5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly by glaciation. The lower surficial deposits include pre-glacial fluvial[8] and lacustrine[9] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The upper surficial deposits include the more traditional glacial deposits of till and meltwater deposits. In Flagstaff County, pre-glacial material is reported to be present in association with the Buried Wainwright Valley.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of three hydraulic parts. The first is the sand and gravel deposits of the lower surficial deposits, the second is the saturated sand and gravel deposits of the upper surficial deposits and third is the sand and gravel close to ground level, which is usually unsaturated. The sand and gravel deposits in the upper part of the surficial deposits can extend above the upper limit of the saturation zone and because they are not saturated, they are not an aquifer. However, these sand and gravel deposits are significant since they provide a pathway for liquid contaminants to move downward into the groundwater. Because of the significance of the shallow sand and gravel deposits, they have been mapped where they are present within one metre of the ground surface and are referred to as the “first sand and gravel”.

Over the majority of the County, the surficial deposits are less than 30 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 60 metres. The main linear bedrock low in the County has been designated as the Buried Wainwright Valley, as shown on the adjacent map. This Valley trends from northwest to southeast through the County and underlies or is close to the towns of Daysland, Killam, Sedgewick and Hardisty. The Buried Wainwright Valley is approximately 8 to 15 kilometres wide, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 30 metres. The above-mentioned towns obtain their municipal water from water supply wells completed in the sand and gravel aquifer associated with the buried valley.

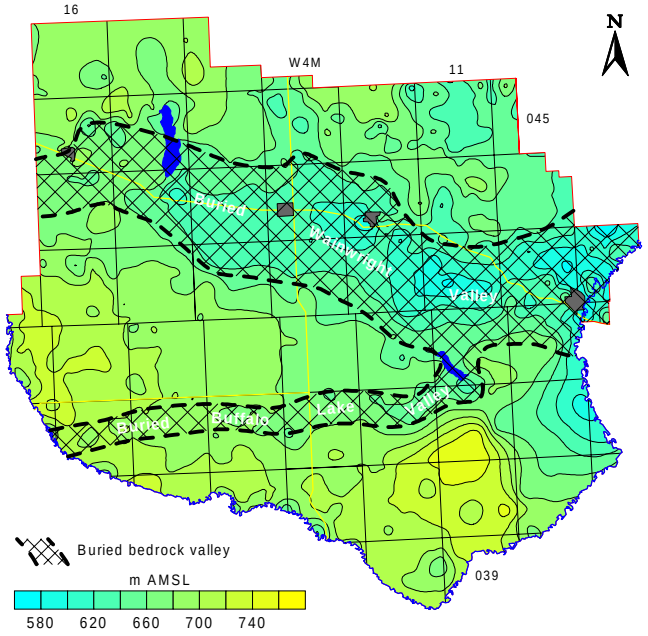

Figure 8. Bedrock Topography

[8] See glossary
[9] See glossary

The second linear bedrock low is designated as the Buried Buffalo Lake Valley. The Buried Buffalo Lake Valley trends from west to east and is a tributary valley to the Buried Wainwright Valley. The Buried Buffalo Lake Valley is approximately five kilometres wide, with local relief being less than 40 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, with the thickness of the deposits expected to be less than 30 metres.

In addition to the linear bedrock lows, there is a significant low in the bedrock surface in the southeastern part of the County. In the eastern part of the County, the bedrock surface is poorly understood. The difficulty in defining the bedrock surface is a result of friable sandstones in the bedrock that can be identified as “sand” by the drillers and the presence of ice-thrusted blocks of bedrock. For example, the bedrock high between the two parts of the Buried Wainwright Valley on cross-section A-A’ may be a result of a block of bedrock having been thrusted into the valley, overlying fluvial deposits at depth.

Sand and gravel deposits can occur throughout the entire unconsolidated section. The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 25% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. The main areas where the sand and gravel percentages are higher are in the southeastern part of the County and in association with linear bedrock lows. The other areas where sand and gravel deposits constitute more than 50% of the surficial deposits may be areas of meltwater channels or areas where linear bedrock lows exist but have not been identified due a shortage of accurate bedrock control points.

