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Province of
British Columbia

Ministry of
Environment

REPORT ON GROUNDWATER - SURFACE WATER INTERRELATIONSHIP LOWER MISSION CREEK, B.C.

by

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and

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October 1981

REPORT ON

GROUNDWATER - SURFACE WATER INTERRELATIONSHIP,

LOWER MISSION CREEK, B.C.

Synopsis

The interrelationship of the surface and groundwater regimes in the Lower Mission Creek area is described. A discharge metering project on Mission Creek determined that the exchange of water between the channel and the groundwater system is relatively minor. Groundwater studies were carried out, consisting of analysis of geological information, well water level data, and pumping data. Information from two recently constructed wells has led to a much better definition of the areal extent and water supply potential of the Rutland aquifer, and the development of further groundwater supplies appears to be practical. The combined results of the two investigations allowed for an interpretation of the recharge - discharge components of the aquifer.

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REPORT ON
GROUNDWATER - SURFACE WATER INTERRELATIONSHIP, LOWER MISSION CREEK, B.C.

1. INTRODUCTION

This report presents the results of investigations carried out into questions regarding surface water and groundwater use in the lower part of Mission Creek, below the Black Mountain Irrigation District intake. These studies were carried out in conjunction with the Tributary Water Management studies of the Okanagan Basin Implementation Program, but were funded almost entirely by the Province as an extra contribution to the Program, beyond the cost-shared activities.

The general question regarding surface water use was whether or not there is a significant amount of water lost from or gained by the Creek, which is of obvious importance to surface water users in this zone. The general question regarding groundwater was about the areal extent and water supply potential of the Rutland aquifer. Separate investigations were carried out into these two questions. The surface water studies consisted of a program of discharge measurements at different points on the creek and at different times. The groundwater studies consisted mainly of analysis of well information, geological logs and water level recordings, and two test wells which were drilled as a result of a previous report on the subject. Both investigations answered the respective questions, and in combination, the results allowed for an interpretation of the interrelationship between the groundwater and surface water regimes in this area. The surface water studies are reported first since the results are used later in the groundwater portion of this report.

2. STREAMFLOW METERING PROJECT

2.1 General Description of Project

In order to determine whether the lower creek gained or lost water, it was decided to carry out a program of metering the discharge at different sites. It was considered desirable to do the flow measurements when the creek flows were low, for two reasons. First, losses or gains are important when flows are low, and second, gains or losses of small magnitude would be easier to identify against low flows than high flows. This was not accomplished to the degree hoped for, since periods of steady low flow are hard to predict, and do not occur very frequently when the creek is free of ice.

There were further complications imposed by the degree of regulation of the creek flows in this zone. It was difficult to account for all the inflows and outflows to correct the observed flows for this effect. It was also difficult to deal with the fact that flows were not necessarily steady during the meterings.

Other problems were encountered in obtaining accurate metering results with shallow depths, low velocities, and bed material which was fairly large in comparison to depth. This was dealt with by metering each site twice on most occasions, and using the average of the results. The coarse bed material also raises the question of possible underflow, where a certain part of the total creek flow is actually moving through the bed materials in an "underground channel" adjacent to and associated with the surface channel. This is not thought to be of significant magnitude relative to creek flows since the coarse bed materials tend to be packed with finer materials, but no firm conclusions can be drawn in this regard since no investigation was done.

Finally, it should be mentioned that the data collected on the first two dates comprised the original project. The later measurements collected at the upper sites were conceived as a result of the first two sets of data. All measurements were done when the metering crews had the opportunity to fit them into their normal work load.

Stream meterings were carried out at eight different sites on five different dates, but not at each site on each date. The sites are described below, and the metering dates were December 12, 1979, and March 27, August 19, September 9, and September 23, 1980.

2.2 Metering Sites

The streamflow metering was carried out at eight sites on lower Mission Creek. In this case, a site is a general location on the creek with a possible range of up to 100 meters between the actual sections measured on different dates. Meterings at a given site on a given date were usually done twice, sometimes at different sections, and sometimes at the same section with different measurement stations. A new alphabetic site code is assigned for this report - previous site labelling was confused when different codes were assigned to the same site on different field sessions. The sites are shown on Figure 1 and the site descriptions are as follows:

(a) Site A - Below B.M.I.D. intake.
Near the stream gauge 8NM239, below the overflow ditch from the B.M.I.D. pipeline intake building.

(b) Site B - above Hydraulic Creek
Near Gallagher Road bridge.

(c) Site C - S.E. Kelowna Trailer Park.
Upstream of the Happy Valley Trailer Court at the end of Senger Road.

(d) Site D - Hollywood Road
At the West Kootenay Power sub-station at the end of the Hollywood Road extension.

(e) Site E - Water Survey Gauge
Near the W.S.C. gauge (8NM116) at the foot of Kiniski Road, along Creekside Drive.

(f) Site F - KLO Road Bridge
Some sections were upstream of bridge and others downstream.

(g) Site G - Casorso Road Bridge.

(h) Site H - Lakeside Drive Bridge.
Site upstream of bridge.

2.3 Inflows to and Withdrawals from Mission Creek

The interpretation of the metering results is somewhat dependent on withdrawals from and inflows to the creek between the metering sites. These inflows and withdrawals are described below.

Between sites B and C, Mission Creek receives tributary inflow from Hydraulic and KLO Creeks. Both these creeks have diversions which effect their flow into Mission Creek. During the irrigation season, inflow to Mission Creek is generally small (in the order of several c.f.s.), except during periods of rainy weather when the flow from the unregulated portion of the basins increases. The South East Kelowna I.D. intake is on Hydraulic Creek, which sometimes results in periods of instability in the flows as a result of the demand variation in that system. There are stream gauges on both of these creeks near the mouth which make it possible to account for the inflows.

There are a number of locations where springs emerge near the creek and which contribute inflow to the creek. These are near the South East Kelowna Bridge, near the KLO Road Bridge, and near the Casorso Road Bridge, as shown on Figure 1.

Between sites E and F there are two ditch diversions from the Creek. The Amalgamated Water Users (A.W.U.) ditch diverts water near Ziprick Road and returns the excess upstream of KLO Road Bridge. Almost directly opposite the A.W.U. intake is the intake for a fisheries spawning channel, which returns all the diverted flow to the creek several hundred yards downstream.

There are also several small pump intakes on this part of Mission Creek. A golf course in South East Kelowna pumps water from the creek intermittently - mostly at night during the summer. There is a small pump house on the left bank near the new foot bridge between sites E and F, which serves the Sutherland Hill Provincial Park.

2.4 Metering Results and Interpretation

As mentioned previously, flows were metered at a total of eight sites on a number of different dates. The results are shown graphically in Figure 2, and are summarized in tabular form in Table 1.

