	-114.77	-120.52	5623.56	456.19
03-05-039-03-W-4	673.49	C	SPRK	756.24	762.00	-82.76	-88.51	5953.83	521.90
03-05-039-03-W-4	673.49	A	CLNY	693.22	699.00	-19.73	-25.51	5316.05	519.83
11-05-039-03-W-4	668.21	B	LDMR	776.24	781.99	-108.03	-113.78	5729.06	473.69
08-06-039-03-W-4	677.60	C	GLCC	794.57	802.23	-116.97	-124.63	5687.00	459.51
08-06-039-03-W-4	677.60	C	CLNY	707.37	713.23	-29.77	-35.63	8151.27	799.06
16-06-039-03-W-4	664.49	B	LDMR	780.27	786.99	-115.78	-122.50	5809.73	473.69
01-28-039-03-W-4	663.88	B	CMGS	778.75	781.51	-114.86	-117.62	5401.54	434.94
14-29-039-03-W-4	666.69	A	CLNY	688.22	692.99	-21.53	-26.30	5156.77	502.28
13-30-039-03-W-4	668.49	C	CMGS	766.24	770.99	-97.76	-102.50	5391.20	449.99
05-32-039-03-W-4	667.91	C	ELRL	778.75	784.95	-110.84	-117.04	5376.03	434.63
05-32-039-03-W-4	667.91	B	CLNY	686.24	696.01	-18.33	-28.10	5216.07	509.04
05-32-039-03-W-4	667.91	C	SPRK	708.22	717.99	-40.31	-50.08	5282.26	493.81
13-34-039-03-W-4	685.19	C	CMGS	788.26	791.99	-103.07	-106.80	5477.39	453.98

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
13-34-039-03-W-4	685.19	B	LDMR	778.26	781.99	-93.07	-96.80	5291.91	445.06
16-12-039-04-W-4	665.20	A	DINA	796.25	801.01	-131.05	-135.82	5695.27	447.72
16-12-039-04-W-4	665.20	B	CMGS	791.25	795.01	-126.05	-129.81	5729.75	456.74
16-12-039-04-W-4	665.20	B	CLNY	700.23	707.99	-35.04	-42.79	5393.96	511.49
06-22-039-04-W-4	667.24	B	LDMR	766.24	777.51	-99.01	-110.28	5464.29	452.94
06-14-039-05-W-4	685.31	B	OCDZ	812.25	816.01	-126.94	-130.70	5496.69	432.07
06-14-039-05-W-4	685.31	C	OCDZ	808.26	814.00	-122.95	-128.69	5552.54	440.77
10-14-039-05-W-4	672.69	C	CLNY	689.07	731.52	-16.38	-58.83	5609.08	534.75
10-14-039-05-W-4	672.69	A	ELRL	801.89	828.75	-129.19	-156.06	5687.69	437.75
16-35-039-05-W-4	684.40	B	DINA	802.77	805.49	-118.37	-121.10	5746.29	466.62
07-10-039-06-W-4	696.19	A	GLCC	837.26	848.87	-141.06	-152.67	6019.34	467.35
05-17-039-06-W-4	686.41	A	BLQZ	856.77	860.15	-170.36	-173.74	6058.64	446.18
13-29-039-06-W-4	677.60	B	NSKU	893.36	902.21	-215.76	-224.61	6660.57	459.47
11-07-039-07-W-4	739.20	A	BLQZ	936.04	965.00	-196.84	-225.80	6384.77	440.19
08-08-039-07-W-4	719.94	B	GLCC	875.79	880.51	-155.86	-160.57	5654.59	418.79
08-08-039-07-W-4	719.94	C	GLCC	868.29	873.01	-148.36	-153.07	6504.74	513.04
10-08-039-07-W-4	722.10	A	GLCC	874.76	880.26	-152.66	-158.16	6074.50	464.44
10-08-039-07-W-4	722.10	C	GLCC	862.56	868.07	-140.46	-145.97	6151.72	484.51
11-08-039-07-W-4	741.91	C	GLCC	885.73	894.59	-143.82	-152.67	6325.47	497.21
11-08-039-07-W-4	741.91	B	BLQZ	914.70	926.59	-172.79	-184.68	6157.24	449.56
11-08-039-07-W-4	741.91	B	GLCC	896.41	905.87	-154.49	-163.95	5895.23	442.33
11-08-039-07-W-4	741.91	C	CLNY	815.61	832.71	-73.69	-90.80	6180.68	548.43
06-09-039-07-W-4	713.20	A	GLCC	852.81	856.18	-139.60	-142.98	6112.42	482.42
11-14-039-07-W-4	699.79	A	SPRK	836.77	841.49	-136.98	-141.70	6131.72	486.35
11-14-039-07-W-4	699.79	A	CLNY	764.26	772.00	-64.47	-72.21	5924.87	536.24
06-16-039-07-W-4	704.09	B	CLNY	757.68	784.86	-53.59	-80.77	5857.30	530.50
06-16-039-07-W-4	704.09	B	GLCC	853.11	867.46	-149.02	-163.37	6056.57	461.82
06-16-039-07-W-4	704.09	C	GLCC	845.18	853.44	-141.09	-149.35	6395.80	507.41
11-30-039-07-W-4	713.51	C	CLNY	740.91	774.19	-27.40	-60.69	5830.41	550.90
03-31-039-07-W-4	740.51	C	GLCC	880.28	890.99	-139.77	-150.48	6252.39	492.88
03-35-039-07-W-4	692.20	B	CLNY	735.24	749.99	-43.04	-57.79	5642.87	525.39
14-08-039-08-W-4	748.99	B	BLQZ	934.31	939.00	-185.32	-190.01	6192.40	444.21
07-14-039-08-W-4	762.27	A	CLNY	817.13	838.20	-54.86	-75.93	6147.58	561.91
10-18-039-08-W-4	740.08	A	BLQZ	932.99	938.78	-192.91	-198.70	6440.62	461.40

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-21-039-08-W-4	752.58	C	ELRL	911.96	923.85	-159.37	-171.27	6386.84	486.40
06-24-039-08-W-4	743.68	A	BLQZ	911.65	916.84	-167.97	-173.16	6011.06	442.81
10-28-039-08-W-4	738.77	C	SPRK	868.97	874.78	-130.19	-136.00	5991.76	478.31
06-34-039-08-W-4	766.21	B	GLCC	927.29	930.49	-161.09	-164.29	6073.81	457.09
06-34-039-08-W-4	766.21	A	BLQZ	942.81	946.01	-176.61	-179.80	5989.00	432.92
06-34-039-08-W-4	766.21	C	BLQZ	914.79	918.00	-148.59	-151.79	6533.70	516.52
10-09-039-09-W-4	739.69	C	BLQZ	922.32	931.16	-182.63	-191.48	6332.37	459.11
14-36-039-09-W-4	748.31	A	DINA	907.29	910.01	-158.98	-161.70	5924.87	444.24
01-03-039-10-W-4	768.60	B	GLCC	966.32	973.99	-197.72	-205.39	6817.09	494.07
02-10-039-10-W-4	772.00	B	BLQZ	1005.32	1010.99	-233.32	-238.99	6630.23	440.40
02-10-039-10-W-4	772.00	C	GLCC	968.33	973.99	-196.33	-201.99	6775.72	492.24
06-33-039-10-W-4	692.51	B	BLQZ	906.77	921.72	-214.27	-229.21	6557.15	447.36
06-30-039-11-W-4	732.13	C	LDUC	1239.72	1249.68	-507.59	-517.55	9708.16	478.06
06-30-039-11-W-4	732.13	A	BLQZ	1058.00	1068.32	-325.87	-336.19	7780.32	462.88
06-05-039-12-W-4	722.68	C	GLCC	948.85	957.99	-226.17	-235.31	7818.24	567.04
06-17-039-12-W-4	669.65	B	GLCC	897.93	922.02	-228.28	-252.37	7860.99	561.81
06-17-039-12-W-4	669.65	B	CLNY	814.08	822.96	-144.44	-153.31	6570.94	521.63
07-20-039-12-W-4	737.30	C	BLQZ	967.33	971.00	-230.03	-233.70	6590.93	440.68
06-29-039-12-W-4	719.33	B	BLQZ	946.10	958.90	-226.78	-239.57	7427.98	524.78
10-32-039-12-W-4	722.38	B	OCDZ	955.56	978.41	-233.18	-256.03	7532.79	524.05
10-32-039-12-W-4	722.38	B	OCDZ	945.19	965.00	-222.81	-242.62	7621.04	544.94
10-32-039-12-W-4	722.38	B	GLCC	974.16	979.93	-251.78	-257.56	7212.17	481.27
06-08-039-13-W-4	746.39	B	GLCC	1023.34	1036.02	-276.94	-289.62	7989.24	531.95
06-08-039-13-W-4	746.39	C	GLCC	1003.33	1021.99	-256.94	-275.60	7879.61	537.77
10-10-039-13-W-4	736.40	B	BLQZ	980.56	990.60	-244.16	-254.20	7687.24	535.23
11-12-039-13-W-4	729.39	B	GLCC	960.13	963.47	-230.74	-234.09	7586.57	541.72
07-13-039-13-W-4	729.69	B	BLQZ	957.39	969.26	-227.69	-239.57	7494.18	531.08
11-14-039-13-W-4	728.69	B	GLCC	970.31	977.01	-241.63	-248.32	7334.90	503.48
06-01-40-01-W-4	691.01	A	SPRK	725.24	741.00	-34.22	-49.99	5053.35	473.54
06-01-040-01-W-4	691.01	B	CMGS	779.26	783.00	-88.25	-91.99	5553.23	476.54
09-01-040-01-W-4	683.70	A	SPRK	723.22	728.01	-39.53	-44.32	5161.60	484.77
07-02-040-01-W-4	681.47	C	SPRK	716.52	726.95	-35.04	-45.48	5208.48	491.22
01-04-040-01-W-4	679.09	A	CLNY	673.22	680.01	5.88	-0.91	4798.92	492.17
01-04-040-01-W-4	679.09	B	DINA	767.25	770.99	-88.16	-91.90	5409.82	462.00

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
07-06-040-01-W-4	680.41	A	MCRN	682.73	689.00	-2.33	-8.60	4947.16	499.35
15-07-040-01-W-4	687.51	A	MCRN	687.21	696.01	0.29	-8.50	4721.01	477.63
03-12-040-01-W-4	687.60	A	CLNY	675.23	685.01	12.37	2.59	4582.42	475.07
06-14-040-01-W-4	674.89	A	CLNY	668.22	675.99	6.67	-1.10	4764.45	488.95
15-21-040-01-W-4	692.78	C	BLQZ	773.84	779.98	-81.06	-87.20	5214.69	447.98
15-21-040-01-W-4	692.78	C	SPRK	685.42	686.71	7.36	6.07	4834.08	499.99
13-22-040-01-W-4	695.00	C	DINA	775.54	780.99	-80.54	-85.98	5435.33	471.36
07-25-040-01-W-4	672.60	B	CLNY	661.21	665.01	11.40	7.59	4045.99	422.35
12-26-040-01-W-4	698.11	B	CLNY	678.71	690.68	19.41	7.44	4764.45	499.59
12-26-040-01-W-4	698.11	C	SPRK	732.25	738.10	-34.13	-39.99	5143.67	487.80
12-27-040-01-W-4	693.08	C	SPRK	731.15	739.75	-38.07	-46.66	5229.17	491.22
12-27-040-01-W-4	693.08	C	SPRK	740.91	747.98	-47.82	-54.89	5372.58	496.86
12-27-040-01-W-4	693.08	B	MCRN	684.81	699.21	8.28	-6.13	4651.37	475.71
16-27-040-01-W-4	703.60	B	SPRK	738.25	743.99	-34.65	-40.39	5076.10	480.45
10-28-040-01-W-4	699.49	B	SPRK	735.42	743.10	-35.93	-43.62	5155.39	486.29
10-28-040-01-W-4	699.49	B	GP	743.35	749.20	-43.86	-49.71	5275.36	491.52
16-34-040-01-W-4	733.99	B	SPRK	770.24	775.01	-36.25	-41.03	4494.16	419.95
07-35-040-01-W-4	691.59	C	CMGS	766.52	781.81	-74.93	-90.22	5230.55	451.16
13-35-040-01-W-4	737.89	C	DINA	829.33	832.10	-91.44	-94.21	5453.95	463.70
05-36-040-01-W-4	669.62	B	SPRK	711.73	715.00	-42.11	-45.38	5117.47	478.44
05-36-040-01-W-4	669.62	C	CMGS	759.26	762.49	-89.65	-92.87	5385.68	458.30
10-01-040-02-W-4	677.51	C	SPRK	720.23	725.00	-42.73	-47.49	5458.08	511.84
07-04-040-02-W-4	708.51	C	SPRK	766.24	781.99	-57.74	-73.49	5497.38	495.35
07-04-040-02-W-4	714.91	A	CLNY	709.23	727.01	5.68	-12.10	5038.87	510.96
10-27-040-02-W-4	675.71	A	CLNY	666.21	673.49	9.50	2.23	4761.69	491.75
14-32-040-02-W-4	679.49	A	MCRN	685.23	690.01	-5.74	-10.52	4760.31	477.62
15-04-040-03-W-4	717.19	B	SPRK	779.26	783.00	-62.07	-65.81	5265.02	473.31
10-09-040-03-W-4	701.41	C	SPRK	762.25	768.00	-60.84	-66.60	5256.06	472.61
06-16-040-03-W-4	674.10	A	CLNY	686.73	690.49	-12.63	-16.40	5009.22	496.63
11-26-040-03-W-4	681.20	A	LDMR	765.91	769.92	-84.71	-88.73	5358.10	460.03
09-27-040-03-W-4	663.24	C	LDMR	745.48	755.90	-82.24	-92.66	5041.62	427.00
10-28-040-03-W-4	664.59	C	LDMR	751.24	759.01	-86.66	-94.43	5114.71	431.37
15-29-040-03-W-4	703.69	A	LDMR	804.27	807.51	-100.57	-103.81	5485.66	457.57
10-33-040-03-W-4	670.86	C	SPRK	713.47	725.42	-42.60	-54.56	5496.69	512.31

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
10-33-040-03-W-4	670.86	B	GLCC	759.81	767.49	-88.95	-96.62	5481.53	466.56
02-35-040-03-W-4	681.20	C	MCRN	687.24	693.12	-6.05	-11.92	5101.61	511.59
12-04-040-04-W-4	686.10	A	CLNY	698.22	711.40	-12.12	-25.30	5067.83	498.42
11-14-040-04-W-4	681.81	B	LDMR	789.69	802.84	-107.88	-121.04	5655.97	462.68
11-14-040-04-W-4	681.81	A	CLNY	695.17	705.61	-13.36	-23.80	5054.04	497.13
07-18-040-04-W-4	693.69	A	CLNY	702.49	712.93	-8.80	-19.23	5143.67	510.85
10-19-040-04-W-4	685.19	A	CLNY	708.22	712.01	-23.03	-26.82	5131.26	498.67
05-20-040-04-W-4	706.19	B	SPRK	771.40	777.24	-65.21	-71.05	5568.40	500.08
11-31-040-04-W-4	697.29	A	SPRK	775.27	785.01	-77.98	-87.72	5465.67	474.87
10-13-040-05-W-4	684.58	C	LDUC	878.11	888.80	-193.53	-204.22	6750.21	489.92
10-13-040-05-W-4	684.58	C	BHL	1212.59	1224.38	-528.01	-539.80	13472.83	840.87
10-15-040-05-W-4	681.41	C	WAS	722.25	727.01	-40.84	-45.60	3013.12	264.24
06-20-040-05-W-4	704.21	A	BLQZ	813.47	833.93	-109.26	-129.72	5709.06	463.06
09-25-040-05-W-4	692.20	A	CLNY	699.75	708.66	-7.54	-16.46	5176.08	516.17
09-25-040-05-W-4	692.20	A	CLNY	708.89	717.80	-16.69	-25.60	5247.10	514.27
07-27-040-05-W-4	697.41	B	CLNY	700.66	717.50	-3.25	-20.09	5047.14	503.35
06-28-040-05-W-4	695.61	A	CLNY	701.88	713.84	-6.27	-18.23	5209.17	519.30
06-29-040-05-W-4	701.41	A	MCRN	716.24	718.99	-14.83	-17.59	5129.19	507.18
06-30-040-05-W-4	694.49	A	MCRN	713.22	722.99	-18.74	-28.50	5284.33	515.60
11-31-040-05-W-4	684.00	A	CLNY	705.23	710.49	-21.23	-26.49	5155.39	502.20
11-31-040-05-W-4	684.00	A	CLNY	711.24	716.49	-27.24	-32.49	5146.43	495.28
03-14-040-06-W-4	694.61	B	GLCC	804.94	828.45	-110.33	-133.84	5642.18	453.65
04-20-040-06-W-4	682.90	A	GLCC	796.52	800.25	-113.62	-117.35	5905.57	487.13
04-20-040-06-W-4	682.90	C	BLQZ	816.28	820.49	-133.37	-137.59	5789.04	455.24
11-08-040-07-W-4	742.49	A	BLQZ	893.36	900.99	-150.86	-158.50	5929.70	450.39
10-09-040-07-W-4	689.31	B	OCDZ	827.29	832.50	-137.98	-143.20	5682.17	439.23
02-21-040-07-W-4	691.19	A	CMGS	808.26	812.99	-117.06	-121.80	5791.80	471.57
11-23-040-07-W-4	696.77	A	BLQZ	836.04	844.30	-139.26	-147.52	5902.12	458.86
13-24-040-07-W-4	702.26	B	ELRL	827.80	839.72	-125.54	-137.46	5969.00	477.58
13-24-040-07-W-4	702.26	B	BLQZ	902.50	909.83	-200.24	-207.57	6486.13	457.94
05-28-040-07-W-4	708.40	C	SPRK	796.25	801.01	-87.85	-92.61	6228.25	545.31
01-33-040-07-W-4	695.71	B	CLNY	730.24	733.99	-34.53	-38.28	5498.76	524.69
04-33-040-07-W-4	697.08	B	GLCC	809.20	813.21	-112.13	-116.13	6184.82	516.98
16-33-040-07-W-4	694.03	C	GLCC	813.47	839.11	-119.44	-145.08	6128.28	493.07

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
04-35-040-07-W-4	685.19	C	MCRN	719.56	743.71	-34.37	-58.52	5333.97	497.84
04-35-040-07-W-4	685.19	C	GLCC	809.51	826.01	-124.32	-140.82	5502.90	428.95
10-02-040-08-W-4	748.89	A	BLQZ	920.80	957.07	-171.90	-208.18	6166.20	439.16
14-08-040-08-W-4	748.99	C	GLCC	898.30	904.01	-149.31	-155.02	6006.92	460.79
10-09-040-08-W-4	743.41	C	BLQZ	886.04	895.50	-142.63	-152.10	7036.35	570.63
11-14-040-08-W-4	738.80	A	OCDZ	880.28	889.99	-141.47	-151.18	6085.53	474.65
08-15-040-08-W-4	740.91	A	GLCC	878.78	883.01	-137.87	-142.10	6082.08	480.63
03-17-040-08-W-4	755.90	B	BLQZ	911.29	915.01	-155.38	-159.11	5801.45	434.74
03-17-040-08-W-4	755.90	C	SPRK	855.27	861.00	-99.37	-105.10	6595.76	570.80
10-22-040-08-W-4	739.44	B	BLQZ	888.17	895.50	-148.73	-156.06	5822.83	441.77
13-24-040-08-W-4	743.10	A	GLCC	875.28	885.99	-132.17	-142.89	5650.45	439.04
13-24-040-08-W-4	743.10	A	GLCC	885.28	889.01	-142.17	-145.91	5602.19	427.61
01-26-040-08-W-4	743.41	C	BLQZ	884.21	903.73	-140.80	-160.32	6088.29	470.69
04-01-040-09-W-4	755.29	A	BLQZ	931.16	943.05	-175.87	-187.76	6246.87	455.62
04-01-040-09-W-4	755.29	A	BLQZ	909.21	915.62	-153.92	-160.32	6198.61	475.39
07-07-040-09-W-4	734.26	C	OCDZ	907.08	907.69	-172.81	-173.43	5956.59	434.69
11-15-040-09-W-4	755.90	C	BLQZ	913.18	919.28	-157.27	-163.37	6016.58	453.61
10-18-040-09-W-4	736.70	B	GLCC	878.72	883.92	-142.02	-147.22	6481.30	516.74
10-21-040-09-W-4	745.24	B	GLCC	900.98	904.65	-155.74	-159.41	5867.65	441.16
06-23-040-09-W-4	754.08	A	VKNG	762.25	783.34	-8.17	-29.26	5859.37	579.18
06-27-040-09-W-4	749.81	C	BLQZ	915.31	924.76	-165.50	-174.96	6228.25	465.31
11-29-040-09-W-4	640.08	A	BLQZ	795.79	800.40	-155.71	-160.32	6002.10	454.44
11-29-040-09-W-4	640.08	A	BLQZ	789.08	793.70	-149.00	-153.62	6204.81	481.83
11-29-040-09-W-4	640.08	A	GLCC	775.06	779.68	-134.98	-139.60	6253.77	500.85
07-31-040-09-W-4	730.91	A	BLQZ	890.00	893.37	-159.09	-162.46	5954.52	446.83
07-31-040-09-W-4	730.91	B	BLQZ	882.38	888.80	-151.47	-157.89	6108.28	468.62
07-31-040-09-W-4	730.91	B	CLNY	791.52	797.97	-60.61	-67.06	5766.98	524.63
06-01-040-10-W-4	738.23	B	GLCC	919.27	937.87	-181.05	-199.64	6130.34	435.20
10-03-040-10-W-4	694.94	C	BLQZ	896.41	900.07	-201.46	-205.13	6494.40	459.40
07-11-040-10-W-4	693.12	A	ELRL	889.39	893.67	-196.28	-200.56	6161.37	430.29
11-13-040-10-W-4	633.68	B	ELRL	801.28	805.59	-167.60	-171.91	5990.38	441.51
16-13-040-10-W-4	702.26	A	BLQZ	861.04	872.64	-158.78	-170.38	6106.90	458.57
16-13-040-10-W-4	702.26	A	GLCC	843.35	849.78	-141.09	-147.52	6164.13	484.68
13-14-040-10-W-4	680.31	C	BLQZ	851.59	854.35	-171.27	-174.04	6125.52	452.40