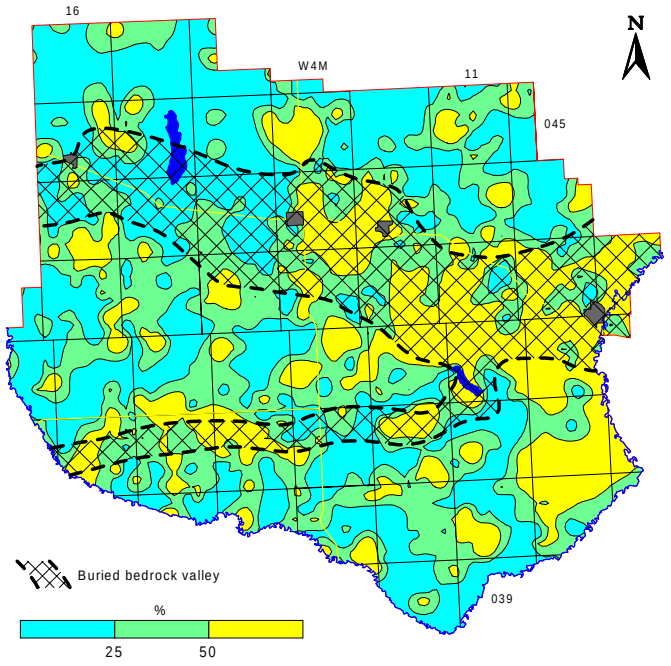

Figure 9. Amount of Sand and Gravel in Surficial Deposits

5.2.2 Sand and Gravel Aquifer(s)

One significant source of groundwater in the County includes aquifers in the surficial deposits. The actual aquifer that is developed is usually dictated by which aquifer is present.

The adjacent map shows water well yields that are expected in the County, based on the surficial aquifers that have been developed by existing water wells. Based on these data, water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in more than 25% of the County. Over approximately 15% of the County, the sand and gravel deposits are not present or, if present, are not saturated.

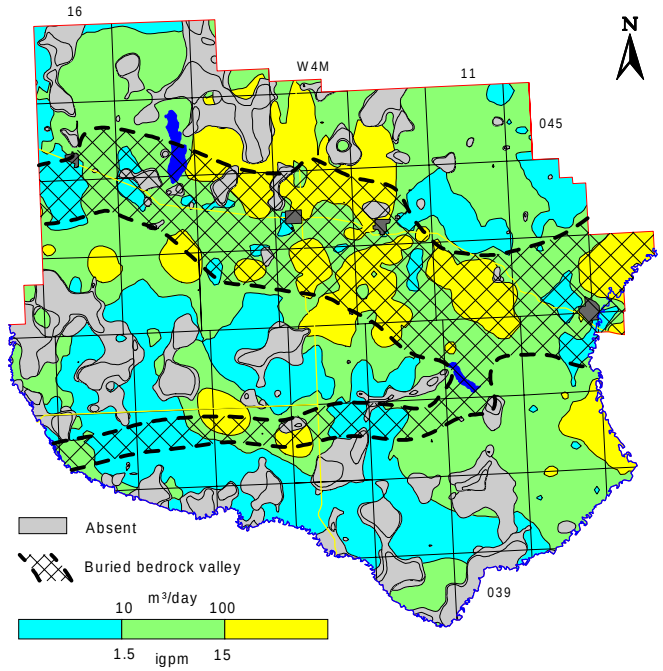

Figure 10. Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

The highest yield from surficial deposits that has been developed in the County for towns along Highway 13 was for the Town of Hardisty. The Town uses a sand and gravel aquifer associated with the Buried Wainwright Valley. Extensive studies of this aquifer indicated a long-term supply of more than 500 m³/day (AEP, 1979). Studies of this aquifer from water wells completed for the Town of Daysland indicated a long-term yield of 330 m³/day (Geoscience, March 1976); and for the Town of Killam, a long-term yield of 420 m³/day (Geoscience, April 1976). Studies for the Town of Sedgewick were not available.