The results of the stream meterings are interpreted in the following manner:

1. In spite of the problems described earlier, the results appear to be reasonably consistent and are considered adequate to reach conclusions regarding the object of the study. The one exception to this statement may be the flow measured at Site

TABLE 1

Summary of Mission Creek Discharge Measurements

Date	Site	Discharge (c.f.s.)*
December 12, 1979	C	22.3
December 12, 1979	D	23.1
December 12, 1979	E	22.9
December 12, 1979	F	25.7
December 12, 1979	G	22.9
December 12, 1979	H	27.7
March 27, 1980	C	31.0
March 27, 1980	D	30.0
March 27, 1980	E	29.8
March 27, 1980	F	31.6
March 27, 1980	G	32.6
March 27, 1980	H	35.6
August 19, 1980	A	130
August 19, 1980	B	137
August 19, 1980	C	128
September 9, 1980	G	89.5
September 9, 1980	H	91.9
September 23, 1980	A	140
September 23, 1980	B	145
September 23, 1980	C	169
September 23, 1980	E	150
September 23, 1980	F	148
September 28, 1980	H	154

* usually average of two measurements

C on September 23, 1980. The inflow from Hydraulic and KLO Creeks on this day was not enough to increase the flow at site B to the value at site C. The metering notes showed no apparent errors, the two separate meterings agreed closely, and the meter used was checked and found to be accurate. In spite of this, the flow must be questioned since the difference between sites B and C on August 19 was quite different, and because there is no apparent way that the creek could gain approximately 21 c.f.s. (not counting tributary inflow) between sites B and C, and then lose approximately 19 c.f.s. between sites C and E.

2. The lower reaches of the creek below site F gain water from the ground, with measured gains ranging between 2 c.f.s. and 6.5 c.f.s.

3. The stretch between sites E and F varied between gaining 3 c.f.s. and losing 2 c.f.s. for three days of data. The loss of 2 c.f.s. may have been net water use from the A.W.U. ditch rather than loss to groundwater, or may have been actual water loss from the creek channel to a lower water table in the adjacent soils.

4. Between sites D and E, the creek is losing a small amount of water to the ground, in the order of 1 c.f.s. or less.

5. Between sites D and E, the creek can be gaining or losing small amounts of water, likely depending on the relative levels of the creek and the adjacent water table, which may vary during the year.

6. Based on one day's measurement, the creek between sites B and C appears to lose water to the ground, and this loss can be

greater than the inflow from Hydraulic and KLO Creeks, when that inflow is small.

7. The creek appears to gain water from the ground between sites A and B, at least during the time of year (August-September) when the data was collected.

8. The general conclusion is that there is not a great volume of water lost from or gained by the creek below the B.M.I.D. intake. Water passing the B.M.I.D. intake should be available for use at any point downstream.

3. GEOLOGICAL HISTORY

The general geology of the lower Mission Creek area has been discussed previously (Lowen, 1979). Two test wells drilled on recommendation of this previous report have increased our knowledge of this area. Two cross-sections have been drawn using the two new wells. The locations of the sections are shown in Figure 1 and the sections are shown in Figures 3 and 4. A complex sequence of deposition and erosion events can be theorized to account for the arrangement of geological units seen in these cross-sections. One possible sequence of events from the oldest to youngest is as follows:

1. A glacial advance with deposition of till (Unit 1) at elevations from 800 to 1,100 feet.
2. Lacustrine deposits of sand, silt, and clay (Unit 2) were deposited in the region between wells NS-1 and NS-3 (north of Rutland) at approximate elevations 860 to 1,000 feet.
3. An extensive outwash body (Rutland aquifer) was deposited (Unit 3) over the entire area of the cross-sections approximately between elevations 1,000 - 1,300 feet.

4. The outwash of the Rutland aquifer was eroded most extensively in the Rutland area leaving a continuous aquifer that thickens to the north and to the south of Rutland. Ice or water moving down Mission Creek Valley into Okanagan Valley may account for this erosion. The erosional contact is shown as event no. 4 in the cross-sections.
5. A glacier advanced over the Rutland outwash depositing a relatively uniform layer of till (Unit 5).
6. A thick section of deltaic and lacustrine materials (Unit 6, 6a) were deposited. The deltaic sands and silts were deposited in the Rutland area grading into clays to the north and south. Water was flowing down Mission Creek Valley into a lake in Okanagan Valley which reached an elevation of 1,450+ feet. The sand and silt unit is shown as Unit 6 and the clay and silt unit as Unit 6a on the cross-sections.
7. Alluvial sands, gravels and boulders (Unit 7) were deposited in the Rutland area by fast flowing water exiting from Mission Creek Valley.

4. HYDROGEOLOGY

4.1 General

The general hydrogeology of the lower Mission Creek area has been discussed previously (Lowen, 1979). The major aquifer in the lower Mission Creek area is the Rutland outwash aquifer. Since the writing of the previous report two test wells have further delineated the extent of this aquifer. The well logs correlated in cross-sections N-S and E-W indicate that the Rutland aquifer is continuous from the Cornish Road area south to the East Kelowna Bench and west as far as the Benvoulin area.

Piezometric levels are also plotted on the cross-sections. These levels were not measured at the same time but their relative positions are representative of the regional piezometric surface. The inferred groundwater flow direction is from north to south in the region north of Rutland and east to west in the Rutland - Kelowna Bench area. The water level gradient on the N-S cross-section is sloping in the north and flat in the south. This is the case because the line of the section is parallel to the groundwater flow direction in the north and perpendicular to it in the south. The slope of the water level gradient between NS-1 and NS-2 is 0.01 and between NS-5 and EW-3 is 0.008. The steeper slope between NS-1 and 2 may indicate lower transmissivity and finer grained aquifer materials in this area. This concept is reinforced by the geological log of NS-1 (all geological logs are attached in Appendix A) which shows much more fine sand than the other cross-section wells. However, the aquifer is thickest in the area of NS-1 and high yielding wells are possible in this area using a long screen design.

The approximate known extent of the Rutland aquifer is shown in Figure 1. The known aquifer aerial extent is approximately 14 square miles. Subsequent test drilling will likely expand the known area of the aquifer. The aquifer varies in thickness from 30 feet to over 200 feet. Transmissivities for the aquifer have been calculated between 2.7×10^4 and 2.0×10^5 US gallons per day per foot. The storage coefficient for the aquifer has been calculated in the order of 10^{-3}. As the Rutland aquifer is comprised of sand and gravel it likely has a porosity of approximately 0.3 and a specific yield of approximately 0.2 (Walton, 1970).