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
13-14-040-10-W-4	680.31	A	BLQZ	854.94	858.01	-174.63	-177.70	6053.81	441.57
01-15-040-10-W-4	622.40	C	BLQZ	803.11	814.43	-180.71	-192.02	6067.60	432.78
01-15-040-10-W-4	622.40	C	ELRL	819.27	826.01	-196.86	-203.61	6202.74	432.70
15-17-040-10-W-4	722.99	B	GLCC	907.08	914.00	-184.09	-191.02	5943.49	418.92
07-20-040-10-W-4	709.57	A	VKNG	737.86	752.86	-28.28	-43.28	5894.54	565.70
07-20-040-10-W-4	709.57	B	GLCC	865.31	871.73	-155.73	-162.15	7003.25	555.67
16-21-040-10-W-4	713.23	B	CLNY	782.37	788.21	-69.14	-74.98	6046.92	544.97
10-22-040-10-W-4	699.52	A	GLCC	866.83	872.64	-167.31	-173.13	6046.92	446.81
11-26-040-10-W-4	728.20	B	GLCC	870.28	874.99	-142.08	-146.79	6208.26	489.06
12-28-040-10-W-4	735.48	C	GLCC	888.48	891.54	-153.00	-156.06	6757.10	534.97
07-32-040-10-W-4	736.40	C	GLCC	894.27	904.65	-157.87	-168.25	7033.59	554.65
07-34-040-10-W-4	742.80	C	GLCC	928.42	932.69	-185.62	-189.89	6216.53	446.58
07-34-040-10-W-4	742.80	C	GLCC	916.22	923.54	-173.43	-180.75	6399.94	475.97
08-10-040-11-W-4	740.02	C	ELRL	976.32	979.99	-236.30	-239.97	6635.75	438.98
07-15-040-11-W-4	738.59	C	BLQZ	965.31	973.84	-226.72	-235.24	6646.78	447.26
11-23-040-11-W-4	729.08	C	GLCC	904.33	911.35	-175.25	-182.27	7140.46	549.86
05-24-040-11-W-4	723.00	C	CLNY	817.25	822.02	-94.25	-99.02	6656.43	582.59
07-25-040-11-W-4	730.00	B	ELRL	914.70	928.12	-184.70	-198.12	6095.18	430.55
07-25-040-11-W-4	730.00	C	ELRL	913.79	923.54	-183.79	-193.55	5976.59	421.19
09-31-040-11-W-4	755.29	C	ELRL	950.31	953.99	-195.02	-198.70	6084.15	423.97
16-31-040-11-W-4	752.55	C	ELRL	946.10	950.98	-193.55	-198.42	6384.08	455.45
14-32-040-11-W-4	753.16	C	DINA	926.90	948.54	-173.74	-195.38	5840.75	411.44
15-32-040-11-W-4	751.94	B	ELRL	948.24	951.59	-196.30	-199.64	6255.14	440.31
15-32-040-11-W-4	751.70	B	BLQZ	944.31	952.01	-192.61	-200.31	5850.41	400.52
10-04-040-12-W-4	726.61	A	WBMN	1010.32	1025.01	-283.70	-298.40	6860.53	409.00
10-04-040-12-W-4	726.61	C	BLQZ	981.32	984.50	-254.71	-257.89	7609.32	520.16
10-04-040-12-W-4	726.61	C	GLCC	953.30	956.49	-226.69	-229.88	7625.18	549.80
07-10-040-12-W-4	733.20	C	BLQZ	979.31	983.01	-246.11	-249.81	6890.86	455.19
13-15-040-12-W-4	740.30	B	CLNY	849.27	861.00	-108.97	-120.70	7114.95	611.18
15-21-040-12-W-4	740.36	B	BLQZ	991.53	999.74	-251.18	-259.38	6801.23	438.72
14-25-040-12-W-4	738.90	B	GLCC	923.82	953.90	-184.92	-215.01	6867.42	500.79
04-26-040-12-W-4	736.31	C	GLCC	969.31	978.01	-233.00	-241.71	6550.94	431.11
06-27-040-12-W-4	737.62	B	GLCC	977.51	982.98	-239.89	-245.36	6661.26	437.09
04-31-040-12-W-4	711.31	B	BLQZ	958.21	963.50	-246.90	-252.19	6408.21	404.35

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
14-33-040-12-W-4	734.51	B	CMRS	1056.84	1067.99	-322.34	-333.48	7578.29	445.39
14-33-040-12-W-4	734.51	B	ELRL	974.63	979.99	-240.32	-245.49	6436.48	413.88
02-34-040-12-W-4	736.70	C	GLCC	961.32	971.00	-224.62	-234.30	6628.16	446.88
11-36-040-12-W-4	741.30	C	ELRL	949.82	957.50	-208.52	-216.19	6131.03	413.26
11-36-040-12-W-4	741.30	B	GLCC	940.80	948.51	-199.50	-207.20	6917.06	502.47
11-36-040-12-W-4	741.30	C	CLNY	858.29	865.94	-116.99	-124.63	8824.91	779.69
10-06-040-13-W-4	720.21	B	OCDZ	984.31	988.50	-264.10	-268.28	7077.03	455.95
10-06-040-13-W-4	720.21	C	OCDZ	972.33	982.00	-252.11	-261.79	7396.96	497.84
10-06-040-13-W-4	720.21	B	OCDZ	979.83	982.49	-259.61	-262.28	6815.02	434.46
10-06-040-13-W-4	720.21	A	BLRV	337.10	345.00	383.11	375.21	2758.00	660.59
15-10-040-13-W-4	717.50	B	BLQZ	989.40	1007.67	-271.90	-290.17	6992.22	432.46
10-11-040-13-W-4	716.71	B	BLQZ	992.33	998.01	-275.62	-281.30	6619.20	396.97
11-11-040-13-W-4	717.50	B	BLQZ	997.02	1002.79	-279.52	-285.29	7129.43	445.08
11-11-040-13-W-4	717.50	C	OCDZ	997.33	1000.05	-279.83	-282.55	7046.00	437.79
12-12-040-13-W-4	719.33	B	ELRL	994.28	1018.95	-274.95	-299.62	7094.96	436.69
10-15-040-13-W-4	717.50	B	GLCC	960.44	979.93	-242.94	-262.43	7435.57	506.05
03-23-040-13-W-4	722.07	B	GLCC	960.13	973.53	-238.06	-251.46	7908.57	562.24
03-23-040-13-W-4	722.07	B	GLCC	990.93	1005.84	-268.85	-283.77	7115.64	449.77
06-23-040-13-W-4	723.11	A	BLQZ	955.31	974.99	-232.21	-251.89	7702.40	543.91
14-31-040-13-W-4	717.01	C	GLCC	1005.32	1015.01	-288.30	-298.00	6981.19	419.21
14-31-040-13-W-4	717.01	A	ELRL	970.31	979.99	-253.30	-262.98	7525.89	509.81
01-36-040-13-W-4	710.61	C	BLQZ	958.30	961.49	-247.69	-250.88	6465.44	410.45
01-36-040-13-W-4	710.61	B	GLCC	919.30	926.99	-208.69	-216.38	7595.53	562.52
15-03-040-14-W-4	730.51	A	GLCC	993.33	998.01	-262.82	-267.49	7718.95	522.49
15-03-040-14-W-4	730.51	B	GLCC	1006.32	1010.99	-275.81	-280.48	7399.02	476.86
07-06-040-14-W-4	743.10	A	GLCC	1055.35	1062.01	-312.25	-318.91	7598.98	459.83
07-06-040-14-W-4	743.10	A	GLCC	1024.83	1031.50	-281.73	-288.40	7762.39	507.02
07-10-040-14-W-4	728.47	A	BLQZ	1029.95	1045.46	-301.48	-316.99	7419.02	447.81
07-10-040-14-W-4	728.47	B	BLQZ	1034.22	1041.81	-305.75	-313.33	7353.52	440.82
07-10-040-14-W-4	728.47	B	GLCC	995.19	1000.66	-266.72	-272.19	7726.54	518.97
09-10-040-14-W-4	725.12	B	BLQZ	1032.09	1040.89	-306.97	-315.77	7332.14	436.81
09-10-040-14-W-4	725.12	B	GLCC	990.93	1001.57	-265.81	-276.45	7798.25	524.61
05-11-040-14-W-4	728.47	C	BLQZ	1043.37	1046.07	-314.90	-317.60	7419.02	440.79
05-11-040-14-W-4	728.47	B	ELRL	1020.20	1041.20	-291.72	-312.72	7515.55	464.67

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
05-11-040-14-W-4	728.47	B	ELRL	1036.05	1041.20	-307.58	-312.72	7432.81	448.30
05-11-040-14-W-4	729.60	C	BLQZ	1035.35	1070.00	-305.75	-340.40	7386.61	430.66
06-11-040-14-W-4	730.30	B	GLCC	1000.07	1008.89	-269.77	-278.59	7943.73	536.41
11-11-040-14-W-4	726.64	C	GLCC	985.74	999.74	-259.10	-273.10	7566.57	506.00
11-11-040-14-W-4	726.64	B	ELRL	1036.05	1041.20	-309.41	-314.55	7469.35	450.20
11-11-040-14-W-4	726.64	C	ELRL	1042.15	1044.55	-315.51	-317.91	7516.93	450.33
11-11-040-14-W-4	726.64	B	ELRL	1045.20	1047.60	-318.55	-320.95	7546.58	450.30
08-12-040-14-W-4	718.51	C	CLNY	879.30	909.01	-160.80	-190.50	5282.95	363.43
03-14-040-14-W-4	723.41	B	GLCC	1007.33	1012.00	-283.92	-288.58	7670.00	496.40
05-23-040-14-W-4	657.76	B	GLCC	925.07	928.12	-267.31	-270.36	7575.54	504.18
05-23-040-14-W-4	657.76	C	OCDZ	953.12	956.77	-295.36	-299.01	7225.96	440.16
05-23-040-14-W-4	657.76	C	NSKU	1027.51	1032.97	-369.75	-375.21	7742.40	417.56
07-29-040-14-W-4	725.42	B	GLCC	1003.12	1019.56	-277.70	-294.13	10756.20	811.66
07-29-040-14-W-4	725.42	B	BLQZ	1048.86	1057.66	-323.43	-332.23	7598.98	447.57
07-29-040-14-W-4	725.42	B	GLCC	996.41	998.52	-270.99	-273.10	7732.05	516.94
10-32-040-14-W-4	717.80	C	LDUC	1161.36	1164.64	-443.56	-446.84	8963.50	469.44
10-32-040-14-W-4	717.80	B	GLCC	979.95	1003.10	-262.14	-285.29	7342.49	475.51
11-36-040-14-W-4	712.20	C	BLQZ	998.33	1015.01	-286.14	-302.82	6881.21	407.69
11-36-040-14-W-4	712.20	C	OCDZ	973.33	987.00	-261.14	-274.81	7209.41	467.68
06-04-041-01-W-4	728.29	B	SPRK	774.26	785.01	-45.97	-56.72	5163.67	475.56
10-09-041-01-W-4	762.30	C	SPRK	803.72	808.94	-41.41	-46.63	4014.96	365.67
10-11-041-01-W-4	710.40	C	CLNY	704.23	707.59	6.17	2.80	4774.79	491.71
02-15-041-01-W-4	721.16	B	SPRK	765.30	768.71	-44.14	-47.55	5536.00	519.05
12-15-041-01-W-4	722.07	C	SPRK	752.80	758.34	-30.73	-36.27	5178.15	494.88
03-16-041-01-W-4	759.90	C	SPRK	790.27	799.00	-30.37	-39.11	10496.26	1036.31
06-16-041-01-W-4	763.83	C	SPRK	795.79	801.01	-31.96	-37.19	5148.50	490.78
01-19-041-01-W-4	739.75	C	SPRK	750.05	779.68	-10.30	-39.93	5217.45	507.28
01-20-041-01-W-4	765.69	B	CLNY	751.24	758.01	14.44	7.68	4649.99	485.55
14-21-041-01-W-4	742.80	A	BLQZ	820.18	839.72	-77.38	-96.93	5364.31	460.22
05-22-041-01-W-4	728.75	C	CLNY	709.23	716.01	19.52	12.74	4765.82	502.44
01-30-041-01-W-4	653.09	B	SPRK	683.22	690.01	-30.12	-36.91	5140.91	491.06
08-03-041-02-W-4	649.28	C	DINA	750.76	756.51	-101.47	-107.23	5398.10	446.48
08-03-041-02-W-4	649.28	B	CLNY	647.70	655.02	1.59	-5.73	4736.87	481.28
14-05-041-02-W-4	663.61	A	MCRN	666.21	676.99	-2.60	-13.38	4796.16	481.42

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
05-06-041-02-W-4	664.40	A	MCRN	664.22	670.99	0.18	-6.58	4712.04	477.62
14-09-041-02-W-4	638.80	B	MCRN	634.71	639.99	4.09	-1.19	4688.60	479.88
14-09-041-02-W-4	638.80	B	MCRN	629.19	634.50	9.61	4.30	4649.30	481.37
06-12-041-02-W-4	672.30	C	SPRK	753.26	758.01	-80.96	-85.71	5262.26	453.63
06-17-041-02-W-4	676.69	A	CLNY	678.92	683.39	-2.23	-6.71	4760.31	481.28
05-25-041-02-W-4	632.31	B	MCRN	613.21	622.49	19.09	9.81	4455.55	469.10
09-25-041-02-W-4	631.52	B	DINA	696.73	704.00	-65.21	-72.48	5042.31	445.68
09-25-041-02-W-4	631.52	C	CLNY	596.69	602.01	34.83	29.50	4323.85	473.37
06-03-041-03-W-4	694.33	B	CLNY	696.09	701.04	-1.75	-6.71	4817.54	487.36
16-03-041-03-W-4	692.51	B	REX	780.54	789.13	-88.04	-96.62	5288.47	447.31
06-11-041-03-W-4	685.50	B	LDMR	775.06	783.34	-89.56	-97.84	5433.95	460.78
14-11-041-03-W-4	680.31	C	LDMR	763.47	767.49	-83.16	-87.17	5612.53	487.54
16-16-041-03-W-4	653.49	A	REX	713.77	716.89	-60.28	-63.40	5281.57	477.10
16-03-041-04-W-4	675.31	B	REX	752.74	763.49	-77.42	-88.18	5682.66	497.08
13-07-041-04-W-4	667.21	A	CLNY	672.30	680.31	-5.10	-13.11	4881.66	489.03
11-09-041-04-W-4	682.69	A	CMGS	781.25	789.01	-98.55	-106.31	5385.00	447.06
11-09-041-04-W-4	682.69	C	CLNY	701.24	709.00	-18.55	-26.30	5005.08	488.30
10-11-041-04-W-4	661.69	C	LDMR	744.23	747.49	-82.54	-85.80	5471.87	474.18
02-25-041-04-W-4	713.99	B	SPRK	760.24	773.49	-46.24	-59.50	5204.35	478.19
11-32-041-04-W-4	695.89	A	CLNY	682.98	688.85	12.91	7.04	4600.34	479.40
07-35-041-05-W-4	673.00	A	MCRN	664.22	669.01	8.77	3.99	4677.57	483.69
07-35-041-05-W-4	673.00	A	NSKU	753.26	759.99	-80.26	-86.99	5271.92	454.33
10-16-041-06-W-4	696.77	A	BLQZ	815.61	819.91	-118.83	-123.14	5689.06	459.53
10-16-041-06-W-4	696.77	B	VKNG	675.66	683.36	21.11	13.41	5853.86	614.59
05-28-041-06-W-4	710.49	C	VKNG	670.23	685.01	40.26	25.48	6126.90	658.06
05-28-041-06-W-4	710.49	B	CLNY	724.23	738.99	-13.74	-28.50	5114.71	500.79
06-07-041-07-W-4	698.30	A	SPRK	734.81	763.52	-36.51	-65.23	5518.76	512.27
06-08-041-07-W-4	699.82	B	GLCC	846.40	850.39	-146.58	-150.57	6002.79	463.95
10-14-041-07-W-4	716.89	B	CLNY	737.86	768.10	-20.97	-51.21	5449.81	520.02
10-14-041-07-W-4	716.89	A	GLCC	842.44	853.44	-125.55	-136.55	5813.86	462.20
10-14-041-07-W-4	716.89	A	GLCC	842.44	847.34	-125.55	-130.45	5689.06	452.52
11-18-041-07-W-4	699.82	A	CLNY	728.71	755.90	-28.89	-56.08	5340.18	502.43
11-18-041-07-W-4	699.82	B	GLCC	826.28	829.67	-126.46	-129.84	5807.66	464.47
06-30-041-07-W-4	706.59	B	LDUC	890.28	899.01	-183.69	-192.42	6153.79	439.88

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-01-041-08-W-4	742.19	B	GLCC	868.97	874.78	-126.78	-132.59	5764.22	458.50
11-01-041-08-W-4	731.52	C	CLNY	764.08	787.91	-32.56	-56.39	5692.51	536.39
06-02-041-08-W-4	739.75	B	BLQZ	877.20	890.32	-137.45	-150.57	5991.76	467.39
11-02-041-08-W-4	742.80	C	BLQZ	866.53	893.67	-123.73	-150.88	6096.56	484.80
06-03-041-08-W-4	734.51	A	BLQZ	871.28	883.01	-136.78	-148.50	5937.97	463.28
08-05-041-08-W-4	749.59	C	BLQZ	886.28	899.01	-136.69	-149.41	5936.60	462.72
07-11-041-08-W-4	733.65	C	CLNY	768.35	795.53	-34.69	-61.87	5458.77	508.73
07-11-041-08-W-4	733.65	C	SPRK	835.43	845.52	-101.77	-111.86	5961.42	501.49
11-14-041-08-W-4	729.69	B	CLNY	762.25	786.38	-32.56	-56.69	5385.68	504.93
11-14-041-08-W-4	729.69	C	BLQZ	893.97	899.77	-164.28	-170.08	6398.56	485.74
06-16-041-08-W-4	733.96	A	GLCC	865.92	877.82	-131.96	-143.87	5881.44	462.23
10-16-041-08-W-4	769.01	C	NSKU	1170.82	1179.58	-401.81	-410.57	10198.39	634.47
10-20-041-08-W-4	741.27	B	GLCC	858.29	892.15	-117.02	-150.88	5911.08	469.22
10-20-041-08-W-4	741.27	A	GLCC	859.21	865.02	-117.93	-123.75	5824.90	473.54
10-20-041-08-W-4	741.27	C	BLQZ	867.44	873.56	-126.17	-132.28	5780.08	460.58
11-21-041-08-W-4	722.99	B	ELRL	861.65	876.60	-138.66	-153.62	5904.19	456.33
11-27-041-08-W-4	708.66	A	BLQZ	824.14	834.54	-115.48	-125.88	5584.95	449.21
11-27-041-08-W-4	708.66	C	CLNY	782.37	813.82	-73.71	-105.16	5759.39	498.26
10-28-041-08-W-4	710.79	C	GLCC	820.18	835.15	-109.39	-124.36	5778.01	472.72
10-28-041-08-W-4	710.79	B	ELRL	850.67	868.68	-139.88	-157.89	6019.34	465.34
10-30-041-08-W-4	727.56	C	GLCC	832.38	844.30	-104.82	-116.74	5942.11	495.56
06-34-041-08-W-4	704.70	A	CCDZ	824.75	837.59	-120.06	-132.89	5703.54	455.52
16-03-041-09-W-4	747.40	B	GLCC	882.29	886.51	-134.89	-139.11	5965.55	471.73
06-09-041-09-W-4	697.20	A	GLCC	810.27	821.01	-113.07	-123.81	4865.80	378.07
11-12-041-09-W-4	740.97	B	GLCC	881.16	884.53	-140.19	-143.56	5964.18	466.71
11-12-041-09-W-4	740.97	C	GLCC	862.87	870.20	-121.90	-129.24	6644.02	552.39
16-13-041-09-W-4	738.01	A	BLQZ	862.29	872.00	-124.28	-133.99	5718.02	454.34
11-14-041-09-W-4	751.94	C	GLCC	878.72	887.58	-126.78	-135.64	6263.42	507.92
11-14-041-09-W-4	751.94	C	CLNY	754.93	814.73	-2.99	-62.79	5296.74	507.59
10-23-041-09-W-4	754.99	B	GLCC	870.18	872.95	-115.20	-117.96	5957.28	491.31
07-25-041-09-W-4	746.91	B	GLCC	874.30	877.31	-127.39	-130.39	5761.46	459.01
10-29-041-09-W-4	666.29	B	NSKU	855.85	863.19	-189.56	-196.90	6750.89	495.64
10-29-041-09-W-4	666.29	A	GLCC	795.79	801.01	-129.50	-134.72	5729.75	452.56
10-29-041-09-W-4	666.29	B	GLCC	795.48	799.80	-129.19	-133.50	5765.60	456.98

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
07-31-041-09-W-4	673.61	B	CLNY	715.30	720.55	-41.69	-46.94	5196.07	485.90
06-33-041-09-W-4	684.58	A	CLNY	736.64	741.58	-52.06	-57.00	5630.46	520.01
14-07-041-10-W-4	732.89	B	CLNY	815.76	820.00	-82.87	-87.11	6589.55	587.41
07-36-041-10-W-4	616.00	B	GLCC	740.30	758.34	-124.30	-142.34	5936.60	472.46
13-01-041-11-W-4	739.69	C	WBMN	990.32	1004.01	-250.63	-264.32	6654.36	421.54
01-05-041-11-W-4	754.99	C	OCDZ	942.14	949.76	-187.15	-194.77	7088.75	532.38
04-05-041-11-W-4	755.60	C	ELRL	945.19	956.46	-189.59	-200.86	6364.77	454.24
04-05-041-11-W-4	755.60	B	ELRL	952.81	956.46	-197.21	-200.86	6193.78	432.98
10-12-041-11-W-4	738.00	C	BLQZ	901.28	908.00	-163.28	-170.00	6985.32	546.15
05-21-041-11-W-4	774.19	C	ELRL	980.25	988.47	-206.06	-214.27	6205.50	423.05
13-01-041-12-W-4	770.84	B	GLCC	964.40	969.26	-193.56	-198.42	6939.13	512.08
10-03-041-12-W-4	732.74	C	ELRL	968.97	974.14	-236.23	-241.40	6660.57	440.83
13-03-041-12-W-4	739.14	C	ELRL	945.19	964.69	-206.05	-225.55	6195.16	416.36
16-04-041-12-W-4	734.99	C	MCRN	861.34	866.24	-126.35	-131.25	7328.70	619.03
06-05-041-12-W-4	728.01	C	BLQZ	963.30	967.01	-235.29	-238.99	6867.42	463.62
14-05-041-12-W-4	729.51	A	GLCC	952.81	961.00	-223.30	-231.50	7339.73	521.55
08-07-041-12-W-4	720.70	C	BLQZ	963.30	967.01	-242.60	-246.31	6643.33	433.44
12-07-041-12-W-4	710.82	A	BLQZ	954.82	957.99	-244.00	-247.16	6529.57	420.70
06-08-041-12-W-4	720.91	A	BLQZ	945.31	948.99	-224.40	-228.08	7341.80	522.92
06-08-041-12-W-4	720.91	B	BLQZ	964.31	968.01	-243.39	-247.10	6546.80	422.79
05-10-041-12-W-4	728.78	C	ELRL	934.52	958.90	-205.74	-230.12	6053.81	399.80
12-10-041-12-W-4	731.52	C	BLQZ	946.71	960.12	-215.19	-228.60	5530.81	347.57
15-10-041-12-W-4	754.59	C	BLQZ	957.33	967.01	-202.73	-212.42	6093.11	414.17
02-12-041-12-W-4	784.56	C	ELRL	979.95	983.28	-195.39	-198.73	6388.91	454.87
16-15-041-12-W-4	733.41	C	ELRL	928.91	931.99	-195.50	-198.58	6764.68	493.24
02-22-041-12-W-4	723.50	A	BLQZ	917.29	921.01	-193.79	-197.51	6037.26	420.40
02-22-041-12-W-4	723.50	B	SPRK	866.28	869.99	-142.78	-146.49	7194.24	589.47
14-27-041-12-W-4	694.30	C	NSKU	992.75	997.31	-298.45	-303.00	7356.97	449.98
01-31-041-12-W-4	697.99	C	BLQZ	910.43	911.96	-212.44	-213.97	6299.96	429.65
05-31-041-12-W-4	691.59	A	BLQZ	909.21	913.79	-217.62	-222.20	6423.38	435.54
08-31-041-12-W-4	694.03	A	BLQZ	905.55	908.30	-211.52	-214.27	6371.67	437.27
12-34-041-12-W-4	691.19	C	ELRL	886.28	910.99	-195.09	-219.79	6217.22	426.97
10-14-041-13-W-4	701.95	B	SPRK	874.45	880.87	-172.50	-178.92	7357.65	575.07
07-23-041-13-W-4	702.87	B	OCDZ	911.65	924.76	-208.78	-221.89	7256.30	525.10