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the upper or lower surficial deposits. The main reason for not separating the chemical analysis results is that there appears to be no major chemical difference between groundwater from the upper and lower sand and gravel aquifers. The groundwaters from these aquifers are generally chemically hard and high in dissolved iron.

The Piper tri-linear diagrams show that the majority of the groundwaters are calcium-magnesium-bicarbonate-type waters; however, there are groundwaters from the surficial deposits that are calcium-magnesium-sulfate, sodium-bicarbonate or sodium-sulfate-type waters.

Fifty percent of the groundwaters from the surficial aquifers have a chemical hardness of less than 400 mg/L. The TDS concentrations in the groundwaters from the surficial deposits range from less than 200 to over 2,000 mg/L, with 60% of the groundwaters having a TDS of less than 1,000 mg/L. The groundwaters with a TDS of more than 2,000 mg/L occur mainly in the northern part of the County. The groundwaters with elevated levels of sulfate occur in areas where there are elevated levels of total dissolved solids. When TDS values exceed 1,200 mg/L, sulfate concentrations exceed 400 mg/L.

There are very few groundwaters with appreciable concentrations of the chloride ion. All of the groundwaters from the surficial deposits are expected to have concentrations of dissolved iron of greater than 1 mg/L.

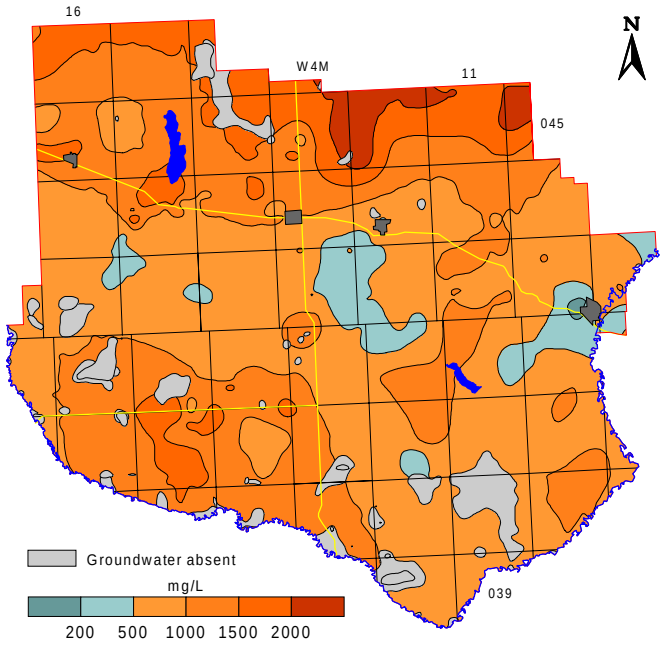

Figure 11. Total Dissolved Solids in Groundwater from Surficial Deposits

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. These aquifers typically occur above an elevation of 670 metres AMSL. Saturated sand and gravel deposits are not continuous but are expected over approximately 90% of the County.

5.2.3.1 Aquifer Thickness

The non-pumping water level in the surficial deposits tends to be a subdued replica of the bedrock surface. Consequently, the thickness of the Upper Sand and Gravel Aquifer tends to be directly proportional to the thickness of the surficial deposits.

While the sand and gravel deposits in the upper surficial deposits are not continuous, the Upper Sand and Gravel Aquifer includes all of the aquifers present in the upper surficial deposits. The Upper Sand and Gravel Aquifer is more than 30 metres thick in a few areas, but over the majority of the County, is less than ten metres thick; over 10% of the County, the Aquifer is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the areas of linear bedrock lows and in the southeastern part of the County. The major bedrock low in the southeastern part of the County is not presently associated with a linear bedrock low.

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the long-term yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 100 m³/day. Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible.