The amount of water in storage in the aquifer can be estimated as follows: Aerial extent x average thickness x porosity or 14 (2.78×10^7) square feet x 100 feet x 0.3 = 1.2×10^{10} cubic feet or $7.48 (1.2 \times 10^{10})$ = <u>9×10^{10} US gallons</u>. This is equal to 275,000 acre-feet.

4.2 Groundwater - Surface Water Interrelationship

There are several sources that contribute recharge to the Rutland aquifer. Recharge water must enter the aquifer via the overlying semi-confining beds or directly where the aquifer crops out. The aquifer may crop out in the upland east of Rutland in the region covered by Units 7, 10, 11, shown on the attached Figure 5 (Surficial Geology map by Nasmith, 1962). The possible sources for recharge water include; precipitation, irrigation waters or Mission Creek. The discharge points for the aquifer include; wells, springs, Mission Creek bed, and possibly Okanagan Lake.

Observation well data is available from 3 observation wells completed in the Rutland aquifer. The three well locations (WR numbers 222-77, 236-79, and 262-80) are plotted in Figure 1. The water level fluctuations in these three wells (Appendix B) are in close correspondence. The length of record from well WR 262-80, however, is not sufficient for a reliable comparison. Both well WR 222-77 and WR 236-79 hydrographs show similar trends with a sharp trough in July and August, 1980 and a smooth peak reaching a maximum in March, 1981. Well WR 222-77 has a maximum recorded yearly fluctuation of approximately 1 meter and WR 236-79 has fluctuated up to 2.5 meters. This is likely due to the proximity of well WR 236-79 to the Rutland production wells. The maximum drawdown in this aquifer should occur in the Rutland area as the largest pumping withdrawals occur here.

It is interesting to note that the aquifer begins the recharge cycle in July and August despite the fact that pumping withdrawals are high at this time. Also, natural recharge is expected to be minimal at this time of year. This suggests that recharge from applied irrigation may be an important phenomenon occuring in this area.

Stream discharge meterings and historical stream discharge records compared with observation well hydrographs indicate that there is not a significant direct connection between Mission Creek and the Rutland aquifer. Five sets of stream discharge meterings taken between December, 1979 and September, 1980 are plotted in Figure 2 and metering sites are shown in Figure 1. Between sites F and H the discharge consistently increases. Here the creek flows through a groundwater discharge area with several known springs and flowing wells. Between sites E and F the creek can be gaining or losing. Here the creek likely recharges the surficial aquifer or is recharged by the surficial aquifer depending on the water table level in the surficial aquifer. Water use and return flow from the A.W.U. ditch is also a factor in this section. Between sites D and E the creek flow is consistently decreasing, by a small amount. Here the creek is recharging the upper water-bearing soils that overlie the Rutland aquifer. Between sites C and D the creek can be gaining or losing. Here the groundwater level versus creek level relationship likely reverses during the year. Between sites B and C, the August 19 data indicate a slight loss from the creek (the data for the September 23 is questionable and not suitable for interpretation). The creek flow increases between A and B indicating groundwater inflow at least for the later summer and fall when the meterings were taken.

Historical discharge records from Water Survey of Canada gauge number 08NM116 on lower Mission Creek show maximum flows occur in May or June and minimum flows usually in late summer, fall or winter. The location of the gauge is plotted in Figure 1. Observation well hydrographs for the Rutland aquifer show the aquifer is recharged from late summer till spring when water levels drop steeply. The drop in water levels in the aquifer correspond to increased pumping from the Rutland well field. It appears that if Mission Creek recharges the Rutland aquifer there is a time lag of several months before the aquifer responds, or the recharge effect is masked by pumping. A time lag for flow from the creek to the aquifer would be expected as the aquifer appears to be overlain everywhere by a layer of very low permeability till.

There are records available for three observation wells also completed in the surficial sand and gravel aquifer, (WR numbers 23-62, 64-65, and 65-65) in the lower Mission Creek area and the hydrographs are attached in Appendix B. The wells range from 7 to 24 feet deep and their locations are shown in Figure 1. These wells are no longer being used for observation purposes. Water levels in wells WR 23-62 and WR 64-65 peaked in mid-summer and were at minimum levels in winter. Well WR 65-65 shows an opposite fluctuation with maximum levels in winter or spring and lowest levels in summer. Well WR 65-65 fluctuates a total of about 2 feet as compared to 8 or 9 feet for the other 2 wells. Observation wells WR 23-62 and WR 64-65 are at higher elevations than WR 65-65 and are located in a recharge area for this surficial aquifer. The sources of recharge for the surficial aquifer here are likely Mission Creek (at freshet time in particular), irrigation water, and direct precipitation. Observation well WR 65-65 is likely located in the discharge region of the surficial aquifer and the fluctuations here are damped and may show a time lag from recharge events as the well is distant from the recharge area.

Direct precipitation is not likely the major source of recharge water for the Rutland aquifer. At Kelowna the mean total precipitation is 12.00 inches, comprised of 8.51 inches of rain and 34.9 inches of snowfall (which equals 3.49 inches of water). At McCulloch, higher in the Mission Creek watershed (4,100 feet ASL), there is an average 12.63 inches rain and 145.1 inches snow for a total of 27.14 inches of total precipitation. The Rutland aquifer may outcrop in the upland east of Rutland as described earlier. The greatest potential for direct recharge would be from snow melt, however, significant recharging of the aquifer in spring-time is not evident from the observation well hydrographs.

Direct precipitation on the outcropping aquifer contributes but is not likely the major recharge component for the Rutland aquifer.

Recharge from the overlying shallow deposits is likely the major source of replenishment for the Rutland aquifer. Moreover, pumping from the aquifer may induce significant leakage from the overlying soils. The water levels in the Rutland aquifer begin to rise in late July and August when water levels are at a minimum from the heavy summer-time pumping,mainly from the Rutland production wells. Also the shallow well observation well records show that water levels in the upper aquifer zones peak in July or August and begin to fall just when the Rutland aquifer levels are rising. The shallow aquifer at WR 65-65 does not follow this pattern likely because it is located in a groundwater discharge area.

The upper aquifer in turn is recharged by excess irrigation water, direct precipitation and from Mission Creek. Irrigation waters may be the most significant source of recharge for the shallow aquifer(s) in the Lower Mission Creek area. The water levels over most of the area in shallow wells peak at the height of the irrigation season. Extensive orchard irrigation occurs on the East Kelowna Bench and in the area east of Rutland,by S.E.K.I.D and B.M.I.D. respectively. There is very little orchard irrigation in Rutland but a large portion of water consumption here is used for lawn watering. In addition to replenishing the shallow aquifers, irrigation water may recharge the Rutland aquifer directly in the area east of Rutland.