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-25-041-13-W-4	694.00	B	GLCC	910.80	916.50	-216.80	-222.50	6284.79	421.65
13-25-041-13-W-4	694.94	B	BLQZ	909.21	914.40	-214.27	-219.46	6208.95	416.70
14-25-041-13-W-4	690.37	C	BLQZ	904.33	910.13	-213.96	-219.76	6503.36	446.75
04-28-041-13-W-4	697.08	B	BLQZ	922.63	927.51	-225.55	-230.43	6577.83	443.22
04-28-041-13-W-4	697.08	A	BLQZ	927.81	930.55	-230.73	-233.48	6577.83	439.10
04-28-041-13-W-4	697.08	C	VKNG	780.85	789.13	-83.77	-92.05	6129.66	537.56
12-33-041-13-W-4	694.64	C	GLCC	926.90	936.96	-232.26	-242.32	7460.39	523.98
01-35-041-13-W-4	700.13	A	BLQZ	920.19	924.46	-220.06	-224.33	6168.96	407.29
04-36-041-13-W-4	698.60	C	BLQZ	916.53	919.89	-217.93	-221.28	6366.15	430.00
10-36-041-13-W-4	694.33	C	GLCC	899.46	908.30	-205.12	-213.97	6966.71	501.34
01-08-041-14-W-4	724.69	B	GLCC	999.99	1004.01	-275.30	-279.32	7495.55	487.55
07-14-041-14-W-4	706.80	B	GLCC	971.49	983.01	-264.69	-276.21	7222.51	466.54
10-18-041-14-W-4	721.46	C	NSKU	1082.04	1089.66	-360.58	-368.20	8416.73	494.46
10-35-041-14-W-4	706.00	B	BLQZ	962.01	978.01	-256.01	-272.01	6826.05	432.52
05-11-042-01-W-4	627.19	B	LDMR	675.99	680.01	-48.80	-52.82	5032.66	462.73
05-11-042-01-W-4	627.19	B	SPRK	645.51	649.50	-18.32	-22.31	4697.56	459.03
10-13-042-01-W-4	636.39	C	SPRK	647.40	675.44	-11.00	-39.04	4801.68	464.94
06-19-042-01-W-4	632.80	C	SPRK	632.16	637.64	0.64	-4.85	4741.00	481.67
06-19-042-01-W-4	632.46	B	LDMR	662.64	679.40	-30.18	-46.94	4969.23	468.51
06-19-042-01-W-4	632.46	B	WSEC	598.02	608.38	34.44	24.08	4091.49	446.76
10-19-042-01-W-4	633.98	B	SPRK	639.17	644.35	-5.18	-10.36	4791.34	481.14
11-19-042-01-W-4	624.99	B	SPRK	625.14	630.02	-0.15	-5.03	5318.80	540.14
12-19-042-01-W-4	622.98	A	SPRK	615.09	621.79	7.89	1.19	4756.86	489.94
04-20-042-01-W-4	651.05	C	LDUC	710.49	713.54	-59.44	-62.48	5247.10	474.46
10-23-042-01-W-4	636.09	A	CLNY	589.48	598.93	46.60	37.16	4330.06	483.72
02-27-042-01-W-4	636.97	A	CLNY	587.65	598.02	49.32	38.95	4262.49	479.08
02-27-042-01-W-4	636.97	A	CMGS	690.37	701.04	-53.40	-64.07	5185.04	470.35
02-27-042-01-W-4	636.97	B	CMGS	691.90	696.16	-54.92	-59.19	5171.25	470.62
06-27-042-01-W-4	609.60	C	CLNY	557.78	563.88	51.82	45.72	4535.53	511.58
06-27-042-01-W-4	609.60	A	CLNY	570.28	577.29	39.32	32.31	4194.92	463.87
05-28-042-01-W-4	647.70	C	CLNY	596.19	605.94	51.51	41.76	4215.60	476.80
08-29-042-01-W-4	653.49	C	CLNY	604.11	613.56	49.38	39.93	3681.93	420.36
07-31-042-01-W-4	614.29	C	SPRK	608.02	612.01	6.28	2.29	4848.56	499.03
07-31-042-01-W-4	614.29	C	GP	613.01	618.01	1.28	-3.72	4648.61	473.13

Well Location	K.B.	Cife	Tested	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure	Hydraulic Head
	(m)	Quality Code	Formation	From (m)	To (m)	From (m)	To (m)	(kPa)	(m)
08-31-042-01-W-4	615.70	B	LDMR	640.08	643.13	-24.38	-27.43	4951.30	479.33
08-31-042-01-W-4	615.70	A	CLNY	560.83	571.20	54.86	44.50	4268.01	485.19
11-31-042-01-W-4	611.70	B	VKNG	476.01	486.00	135.70	125.70	4725.83	612.93
07-34-042-01-W-4	615.21	A	PLZC	655.99	662.00	-40.78	-46.79	4919.58	458.21
07-34-042-01-W-4	615.21	B	CLNY	559.00	565.01	56.21	50.20	4384.53	500.60
10-34-042-01-W-4	613.11	C	CLNY	560.01	570.01	53.10	43.10	4345.92	491.56
11-35-042-01-W-4	602.89	B	DVNN	643.13	653.19	-40.23	-50.29	4906.48	455.40
14-13-042-02-W-4	656.81	A	SPRK	660.01	665.99	-3.20	-9.17	3828.79	384.51
16-13-042-02-W-4	656.48	B	SPRK	673.00	682.14	-16.52	-25.66	4936.82	482.66
08-19-042-02-W-4	625.91	B	SPRK	633.01	638.01	-7.10	-12.10	4341.09	433.37
08-19-042-02-W-4	625.91	A	CLNY	577.99	580.49	47.91	45.42	4052.88	460.22
11-19-042-02-W-4	621.79	C	SPRK	643.01	647.00	-21.21	-25.21	4051.50	390.21
12-19-042-02-W-4	620.91	A	SPRK	635.81	643.13	-14.90	-22.22	4782.37	469.43
12-19-042-02-W-4	620.91	C	SPRK	625.45	630.94	-4.54	-10.03	4296.27	431.11
13-19-042-02-W-4	624.81	A	GP	631.00	647.00	-6.19	-22.19	4029.44	396.98
13-19-042-02-W-4	624.81	A	SPRK	623.99	629.50	0.82	-4.69	4683.08	475.93
16-19-042-02-W-4	625.08	A	SPRK	632.76	637.03	-7.68	-11.95	4647.23	464.39
16-19-042-02-W-4	625.08	C	SPRK	624.84	630.94	0.24	-5.85	4843.05	491.38
04-20-042-02-W-4	628.71	C	GP	628.04	632.00	0.67	-3.29	4647.23	472.90
04-20-042-02-W-4	628.71	A	SPRK	622.04	626.00	6.68	2.71	4398.32	453.50
09-22-042-02-W-4	664.19	A	SPRK	674.00	678.00	-9.81	-13.81	3661.93	361.86
06-24-042-02-W-4	635.81	A	SPRK	640.08	647.70	-4.27	-11.89	4370.74	437.92
10-24-042-02-W-4	630.57	B	SPRK	628.50	638.25	2.07	-7.68	4602.41	466.83
10-24-042-02-W-4	630.57	A	LDMR	654.10	659.28	-23.53	-28.71	5533.24	538.49
02-25-042-02-W-4	619.41	C	SPRK	618.74	624.84	0.67	-5.43	5199.52	528.19
03-26-042-02-W-4	653.49	C	LDMR	679.00	684.00	-25.51	-30.51	4555.53	436.84
03-26-042-02-W-4	653.49	A	SPRK	660.01	665.99	-6.52	-12.50	2542.19	249.90
05-26-042-02-W-4	658.70	C	LDMR	679.00	684.00	-20.30	-25.30	3958.42	381.12
05-26-042-02-W-4	658.70	B	SPRK	659.01	665.99	-0.30	-7.28	2091.94	209.67
10-26-042-02-W-4	640.38	A	SPRK	649.22	655.32	-8.84	-14.94	4681.71	465.84
10-26-042-02-W-4	640.38	C	SPRK	641.60	646.79	-1.22	-6.40	4819.61	487.99
11-26-042-02-W-4	652.88	B	LDMR	673.00	683.67	-20.12	-30.78	5110.57	496.04
11-26-042-02-W-4	652.88	B	SPRK	653.49	659.59	-0.61	-6.71	2200.88	220.92
11-26-042-02-W-4	652.30	B	SPRK	650.99	655.99	1.31	-3.69	2151.93	218.40

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
13-26-042-02-W-4	652.61	A	SPRK	649.22	658.37	3.38	-5.76	2530.47	257.02
13-26-042-02-W-4	648.71	C	SPRK	640.51	645.99	8.20	2.71	4798.23	495.07
14-26-042-02-W-4	657.09	C	SPRK	648.00	653.49	9.08	3.60	4765.82	492.65
14-26-042-02-W-4	657.09	A	CLNY	603.50	609.60	53.58	47.49	4247.32	483.94
14-26-042-02-W-4	657.09	C	LDMR	676.66	694.94	-19.57	-37.86	4931.99	474.55
01-27-042-02-W-4	659.01	B	LDMR	678.00	686.01	-18.99	-27.01	2885.56	271.45
01-27-042-02-W-4	659.01	A	SPRK	658.49	665.01	0.52	-6.00	3461.98	350.52
04-29-042-02-W-4	628.59	A	CLNY	579.49	586.50	49.10	42.09	4088.74	462.82
11-30-042-02-W-4	619.99	C	SPRK	619.99	629.99	0.00	-10.00	4738.24	478.50
16-31-042-02-W-4	618.41	A	CLNY	576.50	581.01	41.91	37.40	4248.70	473.20
07-33-042-02-W-4	677.20	C	LDMR	694.00	702.99	-16.79	-25.79	4876.14	476.28
07-33-042-02-W-4	677.20	C	SPRK	674.00	681.99	3.20	-4.79	4465.20	454.84
07-33-042-02-W-4	677.20	A	SPRK	668.00	673.49	9.20	3.72	4274.21	442.61
16-33-042-02-W-4	681.81	C	CMGS	716.28	724.20	-34.47	-42.40	5071.96	479.11
03-35-042-02-W-4	649.44	B	LDMR	668.00	675.01	-18.56	-25.57	3914.29	377.35
05-35-042-02-W-4	656.39	C	LDMR	682.75	688.85	-26.37	-32.46	4290.76	408.42
06-35-042-02-W-4	645.60	A	LDMR	669.01	675.01	-23.41	-29.41	6197.92	606.03
06-35-042-02-W-4	645.60	C	SPRK	640.99	645.99	4.60	-0.40	3890.16	399.06
10-36-042-02-W-4	614.20	B	SPRK	615.09	620.57	-0.88	-6.37	4570.01	462.70
10-36-042-02-W-4	614.20	A	CLNY	559.31	574.85	54.89	39.35	4144.58	470.04
10-13-042-03-W-4	624.60	C	DVNN	649.01	653.00	-24.41	-28.41	4878.21	471.37
11-14-042-03-W-4	630.91	B	SPRK	633.98	644.65	-3.08	-13.75	4682.39	469.38
12-24-042-03-W-4	627.49	B	SPRK	637.00	647.00	-9.51	-19.51	4111.49	405.03
13-24-042-03-W-4	626.09	B	SPRK	639.99	648.00	-13.90	-21.92	4368.67	427.88
14-24-042-03-W-4	627.49	A	CLNY	579.00	582.99	48.49	44.50	4194.23	474.48
15-24-042-03-W-4	626.21	A	SPRK	648.00	655.02	-21.79	-28.80	4216.29	404.94
08-25-042-03-W-4	624.81	A	SPRK	635.81	642.52	-11.00	-17.71	4174.92	411.66
13-25-042-03-W-4	628.71	A	MCRN	579.49	588.51	49.23	40.20	4207.33	474.03
14-25-042-03-W-4	633.37	C	REX	641.60	654.10	-8.23	-20.73	4248.70	419.06
14-25-042-03-W-4	633.37	C	SPRK	626.36	640.08	7.01	-6.71	4702.39	479.99
15-26-042-03-W-4	628.50	A	SPRK	637.03	644.65	-8.53	-16.15	3296.50	324.03
10-28-042-03-W-4	642.49	C	CLNY	597.41	608.08	45.08	34.41	4312.13	479.76
10-28-042-03-W-4	642.49	A	CLNY	594.97	604.72	47.52	37.76	4304.55	481.88
05-29-042-03-W-4	643.80	A	LDMR	211.84	213.36	431.96	430.44	5089.89	950.58

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
02-34-042-03-W-4	630.60	A	SPRK	681.99	700.67	-51.39	-70.07	5057.48	455.34
10-36-042-03-W-4	631.91	A	CLNY	574.55	586.74	57.36	45.17	4323.17	492.41
01-05-042-04-W-4	681.20	C	CMGS	746.00	754.01	-64.80	-72.82	4259.04	365.79
01-05-042-04-W-4	681.20	C	SPRK	669.01	676.99	12.19	4.21	3410.96	356.26
07-15-042-04-W-4	655.02	C	NSKU	722.38	752.55	-67.36	-97.54	6061.39	536.06
07-15-042-04-W-4	655.02	B	LDUC	882.40	905.87	-227.38	-250.85	6717.80	446.37
03-27-042-04-W-4	651.21	A	CLNY	610.00	614.99	41.21	36.21	4316.96	479.22
06-28-042-04-W-4	684.79	A	CLNY	639.59	644.99	45.20	39.81	3946.01	445.16
10-31-042-04-W-4	715.06	A	CLNY	672.69	682.75	42.37	32.31	4310.06	477.14
06-32-042-04-W-4	712.90	B	SPRK	724.81	729.69	-11.92	-16.79	4764.45	471.81
06-32-042-04-W-4	712.90	A	CLNY	661.42	675.13	51.48	37.76	4331.44	486.61
11-33-042-04-W-4	677.91	C	CLNY	632.16	643.13	45.75	34.78	4164.58	465.22
12-34-042-04-W-4	686.71	A	CLNY	643.49	649.01	43.22	37.70	4143.90	463.31
16-34-042-04-W-4	671.20	C	CLNY	626.06	633.98	45.14	37.22	5019.56	553.38
10-01-042-05-W-4	672.11	A	LDMR	728.47	734.57	-56.36	-62.45	4964.40	447.17
07-15-042-05-W-4	690.71	C	MCRN	679.09	685.19	11.61	5.52	4523.81	470.18
07-15-042-05-W-4	690.71	C	SPRK	717.50	723.60	-26.79	-32.89	4761.00	455.98
02-03-042-06-W-4	703.60	B	CLNY	705.00	716.01	-1.40	-12.41	5022.32	505.58
06-04-042-06-W-4	711.71	B	LDUC	861.97	869.29	-150.27	-157.58	5864.89	444.53
10-17-042-06-W-4	702.59	C	CLNY	693.72	701.65	8.87	0.94	4510.02	465.11
06-05-042-07-W-4	719.02	B	LDUC	883.92	905.26	-164.90	-186.23	5998.65	436.54
10-08-042-07-W-4	712.59	B	CLNY	733.35	737.62	-20.76	-25.02	5141.60	501.76
06-15-042-07-W-4	740.05	C	LDUC	899.16	932.69	-159.11	-192.63	5922.81	428.50
07-17-042-07-W-4	717.80	A	CLNY	725.42	729.69	-7.62	-11.89	5089.20	509.55
12-12-042-08-W-4	698.51	B	CLNY	717.01	722.01	-18.50	-23.50	4879.59	476.92
04-26-042-08-W-4	720.91	A	NSKU	841.49	845.52	-120.58	-124.60	5524.96	441.18
06-32-042-08-W-4	711.49	B	CLNY	700.00	730.00	11.49	-18.50	5221.58	529.31
11-34-042-08-W-4	696.19	C	BLQZ	772.00	777.00	-75.80	-80.80	5604.26	493.56
06-01-042-09-W-4	719.60	C	SPRK	788.21	794.31	-68.61	-74.71	6448.89	586.39
12-05-042-09-W-4	657.30	B	GLCC	768.00	775.01	-110.70	-117.71	5784.91	476.09
12-05-042-09-W-4	657.30	C	GLCC	760.99	764.50	-103.69	-107.20	5872.47	493.79
10-12-042-09-W-4	690.71	B	GLCC	785.77	793.70	-95.07	-102.99	5588.40	471.22
10-22-042-09-W-4	687.90	A	GLCC	794.00	798.00	-106.10	-110.09	5520.83	455.25
10-24-042-09-W-4	693.69	B	BLQZ	793.09	807.72	-99.40	-114.03	5600.81	464.80

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
07-25-042-09-W-4	695.19	C	SPRK	741.27	778.46	-46.09	-83.27	5424.30	488.82
16-25-042-09-W-4	697.29	A	SPRK	780.01	786.99	-82.72	-89.70	5578.74	483.05
10-30-042-09-W-4	643.74	A	SPRK	670.56	731.52	-26.82	-87.78	5346.38	488.25
10-30-042-09-W-4	643.74	C	LDUC	853.44	891.24	-209.70	-247.50	6596.45	444.51
10-33-042-09-W-4	686.99	C	CLNY	714.51	746.49	-27.52	-59.50	5404.99	508.02
14-36-042-09-W-4	697.11	A	CLNY	710.00	726.00	-12.89	-28.90	5168.49	506.50
06-02-042-10-W-4	653.80	A	GLCC	772.67	787.30	-118.87	-133.50	6388.22	525.67
07-14-042-10-W-4	649.28	C	DTRL	827.01	836.01	-177.73	-186.72	6444.76	475.40
11-15-042-10-W-4	719.63	A	GLCC	840.03	857.40	-120.40	-137.77	6342.02	518.06
11-16-042-10-W-4	680.89	C	ELRL	789.43	859.54	-108.54	-178.64	6417.18	511.22
06-19-042-10-W-4	682.11	C	WBMN	854.96	871.73	-172.85	-189.62	13252.19	1171.03
06-23-042-10-W-4	681.20	B	GLCC	815.04	841.86	-133.84	-160.66	5939.35	458.81
06-28-042-10-W-4	709.00	C	GLCC	851.00	865.02	-142.01	-156.03	5595.98	422.00
07-32-042-10-W-4	706.01	C	PLZC	893.00	902.79	-186.99	-196.78	6351.67	456.24
07-03-042-10-W-4	690.68	B	DTRL	877.21	881.18	-186.54	-190.50	6297.89	454.12
10-15-042-11-W-4	691.29	C	WPGS	1555.70	1645.92	-864.41	-954.63	15275.87	649.24
10-24-042-11-W-4	708.11	A	BLQZ	877.82	886.97	-169.71	-178.86	6205.50	458.93
10-30-042-11-W-4	707.72	A	GLCC	882.09	891.84	-174.38	-184.13	6064.84	439.61
10-32-042-11-W-4	712.90	C	GLCC	859.54	868.07	-146.64	-155.17	6232.39	485.05
10-04-042-12-W-4	693.42	B	ELRL	899.16	925.98	-205.74	-232.56	6637.82	458.18
07-05-042-12-W-4	692.51	C	BLQZ	900.99	914.40	-208.48	-221.89	5535.31	349.64
10-35-042-12-W-4	700.13	B	GLCC	861.97	872.64	-161.85	-172.52	6213.08	466.81
07-10-042-13-W-4	689.46	C	LDUC	1036.32	1043.94	-346.86	-354.48	7929.25	458.43
11-17-042-13-W-4	697.99	A	BLQZ	916.23	938.78	-218.24	-240.79	6641.95	448.24
16-19-042-13-W-4	694.70	C	ELRL	920.01	936.99	-225.31	-242.29	6717.11	451.62
16-23-042-13-W-4	704.51	A	GLCC	915.98	919.00	-211.47	-214.49	4361.78	232.10
06-32-042-13-W-4	691.90	A	BLQZ	911.96	915.62	-220.07	-223.72	6708.84	462.68
06-34-042-13-W-4	709.27	B	NSKU	972.92	975.97	-263.65	-266.70	7719.64	522.54
07-34-042-13-W-4	701.98	A	GLCC	896.11	911.35	-194.13	-209.37	6446.83	456.09
14-04-042-14-W-4	707.29	B	GLCC	943.51	947.50	-236.22	-240.21	6723.31	447.84
07-08-042-14-W-4	707.90	C	GLCC	936.01	946.01	-228.11	-238.11	6910.17	472.01
10-10-042-14-W-4	708.39	A	BLQZ	946.40	952.20	-238.02	-243.81	6701.94	442.96
16-10-042-14-W-4	706.31	A	BLRV	284.99	289.99	421.33	416.33	2347.06	658.32
06-12-042-14-W-4	704.09	C	BLQZ	936.96	943.05	-232.87	-238.96	6591.62	436.70