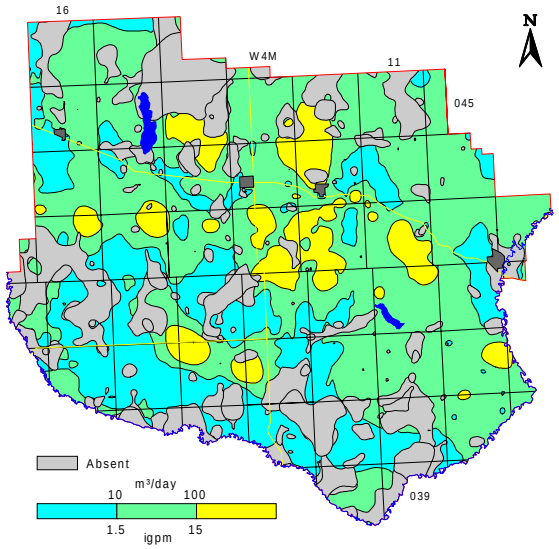

Figure 12. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits where the bedrock surface is below a depth of 670 metres AMSL. The Lower Sand and Gravel Aquifer may be a continuous aquifer in the Buried Wainwright Valley, where the thickness of the sand and gravel deposits is mainly less than 10 metres. The Lower Sand and Gravel Aquifer does not appear to extend west of range 15. In all, the Lower Sand and Gravel Aquifer is mostly restricted to the northeastern and eastern parts of the County.

5.2.4.1 Apparent Yield

Water wells completed in the Lower Sand and Gravel Aquifer may have yields in excess of 100 m³/day. The highest yields are expected in the Buried Wainwright Valley in the vicinity of the Town of Hardisty; in township 043, range 11, W4M; and in the eastern part of township 041, range 10, W4M. The results of detailed studies for the individual towns suggest that long-term yields for some water wells are more than 300 m³/day.

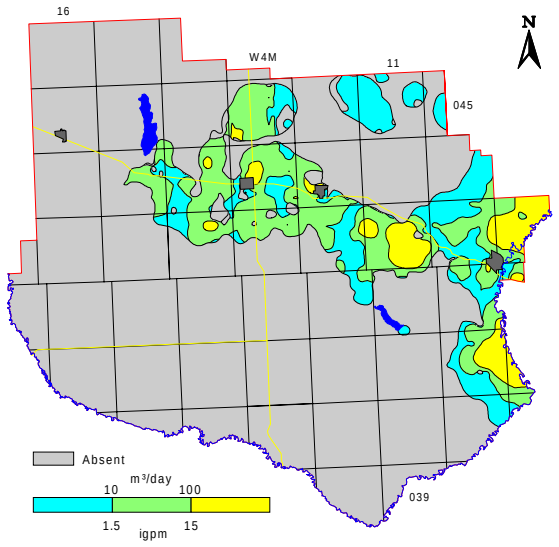

Figure 13. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes the Lower Horseshoe Canyon Formation, the Bearpaw Formation and the Belly River Group. The Lea Park underlies the Belly River Group.

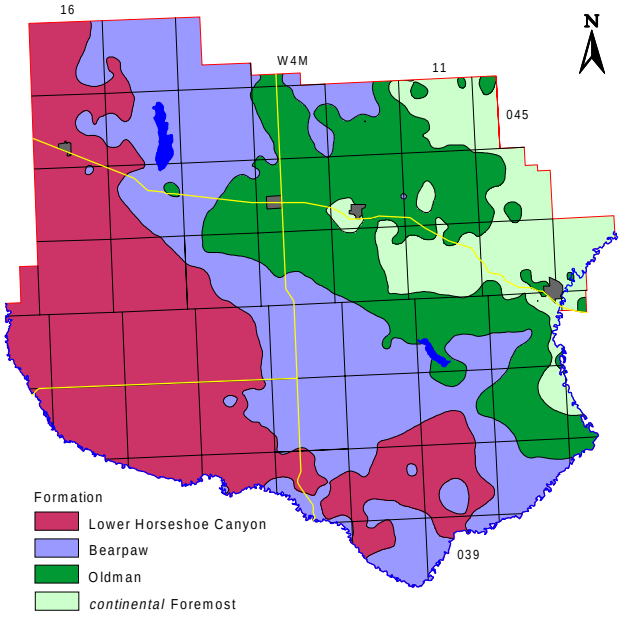

Figure 14. Bedrock Geology

The Lower Horseshoe Canyon Formation is the lower part of the Edmonton Group and is the upper bedrock in the western part of the County. There are also subcrops of the Lower Horseshoe Canyon Formation that occur as outliers within the area of the Bearpaw Formation. The Lower Horseshoe Canyon Formation has a maximum thickness of 170 metres. The Upper and the Middle Horseshoe Canyon formations are absent within the County.

