5.3.13 Lower Horseshoe Canyon Aquifer (Blood Reserve)

The Lower Horseshoe Canyon Aquifer comprises the permeable parts of the Lower Horseshoe Canyon Formation that underlie the Middle Horseshoe Canyon Formation, and subcrop under the surficial deposits. Structure contours have been prepared for the top of the Formation. The structure contours show that the Lower Horseshoe Canyon Formation ranges in elevation from below 0 to more than 1,300 metres AMSL and has an average thickness of 100 metres. The non-pumping water level in the Lower Horseshoe Canyon Aquifer is downgradient to the north toward the Oldman River.

5.3.13.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent, to more than 1,100 metres in the western part of the County (page A-51).

5.3.13.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day, with four of the five water wells having an apparent yield value of more than ten m³/day. There are no dry water test holes completed in the Lower Horseshoe Canyon Aquifer.

In the County, there are nine authorized non-exempt water wells completed in the Lower Horseshoe Canyon Aquifer, for a total of 88 m³/day; the highest single diversion of 64 m³/day is for a water supply well in 14-23-005-23 W4M used for agricultural purposes. One of the nine authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

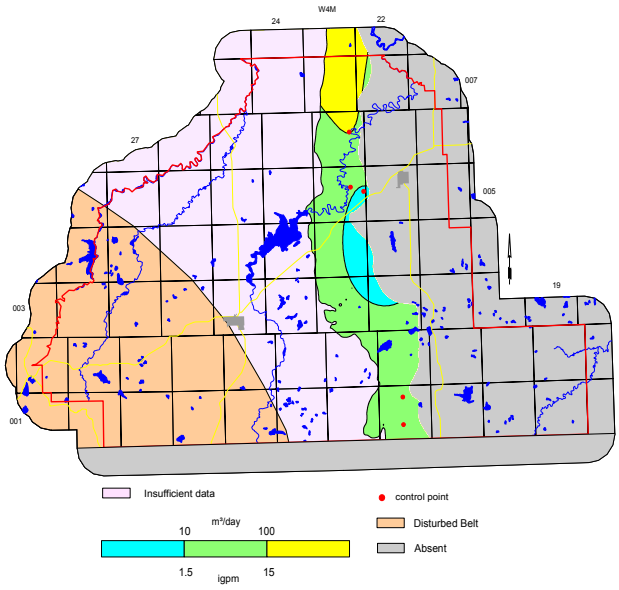

Figure 28. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

5.3.13.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are mainly greater 500 mg/L (page A-53), with only one TDS concentration being less than 500 mg/L. The sulfate concentrations are mainly less that 500 mg/L. Only one of the nine chloride values is greater than ten mg/L.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	9	446	1575	965	998	500
Sodium	5	65	449	202	265	200
Sulfate	9	88	806	413	278	500
Chloride	9	3.0	33	6.0	10	250
Fluoride	6	0.1	1.1	0.5	0.4	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 14. Apparent Concentrations of Constituents in Groundwaters from Lower Horseshoe Canyon Aquifer

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sulfate and fluoride from water wells completed in the Lower Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

5.3.14 Bearpaw Aquifer

The Bearpaw Aquifer comprises the permeable parts of the Bearpaw Formation that underlie the Lower Horseshoe Canyon Formation, and subcrops under the surficial deposits in most of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Bearpaw Formation ranges in elevation from below -100 to more than 1,300 metres AMSL and has an average thickness of 200 metres. The non-pumping water level in the Bearpaw Aquifer is downgradient to the north toward the Oldman River.

5.3.14.1 Depth to Top

The depth to the top of the Bearpaw Formation is variable, ranging from less than ten metres at the eastern extent, to more than 1,100 metres in the western part of the County (page A-54).

5.3.14.2 Apparent Yield

The apparent yields for individual water wells completed through the Bearpaw Aquifer range mainly from 10 to 100 m³/day, with more than 80% of the values being greater than ten m³/day. There are five (2.5%) dry water test holes completed in the Bearpaw Aquifer.

In the County, there are 22 authorized non-exempt water wells completed in the Bearpaw Aquifer, for a total of 94 m³/day; the highest single diversion of 16 m³/day is for a water supply well in 13-21-004-21 W4M licensed to the Hutterian Rockport Colony for municipal purposes. Fifteen of the 22 authorized non-exempt water wells could be linked to a water well in the AENV groundwater database.