The shallow aquifers also appear to be sensitive to precipitation. From Kelowna precipitation records (Appendix B) it is evident that from 1965 to 1967, precipitation was below normal. The two hydrographs WR 23-62 and WR 64-65 show steadily declining water levels in this 3 year period. This trend is broken in 1968 when the water levels increase from the preceding year in response to above average precipitation.

Discharge from the Rutland aquifer can occur in three different manners; production well pumping, natural springs and losses to overlying or underlying formations. Production well pumping is a major discharge component for the Rutland aquifer. The three hydrograph records in Appendix B (WR numbers 222-77, 236-79 and 262-80) show the sharp drawdown and recovery spikes characteristics of pumping effects. Despite the heavy drawdown from pumping in summer-time the aquifer begins to recover in August indicating that recharge exceeds discharge once the piezometric surface is lowered below a certain point. Pumping records from the Rutland Waterworks District from 1974-75, show an average of greater than 600 million gallons per year pumped with approximately two-thirds of this being pumped in the four months from May to August.

Natural springs are another discharge component in the water budget for the Rutland aquifer. The spring flow may occur at surface like the Casorso Spring or may occur in the bed of Mission Creek and possibly Okangan Lake. The stream meterings plotted in Figure 2 show increased flows between site E and site F indicating groundwater inflow. This inflow can be coming from both the surficial sand and gravel aquifers and the Rutland aquifer.

Discharge may occur from the Rutland aquifer to underlying or overlying formations. The aquifer is overlain by till and underlain by silt, till or bedrock. Till has a low permeability but this unit may be discontinuous or may be fractured in places allowing significant flow wherever a hydrostatic potential is present. The underlying silts, till, and bedrock also have low permeability and flow to these units is not expected to be significant.

Recharge and discharge appear to be essentially balanced in the Rutland aquifer. Observation well WR 222-77 has a maximum water level 1 foot lower after 4½ years of record indicating that water levels may be essentially stable over the entire aquifer. The schematic diagram in Figure 6 depicts the various recharge and discharge components involved in the aquifer water budget.

5. CONCLUSIONS AND RECOMMENDATIONS

1. The exchange of water between Mission Creek channel below the B.M.I.D. intake and the groundwater system is relatively minor. Water passing the B.M.I.D. intake should be available in the lower reaches of the creek.
2. Geological correlation is possible in the lower Mission Creek region despite the complexities of the region's geological history.
3. The Rutland aquifer which was first tapped by the Rutland production wells appears to be continuous and extensive, underlying most of the Rutland, Benvoulin, East Kelowna Bench, and Cornish Road areas. The full extent of the aquifer has not been determined. Indications are that the aquifer underlies an area of an approximate minimum size of 14 square miles. The approximate known extent of the aquifer is shown in Figure 1.
4. Despite the large scale pumping from the Rutland aquifer, water levels appear to be stable. However, longer term hydrograph records are necessary to establish a definite trend. A continuous 10 year hydrograph record would be desirable.
5. The observation wells now in place in the lower Mission Creek area should be kept in operation as long as possible.
6. Observation well records for the Rutland aquifer should be examined periodically to determine if and when groundwater mining is taking place.
7. The Rutland aquifer can support more production wells without serious lowering of aquifer water levels or decrease of flows in Mission Creek. Total pumping should not exceed the recharge potential of the aquifer.

The aquifer recharge is at least equal to the present pumping rate of a minimum 6×10^8 US gallons per year recorded pumping by the Rutland Waterworks District. The amount of water estimated in storage is 9×10^{10} US gallons and therefore present annual pumping discharge is approximately $\frac{6 \times 10^8}{9 \times 10^{10}} \times 100 = 0.66\%$ of water in storage. Additional groundwater development is therefore very feasible.

8. Computer modelling of the Rutland aquifer may be feasible in the near future as more data is becoming available yearly. A computer model of the aquifer would be a valuable management tool.

9. The combined water resources of Mission Creek and the Rutland aquifer system provide an excellent opportunity for the conjunctive use of surface water and groundwater. For example, some of the excess freshet flows in Mission Creek could be diverted to the Rutland aquifer by siphoning wells or recharge basins thereby using the aquifer as a storage reservoir that can be tapped later in the year when creek flows are minimal. Water pumped from the aquifer could be used to augment creek flows when the natural flow is too low for fisheries or irrigation requirements.

10. A groundwater chemistry study is recommendedfor the lower Mission Creek area and in particular for the Rutland aquifer. Groundwater chemical analyses can be used to delineate recharge and discharge areas and aid in defining the direction of groundwater movement. Groundwater isotope analyses are particularly useful for this type of study.

11. Eight components have been identified which comprise the water budget for the Rutland aquifer. The inflowing or recharge components are as follows:

    (1) Leakage from the overlying geological formations,
    (2) Leakage from the underlying geological formations,
    (3) Direct precipitation on the outcropping aquifer,
    (4) Direct recharge from Mission Creek on the outcropping aquifer.

The outflowing or discharge components are as follows:

(1) Pumping discharge,

(2) Spring discharge,

(3) Outflow to the overlying geological formations,

(4) Outflow to the underlying geological formations.

With the current amount of pumping from the aquifer and irrigation over the aquifer, the aquifer is no longer operating as a natural system. For the current water budget, pumping is likely a significant portion of the discharge components, and leakage from the overlying formations is likely a significant portion of the recharge components. The observation well hydrograph information to date indicates that the summation of the recharge components is essentially equal to the summation of the discharge components.