The Lower Horseshoe Canyon Formation consists of deltaic[10] and fluvial sandstone, siltstone and shale layers with interbedded coal seams, bentonite and thin nodular beds of ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres of the Lower Horseshoe Canyon can include coarser grained sandstone deposits. The Lower Horseshoe Canyon Formation is underlain by the Bearpaw Formation.

The Bearpaw Formation is the upper bedrock in the west-central part of the County and has been eroded in the northeastern half of the County. The Bearpaw Formation is generally less than 100 metres thick in the County. “The Bearpaw Formation consists of marine shale, siltstone and minor sandstone, and represents the final widespread marine unit in the Western Canada Foreland Basin” (Catuneanu et al, 1997). The border between the bottom of the Bearpaw Formation and the uppermost part of the Belly River Group was used as a geological marker in the e-log interpretation.

The Belly River Group in the County has a maximum thickness of 250 metres and includes the Oldman Formation, and both the *continental* and *marine* facies[11] of the Foremost Formation. There are zones of higher permeability that occur in the *marine* facies of the Belly River Group. These porous and permeable zones are present in the northeastern one quarter of the County but there are very few areas where they are within 100 metres of the ground surface. Where the porous and permeable zones are present, the fluids in the aquifers may be hydrocarbons or groundwater. However, the groundwater could be expected to have total dissolved solids concentrations of 15,000 mg/L.

[10] See glossary
[11] See glossary

The Oldman Formation is the upper bedrock in the east-central part of the County. There are also subcrops of the Oldman Formation that occur as outliers within the area of the *continental* Foremost Formation. The Oldman Formation has a maximum thickness of 75 metres within the County and is composed of sandstone, siltstone, shale and coal deposited in a continental environment. The Oldman Formation is the upper part of the Belly River Group and is composed of three parts: the Comrey, the Upper Siltstone and the Dinosaur members. The uppermost part of the Dinosaur Member is the Lethbridge Coal Zone. Sandstone is predominant in the Comrey Member, the Upper Siltstone is mainly siltstone, and the Dinosaur Member includes shale and coal deposits.

The *continental* Foremost Formation underlies the Oldman Formation and subcrops under the surficial deposits in the northeastern part of the County. The *continental* Foremost Formation, a backshore deposit, consists mainly of shale deposits with minor amounts of sandstone present. Coal zones occur within the *continental* Foremost Formation, with the main ones referred to as the McKay and the Taber Coal Zones. There are also minor amounts of ironstone, a chemical deposit, in the *continental* Foremost Formation. Where the *continental* Foremost Formation is close to the bedrock surface, it can be fractured or weathered and can have significant local permeability. The *marine* Foremost Formation, which includes up to five sandstone members and has a maximum thickness of 50 metres within the County, underlies the *continental* Foremost Formation.

The upper part of the *marine* Foremost Formation is present in the eastern part of the County. The sandstones in the *marine* Foremost Formation cannot always be separated into individual members that are identified east of Flagstaff County. This situation occurs because the sandstone members of the *marine* Foremost Formation thicken and the intervening shale layers thin toward the western edge of the *marine* facies. With this change, distinguishing between the individual sandstone members is not possible. Even though the individual members cannot be distinguished, the sandstone occurrence can be a significant aquifer and has been designated the “Milan Aquifer”. The top of the Milan Aquifer extends up to 10 metres into the overlying *continental* Foremost Formation and can occupy the upper 40 metres of the *marine* Foremost Formation. The westward extent of the Milan Aquifer coincides with the position where the Basal Belly River Sand can be distinguished. In the Flagstaff County, both the *marine* Foremost Formation and the Milan Aquifer are present under the *continental* Foremost Formation in the northeastern part of the County but do not subcrop in the County.