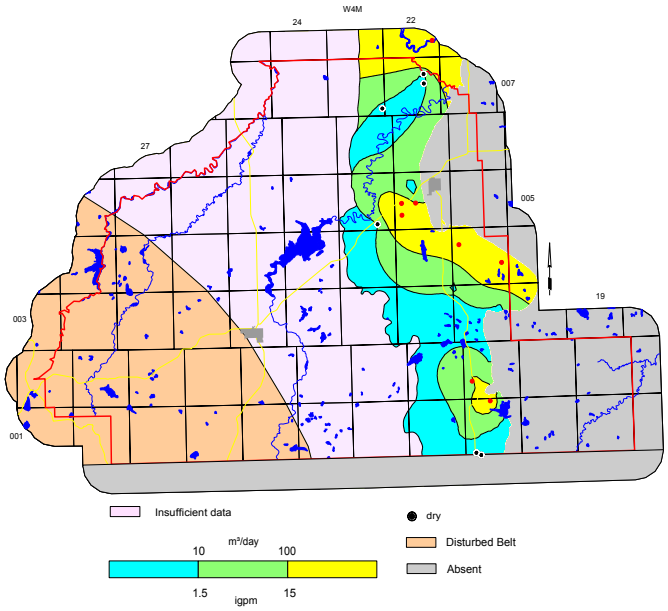

Figure 29. Apparent Yield for Water Wells Completed through Bearpaw Aquifer

5.3.14.3 Quality

The groundwaters from the Bearpaw Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range from less than 500 to more than 3,000 mg/L (page A-56), with 80% of the TDS concentrations being greater than 500 mg/L. The sulfate concentrations are mainly less than 500 mg/L. Ninety percent of the chloride concentrations from the Bearpaw Aquifer are less than 100 mg/L.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	48	277	7248	933	998	500
Sodium	35	33	704	223	265	200
Sulfate	50	7	4165	269	278	500
Chloride	50	0.0	89	7.9	10	250
Fluoride	30	0.1	1.3	0.4	0.4	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 15. Apparent Concentrations of Constituents in Groundwaters from Bearpaw Aquifer

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. None of the mean values from water wells completed in the Bearpaw Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

5.3.15 Oldman Aquifer

The Oldman Aquifer comprises the permeable parts of the Oldman Formation that underlie the Bearpaw Formation, and subcrop under the surficial deposits in most of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Oldman Formation ranges in elevation from below -200 to more than 1,400 metres AMSL and has an average thickness of 250 metres. The non-pumping water level in the Oldman Aquifer is downgradient to the northwest toward the Oldman River and southeast toward the Milk River.

5.3.15.1 Depth to Top

The depth to the top of the Oldman Formation is variable, ranging from less than ten metres at the eastern extent, to more than 1,300 metres in the western part of the County (page A-57).

5.3.15.2 Apparent Yield

The apparent yields for individual water wells completed through the Oldman Aquifer range mainly from 10 to 100 m³/day, with more than 80% of the values being greater than ten m³/day. There are four (2%) dry water test holes completed in the Oldman Aquifer.

In the County, there are 12 authorized non-exempt water wells completed in the Oldman Aquifer, for a total of 26 m³/day; the highest single diversion of 6.9 m³/day is for a water supply well in NW 15-001-21 W4M authorized as a registration. Six of the eight authorized water wells could be linked to a water well in the AENV groundwater database.