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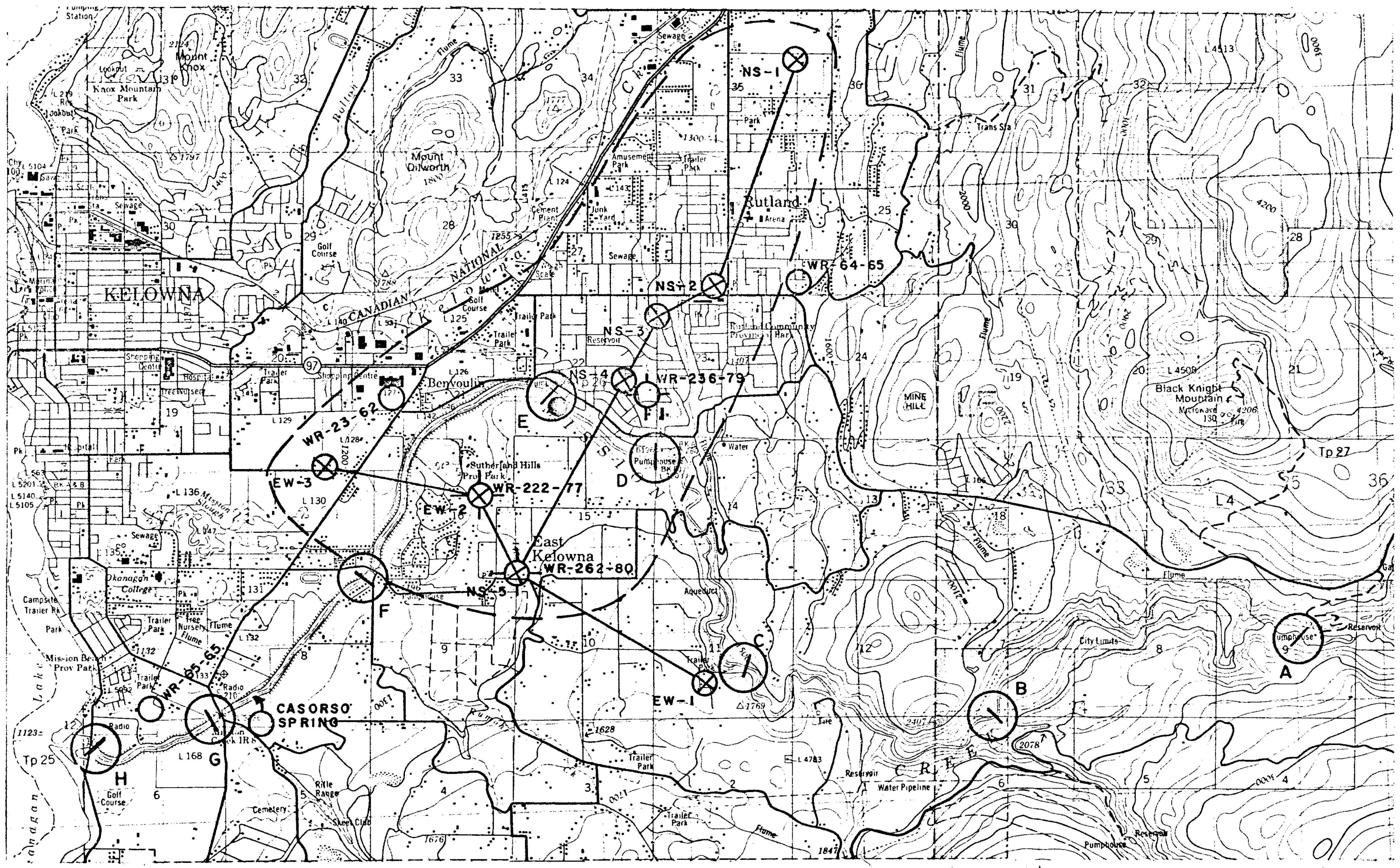
REFERENCES

1. Lowen, D.A., Mission Creek Groundwater Study, B.C. Ministry of Environment, 1979.

2. Nasmith, H., Late Glacial Hisotry and Surficial Deposits of the Okanagan Valley, B.C., Bulletin No. 46, B.C. Dept. of Mines and Petroleum Resources, 1962.

3. Walton, W.C., Groundwater Resource Evaluation, pp. 33-34, 1970.

4. Lowen, D.A. and Letvak, D.B., Memoranda on Mission Creek Discharge Metering, March 13 and June 2, 1980.



LEGEND

- STREAMFLOW METERING STATIONS
- WATER SURVEY GAUGE
- WR-222-77 GROUNDWATER OBSERVATION WELL, DRILLED
- NS-1 WELL USED FOR GEOLOGIC CROSS-SECTION
- WR-65-65 GROUNDWATER OBSERVATION WELL, DUG
- SPRING
- APPROXIMATE KNOWN EXTENT OF RUTLAND AQUIFER

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LOWER MISSION CREEK, B.C.

SCALE	DATE
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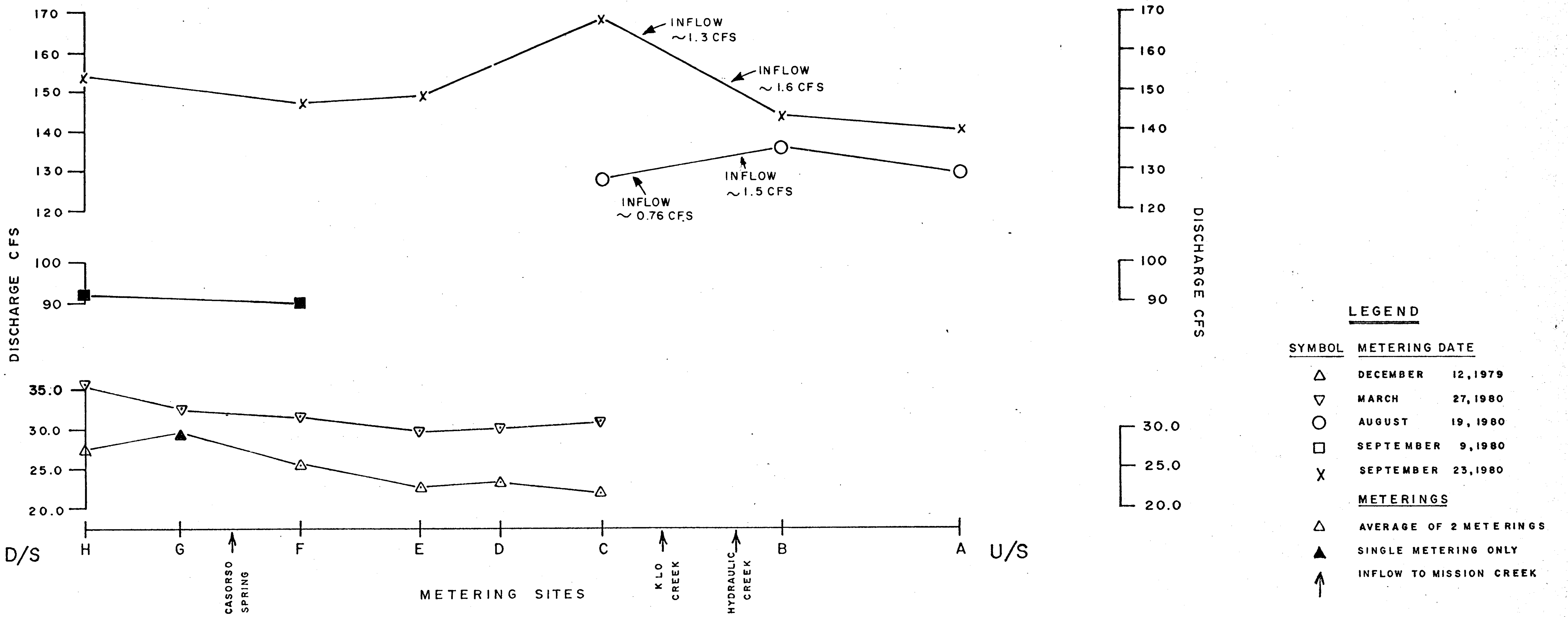
D.A.LOWEN & D.B.LETVAK	ENGINEER
FILE NO. 82E14#28	FIGURE 1



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GROUNDWATER — SURFACE WATER INTERRELATIONSHIP
LOWER MISSION CREEK, B.C.