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-12-042-14-W-4	704.09	C	ELRL	932.08	936.96	-227.99	-232.87	6535.08	436.42
06-13-042-14-W-4	705.00	C	GLCC	937.56	953.41	-232.56	-248.41	6441.31	416.79
10-21-042-14-W-4	707.29	B	CLNY	850.00	869.99	-142.71	-162.70	7114.26	573.24
06-23-042-14-W-4	706.89	A	GLCC	946.01	955.00	-239.12	-248.11	6545.42	424.29
09-23-042-14-W-4	704.61	C	BHL	1404.00	1421.01	-699.39	-716.40	13823.79	702.70
09-23-042-14-W-4	704.61	A	LDUC	1076.00	1096.00	-371.40	-391.39	8113.35	446.50
10-25-042-14-W-4	691.01	A	ELRL	977.01	981.00	-285.99	-289.99	6994.98	425.78
10-25-042-14-W-4	691.01	A	BLRV	281.00	289.01	410.02	402.00	2527.71	663.94
10-33-042-14-W-4	708.05	C	GLCC	955.00	963.99	-246.95	-255.94	6812.26	443.68
07-35-042-14-W-4	692.81	B	GLCC	924.76	929.64	-231.95	-236.83	6841.22	463.69
10-07-043-01-W-4	628.19	C	LDMR	652.27	664.46	-24.08	-36.27	5109.20	491.17
14-11-043-01-W-4	617.01	C	SPRK	607.01	614.99	10.00	2.01	3511.62	364.33
11-18-043-01-W-4	653.80	C	LDMR	685.80	707.14	-32.00	-53.34	4924.41	459.82
01-11-043-02-W-4	620.69	C	LDUC	654.01	660.01	-33.31	-39.32	5402.23	514.93
01-11-043-02-W-4	620.69	A	CLNY	561.01	572.99	59.68	47.70	4348.68	497.43
07-11-043-02-W-4	617.22	C	REX	641.60	654.41	-24.38	-37.19	5186.42	498.44
10-03-043-03-W-4	658.67	C	REX	690.68	694.33	-32.00	-35.66	4624.48	438.05
01-12-043-03-W-4	632.09	A	CLNY	580.00	592.99	52.09	39.11	3996.34	453.39
11-17-043-03-W-4	633.98	B	BLQZ	683.06	687.02	-49.07	-53.04	4846.50	443.49
02-24-043-03-W-4	624.54	C	LDUC	682.75	701.04	-58.22	-76.50	5262.95	469.68
16-34-043-03-W-4	668.12	B	CLNY	620.27	624.84	47.85	43.28	4285.24	482.84
07-02-043-04-W-4	666.41	A	CLNY	614.99	624.99	51.42	41.42	4302.48	485.45
07-05-043-04-W-4	720.24	C	SPRK	721.77	735.18	-1.52	-14.94	3057.24	303.73
02-28-043-04-W-4	694.64	C	BLQZ	758.04	771.75	-63.40	-77.11	4859.60	425.62
07-03-043-08-W-4	696.47	B	LDUC	857.40	860.76	-160.93	-164.29	6034.50	453.15
11-31-043-09-W-4	691.29	B	CLNY	786.38	792.48	-95.10	-101.19	5393.96	452.26
07-32-043-09-W-4	681.23	A	LDUC	856.49	867.16	-175.26	-185.93	6191.71	451.21
07-01-043-11-W-4	716.28	C	LDUC	955.55	964.39	-239.27	-248.11	6577.83	427.52
07-18-043-11-W-4	702.56	B	GLCC	847.95	854.35	-145.39	-151.79	6245.49	488.71
03-18-043-13-W-4	690.49	B	ELRL	946.01	950.00	-255.51	-259.51	6643.33	420.38
06-02-043-14-W-4	692.60	C	GLCC	926.01	932.51	-233.42	-239.91	6922.58	469.72
08-04-043-14-W-4	704.00	C	GLCC	946.01	958.99	-242.01	-255.00	7014.97	467.31
16-08-043-14-W-4	710.18	C	GLCC	965.61	968.35	-255.42	-258.17	6750.21	432.00
10-09-043-14-W-4	699.21	A	GLCC	927.99	940.00	-228.78	-240.79	6741.93	453.16

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
10-09-043-14-W-4	699.21	B	CLNY	798.00	836.01	-98.79	-136.79	6738.48	569.81
13-10-043-14-W-4	693.30	B	GLCC	946.01	957.99	-252.71	-264.69	6782.61	433.40
07-12-043-14-W-4	693.69	C	NSKU	1025.65	1033.27	-331.96	-339.58	7623.11	442.10
15-12-043-14-W-4	693.21	C	BLQZ	939.00	956.01	-245.79	-262.80	6928.79	452.72
06-14-044-01-W-4	617.59	B	WSEC	592.50	599.51	25.09	18.07	4419.70	472.57
09-26-044-01-W-4	#VALUE!	B	SPRK	563.51	566.50	#VALUE!	#VALUE!	4248.01	#VALUE!
01-28-044-03-W-4	658.49	B	WDBD	670.99	675.99	-12.50	-17.50	4503.81	444.58
11-07-044-04-W-4	708.96	A	LDUC	763.52	770.53	-54.56	-61.57	4985.09	450.62
10-17-044-04-W-4	640.69	B	NSKU	640.99	644.99	-0.30	-4.30	4269.38	433.35
10-17-044-04-W-4	640.69	B	NSKU	634.01	644.01	6.68	-3.32	4377.64	448.37
12-17-044-04-W-4	647.61	C	NSKU	638.74	652.00	8.87	-4.39	4570.01	468.57
10-20-044-04-W-4	656.84	C	LDUC	695.55	708.96	-38.71	-52.12	4771.34	441.46
05-26-044-04-W-4	662.39	B	LDMR	653.00	658.00	9.39	4.39	4183.20	433.75
10-30-044-04-W-4	651.30	A	CLNY	580.00	597.01	71.29	54.28	3723.30	442.72
06-34-044-04-W-4	711.59	A	LDMR	716.01	739.99	-4.42	-28.41	4429.35	435.56
06-34-044-04-W-4	711.59	B	CLNY	647.00	656.51	64.59	55.08	4121.83	480.43
01-02-044-05-W-4	683.67	C	WSEC	657.76	659.89	25.91	23.77	4130.11	446.28
11-22-044-05-W-4	657.39	C	CLNY	590.00	597.01	67.39	60.38	3833.62	455.07
10-29-044-10-W-4	673.91	C	LDUC	853.44	876.00	-179.53	-202.08	6274.45	449.45
10-24-044-11-W-4	666.29	B	LDUC	853.44	868.68	-187.15	-202.39	6329.61	451.11
10-28-044-11-W-4	695.86	A	NSKU	836.68	873.25	-140.82	-177.39	5805.59	433.30
13-02-044-13-W-4	671.69	A	GLCC	874.99	879.99	-203.30	-208.30	6309.61	438.04
13-02-044-13-W-4	671.69	C	GLCC	837.99	842.99	-166.30	-171.30	6632.30	507.97
13-02-044-13-W-4	671.69	A	CLNY	767.00	772.00	-95.31	-100.31	6473.72	562.77
13-28-044-13-W-4	677.69	B	BLQZ	889.99	897.00	-212.29	-219.30	6286.86	425.72
13-14-044-15-W-4	701.10	C	GLCC	940.00	944.51	-238.90	-243.41	6655.05	437.93
13-14-044-15-W-4	701.10	B	BLRV	256.00	264.99	445.10	436.11	2326.37	677.99
10-32-045-01-W-4	630.94	C	BHL	937.26	957.68	-306.32	-326.75	9122.09	614.29
10-32-045-01-W-4	630.94	B	WPGS	1193.29	1201.22	-562.36	-570.28	11252.64	581.91
10-32-045-01-W-4	630.94	B	RDRV	1284.73	1295.40	-653.80	-664.46	12278.62	593.79
07-07-045-03-W-4	748.28	D	LDUC	794.61	798.58	-46.33	-50.29	5033.35	465.30
06-10-045-03-W-4	685.80	B	LDUC	701.65	711.71	-15.85	-25.91	4592.76	447.77
10-30-045-03-W-4	656.23	C	LDUC	685.80	698.30	-29.57	-42.06	4881.66	462.31
07-14-045-04-W-4	705.00	B	LDUC	722.68	738.23	-17.68	-33.22	4702.39	454.38

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11-18-045-04-W-4	672.79	C	LDMR	684.00	701.01	-11.22	-28.22	4700.32	459.90
16-20-045-04-W-4	698.60	B	LDUC	714.76	724.81	-16.15	-26.21	4578.28	445.99
02-25-045-04-W-4	685.31	B	SPRK	697.99	704.51	-12.68	-19.20	4407.28	433.78
02-25-045-04-W-4	685.31	A	CLNY	610.51	614.51	74.80	70.81	3119.99	391.17
13-13-045-06-W-4	659.28	C	LDUC	696.47	733.04	-37.19	-73.76	4964.40	451.10
08-15-045-06-W-4	683.61	C	CLNY	608.02	623.01	75.59	60.59	3804.66	456.32
10-10-045-07-W-4	676.69	A	SPRK	657.00	669.01	19.69	7.68	4534.84	476.42
11-05-045-08-W-4	698.81	C	GLCC	744.99	752.00	-46.18	-53.19	4838.22	444.01
11-05-045-08-W-4	698.81	C	GLCC	757.00	762.00	-58.19	-63.19	4934.06	442.79
04-08-045-08-W-4	691.50	B	GLCC	752.00	756.00	-60.50	-64.50	4703.77	417.48
10-18-045-08-W-4	659.10	B	VKNG	592.99	634.01	66.11	25.09	4762.38	531.55
12-25-045-08-W-4	680.59	C	CLNY	639.01	643.01	41.57	37.58	4303.17	478.68
12-25-045-08-W-4	680.59	C	CLNY	643.01	647.00	37.58	33.59	4392.12	483.76
12-25-045-08-W-4	680.59	C	VKNG	634.99	639.01	45.60	41.57	4299.03	482.26
14-27-045-08-W-4	711.19	A	GLCC	778.49	782.51	-67.30	-71.32	5376.03	479.26
14-27-045-08-W-4	711.19	B	SPRK	681.99	701.98	29.20	9.20	4787.89	507.76
07-32-045-08-W-4	722.07	C	NSKU	778.76	782.73	-56.69	-60.66	4936.13	445.01
16-26-045-09-W-4	681.20	A	BLQZ	717.50	721.49	-36.30	-40.29	4170.10	387.22
16-26-045-09-W-4	681.20	C	GLCC	712.01	716.01	-30.82	-34.81	5442.91	522.59
10-22-045-10-W-4	684.89	A	LDUC	824.18	827.53	-139.29	-142.65	5833.17	454.25
10-29-045-10-W-4	718.41	B	GLCC	763.83	777.24	-45.42	-58.83	5481.53	507.22
03-35-045-10-W-4	707.41	C	CLNY	696.99	701.01	10.42	6.40	5109.20	529.76
03-35-045-10-W-4	707.41	B	GLCC	741.49	744.99	-34.08	-37.58	5367.07	511.83
03-35-045-10-W-4	707.41	B	CLNY	708.51	712.99	-1.10	-5.58	5367.76	544.39
02-15-045-12-W-4	712.71	C	ELRL	804.00	822.02	-91.29	-109.30	5687.69	480.08
16-13-045-15-W-4	693.21	C	GLCC	942.99	951.01	-249.78	-257.80	6777.79	437.82
12-12-046-02-W-4	640.60	B	SPRK	579.00	582.99	61.60	57.61	4307.31	499.12
08-24-046-02-W-4	643.40	A	SPRK	586.01	592.01	57.39	51.39	4058.40	468.51
08-24-046-02-W-4	643.40	A	CLNY	540.50	546.51	102.90	96.90	3635.73	470.89
08-28-046-02-W-4	642.91	B	CLNY	554.00	564.00	88.91	78.91	3763.29	467.92
08-28-046-02-W-4	642.91	B	CLNY	545.01	555.01	97.90	87.90	3292.36	428.86
11-30-046-02-W-4	636.61	C	CLNY	540.01	547.30	96.59	89.31	3728.13	473.37
01-15-046-03-W-4	665.07	C	BLQZ	716.28	725.42	-51.21	-60.35	5005.77	455.01
13-27-046-05-W-4	721.10	B	LDMR	705.00	711.01	16.09	10.09	3119.99	331.46

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
13-27-046-05-W-4	721.10	B	GP	675.99	681.99	45.11	39.11	4043.92	454.75
07-33-046-05-W-4	708.39	A	LDMR	691.99	702.99	16.40	5.39	4281.80	447.81
10-33-046-05-W-4	707.11	C	LDMR	690.01	697.99	17.10	9.11	1943.01	211.37
10-33-046-05-W-4	707.11	C	CLNY	614.51	622.49	92.60	84.61	3227.55	417.95
11-13-046-07-W-4	685.80	C	LDMR	690.37	701.04	-4.57	-15.24	4516.23	450.93
16-08-046-09-W-4	711.89	A	CLNY	680.01	684.00	31.88	27.89	4849.94	524.78
10-08-046-12-W-4	723.81	A	GLCC	852.01	858.99	-128.20	-135.18	5165.73	395.43
09-20-046-12-W-4	715.00	A	SPRK	812.51	816.50	-97.51	-101.50	5855.92	498.04
09-20-046-12-W-4	715.00	B	GLCC	853.01	857.01	-138.01	-142.01	5150.57	385.56
10-28-046-12-W-4	729.39	B	GLCC	826.80	832.90	-97.41	-103.51	5604.95	471.47
10-24-046-13-W-4	716.89	B	GLCC	864.11	873.25	-147.22	-156.36	5936.60	453.98
06-35-046-15-W-4	710.55	C	DNVG	1213.01	1219.99	-502.46	-509.44	13291.49	850.32
03-10-047-04-W-4	657.45	C	BHL	972.31	985.72	-314.86	-328.27	9149.67	612.08
03-10-047-04-W-4	657.45	C	KEGR	1344.17	1362.46	-686.71	-705.00	13007.42	631.43
03-10-047-04-W-4	657.45	C	LDUC	716.28	734.57	-58.83	-77.11	5441.53	487.29
12-20-047-05-W-4	648.31	B	CLNY	558.00	561.99	90.31	86.32	3704.68	466.34
10-06-047-06-W-4	686.10	C	CLNY	592.50	598.51	93.60	87.60	3626.77	460.68
01-27-047-07-W-4	680.59	B	CLNY	597.01	602.01	83.58	78.58	4388.67	528.90
15-05-047-08-W-4	669.19	B	CLNY	575.01	624.50	94.18	44.68	5387.75	619.20
06-08-047-08-W-4	673.00	A	CLNY	616.00	626.06	57.00	46.94	4598.97	521.25
15-10-047-10-W-4	702.11	A	SPRK	734.99	746.00	-32.89	-43.89	5259.51	498.29
15-10-047-10-W-4	702.11	B	LDMR	748.01	759.99	-45.90	-57.88	5140.22	472.62
15-10-047-10-W-4	702.11	B	SPRK	738.50	743.01	-36.39	-40.90	5189.87	490.93
11-20-048-06-W-4	705.31	B	CLNY	607.77	611.43	97.54	93.88	3928.77	496.60
06-13-048-07-W-4	685.19	C	CLNY	594.97	598.63	90.22	86.56	4035.64	500.19
01-17-048-07-W-4	695.40	A	CLNY	609.51	616.49	85.89	78.91	4223.88	513.41
06-23-048-07-W-4	680.31	A	SPRK	622.49	626.49	57.82	53.83	4271.45	491.69
02-18-048-08-W-4	664.77	C	GLCC	684.58	691.29	-19.81	-26.52	5249.16	512.46
02-26-048-09-W-4	684.28	B	CLNY	644.96	650.44	39.32	33.83	4699.63	516.13
14-27-048-09-W-4	686.50	B	CLNY	639.99	649.99	46.51	36.52	4669.29	517.97
14-27-048-09-W-4	686.50	B	CLNY	634.01	639.01	52.49	47.49	4754.79	535.17
02-29-048-11-W-4	726.49	C	SPRK	743.99	748.01	-17.50	-21.52	5393.96	530.90
02-29-048-11-W-4	726.49	B	CLNY	702.99	709.00	23.50	17.50	5226.41	553.80
15-05-048-13-W-4	690.31	B	GLCC	801.01	816.01	-110.70	-125.70	5271.92	419.75

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
15-05-048-13-W-4	690.31	C	GLCC	816.01	820.00	-125.70	-129.69	5042.31	386.83
07-09-048-13-W-4	694.94	B	LDMR	777.24	807.72	-82.30	-112.78	5844.20	498.81
10-10-048-13-W-4	697.38	B	LDMR	780.29	787.91	-82.91	-90.53	5996.58	525.18
10-10-048-13-W-4	697.38	B	GLCC	792.48	807.72	-95.10	-110.34	5619.43	470.69
06-14-048-13-W-4	705.61	B	GLCC	809.24	818.08	-103.63	-112.47	5260.89	428.77
06-14-048-13-W-4	705.61	B	LDMR	778.46	783.95	-72.85	-78.33	5637.35	499.65
07-15-048-13-W-4	698.91	B	GLCC	786.99	793.00	-88.09	-94.09	5391.89	459.10
11-16-048-13-W-4	696.77	C	SPRK	696.77	778.76	0.00	-81.99	5038.87	473.17
15-18-048-13-W-4	689.61	A	BLQZ	809.00	814.00	-119.39	-124.39	5204.35	409.17
11-21-048-13-W-4	697.99	C	GLCC	788.21	808.94	-90.22	-110.95	5643.56	475.29
11-21-048-13-W-4	697.99	C	CMGS	768.10	808.33	-70.10	-110.34	6517.15	574.79
07-23-048-13-W-4	705.49	B	DTRL	857.01	864.99	-151.52	-159.50	5553.92	411.22
07-23-048-13-W-4	705.49	C	CLNY	689.00	733.01	16.49	-27.52	4878.90	492.33
10-32-048-13-W-4	696.16	C	BLQZ	817.47	820.52	-121.31	-124.36	5309.15	418.92
11-33-048-13-W-4	697.99	C	GLCC	819.00	826.01	-121.01	-128.02	5269.85	413.23
11-33-048-13-W-4	697.99	C	SPRK	751.00	754.99	-53.00	-57.00	6142.07	571.74
10-03-048-14-W-4	692.81	B	GLCC	792.48	843.69	-99.67	-150.88	5267.78	412.26
07-04-048-14-W-4	693.69	C	BLQZ	874.99	892.00	-181.30	-198.30	5740.09	395.92
07-04-048-14-W-4	693.69	C	LDUC	921.99	930.01	-228.30	-236.31	6290.31	409.56
11-05-048-14-W-4	696.47	C	SPRK	702.56	816.86	-6.10	-120.40	7037.73	654.89
11-06-048-14-W-4	697.69	B	BLQZ	871.12	878.74	-173.43	-181.05	5899.36	424.73
11-06-048-14-W-4	697.69	B	GLCC	863.80	869.90	-166.12	-172.21	5748.36	417.40
04-11-048-14-W-4	690.31	A	GLCC	827.01	843.99	-136.70	-153.68	5293.29	394.94
11-12-048-14-W-4	688.85	C	BLQZ	853.44	878.13	-164.59	-189.28	5657.35	400.34
13-18-048-14-W-4	693.91	B	GLCC	898.00	906.99	-204.09	-213.09	6048.98	408.65
15-23-049-10-W-4	709.70	C	CLNY	673.49	686.01	36.21	23.68	5023.01	542.50
16-06-49-11-W-4	670.01	A	WNTBN	777.51	790.99	-107.50	-120.98	4463.13	341.18
06-21-049-12-W-4	700.64	B	BLQZ	770.99	775.01	-70.35	-74.37	4501.06	386.93
06-21-049-12-W-4	700.64	C	BLQZ	763.01	767.00	-62.36	-66.35	5101.61	456.21
11-05-049-13-W-4	693.72	C	ELRL	781.81	827.23	-88.09	-133.50	5748.36	475.77
11-05-049-13-W-4	693.72	C	BLQZ	744.32	763.22	-50.60	-69.49	6459.24	599.06
10-07-049-13-W-4	690.07	B	GLCC	787.60	814.73	-97.54	-124.66	5054.04	404.62
10-12-049-13-W-4	691.41	C	BLQZ	736.91	785.99	-45.51	-94.58	5078.17	448.14
11-34-049-13-W-4	685.50	C	ELRL	774.19	795.53	-88.70	-110.03	4924.41	403.13

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
06-12-049-14-W-4	685.50	C	BLQZ	812.60	829.06	-127.10	-143.56	5253.99	400.79
09-14-049-14-W-4	683.97	B	NSKU	850.39	862.89	-166.42	-178.92	5690.44	407.99
06-18-049-14-W-4	677.27	A	NSKU	857.10	874.47	-179.83	-197.21	5874.54	410.92
06-18-049-14-W-4	677.27	C	GLCC	825.70	836.07	-148.44	-158.80	5804.21	438.65
07-19-049-14-W-4	676.11	C	GLCC	819.00	833.99	-142.89	-157.89	6262.04	488.60
10-24-049-14-W-4	687.63	C	CLNY	710.18	713.84	-22.56	-26.21	6275.14	615.94
10-24-049-14-W-4	687.63	C	GLCC	809.24	854.05	-121.62	-166.42	5251.23	391.82
07-25-049-14-W-4	686.41	C	GLCC	821.13	827.23	-134.72	-140.82	5302.26	403.28
10-29-049-14-W-4	674.83	B	DVNN	864.72	873.86	-189.89	-199.03	5591.16	376.06
10-29-049-14-W-4	674.83	B	GLCC	783.34	813.82	-108.51	-138.99	5841.44	472.32
14-31-050-03-W-4	659.80	C	CLNY	531.51	539.01	128.29	120.79	3542.65	486.04
06-36-050-07-W-4	631.30	C	CLNY	514.99	519.01	116.31	112.29	3537.14	475.23
11-10-050-08-W-4	637.09	A	GLCC	629.50	633.50	7.59	3.60	4510.71	465.87
11-10-050-08-W-4	637.09	A	CLNY	551.99	556.99	85.10	80.10	4093.56	500.31
05-29-050-09-W-4	649.59	A	ELRL	692.99	696.99	-43.40	-47.40	5037.49	468.63
10-27-050-10-W-4	688.79	B	LDUC	754.08	757.12	-65.29	-68.34	5235.37	467.41
07-31-050-10-W-4	683.67	B	BHL	1045.46	1054.91	-361.80	-371.25	8811.81	532.64
16-36-050-10-W-4	679.00	A	CLNY	598.99	605.49	80.01	73.52	4188.71	504.18
10-09-050-11-W-4	664.77	C	BHL	1061.92	1072.90	-397.15	-408.13	9185.52	534.66
08-11-050-11-W-4	658.40	C	IRTN	702.99	711.01	-44.59	-52.61	3001.39	257.66
08-11-050-11-W-4	658.40	C	GLCC	675.99	689.00	-17.59	-30.60	5302.26	516.95
08-11-050-11-W-4	658.40	A	SPRK	634.01	640.99	24.38	17.40	5000.94	531.19
09-21-050-11-W-4	0.00	C	CMRS	528.01	571.99	-528.01	-571.99	5091.27	-30.48
01-25-050-11-W-4	662.09	B	CLNY	639.50	643.49	22.59	18.59	4793.40	509.71
01-25-050-11-W-4	662.09	C	SPRK	666.99	669.49	-4.91	-7.41	5050.59	509.21
01-25-050-11-W-4	662.09	C	CLNY	648.00	650.50	14.08	11.58	4798.23	502.45
01-25-050-11-W-4	662.09	B	SPRK	670.01	673.00	-7.92	-10.91	4970.61	497.79
04-29-050-11-W-4	0.00	B	IRTN	600.00	633.01	-600.00	-633.01	5029.90	-103.25
14-33-050-11-W-4	0.00	C	CMRS	566.99	600.00	-566.99	-600.00	4512.09	-123.08
04-16-050-13-W-4	687.20	C	WBMN	780.01	784.01	-92.81	-96.80	5085.75	424.15
04-16-050-13-W-4	687.20	A	CLNY	683.00	686.99	4.21	0.21	7637.59	781.56
13-20-050-13-W-4	683.57	A	NSKU	807.99	814.49	-124.42	-130.91	4550.70	336.69
10-21-050-13-W-4	687.32	A	NSKU	804.06	808.33	-116.74	-121.01	4978.19	389.11
09-13-050-14-W-4	681.01	B	GLCC	804.00	807.99	-122.99	-126.98	4733.42	358.02