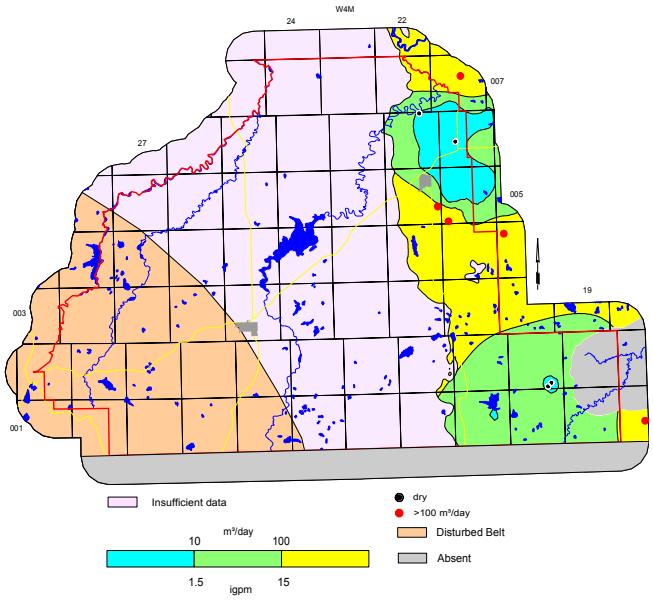

Figure 30. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.15.3 Quality

The groundwaters from the Oldman Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly from greater than 500 to less than 2,000 mg/L (page A-59), with only two TDS concentrations being less than 500 mg/L. The sulfate concentrations range mainly between 100 and 1,000 mg/L. Seventy-seven percent of the chloride concentrations from the Oldman Aquifer are less than 100 mg/L. The fluoride concentrations in the Oldman Aquifer are expected to be more than 1.5 mg/L where the depth to top of the Oldman Aquifer is mainly less than ten metres below ground surface.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	35	456	3320	1420	998	500
Sodium	32	154	1265	322	265	200
Sulfate	35	28	1785	522	278	500
Chloride	35	7.0	135	20.0	10	250
Fluoride	21	0.0	3.6	0.4	0.4	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 16. Apparent Concentrations of Constituents in Groundwaters from Oldman Aquifer

Of the five constituents that have been compared to the SGCDWQ, the median values of TDS, sodium and sulfate exceed the guidelines. The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Oldman Aquifer are greater than the median concentrations, and fluoride is equal to the median concentrations, from water wells completed in all upper bedrock aquifer(s).

5.3.16 Foremost Aquifer

The Foremost Aquifer comprises the permeable parts of the Foremost Formation, as defined for the present program. Structure contours have been prepared for the top of the Foremost Formation. The structure contours show that the Foremost Formation ranges in elevation from below -400 to more than 1,100 metres AMSL and is mainly less than 200 metres thick. The Foremost Formation is underlain by the Lea Park Formation, a regional aquitard.

5.3.16.1 Depth to Top

The depth to the top of the Foremost Formation ranges from less than ten metres below ground surface at the eastern extent to more than 1,500 metres in the western part of the County (page A-60).

5.3.16.2 Apparent Yield

There are no apparent yield values available for water wells completed through the Foremost Aquifer.

5.3.16.3 Quality

There are three values for TDS concentrations for water wells completed through the Foremost Aquifer. All three values are greater than 1,000 mg/L. The four values for sulfate for water wells completed through the Foremost Aquifer are less than 1,000 mg/L. The three values for chloride for water wells completed through the Foremost Aquifer are less than 50 mg/L.

6. Groundwater Budget

6.1 Hydrographs

In the County, there are two observation water wells that are part of the AENV regional groundwater-monitoring network. These are locations where water levels are being measured and recorded as a function of time: AENV Obs Water Well No. 105 in 13-19-004-27 W4M, approximately two kilometres east of the Waterton Reservoir and one kilometre southwest of Cochrane Lake, and AENV Obs WW No. 101 in 13-11-001-22 W4M, approximately four kilometres northeast of the Hamlet of Del Bonita. The water level in AENV Obs WW No. 105 was measured from April 27, 1965 to October 21, 1993, and the water level in AENV Obs WW No. 101 has been measured since June 19, 1985 (see page A-63).

AENV Obs WW No. 105 is drilled to a depth of 12.2 metres below ground surface and completed open hole in the upper part of the Lower Sand and Gravel Aquifer in association with the Buried Cochrane Valley. The upper part of the Buried Cochrane Valley consists primarily of silt and clay. AENV Obs WW No. 105 encountered only till from surface to its completed depth of 12.2 metres. This observation water well was drilled by the Groundwater Division of the Alberta Research Council (ARC) on October 23, 1964. The filling of the Waterton Reservoir began on March 18, 1965, and with the combined efforts of ARC and PFRA, a study was conducted in order to determine the effects that the reservoir would have on the Lower Sand and Gravel Aquifer in association with the Buried Cochrane Valley (Vanden Berg and Geiger, 1973). During 1964, as part of the study, the Alberta Research Council installed five piezometer nests, each nest consisting of a shallow water well and a deep water well, in order to observe any changes the Waterton Reservoir would have on the groundwater. All ten water wells were completed in the lower surficial deposits associated with the Lower Sand and Gravel Aquifer. AENV Obs WW No. 105, one of the shallow water wells, was completed to observe any changes on the depth of the water table. The deep water wells were completed at the base of the lower sand and gravel deposits in order to measure the hydraulic pressure in the Lower Sand and Gravel Aquifer in association with the Buried Cochrane Valley.