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D.A. LOWEN & D.B. LETVAK		ENGINEER
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GROUNDWATER — SURFACE WATER INTERRELATIONSHIP

LOWER MISSION CREEK, B.C.

SCALE: VERT. 1" = 100' HOR. 1" = 1000'	DATE JUNE 1981
D.A. LOWEN ENGINEER	
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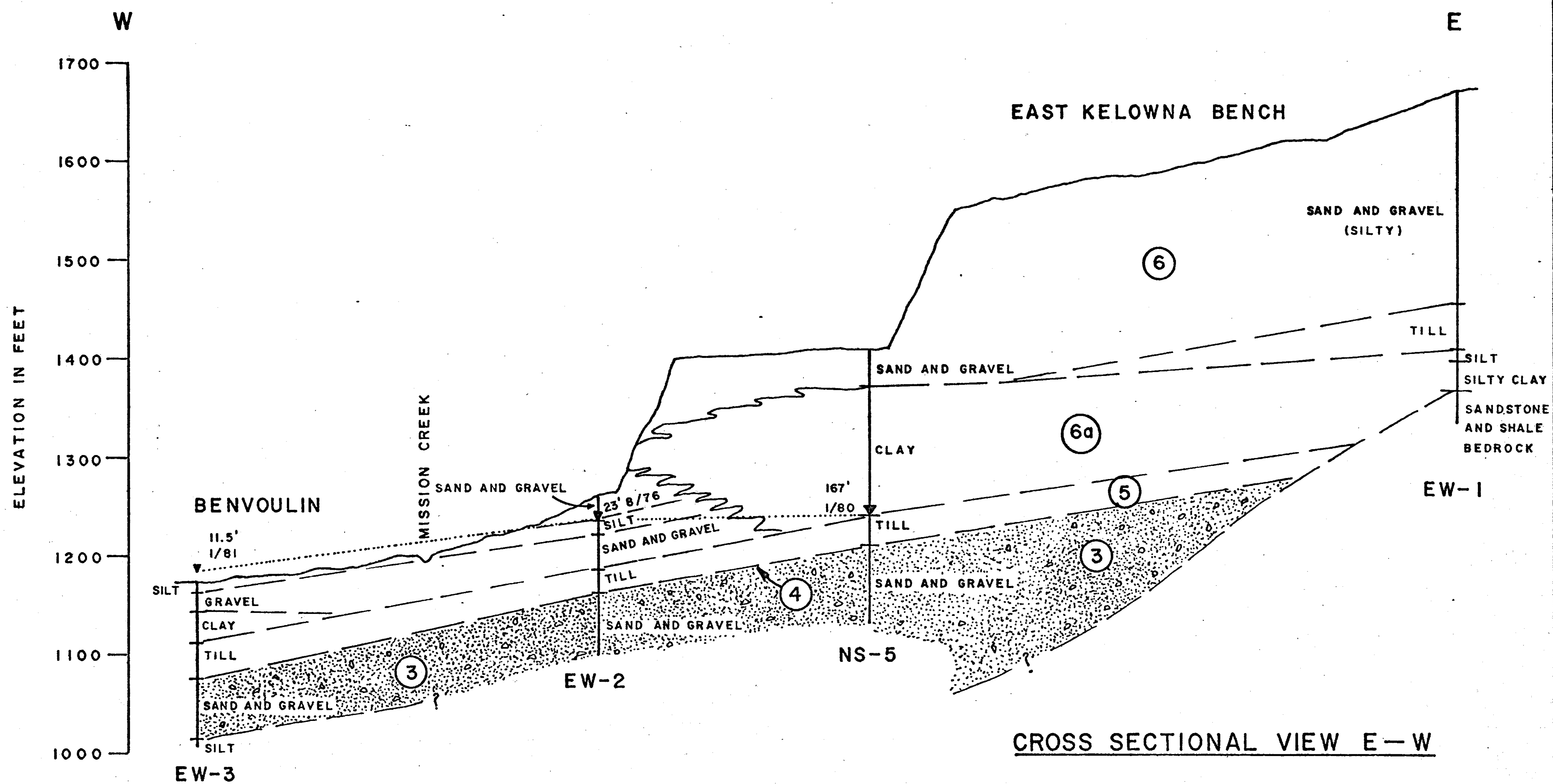

CROSS SECTIONAL VIEW E—W

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GROUNDWATER — SURFACE WATER INTERRELATIONSHIP LOWER MISSION CREEK, B.C.

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D.A. LOWEN		ENGINEER
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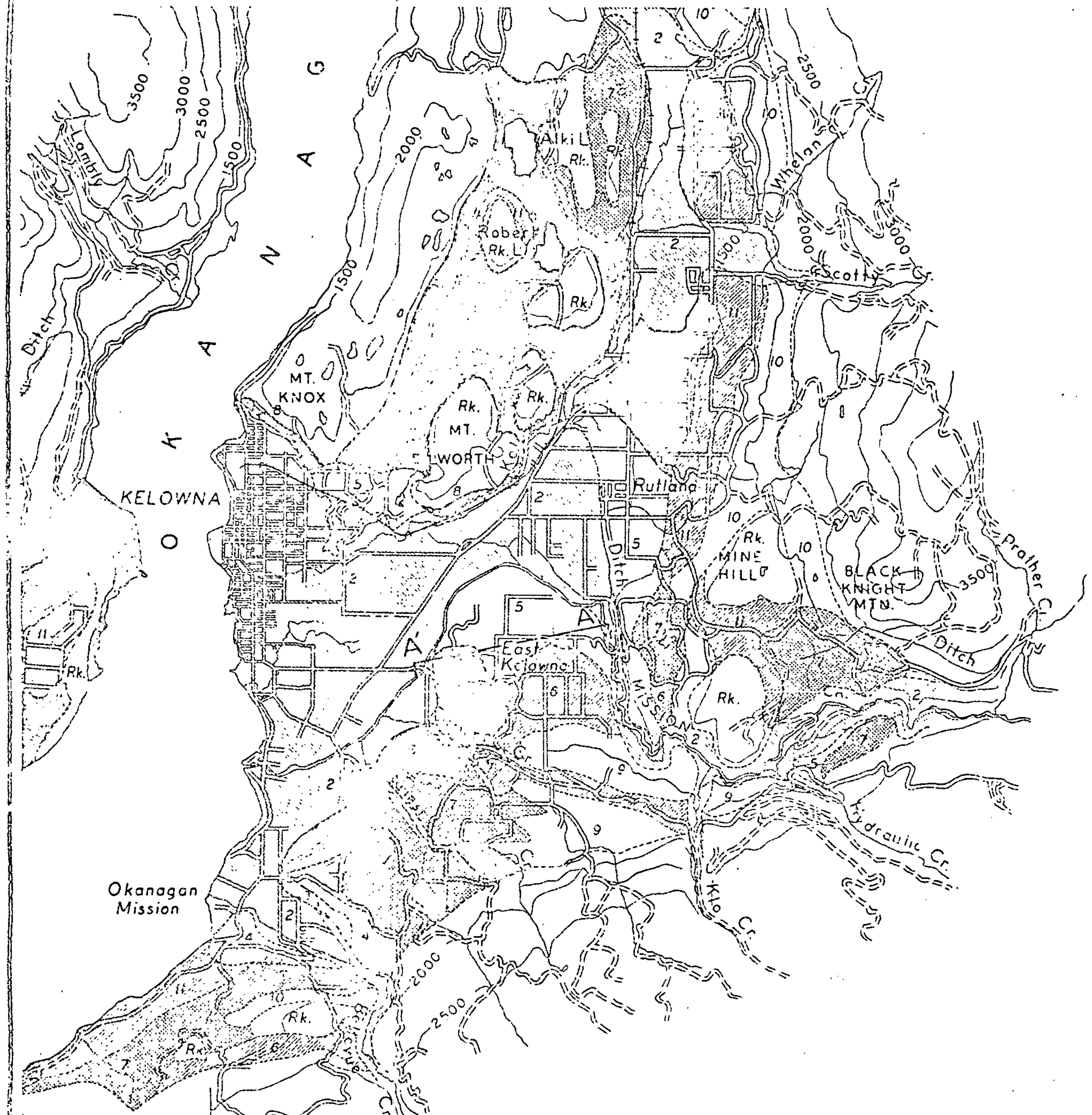