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-28-050-14-W-4	671.47	C	SPRK	731.52	740.66	-60.05	-69.19	6411.66	589.63
06-32-050-14-W-4	664.49	B	NSKU	815.00	832.99	-150.51	-168.49	4924.41	342.99
06-32-050-14-W-4	664.49	A	BLOZ	800.01	803.00	-135.51	-138.50	5430.50	417.13
12-24-050-15-W-4	662.00	B	CLNY	690.01	700.00	-28.01	-38.01	6147.58	594.29
04-16-051-03-W-4	652.61	C	FEX	587.99	595.00	64.62	57.61	4261.80	495.99
04-16-051-03-W-4	652.61	A	CLNY	512.00	519.01	140.60	133.59	3289.60	472.77
05-25-051-04-W-4	639.90	C	SPRK	542.00	560.01	97.90	79.89	3531.62	449.26
10-15-051-06-W-4	629.11	A	LDUC	643.13	664.46	-14.02	-35.36	4585.18	443.19
13-36-051-07-W-4	629.11	B	BHL	938.78	970.18	-309.68	-341.07	8045.78	495.62
12-13-051-08-W-4	652.27	C	BHL	972.31	999.74	-320.04	-347.47	8754.58	559.57
11-26-051-08-W-4	657.39	B	SPRK	612.01	622.01	45.38	35.39	4486.58	498.20
14-35-051-08-W-4	677.60	C	SPRK	615.51	619.99	62.09	57.61	3310.29	397.63
14-35-051-08-W-4	677.60	C	CLNY	567.99	581.99	109.61	95.62	3992.89	510.05
05-12-051-09-W-4	665.41	C	SPRK	619.99	623.99	45.42	41.42	4027.37	454.37
09-03-051-10-W-4	688.39	A	BLOZ	749.99	759.01	-61.60	-70.62	5282.26	472.89
11-20-051-10-W-4	682.69	B	CLNY	618.01	628.01	64.68	54.68	4615.51	530.65
11-28-051-10-W-4	681.50	B	BLOZ	768.00	775.01	-86.50	-93.51	5422.23	463.28
11-28-051-10-W-4	681.50	C	SPRK	638.01	644.99	43.49	36.52	4953.37	545.45
11-28-051-10-W-4	681.50	B	CLNY	613.01	619.99	68.49	61.51	4625.17	536.95
13-11-051-11-W-4	677.30	C	SPRK	631.00	637.00	46.30	40.29	4852.70	538.47
08-36-051-11-W-4	697.20	C	GLCC	728.01	743.99	-30.82	-46.79	5484.97	520.89
03-05-051-12-W-4	703.20	C	CMRS	790.01	795.50	-86.81	-92.29	4310.06	350.25
01-19-051-12-W-4	686.41	B	CLNY	600.00	665.01	86.41	21.40	4741.00	537.68
01-19-051-12-W-4	686.41	A	BLOZ	754.01	767.00	-67.60	-80.59	4503.12	385.41
11-26-051-12-W-4	685.89	A	DTRL	775.50	779.50	-89.61	-93.60	5560.13	475.75
12-01-051-13-W-4	688.51	A	NSKU	795.01	820.00	-106.50	-131.49	4529.33	343.18
12-01-051-13-W-4	688.51	A	SPRK	695.49	707.50	-6.98	-18.99	5623.56	560.85
12-01-051-13-W-4	688.51	B	CLNY	660.01	665.01	28.50	23.50	5436.02	580.70
11-06-051-13-W-4	677.30	A	NSKU	805.28	811.68	-127.99	-134.39	5081.62	387.35
06-15-051-13-W-4	689.79	B	NSKU	774.80	782.42	-85.01	-92.63	4793.40	400.30
11-19-051-13-W-4	686.07	C	ELRL	758.95	761.39	-72.88	-75.32	4818.92	417.63
11-19-051-13-W-4	686.07	C	NSKU	762.91	765.96	-76.84	-79.89	4810.64	412.52
05-23-051-13-W-4	724.69	A	GLCC	764.99	795.01	-40.29	-70.32	4231.46	376.48
10-29-051-13-W-4	685.80	A	LDUC	807.72	817.47	-121.92	-131.67	5371.21	421.29

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-34-051-13-W-4	668.79	C	NSKU	760.99	764.50	-92.20	-95.71	4147.34	329.24
15-04-051-14-W-4	670.50	A	GLCC	770.99	778.00	-100.49	-107.50	4961.64	402.29
15-04-051-14-W-4	670.50	A	CMGS	762.00	769.01	-91.50	-98.51	4719.63	386.59
15-04-051-14-W-4	670.50	A	CMGS	753.01	759.99	-82.51	-89.49	5027.83	427.04
11-08-051-14-W-4	652.27	A	NSKU	815.34	826.62	-163.07	-174.35	5288.47	370.93
08-19-051-14-W-4	648.61	A	GLCC	756.00	759.99	-107.38	-111.37	4655.50	365.67
08-19-051-14-W-4	648.61	C	CLNY	655.50	659.50	-6.89	-10.88	5564.27	558.90
10-24-051-14-W-4	680.31	C	REX	744.93	752.25	-64.62	-71.93	5070.58	449.13
10-24-051-14-W-4	680.31	C	CLNY	659.59	666.90	20.73	13.41	4825.12	509.43
10-26-051-14-W-4	675.74	C	GLCC	743.71	758.95	-67.97	-83.21	4998.19	434.43
11-33-051-14-W-4	646.18	A	NSKU	784.56	788.82	-138.38	-142.65	5233.31	393.50
14-29-052-02-W-4	636.73	B	BHL	769.32	795.53	-132.59	-158.80	6158.61	482.74
14-29-052-02-W-4	636.73	B	BHL	795.53	826.01	-158.80	-189.28	6481.30	487.32
14-29-052-02-W-4	636.73	C	ODVC	1132.33	1148.79	-495.60	-512.06	10411.45	558.56
14-29-052-02-W-4	636.73	C	UCMB	1148.79	1159.76	-512.06	-523.04	10466.61	550.47
11-11-052-03-W-4	612.89	A	CLNY	451.01	456.99	161.88	155.91	3053.11	470.43
03-15-052-06-W-4	639.81	C	CLNY	498.01	506.00	141.79	133.81	3386.82	483.39
06-07-052-08-W-4	681.23	B	MCRN	581.86	589.79	99.36	91.44	4157.00	519.59
15-20-052-08-W-4	693.08	A	CLNY	580.00	584.00	113.08	109.09	3810.87	499.95
15-20-052-08-W-4	693.08	C	CLNY	593.99	597.99	99.09	95.10	4072.19	512.62
15-20-052-08-W-4	693.08	B	CLNY	587.99	592.01	105.10	101.07	3867.41	497.72
13-23-052-08-W-4	690.01	A	GLCC	681.99	686.01	8.02	3.99	4347.30	449.61
13-23-052-08-W-4	690.01	B	SPRK	621.00	624.99	69.01	65.01	3966.69	471.77
04-26-052-08-W-4	685.80	C	GLCC	679.00	683.00	6.80	2.80	4394.87	453.26
01-12-052-09-W-4	687.11	B	CLNY	595.00	598.99	92.11	88.12	4441.07	543.28
01-12-052-09-W-4	687.11	C	CLNY	590.00	593.99	97.11	93.12	4251.46	528.93
11-15-052-09-W-4	686.99	C	VKNG	534.98	560.01	152.00	126.98	4321.79	580.49
11-15-052-09-W-4	686.99	C	GLCC	699.00	702.99	-12.01	-16.00	4627.92	458.23
11-15-052-09-W-4	686.99	A	SPRK	628.01	632.00	58.98	54.99	4236.29	489.26
11-15-052-09-W-4	686.99	A	CLNY	585.00	589.00	101.99	97.99	2942.10	400.20
13-26-052-09-W-4	685.80	B	CLNY	585.00	590.00	100.80	95.80	2409.11	344.13
10-28-052-12-W-4	683.97	A	CMRS	730.91	741.58	-46.94	-57.61	4159.06	372.12
11-06-052-03-W-4	680.31	A	BLQZ	752.25	757.12	-71.93	-76.81	4026.68	336.51
11-06-052-13-W-4	680.31	C	SPRK	704.09	708.96	-23.77	-28.65	5358.79	520.60

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
13-08-052-13-W-4	672.51	B	GLCC	720.00	751.51	-47.49	-79.00	4373.50	383.03
13-08-052-13-W-4	672.51	A	CLNY	636.00	649.99	36.52	22.52	5478.77	588.58
13-08-052-13-W-4	672.51	A	CLNY	669.01	675.50	3.51	-2.99	5516.00	563.12
05-16-052-13-W-4	659.31	A	CMRS	758.77	783.49	-99.46	-124.18	4525.19	349.94
01-18-052-13-W-4	672.69	A	GLCC	734.99	744.99	-62.30	-72.30	3987.38	339.58
01-18-052-13-W-4	672.69	A	CLNY	634.99	644.99	37.70	27.71	5477.29	591.62
01-18-052-13-W-4	672.69	C	LDMR	696.01	701.01	-23.32	-28.32	4714.11	455.22
01-18-052-13-W-4	672.69	C	SPRK	686.50	691.50	-13.81	-18.81	4990.60	492.94
06-19-052-13-W-4	667.79	A	GLCC	731.00	739.51	-63.22	-71.72	4334.89	374.87
06-19-052-13-W-4	667.79	A	GLCC	720.00	725.00	-52.21	-57.21	4751.34	430.12
06-19-052-13-W-4	667.79	A	CMGS	710.00	715.00	-42.21	-47.21	5184.35	484.30
06-19-052-13-W-4	667.79	B	SPRK	670.99	675.99	-3.20	-8.20	5390.51	544.35
06-19-052-13-W-4	667.79	C	CLNY	626.00	631.00	41.79	36.79	5371.89	587.44
10-25-052-13-W-4	673.61	B	IRTN	734.57	762.30	-60.96	-88.70	4674.81	402.19
16-29-052-13-W-4	673.49	A	NSKU	752.00	756.00	-78.52	-82.51	4026.68	330.37
11-30-052-13-W-4	650.41	C	IRTN	751.00	759.99	-100.58	-109.58	4372.81	341.13
07-25-052-14-W-4	645.51	A	GLCC	712.01	716.01	-66.51	-70.50	3924.63	331.97
07-25-052-14-W-4	645.51	A	CMGS	706.01	710.00	-60.50	-64.50	4849.94	432.39
10-04-053-01-W-4	666.60	A	CLNY	493.01	501.00	173.58	165.60	2899.35	465.44
10-04-053-01-W-4	666.60	A	CLNY	478.99	487.01	187.60	179.59	2830.40	472.41
06-08-053-03-W-4	590.09	C	CMGS	551.99	556.87	38.10	33.22	4216.98	465.97
06-08-053-03-W-4	590.09	C	CMGS	546.99	551.99	43.10	38.10	4239.05	473.16
06-08-053-03-W-4	590.09	B	SPRK	500.51	508.99	89.58	81.11	3680.55	460.91
06-08-053-03-W-4	590.09	B	CLNY	434.49	443.00	155.60	147.10	3132.40	470.98
06-08-053-03-W-4	590.09	B	CLNY	422.51	430.50	167.58	159.59	2961.40	465.77
06-24-053-05-W-4	627.28	C	BHL	805.28	816.86	-178.00	-189.59	6381.32	467.36
08-22-053-06-W-4	635.60	A	WSEC	525.99	535.99	109.61	99.61	3553.68	467.23
08-22-053-06-W-4	635.05	C	CLNY	483.99	493.99	151.06	141.06	3264.78	479.20
06-24-053-06-W-4	634.90	B	LDUC	644.99	654.01	-10.09	-19.11	4714.45	469.53
06-30-053-08-W-4	674.40	B	SPRK	581.99	597.01	92.42	77.39	3951.52	488.12
10-35-053-09-W-4	654.31	A	CLNY	534.01	538.00	120.30	116.31	2939.34	418.24
10-35-053-09-W-4	654.31	A	CLNY	529.99	534.01	124.33	120.30	3001.39	428.58
06-12-053-10-W-4	625.78	C	SPRK	558.00	565.01	67.79	60.78	4456.93	519.07
06-32-053-10-W-4	609.20	A	CLNY	508.01	513.01	101.19	96.19	4239.74	531.32

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
14-31-053-11-W-4	692.20	A	CLNY	613.01	617.01	79.19	75.19	3740.54	458.88
07-05-053-12-W-4	680.59	C	NSKU	725.42	736.09	-44.84	-55.50	5282.26	488.84
16-36-053-12-W-4	680.80	A	CLNY	608.02	612.01	72.79	68.79	3645.39	442.77
10-29-053-13-W-4	656.78	A	DTRL	745.24	766.57	-88.45	-109.79	4974.05	408.44
13-14-053-14-W-4	633.40	B	GLCC	659.01	686.01	-25.60	-52.61	4012.20	370.30
13-14-053-14-W-4	633.40	C	MCRN	614.99	633.01	18.41	0.40	5280.88	548.27
11-20-053-14-W-4	628.19	A	CMRS	726.64	754.38	-98.45	-126.19	4826.50	380.18
06-31-053-14-W-4	629.11	C	CMRS	734.57	738.84	-105.46	-109.73	4854.08	387.72
08-01-053-15-W-4	634.81	A	CMRS	765.99	769.99	-131.19	-135.18	4738.93	350.38
10-01-053-15-W-4	633.07	B	CMRS	758.95	807.72	-125.88	-174.65	5233.31	383.74
11-06-054-01-W-4	584.30	A	BHL	687.32	705.61	-103.02	-121.31	5604.95	459.77
11-34-054-03-W-4	568.09	B	CLNY	378.99	386.00	189.10	182.09	3050.35	496.85
06-19-054-04-W-4	613.26	A	LDUC	591.31	603.50	21.95	9.75	4274.90	452.06
10-16-054-05-W-4	638.10	B	CMGS	592.01	596.01	46.09	42.09	4099.77	462.43
10-16-054-05-W-4	638.10	C	CMGS	584.00	587.99	54.10	50.11	4126.66	473.19
10-16-054-05-W-4	638.10	B	CLNY	461.99	466.01	176.11	172.09	3139.98	494.51
10-18-054-05-W-4	636.30	C	SPRK	518.01	522.00	118.29	114.30	3684.00	492.21
10-18-054-05-W-4	636.30	A	CLNY	464.00	467.99	172.30	168.31	3027.59	479.25
10-20-054-05-W-4	619.90	A	CMGS	571.01	575.01	48.89	44.90	3890.85	443.92
10-20-054-05-W-4	619.90	B	WSEC	466.01	470.00	153.89	149.90	3193.07	477.72
10-21-054-05-W-4	621.21	A	CLNY	444.00	448.00	177.21	173.22	3136.54	495.27
06-29-054-05-W-4	622.10	B	CMGS	569.37	574.24	52.73	47.85	3928.08	451.12
10-30-054-05-W-4	637.09	C	CMGS	585.00	590.00	52.09	47.09	3952.21	452.88
10-10-054-06-W-4	644.04	C	BLOZ	607.16	611.43	36.88	32.61	4236.29	467.02
10-10-054-06-W-4	644.04	B	CMGS	615.70	624.84	28.35	19.20	4260.42	458.51
07-24-054-06-W-4	655.99	B	CLNY	534.01	536.51	121.98	119.48	3539.20	481.87
14-36-054-06-W-4	655.20	A	CMGS	593.99	597.01	61.20	58.19	3938.42	461.58
06-13-054-07-W-4	671.47	B	CMGS	634.59	639.47	36.88	32.00	4248.01	467.91
10-04-054-08-W-4	639.71	B	CLNY	514.01	522.00	125.70	117.71	3355.11	464.06
10-04-054-08-W-4	639.71	B	CLNY	506.00	514.01	133.72	125.70	3162.74	452.44
02-06-054-08-W-4	629.99	A	SPRK	565.01	570.01	64.98	59.98	4129.42	483.85
02-06-054-08-W-4	629.99	A	CLNY	512.00	517.00	117.99	112.99	2608.38	381.65
06-11-054-08-W-4	653.00	B	CLNY	517.00	523.01	136.00	130.00	3344.08	474.23
06-11-054-08-W-4	653.00	C	CLNY	523.01	539.01	130.00	114.00	3870.85	516.98

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
13-21-054-08-W-4	605.49	C	CLNY	477.99	482.01	127.50	123.47	3244.10	456.52
13-21-054-08-W-4	605.49	B	CLNY	473.51	477.50	131.98	127.99	3438.54	480.85
01-06-054-09-W-4	681.90	B	SPRK	629.99	638.01	51.91	43.89	4396.94	496.57
10-07-054-10-W-4	608.29	A	CLNY	504.99	508.99	103.3C	99.30	4186.64	528.51
10-11-054-10-W-4	612.01	A	CLNY	498.99	503.99	113.02	108.02	4112.18	530.13
12-28-054-10-W-4	685.31	B	CLNY	580.00	585.49	105.31	99.82	3870.16	497.48
11-02-054-11-W-4	662.91	A	MCRN	576.50	580.49	86.41	82.42	4081.15	500.86
02-06-054-11-W-4	676.20	A	MCRN	598.99	602.99	77.21	73.21	3395.79	421.72
08-09-054-11-W-4	679.89	A	CLNY	591.01	596.01	88.88	83.88	4043.23	498.95
08-10-054-11-W-4	635.39	B	ELRL	668.00	678.00	-32.61	-42.61	5011.29	473.74
07-23-054-11-W-4	654.89	B	CLNY	559.49	564.00	95.40	90.89	4276.97	529.57
06-01-054-12-W-4	669.80	A	CLNY	587.99	592.01	81.81	77.78	3595.74	446.71
06-05-054-12-W-4	667.60	A	CLNY	600.49	603.99	67.12	63.61	4406.59	515.02
07-28-054-12-W-4	605.39	A	VKNG	472.99	477.99	132.41	127.41	1867.86	320.50
07-31-054-12-W-4	607.77	C	CLNY	535.53	538.58	72.24	69.19	3861.20	464.71
06-07-054-14-W-4	630.63	A	NSKU	711.40	734.57	-80.77	-103.94	4474.86	364.26
11-21-054-14-W-4	625.21	B	CMRS	707.44	722.07	-82.24	-96.87	4529.33	372.63
11-34-054-14-W-4	666.29	A	CMRS	705.00	737.62	-38.71	-71.32	4233.53	376.98
12-11-055-01-W-4	608.69	B	CMGS	543.76	553.82	64.92	54.86	3943.94	462.34
02-26-055-01-W-4	667.51	C	BHL	721.16	740.05	-53.64	-72.54	5054.04	452.62
12-16-055-02-W-4	594.79	B	CLNY	388.01	399.01	206.78	195.77	2973.81	504.73
06-29-055-02-W-4	613.11	B	SPRK	462.50	473.51	150.60	139.60	3216.52	473.32
10-08-055-04-W-4	605.21	A	CLNY	404.99	409.99	200.22	195.22	2771.79	480.56
05-05-055-05-W-4	634.11	C	CMGS	570.01	574.00	64.10	60.11	3867.41	456.74
05-05-055-05-W-4	634.11	A	SPRK	482.99	487.01	151.12	147.10	3187.56	474.37
05-05-055-05-W-4	634.11	A	WSEC	472.01	476.01	162.09	158.10	3091.03	475.51
01-07-055-05-W-4	640.60	A	CLNY	464.00	470.00	176.60	170.60	3072.41	487.11
06-09-055-05-W-4	636.12	B	CLNY	452.32	467.56	183.79	168.55	3230.31	505.80
10-11-055-05-W-4	615.70	C	CMGS	555.65	559.92	60.05	55.78	4258.35	492.44
11-16-055-05-W-4	649.01	B	CLNY	460.40	472.20	188.61	176.81	3036.56	492.57
06-20-055-05-W-4	653.09	B	DINA	587.01	607.01	66.08	46.09	3830.86	446.99
07-26-055-05-W-4	616.61	C	DINA	543.15	546.81	73.46	69.80	3654.35	444.52
07-29-055-05-W-4	645.81	B	CLNY	459.49	461.01	186.32	184.80	2920.72	483.60
11-29-055-05-W-4	660.50	B	CMGS	586.13	592.53	74.37	67.97	3888.78	467.99