The Waterton Reservoir was initially filled from March 18, 1965 to June 18, 1965 and, during this period, the surface water level in the reservoir rose in the order of 40 metres. On March 18, 1965 when the Waterton Reservoir began to fill, there was a rapid rise in the groundwater levels in the five deep water wells, causing the water levels to flow in three of the deep water wells, creating a spring, and forcing up the surface casing of a farmer's water well until the groundwater flowed without control. It was determined that the lower sand and gravel deposits of the Lower Sand and Gravel Aquifer are hydraulically associated with the water level in the Waterton Reservoir. In order to prevent further farm water wells from flowing, PFRA installed a series of pressure-relief water wells.

The non-pumping water level in AENV Obs WW No. 105 on October 23, 1964 was 3.51 metres below ground surface as shown on the figure on the following page. The next water level measured in AENV Obs WW No. 105 was on April 27, 1965, approximately six weeks after the filling of the Waterton Reservoir began. Between October 23, 1964 and April 27, 1965, the water level in AENV Obs WW No. 105 rose 0.62 metres. On May 22, 1965, the last measured water level recorded prior to the completion of the filled reservoir was 2.89 metres below ground surface. The first measured water level following the filling of the reservoir was on June 17, 1965 and the measured water level rose to a depth of 2.08 metres below ground surface, a rise of 0.81 metres.

The water-level fluctuations in AENV Obs WW No. 105 from 1964 to 1970 have been compared to the monthly precipitation measured at the Cardston weather station. A six-year interval was chosen in order to make an easier visual comparison between the water-level fluctuation in AENV Obs WW No. 105 and the monthly precipitation recorded at the Cardston weather station. The change in precipitation would give an indication of changes that would be reflected in the water level in the Waterton Reservoir.

The water levels in water wells that do not flow follow the reservoir level closely and instantaneously (Vanden Berg and Geiger, 1973). This trend is shown on the adjacent figure. There is a reasonable relationship between the monthly precipitation recorded at the Cardston weather station and the water levels measured in AENV Obs WW No. 105.

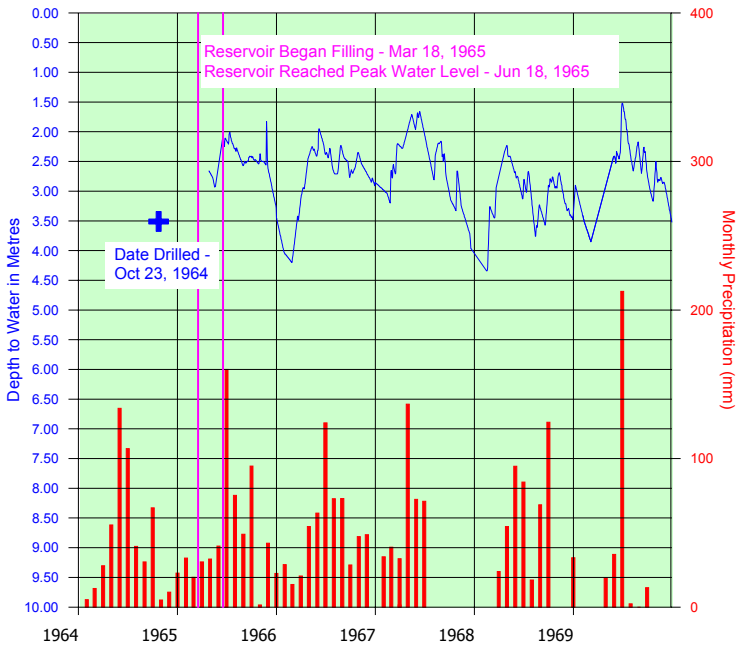

Figure 31. Precipitation vs Water Levels in AENV Obs WW No. 105

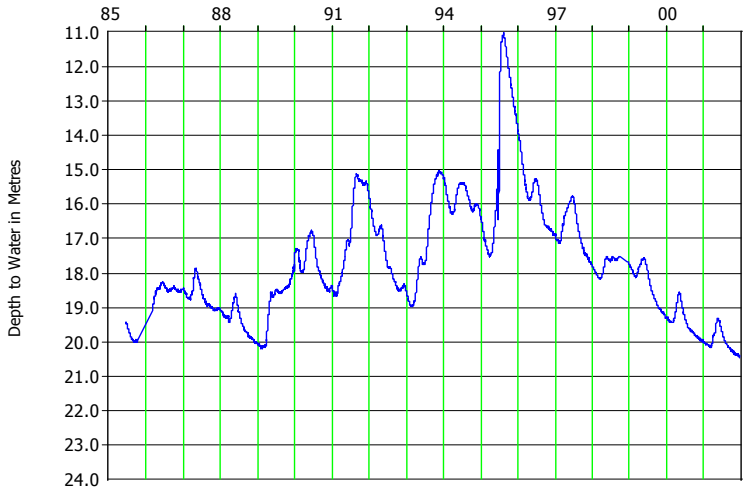

Figure 32. Water-Level Measurements in AENV Obs WW No. 101

AENV Obs WW No. 101 is completed open hole from 26.5 to 73.2 metres in the Lower Horseshoe Canyon and the Bearpaw aquifers.