TAKEN FROM

SURFICIAL DEPOSITS OF LATE GLACIAL AND RECENT AGE

NORTHERN OKANAGAN VALLEY

by
Hugh Nasmith

LEGEND

RECENT
- 1 Okanagan River Floodplain
- 2 Alluvial fans, deltas, and associated gullies and stream channels
- 3 Beaches, spits, and dunes

LATE GLACIAL
- 4 River channels and stream-cut terraces
- 5 Raised alluvial fans, terraces, and deltas

STAGE OF GLACIAL RETREAT
- 6 Outwash terraces
- 7 Kettled outwash
- 8 Glacial lake sediments

STAGE OF GLACIAL OCCUPATION
- 9 Moraine ridges
- 10 Kame terraces and meltwater channels
- Meltwater channels

GLACIAL ADVANCE AND EARLIER
- 11 Mixed unconsolidated deposits
- Roads

Scale 1 0 1 2 3 Miles

Contour interval 500 feet

TO ACCOMPANY REPORT ON

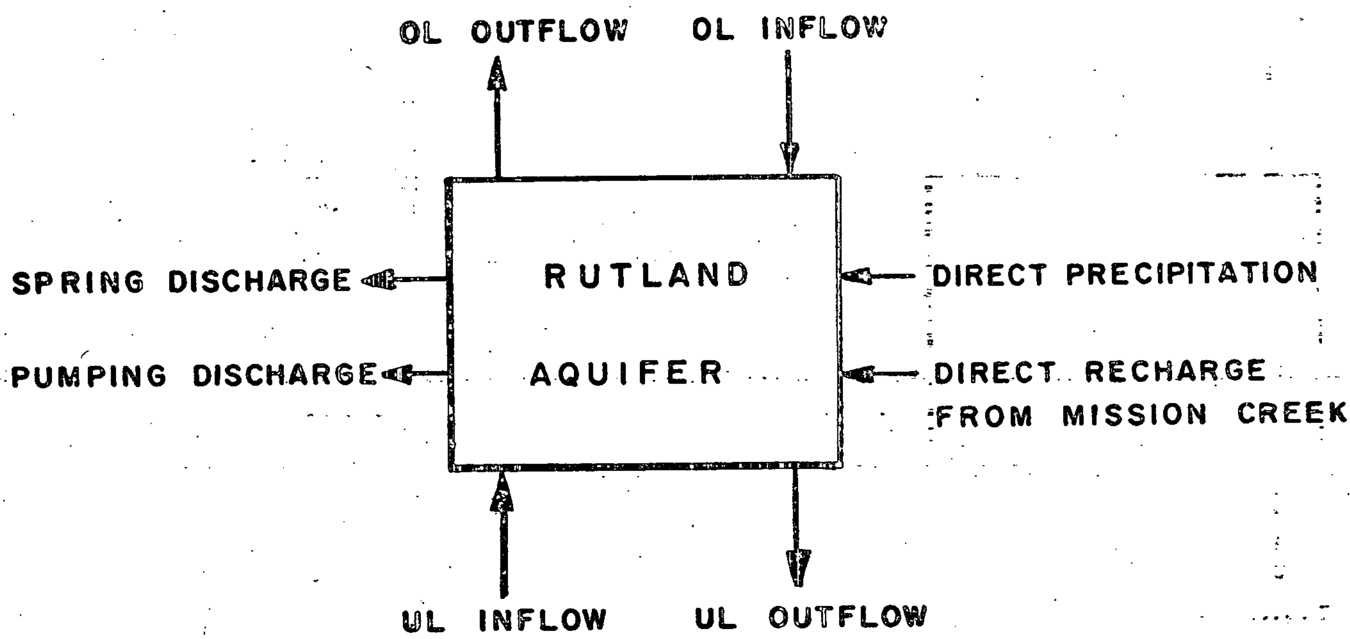
GROUNDWATER—SURFACE WATER INTER-RELATIONSHIP

LOWER MISSION CREEK, B.C.

D.A. LOWEN — ENGINEER

FILE No. 32E 14 28 — DWG. No. — FIG. 3

SCHEMATIC DIAGRAM OF RUTLAND AQUIFER WATER BUDGET



LEGEND

→ COMPONENT OF WATER BUDGET
OL — OVERLYING GEOLOGIC FORMATION
UL — UNDERLYING GEOLOGIC FORMATION

Province of British Columbia Ministry of Environment INVENTORY AND ENGINEERING BRANCH	TO ACCOMPANY REPORT ON GROUNDWATER-SURFACE WATER INTER-RELATIONSHIP LOWER MISSION CREEK, B.C.
SCALE: VERT. N.T.S. HOR. N.T.S. | DATE JUNE 1981	D.A. LOWEN ENGINEER FILE No. 82 E 14 #28 DWG No FIG. 6

BCIL 7290 WRS

Appendix A

Cross-section

Well Logs

EW-1

Log

From	To	Description
0	214 (feet)	Silty sandy gravelly outwash probably with occasional patches of till.
214	262	Light brown compact till.
262	272	Sandy silt, quite soft, grey.
272	320	Compact sticky chocolate brown silty clay with pebbles of shale and deeply weathered greenish sandstone. This may be an old weathered till.
320	337	Tertiary sandstone and shale.