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
16-30-055-05-W-4	664.40	A	CLNY	467.01	471.01	197.39	193.40	3048.28	506.44
03-31-055-05-W-4	666.20	A	CLNY	470.00	475.00	196.20	191.20	1781.67	375.50
13-35-055-05-W-4	604.91	A	CLNY	417.00	420.99	187.91	183.92	2991.05	491.12
02-04-055-06-W-4	636.39	B	DINA	585.00	589.00	51.39	47.40	3848.79	442.13
02-04-055-06-W-4	636.39	B	MCRN	480.00	483.99	156.39	152.40	3031.04	463.69
02-04-055-06-W-4	636.39	B	CLNY	459.00	462.99	177.39	173.40	2972.43	478.71
02-04-055-06-W-4	636.39	C	DVNN	656.51	660.50	-20.12	-24.11	4769.27	464.55
02-04-055-06-W-4	636.39	B	DINA	592.01	596.01	44.38	40.39	3910.15	441.38
02-04-055-06-W-4	636.39	B	LDMR	569.49	573.51	66.90	62.88	3859.82	458.75
02-04-055-06-W-4	636.39	C	GP	519.01	523.01	117.38	113.39	2396.70	359.94
02-04-055-06-W-4	636.39	A	CLNY	464.00	467.99	172.39	168.40	2964.16	472.86
07-08-055-06-W-4	632.46	C	DINA	584.30	592.23	48.16	40.23	4241.11	476.96
10-11-055-06-W-4	656.84	B	DINA	609.60	614.48	47.24	42.37	3997.03	452.67
10-11-055-06-W-4	656.84	B	CMGS	598.63	607.16	58.22	49.68	4026.68	464.84
11-20-055-06-W-4	676.05	B	CMGS	615.70	629.72	60.35	46.33	3938.42	455.22
07-24-055-06-W-4	640.69	A	DIA	588.26	594.36	52.43	46.33	4095.63	467.30
07-24-055-06-W-4	640.69	C	DINA	600.46	606.25	40.23	34.44	4238.36	469.82
07-24-055-06-W-4	640.69	B	CMGS	577.90	586.44	62.79	54.25	3999.10	466.59
12-24-055-06-W-4	645.20	A	MCRN	481.00	484.60	164.20	160.60	3112.40	479.99
07-34-055-06-W-4	645.57	B	DVNN	603.50	622.71	42.06	22.86	4063.22	447.08
16-34-055-06-W-4	661.20	A	CLNY	478.99	482.99	182.21	178.22	3057.24	492.18
11-35-055-06-W-4	667.51	A	CMGS	597.10	603.20	70.41	64.31	3902.57	465.58
06-04-055-07-W-4	623.01	B	CLNY	472.01	477.01	151.00	146.00	3287.54	483.96
06-11-055-07-W-4	#VALUE!	B	DINA	604.11	609.90	#VALUE!	#VALUE!	4430.73	#VALUE!
11-15-055-07-W-4	617.19	B	CLNY	467.99	474.51	149.20	142.68	3311.67	483.86
11-03-055-08-W-4	587.11	B	SPRK	513.01	517.00	74.10	70.10	4194.92	500.15
15-12-055-08-W-4	616.49	C	SPRK	523.01	526.60	93.48	89.89	4149.41	515.09
07-11-055-09-W-4	655.62	B	DVNN	793.39	816.25	-137.77	-160.63	6788.82	543.54
12-33-055-09-W-4	637.03	B	BHL	758.95	829.67	-121.92	-192.63	6136.55	468.90
07-11-055-10-W-4	682.20	B	CLNY	559.00	573.51	123.20	108.69	3614.36	484.76
07-11-055-10-W-4	682.20	C	SPRK	592.99	597.99	89.21	84.22	4059.09	500.91
07-16-055-10-W-4	664.10	C	SPRK	587.01	592.99	77.08	71.11	4159.75	498.56
10-32-055-10-W-4	642.70	A	CLNY	511.00	514.65	131.70	128.05	3864.65	524.23
16-01-055-11-W-4	690.01	A	GLCC	719.51	723.50	-29.50	-33.50	4736.18	451.78

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
16-01-055-11-W-4	690.01	C	CLNY	586.50	590.49	103.51	99.52	4169.41	526.96
12-19-055-11-W-4	595.49	A	GLCC	586.01	590.00	9.48	5.49	4261.11	442.29
06-08-055-12-W-4	635.90	A	CLNY	545.99	550.01	89.92	85.89	3430.26	437.93
02-09-055-12-W-4	648.00	B	LDMR	640.99	647.00	7.01	1.01	4481.06	461.26
06-10-055-12-W-4	633.37	B	CLNY	527.30	534.01	106.07	99.36	4152.86	526.48
06-17-055-12-W-4	609.39	B	SPRK	549.01	555.01	60.38	54.38	4325.92	498.80
06-17-055-12-W-4	609.39	C	CLNY	511.00	517.00	98.39	92.38	3866.03	489.88
13-07-055-13-W-4	605.70	C	MCRN	532.00	538.00	73.70	67.70	3573.68	435.36
06-21-055-13-W-4	624.23	B	CLNY	527.91	536.45	96.32	87.78	3523.35	451.57
11-07-055-14-W-4	629.11	A	NSKU	666.99	671.99	-37.89	-42.89	3903.95	357.98
11-07-055-14-W-4	629.11	A	NSKU	660.01	665.01	-30.91	-35.91	3899.12	364.46
11-07-055-14-W-4	629.11	A	ELRL	631.00	636.00	-1.89	-6.89	4308.00	435.20
11-07-055-14-W-4	629.11	B	CLNY	547.51	552.51	81.59	76.60	4133.55	500.89
09-13-055-14-W-4	609.69	B	CLNY	515.51	536.51	94.18	73.18	3595.74	450.60
11-18-055-14-W-4	627.31	A	NSKU	657.00	662.00	-29.69	-34.69	3840.52	359.70
10-26-055-14-W-4	626.06	A	NSKU	649.83	658.98	-23.77	-32.92	4164.58	396.61
08-28-055-14-W-4	618.99	C	BLQZ	639.99	644.01	-21.00	-25.02	4314.20	417.21
08-28-055-14-W-4	618.99	A	GLCC	623.01	627.00	-4.02	-8.02	4303.86	433.15
08-28-055-14-W-4	618.99	A	GLCC	608.99	613.01	10.00	5.97	4243.87	441.03
08-28-055-14-W-4	618.99	A	SPRK	561.99	566.01	57.00	52.97	4239.05	487.54
07-34-055-14-W-4	638.25	A	IRTN	665.99	676.66	-27.74	-38.40	4157.69	391.18
13-35-056-02-W-4	641.21	A	CLNY	419.01	430.01	222.20	211.20	2537.36	475.61
06-31-056-04-W-4	621.70	A	CLNY	416.45	425.50	205.25	196.20	2484.27	454.22
05-02-056-05-W-4	602.41	A	CLNY	396.00	399.99	206.41	202.42	2642.16	474.02
04-01-056-06-W-4	670.71	C	DINA	616.49	622.01	54.22	48.71	3917.05	451.16
07-02-056-06-W-4	666.60	B	DINA	605.03	616.31	61.57	50.29	4026.68	466.82
10-06-056-06-W-4	629.72	A	DINA	576.38	593.75	53.34	35.97	3971.52	449.91
07-11-056-06-W-4	680.62	C	CMGS	611.12	622.40	69.49	58.22	4398.32	512.66
10-17-056-06-W-4	613.20	B	DINA	564.00	571.99	49.19	41.21	4259.04	479.80
16-24-056-06-W-4	549.71	A	CMGS	446.99	452.99	102.72	96.71	3581.95	465.22
16-24-056-06-W-4	549.71	A	CLNY	342.50	351.01	207.20	198.70	2719.39	480.44
07-25-056-06-W-4	591.31	A	LDMR	453.54	509.99	137.77	81.32	3445.43	461.12
07-25-056-06-W-4	591.31	A	CMGS	489.51	495.60	101.80	95.71	3581.26	464.19
11-26-056-06-W-4	601.31	A	SPRK	409.99	509.99	191.32	91.32	2730.42	419.93

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
09-23-056-07-W-4	590.00	A	CLNY	409.99	423.00	180.01	167.00	3390.27	519.45
07-24-056-07-W-4	594.36	A	GLCC	547.42	553.52	46.94	40.84	4133.55	465.68
07-18-056-08-W-4	640.60	A	CLNY	513.01	517.00	127.59	123.60	3452.33	477.87
07-28-056-08-W-4	655.69	B	MCRN	539.50	549.89	116.19	105.80	3573.68	475.65
07-28-056-08-W-4	655.69	A	JLFU	485.09	490.00	170.60	165.69	3172.39	491.86
11-31-056-09-W-4	669.71	A	GLCC	637.00	640.99	32.71	28.71	2492.54	285.05
11-31-056-09-W-4	669.71	A	CLNY	528.01	532.00	141.70	137.71	3424.06	489.10
11-31-056-09-W-4	669.71	A	JLFU	512.00	516.00	157.70	153.71	3194.45	481.67
04-08-056-10-W-4	655.69	A	GLCC	636.00	639.65	19.69	16.03	4288.00	455.41
04-08-056-10-W-4	655.69	A	SPRK	590.00	593.66	65.68	62.03	4003.93	472.42
04-08-056-10-W-4	655.69	A	MCRN	567.35	571.01	88.33	84.67	3972.90	491.90
04-08-056-10-W-4	655.69	A	CLNY	533.00	536.66	122.68	119.02	3825.35	511.19
09-16-056-10-W-4	658.89	A	SPRK	581.01	585.00	77.88	73.88	3884.64	472.27
09-16-056-10-W-4	658.89	A	SPRK	564.00	567.99	94.88	90.89	3877.06	488.51
09-16-056-10-W-4	658.89	A	WSEC	558.00	561.99	100.89	96.90	3836.38	490.36
15-20-056-10-W-4	640.42	A	CLNY	509.99	514.01	130.42	126.40	3654.35	501.31
15-20-056-10-W-4	640.42	C	CLNY	501.00	504.99	139.42	135.42	3596.43	504.40
15-20-056-10-W-4	640.42	A	CLNY	503.99	508.99	136.43	131.43	3566.09	497.82
13-24-056-10-W-4	679.00	A	CLNY	535.50	539.50	143.50	139.51	3053.80	453.12
13-02-056-11-W-4	635.29	A	MCRN	534.98	540.01	100.31	95.28	3821.90	487.78
13-02-056-11-W-4	635.29	A	CLNY	511.00	516.00	124.30	119.30	3364.76	465.14
06-07-056-11-W-4	618.41	A	BLQZ	623.99	633.01	-5.58	-14.60	4361.78	434.99
06-07-056-11-W-4	618.41	A	GLCC	605.00	611.00	13.41	7.41	4144.58	433.33
06-07-056-11-W-4	618.41	A	SPRK	527.00	533.00	91.41	85.40	3896.36	486.00
06-07-056-11-W-4	618.41	A	CLNY	512.00	518.01	106.41	100.40	3877.75	499.09
06-07-056-11-W-4	618.41	A	CLNY	492.01	502.01	126.40	116.40	3747.43	503.79
14-19-056-11-W-4	641.79	A	CLNY	516.51	523.01	125.27	118.78	3837.07	513.56
10-35-056-12-W-4	579.44	A	SPRK	493.01	497.01	86.42	82.43	3968.07	489.33
11-36-056-13-W-4	654.41	B	CLNY	544.01	547.51	110.40	106.89	3762.60	492.58
10-03-056-14-W-4	634.69	B	IRTN	654.50	682.69	-19.81	-48.01	3655.04	339.05
16-33-056-14-W-4	667.91	A	GLCC	660.01	664.01	7.89	3.90	4259.04	440.49
16-33-056-14-W-4	667.91	A	CLNY	561.99	570.01	105.92	97.90	3073.10	415.49
07-22-057-01-W-4	662.91	C	VKNG	473.99	477.01	188.92	185.90	2623.55	455.12
06-23-057-01-W-4	668.49	B	VKNG	471.01	478.99	197.48	189.49	2560.80	454.79

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
15-12-057-02-W-4	626.39	A	CLNY	409.99	414.01	216.41	212.38	2513.23	470.85
16-06-057-03-W-4	621.00	A	REX	471.01	477.01	149.99	143.99	3340.63	487.87
16-06-057-03-W-4	621.00	A	WSEC	423.00	429.01	198.00	191.99	2933.13	494.30
16-06-057-03-W-4	621.00	A	CLNY	398.01	404.01	222.99	216.99	2780.75	503.74
02-25-057-04-W-4	638.10	B	SPRK	475.00	482.99	163.10	155.11	3121.37	477.61
02-25-057-04-W-4	638.10	A	CLNY	414.01	422.00	224.09	216.10	2627.00	488.16
01-18-057-05-W-4	594.91	B	VKNG	326.99	345.00	267.92	249.91	2786.96	543.30
01-18-057-05-W-4	594.91	A	CLNY	379.99	383.99	214.91	210.92	2133.31	430.60
08-18-057-05-W-4	600.30	A	CLNY	378.01	387.00	222.29	213.30	923.24	312.00
16-20-057-05-W-4	587.90	A	CLNY	360.00	375.00	227.90	212.90	1304.53	353.52
01-29-057-05-W-4	609.69	B	VKNG	289.99	399.01	319.70	210.68	1600.33	428.49
10-03-057-08-W-4	634.29	C	CLNY	463.30	466.95	170.99	167.34	2735.25	448.27
05-11-057-08-W-4	652.61	B	CLNY	477.50	482.50	175.11	170.11	2941.41	472.75
10-16-057-08-W-4	679.19	B	CLNY	503.01	509.99	176.17	169.19	3104.13	489.43
11-06-057-09-W-4	696.29	A	CLNY	514.01	544.01	182.27	152.28	3070.34	480.57
11-06-057-09-W-4	696.29	A	GLCC	661.51	665.50	34.78	30.78	2620.79	300.21
11-06-057-09-W-4	696.29	B	SPRK	581.99	586.01	114.30	110.28	3595.05	479.13
11-06-057-09-W-4	696.29	A	SPRK	555.99	560.01	140.30	136.28	3484.73	493.87
10-10-057-09-W-4	674.31	A	SPRK	552.51	555.99	121.80	118.32	3604.02	487.82
10-10-057-09-W-4	674.31	A	SPRK	548.00	551.51	126.31	122.80	3581.95	490.06
10-10-057-09-W-4	674.31	A	CLNY	513.74	517.25	160.57	157.06	3280.64	493.58
07-25-057-09-W-4	692.20	B	SPRK	571.01	574.00	121.19	118.20	3644.01	491.53
07-25-057-09-W-4	692.20	A	CLNY	517.00	519.99	175.20	172.21	3126.88	492.78
12-07-057-10-W-4	634.99	C	GLCC	612.50	616.49	22.49	18.50	4388.67	468.32
12-07-057-10-W-4	634.99	B	CLNY	488.02	492.01	146.97	142.98	2761.45	426.76
06-04-057-11-W-4	641.60	A	MCRN	509.99	514.99	131.61	126.61	3621.94	498.70
07-06-057-11-W-4	644.10	B	MCRN	512.49	517.49	131.61	126.61	3836.38	520.58
07-06-057-11-W-4	644.10	B	CLNY	507.00	512.00	137.10	132.10	3796.39	521.99
13-02-057-12-W-4	630.63	C	BHL	822.96	883.62	-192.33	-252.98	7240.44	516.16
04-26-057-13-W-4	640.08	C	BHL	841.25	914.40	-201.17	-274.32	7332.14	510.43
02-31-057-13-W-4	646.30	B	CLNY	514.01	519.50	132.28	126.80	3436.47	480.20
02-31-057-13-W-4	646.30	C	SPRK	573.51	579.00	72.79	67.30	3813.62	459.19
01-01-057-14-W-4	648.19	A	CLNY	534.01	543.00	114.18	105.19	3926.70	510.37
04-02-057-14-W-4	614.69	A	CLNY	512.00	519.01	102.69	95.68	3891.54	496.28

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
14-31-057-14-W-4	639.90	A	IRTN	644.01	650.99	-4.11	-11.09	4134.93	414.33
11-06-058-01-W-4	670.90	C	CLNY	469.00	472.99	201.90	197.91	2915.90	497.44
07-10-058-01-W-4	667.60	A	CLNY	470.00	477.99	197.60	189.62	2659.40	464.98
07-15-058-01-W-4	674.40	B	CLNY	477.01	482.01	197.39	192.39	2767.65	477.30
07-15-058-01-W-4	674.40	B	CLNY	470.00	475.00	204.40	199.40	2909.69	498.81
07-15-058-01-W-4	674.40	B	SPRK	496.49	501.49	177.91	172.91	3143.43	496.17
09-29-058-01-W-4	700.00	A	CLNY	493.99	499.99	206.01	200.01	2486.34	456.72
11-31-058-01-W-4	703.51	B	CLNY	493.99	499.99	209.52	203.51	2523.57	464.02
11-33-058-01-W-4	701.31	A	CLNY	497.01	501.00	204.31	200.31	2524.95	459.96
05-10-058-02-W-4	669.10	A	CLNY	451.99	458.78	217.11	210.31	2435.31	462.21
08-17-058-02-W-4	667.79	C	CLNY	451.99	461.01	215.80	206.78	2065.74	422.08
10-17-058-02-W-4	676.66	C	DINA	615.09	621.18	61.57	55.47	3873.61	453.79
07-23-058-02-W-4	683.39	B	CLNY	471.01	475.00	212.38	208.39	2453.24	460.72
08-26-058-02-W-4	681.81	B	CLNY	475.00	481.00	206.81	200.80	2526.33	461.59
08-26-058-02-W-4	681.81	C	CLNY	467.01	472.99	214.79	208.82	2535.98	470.58
10-28-058-02-W-4	684.40	A	JLFU	445.01	454.00	239.39	230.40	2487.72	488.74
10-28-058-02-W-4	684.40	B	GP	509.99	514.99	174.41	169.41	2835.91	461.29
15-30-058-02-W-4	670.01	A	CLNY	440.01	444.00	230.00	226.01	2576.66	490.93
15-30-058-02-W-4	670.01	A	CLNY	433.00	436.99	237.01	233.02	2523.57	492.52
04-08-058-03-W-4	620.39	A	REX	475.00	485.00	145.39	135.39	3239.96	471.00
04-08-058-03-W-4	620.39	A	CLNY	398.50	408.49	221.89	211.90	2991.05	522.10
12-24-058-07-W-4	#VALUE!	B	CLNY	379.99	387.00	#VALUE!	#VALUE!	2804.89	#VALUE!
06-26-058-07-W-4	641.79	C	CLNY	441.99	448.00	199.80	193.79	2752.48	477.66
14-28-058-07-W-4	652.00	A	CLNY	456.99	465.00	195.01	186.99	2966.23	493.68
06-07-058-08-W-4	673.00	B	SPRK	537.00	540.99	136.00	132.01	3337.87	474.60
06-07-058-08-W-4	673.00	B	SPRK	529.01	533.00	143.99	139.99	3271.68	475.84
14-09-058-08-W-4	653.40	A	SPRK	517.00	520.99	136.40	132.41	3366.83	477.96
14-09-058-08-W-4	653.40	A	SPRK	512.00	516.00	141.40	137.40	3234.44	469.45
14-09-058-08-W-4	653.40	C	SPRK	503.99	508.01	149.41	145.39	3166.87	470.55
15-18-058-08-W-4	650.81	A	SPRK	508.99	513.01	141.82	137.80	3266.16	473.09
15-18-058-08-W-4	650.81	A	CLNY	488.02	492.01	162.79	158.80	3115.16	478.67
15-18-058-08-W-4	650.81	A	CLNY	467.99	472.01	182.82	178.80	3016.56	488.62
10-01-058-09-W-4	662.91	A	SPRK	545.99	550.01	116.92	112.90	3414.40	463.32
10-01-058-09-W-4	662.91	A	SPRK	540.99	545.01	121.92	117.90	3430.95	470.01

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Prossure (kPa)	Hydraulic Head (m)
10-01-058-09-W-4	662.91	A	SPRK	524.01	528.01	138.90	134.90	3312.36	474.90
10-01-058-09-W-4	662.91	A	CLNY	499.99	503.99	162.92	158.92	3177.91	485.20
10-01-058-09-W-4	662.91	A	CLNY	481.00	485.00	181.90	177.91	2793.16	464.92
16-14-058-09-W-4	648.61	A	SPRK	529.01	533.00	119.60	115.61	3467.50	471.43
16-14-058-09-W-4	648.61	A	SPRK	501.49	505.51	147.13	143.10	3358.55	487.82
16-14-058-09-W-4	648.61	A	CLNY	473.99	477.99	174.62	170.63	3226.86	501.89
15-23-058-09-W-4	656.39	A	SPRK	540.01	544.01	116.37	112.38	3486.80	470.17
15-23-058-09-W-4	656.39	A	SPRK	508.99	513.01	147.40	143.38	3333.04	485.50
04-26-058-09-W-4	652.70	A	CLNY	467.01	472.01	185.68	180.69	2980.02	487.27
04-35-058-11-W-4	640.38	B	CKGK	769.62	776.02	-129.24	-135.64	7036.35	585.56
14-16-058-14-W-4	662.30	B	GLCC	637.03	646.18	25.27	16.12	4019.79	430.88
07-10-044-03-W-4	643.43	C	BLQZ	688.85	701.04	-45.42	-57.61	4971.30	455.76
10-29-043-01-W-4	650.75	B	CLNY	603.20	606.86	47.55	43.89	4340.40	488.62
07-32-044-03-W-4	674.52	A	CLNY	600.46	609.60	74.07	64.92	3943.94	471.94
06-20-044-03-W-4	647.40	C	SPRK	634.59	665.99	12.80	-18.59	4727.90	479.54
07-10-044-03-W-4	643.43	B	CLNY	588.26	595.58	55.17	47.85	4125.97	472.53
07-10-044-03-W-4	643.43	B	SPRK	635.20	646.18	8.23	-2.74	4709.97	483.35
10-23-043-04-W-4	639.81	A	BLQZ	669.04	711.71	-29.23	-71.90	4778.24	437.01
13-06-044-02-W-4	653.00	B	VKNG	561.00	566.00	92.00	87.00	4779.89	577.24
06-19-044-02-W-4	658.06	C	CLNY	593.14	605.33	64.92	52.73	4185.95	485.96
06-19-044-02-W-4	658.06	B	VKNG	551.69	563.88	106.38	94.18	4892.00	599.46
06-19-044-02-W-4	658.06	B	JLFU	513.28	525.48	144.78	132.59	4547.94	602.76
07-33-044-02-W-4	655.32	C	SPRK	644.65	652.27	10.67	3.05	4561.04	472.27
07-33-044-02-W-4	655.32	B	CLNY	585.22	608.08	70.10	47.24	4176.30	484.83
07-33-044-02-W-4	655.32	B	BSFS	513.89	521.51	141.43	133.81	4486.58	595.43
07-33-044-02-W-4	655.32	A	VKNG	547.12	554.74	108.20	100.58	4879.59	602.31
11-26-045-02-W-4	560.50	B	VKNG	423.67	470.92	136.82	89.58	4964.40	619.77
06-11-045-02-W-4	639.52	B	BSFS	464.50	495.00	175.02	144.52	4457.76	614.64
06-07-045-02-W-4	653.19	C	BSFS	505.97	518.16	147.22	135.03	4496.92	599.99
06-07-045-02-W-4	653.19	A	VKNG	544.98	557.17	108.20	96.01	4957.51	607.98
06-07-045-02-W-4	653.19	A	CLNY	588.26	600.46	64.92	52.73	3925.32	459.37
06-02-045-03-W-4	667.79	C	CLNY	598.63	610.82	69.16	56.97	4112.87	482.74
06-02-045-03-W-4	667.79	C	LDMN	652.27	664.46	15.51	3.32	4661.02	485.03