The Lea Park Formation is mostly composed of shale, with only minor amounts of bentonitic sandstone present in some areas. Regionally, the Lea Park Formation is an aquitard[12].

5.3.2 Aquifers

Of the 3,926 water wells in the database, 719 were defined as being completed in bedrock aquifers. This designation is based on the top of the completion interval being below the bedrock surface. The completion depth is available for the majority of water wells. In order to make use of additional information within the groundwater database, it was statistically determined that water wells typically have completion intervals

Bedrock Aquifer	No. of Water Wells
Lower Horseshoe Canyon	570
Bearpaw	390
Oldman	416
continental Foremost	389
marine Foremost	8
Milan	6
Lea Park	0

Table 2. Bedrock Aquifer Completion

[12] See glossary

equivalent to one quarter of their completed depth. This relationship was used to increase the number of water wells identified as completed in bedrock aquifers to 2,092 from 719. With the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to assign the water wells completed in bedrock aquifers to specific aquifers based on their completion intervals. The bedrock water wells are mainly completed in the Lower Horseshoe Canyon, the Bearpaw, the Oldman, and the *continental* Foremost aquifers as shown in the adjacent table; 313 bedrock water wells are completed in more than one aquifer. The discussions related to specific aquifers, later in this report, do not include the Milan or *marine* Foremost Aquifers. However, maps associated with these two aquifers are included on the CD-ROM.

The records for the existing water wells completed in bedrock aquifer(s) indicate that, in Flagstaff County, water well yields can be expected to be mainly less than 30 m³/day, with large areas having expected long-term yields of less than 10 m³/day. The adjacent map shows that water well yields in the eastern part of the County are generally higher. In some of the eastern area, projected long-term yields are greater than 100 m³/day. These higher yields may be a result of fracturing caused by ice thrusting of bedrock blocks.

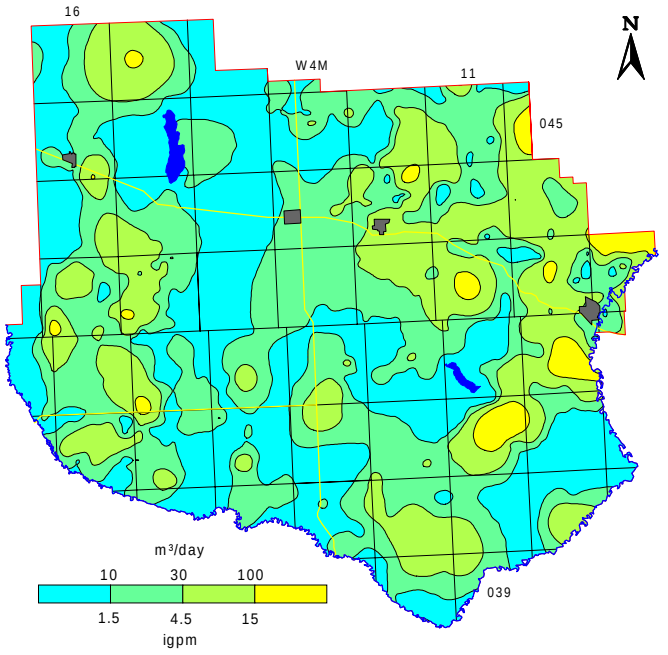

Figure 15. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

The general area of lower projected yields in the central part of the County corresponds to the subcrop area of the Bearpaw Formation. Immediately west of the Bearpaw Formation subcrop is the subcrop of the Lower Horseshoe Canyon Formation. And in this area, water well yields tend to be higher. Further east, water well yields decline as the lower part of the Lower Horseshoe Canyon Formation is at a greater depth and the upper bedrock is the upper part of the Lower Horseshoe Canyon Formation.