The water level has been measured in AENV Obs WW No. 101 since mid-1985. The adjacent hydrograph shows annual cycles of recharge and decline throughout the year. In an area where there are no expected seasonal uses of groundwater, the highest water level will usually occur in late spring/early summer and the lowest water level will be in late winter/early spring. From 1986 to 1990, the highest water level in AENV Obs WW No. 101 generally occurs in late spring/early summer. The rise in water level in late spring/early summer could be associated with recharge when the frost leaves the ground. From 1991 to 1995, the highest water level in AENV Obs WW No. 101 occurs in late fall/early winter. The rise in water level late in the year could be associated with excess precipitation after most vegetation has been killed by frost and before the ground has frozen. From 1996 to the end of 2001, the highest water level occurs again in late spring/early summer and the lowest water level generally occurs in late winter/early spring. Overall annual fluctuations in AENV Obs WW No. 101 mainly range from two to four metres. In 1995, the water level rose from a low of 17.4 metres on April 14 to a high of 11.2 metres below ground surface on August 24. From 1985 to the end of 1995, there was a net rise in the water level of approximately nine metres, and from 1995 to the end of 2001, there has been a net decline in the water level of approximately 9.4 metres.

The water-level fluctuations in AENV Obs WW No. 101 have been compared to the precipitation measured at the Del Bonita weather station. Recorded precipitation is available from May 1985 to February 1990. From 1986 to 1990, there were no annual cycles of recharge in response to a decrease in precipitation. In 1989 and 1990, the rise in water level in late spring/early summer could be associated with recharge when the frost leaves the ground. From 1991 to 1996, the rise in water level late in the year could be associated with excess precipitation after most vegetation has been killed by frost and before the ground has frozen.

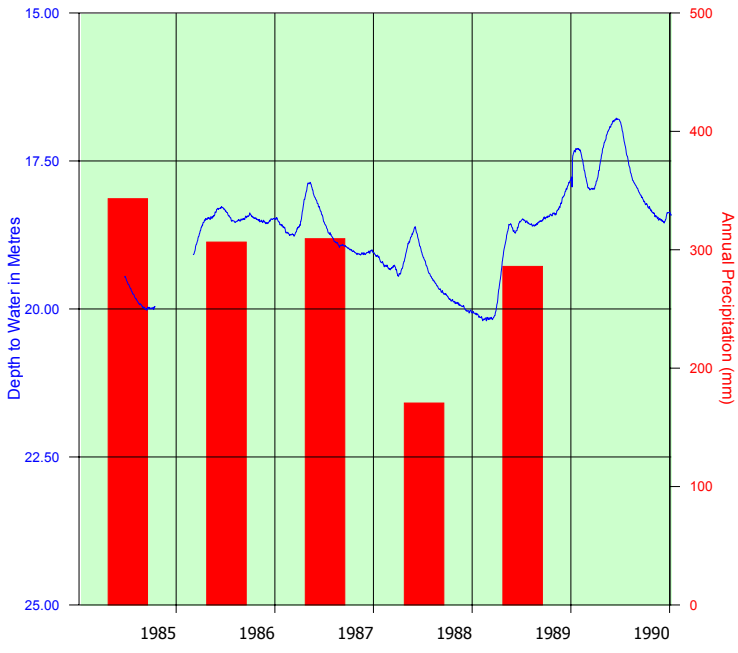

Figure 33. Annual Groundwater Precipitation vs Water Levels in AENV Obs WW No. 101

The closest authorized non-exempt water well to AENV Obs WW No. 101, completed in the Bearpaw Aquifer, is 1.3 kilometres east of AENV Obs WW No. 101 in NE 11-001-22 W4M and is authorized to divert 2.2 m³/day. Within a 5,000-metre radius of AENV Obs WW No. 101, there are eleven non-exempt groundwater users that are authorized to divert a total of 26.1 m³/day. Of these eleven authorized non-exempt water wells, five are completed in the Bearpaw Aquifer.

It does not appear that groundwater diversion from authorized non-exempt water wells within a 5,000-metre radius of AENV Obs WW No. 101 is having an effect on the water-level fluctuations in AENV Obs WW No. 101.