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-02-045-03-W-4	667.79	B	VKNG	557.78	563.88	110.00	103.91	4927.86	609.80
10-36-045-03-W-4	638.56	A	VKNG	504.44	516.64	134.11	121.92	4905.10	628.54
10-36-045-03-W-4	638.56	A	BSFS	474.88	479.76	163.68	158.80	4438.31	614.13
06-20-046-03-W-4	676.05	A	VKNG	555.65	563.27	120.40	112.78	5511.17	678.95
13-24-054-04-W-4	595.00	C	CLNY	423.00	428.00	172.00	167.00	3307.32	506.98
13-24-054-04-W-4	595.00	B	WSEC	448.00	452.00	147.00	143.00	3222.79	473.86
13-24-054-04-W-4	595.00	C	SPRK	467.50	471.50	127.50	123.50	3027.32	434.41
13-24-054-04-W-4	595.00	B	LDMR	485.00	492.50	110.00	102.50	3639.53	477.63
13-24-054-04-W-4	595.00	C	VKNG	330.00	384.00	265.00	211.00	2754.83	519.10
07-11-054-04-W-4	586.44	B	CLNY	417.27	423.37	169.16	163.07	2996.57	471.89
07-11-054-04-W-4	586.44	C	VKNG	365.76	396.24	220.68	190.20	3097.92	521.55
11-32-053-04-W-4	607.12	A	CLNY	438.00	442.00	169.12	165.12	3023.18	475.61
11-32-053-04-W-4	607.12	A	MCRN	447.60	452.00	159.52	155.12	2959.13	459.27
10-11-053-04-W-4	597.26	B	CMGS	574.85	579.73	22.40	17.53	4464.51	475.53
10-18-052-04-W-4	631.65	A	CLNY	477.00	482.00	154.65	149.65	3281.12	486.96
10-18-052-04-W-4	631.65	A	WSEC	519.00	524.00	112.65	107.65	3650.14	482.61
10-18-052-04-W-4	631.65	C	CMGS	615.00	620.00	16.65	11.65	4440.72	467.28
06-13-052-04-W-4	634.50	B	VKNG	445.00	460.00	189.50	174.50	3641.94	553.63
06-13-052-04-W-4	634.50	B	SPRK	531.00	535.00	103.50	99.50	3715.16	480.60
06-13-052-04-W-4	634.50	C	CLNY	485.50	489.50	149.00	145.00	3395.03	493.43
07-16-051-04-W-4	612.85	A	CLNY	470.00	475.00	142.85	137.85	3155.15	462.30
06-14-050-04-W-4	612.65	C	VKNG	472.44	475.49	140.21	137.16	3667.45	512.91
05-22-049-04-W-4	684.28	A	SPRK	611.12	617.52	73.15	66.75	3978.42	475.91
10-02-044-01-W-4	611.12	B	BSFS	461.77	470.92	149.35	140.21	4399.70	593.73
07-29-044-01-W-4	628.50	C	BSFS	470.00	482.19	158.50	146.30	4461.75	607.68
06-05-044-01-W-4	660.81	B	BSFS	516.94	525.17	143.87	135.64	4655.50	614.80
11-02-045-01-W-4	608.69	C	BSFS	449.28	458.42	159.41	150.27	4404.53	604.28
11-02-045-01-W-4	608.69	A	BSFS	425.50	434.64	183.18	174.04	3657.80	551.86
06-08-045-01-W-4	608.08	B	SCD SPKLD SH	417.58	435.86	190.50	172.21	3566.78	545.31
11-26-045-01-W-4	760.48	A	BSFS	568.15	572.41	192.33	188.06	4187.33	617.47
11-26-045-01-W-4	760.48	A	BSFS	521.82	526.08	238.66	234.39	3732.26	617.37
07-30-045-01-W-4	624.81	B	VKNG	490.73	505.97	134.08	118.84	4718.25	607.92
07-30-045-01-W-4	624.81	B	BSFS	448.06	463.30	176.75	161.51	4556.22	634.05
10-03-046-01-W-4	635.51	C	BSFS	429.77	446.53	205.74	188.98	4030.82	608.67

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
10-03-046-01-W-4	635.51	C	SPRK	585.83	591.31	49.68	44.20	4365.22	492.37
10-03-046-01-W-4	635.51	C	WSEC	544.98	548.03	90.53	87.48	3806.04	477.37
10-03-046-01-W-4	635.51	A	VKNG	492.56	497.43	142.95	138.07	4664.47	616.48
10-03-046-01-W-4	635.51	A	SPRK	585.83	589.18	49.68	46.33	3999.10	456.08
10-08-046-01-W-4	659.46	B	SPRK	602.00	608.00	57.46	51.46	4075.15	470.29
10-08-046-01-W-4	659.46	B	GP	612.00	618.00	47.46	41.46	4020.13	454.68
06-29-046-01-W-4	662.10	A	CLNY	549.00	552.60	113.10	109.50	3533.76	471.89
06-24-052-06-W-4	618.74	A	CLNY	478.54	493.78	140.21	124.97	3505.42	490.28
06-24-052-06-W-4	618.74	A	SPRK	544.98	548.64	73.76	70.10	3971.52	477.19
06-24-052-06-W-4	618.74	A	LDMR	571.80	574.85	46.94	43.89	4240.43	478.11
10-15-051-06-W-4	629.10	A	LDUC	643.13	664.46	-14.03	-35.37	4585.45	443.21
06-10-050-06-W-4	616.80	A	CLNY	505.09	513.00	111.71	103.80	3690.34	484.32
06-10-050-06-W-4	616.80	C	WSEC	523.18	532.00	93.62	84.80	3960.14	493.31
06-10-050-06-W-4	616.80	C	SPRK	544.09	552.00	72.71	64.80	4385.15	516.22
11-32-049-06-W-4	635.51	C	CLNY	519.38	526.69	116.13	108.81	3557.82	475.51
10-05-049-06-W-4	665.07	B	LDMR	650.75	658.37	14.33	6.71	4518.98	471.64
10-05-049-06-W-4	665.07	B	CLNY	562.36	574.55	102.72	90.53	3994.27	504.20
07-02-049-06-W-4	640.69	B	REX	600.46	615.70	40.23	24.99	4456.93	487.40
07-02-049-06-W-4	640.69	C	VKNG	483.11	516.64	157.58	124.05	4354.88	585.19
11-25-048-06-W-4	635.51	C	CLNY	534.92	545.59	100.58	89.92	3995.65	502.97
10-01-048-06-W-4	678.48	C	SPRK	641.30	652.27	37.19	26.21	4459.69	486.77
11-26-047-06-W-4	671.78	A	VKNG	536.45	547.42	135.33	124.36	5077.48	647.95
07-17-047-06-W-4	705.00	C	CLNY	615.09	618.13	89.92	86.87	4164.58	513.35
10-12-052-05-W-4	621.18	A	CLNY	469.09	474.57	152.10	146.61	3122.75	468.00
10-12-052-05-W-4	621.18	C	SPRK	523.04	526.69	98.15	94.49	3803.97	484.48
10-12-052-05-W-4	621.18	C	MCRN	483.41	486.46	137.77	134.72	3233.76	466.22
10-12-052-05-W-4	621.18	B	CLNY	473.05	476.71	148.13	144.48	3171.70	469.95
10-21-051-05-W-4	597.41	C	VKNG	420.01	436.78	177.39	160.63	3564.72	532.76
10-21-051-05-W-4	597.41	A	CLNY	450.80	467.56	146.61	129.84	3288.92	473.83
11-14-051-05-W-4	666.90	C	CLNY	530.35	536.45	136.55	130.45	3550.24	495.77
11-18-050-05-W-4	647.09	C	SPRK	576.07	580.95	71.02	66.14	3901.88	466.73
06-07-049-05-W-4	636.73	B	SPRK	571.20	575.77	65.53	60.96	4077.70	479.34
10-08-048-05-W-4	648.92	A	CLNY	559.61	563.27	89.31	85.65	3231.00	417.17
12-20-047-05-W-4	648.30	B	CLNY	558.00	562.00	90.30	86.30	3704.68	466.33

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
11-35-054-04-W-4	602.90	C	VKNG	378.00	395.00	224.90	207.90	3236.24	546.63
13-24-054-04-W-4	595.00	A	CLNY	415.00	420.00	180.00	175.00	2795.30	462.74
07-31-051-07-W-4	646.50	A	BSFS	443.48	541.63	203.02	104.87	3544.03	515.58
11-14-051-07-W-4	614.50	A	CLNY	488.90	502.01	125.60	112.49	3548.17	481.10
06-08-051-07-W-4	614.80	B	BSFS	466.34	475.49	148.46	139.31	4341.78	586.92
10-07-050-07-W-4	669.00	A	REX	648.00	651.00	21.00	18.00	4531.88	481.94
10-07-050-07-W-4	669.00	A	CLNY	575.00	577.00	94.00	92.00	3971.11	498.22
11-34-049-07-W-4	701.10	A	VKNG	563.88	569.98	137.22	131.12	4061.16	548.57
11-34-049-07-W-4	701.10	A	SPRK	637.03	644.65	64.07	56.45	4564.49	526.02
11-34-049-07-W-4	701.10	A	REX	646.18	652.88	54.92	48.22	4585.18	519.44
10-21-049-07-W-4	643.63	B	CLNY	556.56	574.85	87.07	68.78	4820.29	569.79
07-08-049-07-W-4	709.60	C	VKNG	566.93	597.41	142.67	112.19	5267.78	664.96
11-01-049-07-W-4	696.20	C	VKNG	550.50	563.90	145.70	132.30	5045.76	653.87
06-31-048-07-W-4	700.10	B	VKNG	585.20	594.40	114.90	105.70	5335.35	654.72
04-01-048-07-W-4	682.60	C	CLNY	587.00	593.00	95.60	89.60	4000.13	500.78
04-01-048-07-W-4	682.60	A	SPRK	538.00	644.00	144.60	38.60	4330.96	533.53
11-31-047-07-W-4	667.00	B	VKNG	530.00	558.00	137.00	109.00	5318.80	665.73
01-27-047-07-W-4	680.60	B	CLNY	597.00	602.00	83.60	78.60	4388.32	528.89
06-18-047-07-W-4	667.80	A	VKNG	548.60	581.60	119.20	86.20	5385.68	652.26
11-14-047-07-W-4	679.70	C	CLNY	601.37	606.86	78.33	72.84	3134.47	395.43
06-03-047-07-W-4	673.50	B	VKNG	548.00	569.00	125.50	104.50	5273.16	653.08
11-07-053-06-W-4	636.42	A	SPRK	534.62	543.46	101.80	92.96	3737.78	478.79
10-02-053-06-W-4	620.05	B	SPRK	507.19	514.50	112.87	105.55	3578.51	474.36
10-02-053-06-W-4	620.05	B	LDMR	538.28	541.93	81.78	78.12	3833.62	471.13
10-02-053-06-W-4	620.05	B	CLNY	469.39	478.54	150.66	141.52	3247.55	477.47
10-02-053-06-W-4	620.05	B	SPRK	520.90	524.26	99.15	95.80	3675.04	472.48
10-02-053-06-W-4	620.05	C	GLCC	565.10	573.02	54.96	47.03	4207.33	480.31
10-02-053-06-W-4	620.05	B	VKNG	408.43	438.91	211.62	181.14	3357.87	539.02
11-34-052-06-W-4	637.95	A	WSEC	500.48	516.33	137.46	121.62	3550.93	491.88
11-34-052-06-W-4	637.95	A	CLNY	491.95	499.26	146.00	138.68	3440.61	493.42
11-34-052-06-W-4	637.95	A	VKNG	439.83	464.21	198.12	173.74	3505.42	543.62
10-06-053-03-W-4	597.10	B	CLNY	440.00	444.00	157.10	153.10	3383.24	500.33
06-18-053-03-W-4	596.49	B	VKNG	391.97	402.64	204.52	193.85	3178.60	523.53
06-18-053-03-W-4	596.49	B	CMGS	553.21	563.88	43.28	32.61	4112.18	457.56

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
06-18-053-03-W-4	596.49	A	SPRK	478.23	481.89	118.26	114.60	3556.44	479.34
06-18-053-03-W-4	596.49	A	CLNY	435.86	439.52	160.63	156.97	3130.33	478.22
07-02-054-03-W-4	578.51	B	DINA	530.35	534.92	48.16	43.59	4047.37	458.87
07-02-054-03-W-4	578.51	B	REX	472.44	476.10	106.07	102.41	3623.32	473 97
07-02-054-03-W-4	578.51	B	CLNY	396.24	400.51	182.27	178.00	2873.15	473.32
10-11-047-04-W-4	640.00	B	CLNY	559.30	571.50	80.70	68.50	3883.13	470.84
01-10-048-04-W-4	659.89	C	SPRK	626.06	630.94	33.83	28.96	4348.68	475.14
11-22-048-04-W-4	673.61	C	GP	628.80	631.55	44.81	42.06	4224.57	474.51
06-36-048-04-W-4	690.98	C	CLNY	588.26	598.93	102.72	92.05	3729.51	477.95
11-26-054-07-W-4	643.10	C	MCRN	492.25	502.92	150.85	140.18	3604.71	513.34
11-26-054-07-W-4	643.10	B	VKNG	432.82	464.82	210.28	178.28	3444.05	545.71
06-30-053-07-W-4	586.13	A	SPRK	495.00	501.70	91.13	84.42	3544.03	449.41
06-32-052-07-W-4	648.90	A	CLNY	513.20	516.00	135.70	132.90	3508.18	492.28
06-32-052-07-W-4	648.90	A	CLNY	519.30	523.00	129.60	125.90	3505.42	485.45
06-24-052-07-W-4	628.20	A	SPRK	554.00	557.80	74.20	70.40	4067.77	487.38
07-18-052-07-W-4	672.40	B	VKNG	507.19	514.81	165.21	157.59	4108.04	580.59
10-10-052-07-W-4	628.80	A	CLNY	488.30	492.00	140.50	136.80	3430.12	488.66
10-10-052-07-W-4	628.80	B	CLNY	492.60	496.20	136.20	132.60	3465.70	488.04
10-10-052-07-W-4	628.80	A	SPRK	542.00	545.60	86.80	83.20	3910.15	483.99
10-10-052-07-W-4	628.80	A	LDMR	584.60	588.30	44.20	40.50	4293.24	480.43
10-10-052-07-W-4	628.80	A	LDMR	590.70	594.40	38.10	34.40	4376.26	482.81
10-10-052-07-W-4	628.80	A	CMGS	600.80	604.40	28.00	24.40	4345.64	469.63
10-10-052-07-W-4	628.80	A	CMGS	608.40	612.30	20.40	16.50	4400.25	467.45
10-10-052-07-W-4	628.80	A	DINA	621.18	624.84	7.62	3.96	4438.93	458.74
13-36-051-07-W-4	629.11	B	BHL	938.78	970.18	-309.68	-341.07	8045.78	495.62
10-19-048-03-W-4	651.97	C	VKNG	503.53	518.77	148.44	133.20	5000.94	651.12
10-19-048-03-W-4	651.97	C	CLNY	546.20	561.44	105.77	90.53	3681.93	473.85
10-22-048-03-W-4	675.44	B	CLNY	566.62	577.29	108.81	98.15	3779.15	489.11
10-10-049-03-W-4	701.95	A	SPRK	625.45	629.11	76.50	72.85	3906.02	473.25
04-22-049-03-W-4	683.67	C	SPRK	607.16	610.82	76.50	72.85	3930.15	475.71
06-26-049-03-W-4	677.88	A	SPRK	600.76	606.86	77.11	71.02	3902.57	472.29
07-29-049-03-W-4	680.01	A	CLNY	559.31	566.93	120.70	113.08	4049.43	530.10
10-21-051-03-W-4	687.02	B	SPRK	598.02	602.89	89.00	84.12	3906.71	485.21
11-35-051-03-W-4	623.93	B	CLNY	484.33	487.98	139.60	135.94	3287.54	473.23

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	To (m)	Test Interval (Elevation) From (m)	To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
11-35-051-03-W-4	623.93	A	CLNY	475.18	478.84	148.74	145.08	3204.80	473.93
11-04-052-03-W-4	641.70	C	CLNY	480.00	500.00	161.70	141.70	3034.63	461.35
10-06-053-03-W-4	597.10	A	REX	503.00	508.00	94.10	89.10	3732.19	472.44
10-06-053-03-W-4	597.10	A	CLNY	428.50	433.50	168.60	163.60	2975.61	469.73
10-06-053-03-W-4	597.10	A	GP	489.00	494.00	108.10	103.10	3588.23	471.75
10-06-053-03-W-4	597.10	A	MCRN	444.00	449.00	153.10	148.10	3138.60	470.87
10-06-053-03-W-4	597.10	A	LDMR	523.00	527.00	74.10	70.10	4030.27	483.35
10-06-053-03-W-4	597.10	A	SPRK	474.00	478.00	123.10	119.10	3558.72	484.23
10-17-049-01-W-4	663.49	C	SPRK	579.12	583.69	84.37	79.80	3785.36	468.34
06-28-051-01-W-4	648.00	A	MCRN	519.00	525.00	129.00	123.00	3257.89	458.44
06-28-051-01-W-4	648.00	A	CMGS	619.00	625.00	29.00	23.00	4341.09	468.97
04-08-052-01-W-4	651.05	A	CLNY	491.34	495.00	159.72	156.06	2964.85	460.42
10-12-052-01-W-4	584.91	A	SPRK	475.49	482.19	109.42	102.72	3509.56	464.19
10-12-052-01-W-4	584.91	A	CLNY	415.14	424.89	169.77	160.02	2964.85	467.43
11-08-053-01-W-4	605.58	B	VKNG	385.57	396.24	220.00	209.34	2661.47	486.25
11-18-053-01-W-4	605.64	A	CLNY	421.23	424.89	184.40	180.75	2967.61	485.39
04-32-053-01-W-4	627.58	C	DINA	559.00	582.17	68.58	45.42	3868.10	451.70
10-26-054-01-W-4	613.56	C	BSFS	292.30	295.66	321.26	317.91	2811.78	606.50
10-29-054-01-W-4	601.37	C	CLNY	396.24	406.91	205.13	194.46	2671.12	472.36
10-08-047-02-W-4	628.19	B	CLNY	528.52	533.40	99.67	94.79	4033.58	508.82
11-21-047-02-W-4	644.04	A	CLNY	538.89	544.98	105.16	99.06	3681.93	477.82
15-26-050-02-W-4	667.51	A	CMGS	671.78	705.61	-4.27	-38.10	4571.39	445.28
10-32-050-02-W-4	681.84	C	SPRK	599.54	603.50	82.30	78.33	3987.38	487.19
10-32-050-02-W-4	681.84	A	SPRK	599.85	610.82	81.99	71.02	3826.73	466.99
05-18-052-02-W-4	611.50	A	VKNG	405.00	428.00	206.50	183.50	3260.44	527.70
05-18-052-02-W-4	611.50	C	CMGS	572.50	577.50	39.00	34.00	4149.27	459.89
07-14-053-02-W-4	622.00	A	VKNG	388.00	420.00	234.00	202.00	2886.94	512.58
10-11-054-02-W-4	603.20	B	CLNY	420.62	426.72	182.58	176.48	2833.16	468.62
10-11-054-02-W-4	603.20	B	CLNY	409.65	415.75	193.55	187.45	2711.80	467.21
10-22-054-02-W-4	574.24	A	WSEC	426.72	430.99	147.52	143.26	3205.49	472.48
10-32-054-02-W-4	577.29	A	CLNY	381.00	389.53	196.29	187.76	2675.26	465.01
10-32-054-02-W-4	577.29	A	CLNY	371.25	379.78	206.04	197.51	2660.09	473.22
10-32-054-02-W-4	577.29	A	SSPSH	256.03	263.96	321.26	313.33	2499.44	572.34
10-02-047-03-W-4	639.47	C	CLNY	548.64	554.74	90.83	84.73	4021.16	498.11

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth)		Test Interval (Elevation)		Max. Pressure (kPa)	Hydraulic Head (m)
				From (m)	To (m)	From (m)	To (m)		
10-02-047-03-W-4	639.47	A	MCRN	555.65	561.75	83.82	77.72	3861.20	474.77
10-22-047-03-W-4	653.80	B	VKNG	518.16	530.35	135.64	123.44	4908.55	630.41
10-22-047-03-W-4	653.80	C	BSFS	476.71	488.90	177.09	164.90	4747.90	655.47
10-22-047-03-W-4	653.80	B	BSFS	462.99	475.18	190.80	178.61	4495.54	643.44
06-10-048-03-W-4	665.38	C	CLNY	563.27	575.46	102.11	89.92	3415.09	444.49
10-11-045-05-W-4	664.49	C	WSEC	603.81	606.55	60.69	57.94	4308.69	498.98
07-29-045-05-W-4	650.11	A	CMGS	628.50	634.59	21.61	15.51	4550.70	482.92
07-29-045-05-W-4	650.11	B	VKNG	529.13	548.64	120.98	101.47	5305.70	652.62
10-04-046-05-W-4	674.83	B	VKNG	515.11	563.88	159.72	110.95	5104.37	656.19
06-34-046-05-W-4	689.46	B	CLNY	594.36	603.50	95.10	85.95	3071.72	403.97
11-06-044-06-W-4	682.45	A	CLNY	644.35	648.61	38.10	33.83	4047.37	448.96
11-06-044-06-W-4	682.45	B	VKNG	595.88	603.50	86.56	78.94	5577.37	651.87
10-06-046-06-W-4	701.40	A	VKNG	582.00	596.00	119.40	105.40	5091.41	631.93
10-10-046-06-W-4	656.84	A	SPRK	606.55	614.48	50.29	42.37	4290.76	484.16
12-11-046-07-W-4	693.12	A	DVNN	708.36	729.69	-15.24	-36.58	4632.06	446.75
12-11-046-07-W-4	693.12	C	SPRK	658.37	665.07	34.75	28.04	4498.30	490.40
06-23-046-07-W-4	712.00	A	CLNY	630.90	637.00	81.10	75.00	4376.67	524.65
06-23-046-07-W-4	712.00	C	VKNG	588.26	592.53	123.74	119.47	4881.04	619.67
11-30-046-07-W-4	690.07	C	LDMR	737.62	741.88	-47.55	-51.82	6064.15	569.11
15-31-046-07-W-4	690.30	A	VKNG	565.00	586.00	125.30	104.30	5572.26	683.40
15-31-046-07-W-4	690.30	B	CLNY	615.00	622.80	75.30	67.50	4309.03	511.09
06-36-046-07-W-4	669.00	A	CLNY	583.39	588.87	85.61	80.13	4157.69	507.12
06-36-046-07-W-4	669.00	A	CLNY	573.63	579.12	95.37	89.88	4164.58	517.58
11-08-047-01-W-4	666.90	B	CLNY	551.08	554.74	115.82	112.17	3612.29	482.60
11-08-047-01-W-4	666.90	B	CLNY	547.42	555.96	119.48	110.95	3457.84	468.06
11-08-047-01-W-4	666.90	A	VKNG	507.80	516.33	159.11	150.57	4551.39	619.27
07-20-047-01-W-4	#VALUE!	A	CLNY	534.50	538.50	#VALUE!	#VALUE!	3471.84	#VALUE!
10-07-048-01-W-4	640.08	C	VKNG	443.48	451.10	196.60	188.98	4650.68	667.34
10-11-048-01-W-4	651.66	C	SPRK	576.38	580.03	75.29	71.63	3828.10	464.08
04-14-044-04-W-4	671.30	C	VKNG	570.00	587.00	101.30	84.30	5431.67	647.05
04-14-044-04-W-4	671.30	A	REX	678.50	682.00	-7.20	-10.70	4549.53	455.29
10-23-044-04-W-4	652.60	B	CLNY	593.00	597.00	59.60	55.60	3992.76	465.03
07-08-045-04-W-4	695.89	C	CLNY	621.18	626.67	74.71	69.22	4121.14	492.49
07-08-045-04-W-4	695.89	B	VKNG	580.34	585.83	115.55	110.06	5213.31	644.78

Well Location	K.B. (m)	Cife Quality Code	Tested Formation	Test Interval (Depth) From (m)	Test Interval (Depth) To (m)	Test Interval (Elevation) From (m)	Test Interval (Elevation) To (m)	Max. Pressure (kPa)	Hydraulic Head (m)
07-32-045-04-W-4	710.18	C	VKNG	582.78	609.60	127.41	100.58	5191.94	643.78
07-32-045-04-W-4	710.18	C	WSEC	653.80	667.51	56.39	42.67	8320.20	898.53
07-13-044-05-W-4	695.19	B	VKNG	593.75	609.60	101.44	85.59	5247.78	629.00
10-31-044-05-W-4	666.60	B	VKNG	573.02	588.26	93.57	78.33	5336.73	630.52
07-07-045-05-W-4	661.39	C	CLNY	591.92	598.63	69.46	62.76	4164.58	491.07
10-11-045-05-W-4	664.49	A	CLNY	591.31	598.32	73.18	66.17	4033.58	481.27
06-27-043-05-W-4	681.23	B	SPRK	676.66	682.75	4.57	-1.52	4279.04	438.16
06-29-043-05-W-4	660.81	C	SPRK	661.42	667.51	-0.61	-6.71	4852.70	491.52
14-35-044-05-W-4	675.40	C	DINA	676.00	681.00	-0.60	-5.60	4234.22	428.96
11-18-046-05-W-4	689.76	A	WSEC	630.94	637.64	58.83	52.12	4047.37	468.47
06-25-043-06-W-4	663.55	B	VKNG	591.31	597.41	72.24	66.14	5621.49	642.81
11-29-043-06-W-4	673.91	B	VKNG	601.98	608.08	71.93	65.84	5415.33	621.47
07-21-045-07-W-4	672.08	B	CLNY	624.84	630.94	47.24	41.15	4175.61	470.28
10-18-054-03-W-4	582.17	A	CLNY	416.05	420.62	166.12	161.54	3015.18	471.50
03-06-047-04-W-4	686.30	B	LDMR	681.00	694.00	5.30	-7.70	4541.18	462.19
03-06-047-04-W-4	686.30	A	WSEC	612.00	621.00	74.30	65.30	3973.93	475.30
11-20-053-04-W-4	608.80	C	CLNY	446.00	451.00	162.80	157.80	2803.92	446.42
06-30-047-06-W-4	678.48	B	WSEC	601.98	612.65	76.50	65.84	4102.53	489.80
13-04-052-06-W-4	654.10	B	VKNG	465.00	495.00	189.10	159.10	3636.15	545.14
13-04-052-06-W-4	654.10	A	MCRN	520.00	536.00	134.10	118.10	3491.90	482.42

APPENDIX C

DIFFUSION CALCULATIONS

Diffusion of Cl⁻ from Mannville Formation to the Ribstone Creek Sandstone

From Freeze and Cherry, 1979;

$$Ci\ (x,t) = Co\ \mathrm{erfc}\left(\frac{x}{2\sqrt{D^{*}t}}\right)$$

Where: $Ci = 700$ mg/l (Cl⁻ in the Ribstone Creek Sandstone)
$Co = 50\ 000$ mg/l (Cl- in Mannville Formation)
$x = 650$ metres (Distance between units)

and From Ranganathon and Hanor, 1987;

$$D^{*} = D\sigma^{n}$$

Where: $D = 1.5\cdot10^{-5}\ \mathrm{cm^2/s}$ (For Cl⁻)
$\sigma = 10\%$ (For shales)
$n = 4$ (For shales)

Therefore, $D^{*} = (1.5\cdot10^{-5})\ (0.1)^{4}$
$= 1.5\cdot10^{-13}\ \mathrm{m^2/s}$

Other reported values of D^*: $6 \cdot 10^{-12}$ m^2/s (Hendry and Schwartz, 1988)

$3 \cdot 10^{-10}$ m^2/s (Hendry and Schwartz, 1988)

Solving for t in the initial equation:

$$\frac{700}{50\,000} = \mathrm{erfc}\left(\frac{650}{2\sqrt{1.5 \cdot 10^{-13}\, t}}\right)$$

$$1.4 \cdot 10^{-2} = \mathrm{erfc}\left(\frac{650}{2\sqrt{1.5 \cdot 10^{-13}\, t}}\right)$$

From tables; $\mathrm{erfc}(1.75) = 1.4 \cdot 10^{-2}$

$$\therefore \frac{650}{2\sqrt{1.5 \cdot 10^{-13}\, t}} = 1.75$$

$$t = 7.29 \cdot 10^{9} \text{ years}$$

Using $D^* = 3 \cdot 10^{-10}$ m^2/s

$$t = 3.65 \cdot 10^{6} \text{ years}$$

APPENDIX D

i) SHALLOW WATER CHEMISTRY

ii) MANNVILLE BRINE CHEMISTRY

Well	TDS(mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	Br (ppm)	I (ppm)
WW1	854	276	7	25	14		640	156	34	0.4	0.1
WW2	991	310	4	34	17		645	257	30	0.3	0.1
WW3	893	300	9	18	10		640	168	41	0.7	0.1
WW4	593	102	6	79	27		570	54	13	0.3	0.1
WW5	573	91	5	83	30		575	54	8	0.3	0.1
WW6	1713	650	3	6	2	24	615	3	635	3.7	1.7
WW7	1337	510	0	15	5		600	3	475	4.1	1.7
WW8	582	212	0	11	5	6	530	2	43	0.3	0.1
WW9	1546	565	4	10	3	6	510	2	600	3.5	1.7
WW10	2704	300	0	317	124		505	1394	42	0.5	0.1
WW11	3360	1280	0	20	6		340	2	1810	12.7	6.7
WW12	724	200	4	42	17		580	122	11	0.3	0.1
WW13	1291	500	2	4	1	18	605	2	363	2.9	1.5
WW14	1514	560	29	7	2	24	530	2	588	4.7	2.6
WW15	1759	675	4	9	3	18	465	1	780	5.9	3.4
WW16	1005	244	1	82	40		720	18	208	1.9	0.7
WW17	1019	240	3	88	38		745	2	210	0.7	0.4
WW18	789	240	1	27	11		615	106	16	0.5	0.1
WW19	1331	324	7	116	50		755	33	398	2.9	1.5
WW20	767	288	1	10	3	18	560	2	124	1	0.3
WW21	1030	325	3	42	19		585	4	293	2.1	1
WW22	1008	380	0	4	1	37	615	151	80	0.5	0.2
WW23	1337	520	6	8	2	12	545	2	500	3.4	1.5
WW24	692	36	2	98	35		325	81	11	0.2	0.1
WW25	551	116	6	61	19		564	25	5	0.3	0.1
WW26	983	188	0	88	39		580	290	8	0.2	0.1
WW27	863	111	2	100	52		495	283	6	0.3	0.1
WW28	946	230	0	68	33		645	248	13	0.2	0.1
WW29	502	19	3	103	36		444	61	18	0.3	0.1
WW30	760	278	4	6	2	30	590	88	7	0.2	0.5
WW31	1021	365	4	7	3	42	635	225	5	0.2	0.04
WW32	1028	370	10	3	1	37	710	174	9	0.2	0.1
WW33	529	178	11	7	2	24	390	67	5	0.2	0.03
WW34	774	280	9	6	3	24	575	110	6	0.3	0.1
WW35	1292	420	8	24	5	24	690	378	9	0.2	0.1
WW36	277	8.8	1.2	66	14		248	34	3	0.2	0.04

Well	TDS(mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	Br (ppm)	I (ppm)
WW37	2493	930	30	11	4	36	460	3	1200	7.9	4.1
WW38	776	230	5	38	16		630	145	4	0.3	0.04
WW39	924	149	5	106	39		490	334	8	0.3	0.03
WW40	2327	810	12	58	20		640	24	1038	8.5	4.5
WW41	704	127	3	78	28		510	159	6	0.2	0.03
WW42	781	228	7	43	18		600	177	12	0.4	0.1
WW43	679	139	8	68	26		520	156	5	0.3	0.1
WW44	744	154	4	73	30		560	178	4	0.2	0.03
WW45	1722	670	8	7	1	12	610	3	690	4	1.9
WW46	669	101	3	90	33		535	137	4	0.2	0.04
WW47	2164	830	14	10	2		565	2	995	5.8	2.7
WW48	747	244	1	29	8		615	92	27	0.2	0.03
WW49	619	220	0	8	2	12	525	49	4	0.2	0.03
WW50	732	34	5	118	63		575	149	9	0.3	0.03
WW51	726	246	3	19	4	12	585	91	9	0.1	0.1
WW52	1052	37	4	184	63		510	360	11	0.3	0.1
WW53	556	100	6	73	21		512	67	7	0.2	0.03
WW54	1244	480	11	5	1	24	600	2	390	3.2	1.7
WW55	1362	515	10	5	1	18	590	2	455	3.5	2.1
WW56	1595	129	0	208	83		460	675	43	0.4	0.04
WW57	1127	418	3	10	2	12	545	49	305	2.1	1
WW58	1083	385	6	10	3	37	560	75	205	1.5	0.6
WW59	1711	575	12	40	17		535	1	715	4.9	2.7
WW60	1294	248	7	120	49		645	480	19	0.3	0.1
WW61	1236	418	2	38	15		550	5	435	3.2	1.7
WW62	695	122	3	81	31		495	182	4	0.3	0.04
WW63	929	198	11	82	30		560	300	8	0.4	0.03
WW64	863	310	6	1	1		590	182	11	0.3	0.1
WW65	1165	78	5	164	68		525	393	21	0.3	0.04
WW66	401	18	4	89	16		330	30	24	0.4	0.04
WW67	579	212	7	8	3	37	490	35	6	0.3	0.1
WW68	680	248	2	12	5	37	610	9	16	0.3	0.1
WW69	523	15	0	110	31		415	60	12	0.2	0.03
WW70	663	224	7	17	6	18	530	4	72	0.6	0.2
WW71	1243	455	3	4	1	18	715	347	23	0.3	0.1
WW72	553	182	3	21	6		520	4	34	0.3	0.1

Well	TDS(mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	Br (ppm)	I (ppm)
WW73	757	120	5	76	40		490	201	10	0.3	0.03
WW74	751	122	7	74	39		480	209	11	0.3	0.03
WW75	794	270	4	22	10		780	21	22	0.3	0.2
WW76	663	254	0	2	1	18	585	13	26	0.3	0.1
WW77	1056	234	14	84	27	12	500	17	293	2.3	0.8

Well	Ba (ppb)	Sr (ppb)	Li (ppb)	B (ppb)	U (ppb)	Co (ppb)	∂18O (o/oo)	∂D (o/oo)
WW1	4.15	0.47	45.00	450.00	1.30	0.43	-19.38	-150.00
WW2	4.25	0.67	68.00	430.00	0.97	0.57	-19.90	-148.00
WW3	4.40	0.37	49.00	450.00	0.67	0.45	-19.27	-145.00
WW4	13.50	1.30	89.00	160.00	0.63	1.00		
WW5	18.50	1.40	95.00	140.00	0.36	1.10		
WW6	14.00	0.18	57.00	1300.00	0.48	0.24		
WW7	20.50	0.24	43.50	500.00	0.40	0.24	-18.26	-144.00
WW8	42.50	0.16	14.50	640.00	0.34	0.21		
WW9	20.00	0.27	63.00	1500.00	0.41	0.24		
WW10	5.35	2.40	340.00	190.00	46.00	3.70		
WW11	51.50	0.66	115.00	1400.00	0.73	0.43	-17.53	-138.00
WW12	7.15	0.61	90.00	340.00	0.44	0.60		
WW13	12.00	0.14	50.00	910.00	0.41	0.17		
WW14	17.50	0.19	58.00	1000.00	0.46	0.19		
WW15	19.00	0.27	77.00	530.00	0.53	0.18		
WW16	20.00	0.88	77.00	270.00	0.44	1.30	-19.55	-157.00
WW17	18.50	0.85	79.00	260.00	0.43	1.20	-20.21	-157.00
WW18	5.95	0.30	64.00	450.00	1.20	0.41		
WW19	115.00	1.20	83.00	260.00	0.50	3.10		
WW20	13.50	0.13	32.00	830.00	0.31	0.22	-17.81	-144.00
WW21	44.00	0.52	33.00	800.00	0.33	0.63		
WW22	4.50	0.10	56.00	690.00	0.42	0.14		
WW23	14.50	0.22	62.00	1200.00	0.38	0.20		
WW24	17.00	0.32	32.00	100.00	4.90	1.50		
WW25	9.60	0.82	103.00	180.00	0.33	0.84		
WW26	5.20	0.74	87.00	310.00	0.44	1.20	-20.22	-158.00
WW27	16.00	0.74	58.00	170.00	1.10	1.40		
WW28	29.00	0.51	51.00	290.00	1.10	0.87		
WW29	77.00	0.47	53.50	60.00	12.00	1.50		
WW30	19.00	0.10	70.00	780.00	1.10	0.71		
WW31	13.00	0.17	145.00	510.00	1.20	0.25		
WW32	18.00	0.07	61.50	1200.00	1.60	0.42	-18.76	-146.00
WW33	16.00	0.12	91.00	360.00	0.93	0.27		
WW34	6.20	0.11	85.00	920.00	1.30	0.39		
WW35	6.80	0.43	145.00	800.00	1.50	0.48		
WW36	103.00	0.16	14.00	26.00	1.70	1.10	-18.68	-140.00

Well	Ba (ppb)	Sr (ppb)	Li (ppb)	B (ppb)	U (ppb)	Co (ppb)	∂18O (o/oo)	∂D (o/oo)
WW37	250.00	0.34	82.00	1400.00	1.60	0.48		
WW38	13.00	0.36	75.00	590.00	1.40	0.65	-20.00	-155.00
WW39	19.00	0.90	88.00	350.00	1.10	1.80		
WW40	400.00	0.87	145.00	440.00	2.20	0.82		
WW41	36.00	0.75	53.50	190.00	2.20	1.20		
WW42	10.00	0.50	76.00	330.00	1.40	1.10		
WW43	31.00	0.52	49.50	250.00	1.00	1.30	-19.72	-155.00
WW44	17.50	0.57	85.00	330.00	1.10	1.60		
WW45	103.00	0.16	58.00	1500.00	2.40	0.45		
WW46	44.00	0.59	66.00	200.00	6.80	1.60	-21.11	-151.00
WW47	150.00	0.25	72.00	1400.00	2.40	0.40	-18.01	-141.00
WW48	55.00	0.39	170.00	370.00	1.80	0.81		
WW49	21.00	0.10	63.00	870.00	1.60	0.33		
WW50	45.00	0.72	51.00	92.00	13.00	2.40		
WW51	38.00	0.23	88.00	320.00	1.00	0.49		
WW52	15.00	1.50	72.00	81.00	16.00	4.40		
WW53	58.00	0.98	140.00	310.00	1.40	1.50	-20.84	-160.00
WW54	55.00	0.11	48.00	1100.00	1.40	0.35	-18.27	-139.00
WW55	80.00	0.14	55.00	800.00	1.20	0.27		
WW56	21.00	1.31	120.00	210.00	27.00	4.10		
WW57	100.00	0.24	53.00	830.00	0.89	0.33		
WW58	83.00	0.19	51.00	700.00	1.50	0.39		
WW59	83.00	0.69	49.00	1000.00	1.50	1.00	-18.04	-141.00
WW60	19.00	1.10	98.00	430.00	1.50	2.50		
WW61	460.00	0.48	30.00	910.00	1.50	1.10		
WW62	19.50	0.74	91.00	300.00	1.10	1.80	-20.08	-153.00
WW63	30.00	0.60	69.00	380.00	1.80	1.50		
WW64	3.80	0.01	16.00	270.00	2.00	0.26		
WW65	11.00	0.83	99.00	160.00	15.00	4.00		
WW66	250.00	0.25	29.00	56.00	1.00	1.80		
WW67	170.00	0.13	26.00	550.00	1.60	0.20		
WW68	80.00	0.10	19.00	1200.00	1.30	0.36		
WW69	210.00	0.31	20.00	55.00	3.20	1.60	-18.72	-145.00
WW70	140.00	0.16	17.00	730.00	2.60	0.80	-18.79	-148.00
WW71	13.00	0.08	70.00	600.00	2.40	0.31		
WW72	140.00	0.19	15.00	760.00	1.20	0.59		

Well	Ba (ppb)	Sr (ppb)	Li (ppb)	B (ppb)	U (ppb)	Co (ppb)	∂18O (o/oo)	∂D (o/oo)
WW73	25.00	0.60	43.00	200.00	1.60	1.20	-19.57	-153.00
WW74	26.00	0.62	42.00	190.00	1.20	1.30		
WW75	120.00	0.29	23.00	940.00	1.90	0.40		
WW76	26.00	0.05	24.00	930.00	1.70	0.19		
WW77	730.00	1.10	90.00	550.00	2.60	2.80		

Well	TDS (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	I (mg/l)	Br (mg/l)
3-24-42-2	74625	22300	312	1122	778	1090	1	38500	0.69	5.09
7-11-43-2									3.44	51.31
7-24-43-3	90459	26800	212	2124	1143	870	3	48250	3.41	45.89
9a-29-41-1	94604	27200	683	1924	1192	670	1	49500	5.69	67.07
11-19-42-2	91604	27000	886	2445	1192	970	4	50250	6.30	85.62
13-27-43-1	97720	29000	737	2244	1216	670	1	53000	5.24	76.83
13c-16-41-1	100922	31200	407	1723	900	730	5	54000	0.21	1.61
14-23-43-1	96742	29200	337	2164	1167	505	1	52500	4.62	65.62
15d-22-42-1	56472	16800	431	641	462	965	1	28500	0.61	5.10
1b-27-42-1	56552	16800	221	681	389	1025	1	28000	6.80	68.03
1c-27-42-1	56396	16800	266	621	397	1000	1	28000	6.73	62.58
4c-29-41-1	100616	31800	590	2084	1046	330	11	56500	11.20	181.94
5-12-43-2	99124	29800	381	2405	1240	730	3	54000	13.28	216.72
6-21-42-2	82087	24300	408	2004	802	855	1	43500	8.99	138.31
6-11-43-2	74040	23900	627	1523	876	1000	1	42500	12.38	151.36
7-34-42-2	54700	19300	0	802	511	1000	1	32000	6.66	74.74
9c-25-41-2	106233	33000	741	2164	1046	720	8	58500	10.53	203.65
10-28-43-1	98200	29000	590	2365	1216	640	1	53000	14.67	230.57
11-35-42-1W	91540	27800	408	1523	1070	560	1	49000	11.13	166.98
11-35-42-1T	89927	27900	611	1523	1070	505	1	49500	10.43	139.01
12-19-42-1	73088	22500	313	1202	803	1130	1	39000	11.69	151.27
12-22-43-1	98370	29000	1111	2244	1192	675	1	53500	13.98	195.66
13b-28-41-1	105213	31800	346	2244	924	410	19	56000	11.93	182.47
1-29-41-1*	100328	30800	240	1924	1046	555	7	54000	10.49	167.91
5-27-43-1*	99469	30300	618	2365	1216	725	1	55000	13.99	202.79
6-19-42-1*	64376	20500	417	922	584	1025	4	35000	9.57	143.58
8-16-41-1*	98477	29000	985	1683	1094	720	3	52000	9.78	160.73
CT 1*	81457	26100	826	1964	851	785	46	47000	11.75	179.73
6-19-42-1+	74250	23000	389	1283	730	815	5	40000	9.63	116.98
7-28-43-1+	99992	30800	678	2285	1046	685	1	55250	11.89	174.87
11-26-42-2+	54010	19000	0	762	559	1020	1	31500	4.82	51.61
1c-29-41-1	2575	980	0	8	4	380	3	1275	3.94	7.88

Well	B (ppm)	Ba (ppm)	Li (ppm)	∂18O (o/oo)	∂D (o/oo)
3-24-42-2					
7-11-43-2					
7-24-43-3					
9a-29-41-1					
11-19-42-2					
13-27-43-1					
13c-16-41-1					
14-23-43-1					
15d-22-42-1					
1b-27-42-1				-11.85	-102.00
1c-27-42-1				-12.14	-108.00
4c-29-41-1				-10.57	-101.00
5-12-43-2	27.00	60.00	18.00	-9.10	-98.00
6-21-42-2				-10.20	-93.00
6-11-43-2				-10.18	-97.00
7-34-42-2	11.00	23.00	7.90	-11.44	-95.00
9c-25-41-2				10.63	-96.00
10-28-43-1				-9.08	-83.00
11-35-42-1W	10.00	58.00	12.00	-11.02	-97.00
11-35-42-1T				-10.76	
12-19-42-1				-10.94	-96.00
12-22-43-1				-9.36	-99.00
13b-28-41-1				-10.39	-103.00
1-29-41-1*	21.00	33.00	14.00		
5-27-43-1*	19.00	51.00	16.00	-9.24	-92.00
6-19-42-1*	14.00	49.00	11.00	-11.41	-102.00
8-16-41-1*					
CT 1*	17.00	62.00	13.00	-10.16	-98.00
6-19-42-1+	12.00	23.00	9.00		
7-28-43-1+	24.00	24.00	16.00	-9.73	-100.00
11-26-42-2+	11.00	21.00	8.00	-11.30	-99.00
1c-29-41-1	<0.2	0.35	0.18		

AVERAGE % ERROR OF CHEMICAL CONSTITUENTS
(From Duplicate Samples)

TDS	1.05%
Na	1.10%
Ca	6.32%
Mg	3.23%
HCO3	2.65%
SO4	54.63%
Cl	3.9%
Br	33.55%
I	18.82%
K	50.60%
Ba	5.86%
Sr	3.38%
Li	2.46%
B	4.45%
U	15.44%
Co	8.0%