EW-2

Log

From	To	Description
0	12	Silty tan sand.
12	17	Medium coarse sand with small cobbly gravel.
17	26	Medium coarse gravel and coarse sand (water-bearing).
26	39	Compact tan silt with clay lens.
39	40	Compact tan silt with gravel.
40	74	Compact coarse gravel and sand. Some tan silt, changes to cobbly gravel.
74	86	Till, hard, gravelly tan coloured.
86	96	Very fine to coarse sand with fine and coarse gravel, with thin till lens, high tan silt content.
96	103	Fine and medium loose pebbly gravel. High fine to coarse sand content. Interbeds of tan till, high tan silt content.
103	108	Fine to coarse loose pebbly gravel, some very coarse gravel, some tan silt.
108	112	Medium to coarse pebbly gravel, tan silt.
112	114	Fine to coarse sand, tan silt.
114	120	Cemented coarse cobbly gravel.
120	128	Coarse, very coarse pebbly gravel. (water-bearing)
128	129	Medium coarse sand, some fine sand, some pebbly gravel.
129	135	Fine to coarse pebbly gravel and medium coarse sand (water-bearing).
135	140	Medium coarse pebbly gravel (water-bearing).
140	148	Very coarse cobbly gravel, quite compact, traces of till

EW-2 (Cont)

Log

From	To	Description
148	154 (feet)	Medium coarse, loose pebbly gravel, clean.
154	158	Fine to coarse pebbly gravel with higher medium coarse sand content (water-bearing)
158	161	Fine to coarse compact gravel and sand (poor water-bearing)

EW-3

Log

From	To	Description	
0	5.5 (metres)	Clayey silt with thin layers of gravel.	
5.5	6.1	Coarse gravel with cobbles to 1.6 cm. diameter, loose.	Shallow Aquifer
6.1	8.5	Coarse gravel; static water level approx. 0.5 m below ground.	
8.5	9.1	Clay.	
9.1	11.6	Clay with seams of gravel.	
11.6	12.8	Coarse gravel with layers of clay.	
12.8	19.2	Clay.	
19.2	27.4	Till, very dense.	
27.4	29.3	Sloppy gravel with hard layers.	
29.3	32.3	Sand and gravel.	
32.3	33.5	Sand and gravel, loose.	
33.5	37.2	Sand and gravel, very loose.	Deep Aquifer
37.2	41.2	Sand and gravel.	
41.2	41.8	Sand and gravel, layer of very coarse gravel 41.2 to 41.5.	
41.8	44.5	Silty sand and gravel with clay binder.	
44.5	46.3	Silty sand and gravel with clay binder, can drill approx. 1 m ahead with heavy mud.	
46.3	48.2	Silty sand and medium gravel.	
48.2	50.0	Dense silt with some clay.	

NS-1

Log

From	To	Description
0	36 (feet)	Brown clay and silt.
36	73	Blue clay silt with sand lenses.
73	96	Mixture of silty stoney deposits, may have patches of till.
96	146	Till, very compact.
146	242	Sand, medium to fine, some gravelley and some silty zones, all contains plant remains.
242	250	Very fine silty sand with plant remains.
		ROTARY HOLE FROM HERE DOWN
250	260	Very fine silty sand, plant remains.
260	306	Probably interbedded fine sand and silt, with plant remains.
306	331	Same as 260-306 except more silt.
331	340	Interbedded fat clay and silt.
340	472	Fat grey clay.
472	510	Gravel and sand, some boulders could be till.

NS-2

Log

From	To	Description
0	33 (feet)	Loose bouldery gravel.
33	36	Fine brown sand. (water-bearing)
36	47	Medium sandy gravel.
47	49	Soft silt. Colour brown.
49	63	Medium sandy gravel.
63	163	Sticky grey clay.
163	199	Compacted grey sandy till with occasional sand and gravel layers.
199	201	Coarse silty sand.
201	244	Very hard abrasive till getting softer at the bottom.
244	259	Silty sand occasional silty varves and sandstone concretions.
259	300	Hard grey till with occasional silty and sand layers.
300	316	Interbedded gravelly sand and silt.
316	329	Medium sand with some fine gravel.
329	331	Greenish grey till.
331	348	Medium gravelley sand.
348	356	Medium sand with occasional silt and sand varves.

NS-3

Log

From	To	Description
0	8	Loose coarse silty gravel (some boulders).
8	14	Finer and sandier gravel.
14	45	Tan coloured fine to medium sand and silt layer.
45	76	Grey silt.
76	81	Interbedded fine sand, gravel and silts.
81	90	Greenish grey silts (clay).
90	96	Interbedded fine sand, gravel and silts.
96	115	Fine sand with occasional silty (varves?)
115	130	Clean fine sand.
130	132	Soft tan silt layers.
132	146	Tan sand coarser and cleaner.
146	169	Medium to coarse sand, some cobbles.
169	178	Fine sand (siltier, organic)
178	183	Grey sand.
183	188	Coarse sandy gravel.
188	208	Tight sand and gravel.
208	213	Very tight silty gravel.
213	216	Loose clean gravel.
216	219	Very tight silty gravel (boulders?)
219	220	Very tight silty gravel.
220	229	Loose sandy gravel (silt varve 228')
229	231	Very tight gravel.
231	250	Loose sandy gravel.
250	252	Loose sandy gravel.
252	260	Grey brown silt with small layers of coarse sand.
260	264	Sandy till.

NS-4

Log

From	To	Description
0	15 (feet)	Gravel and sand.
15	104	Silts and fine sand lens.
104	145	Medium to coarse sand with gravel (water-bearing)
145	148	Till - coarse gravel.
148	150	Compact silty sand.
150	158	Till and interbedded gravel.
158	206	Sands and gravel, some silts, occasional till.
206	222	Very compact till-like sand and gravel.

NS-5

Log

From	To	Description
0	11.6 (meters)	Sand and gravel.
11.6	25.6	Brown clay, layers of sand.
25.6	28.9	Brown clay.
28.9	32.6	Blue clay.
32.6	51.5	Till, dense, casing driving hard into open hole.
51.5	60.1	Till.
60.1	66.2	Medium sandy gravel with binder, making water.
66.2	72.2	Sand and gravel with clay binder, dense layer 67.4 to 69.2 m.
72.2	77.1	Sand and gravel with binder.
77.1	84.4	Sand and gravel dense layer 79.3 to 80.5.

Appendix B

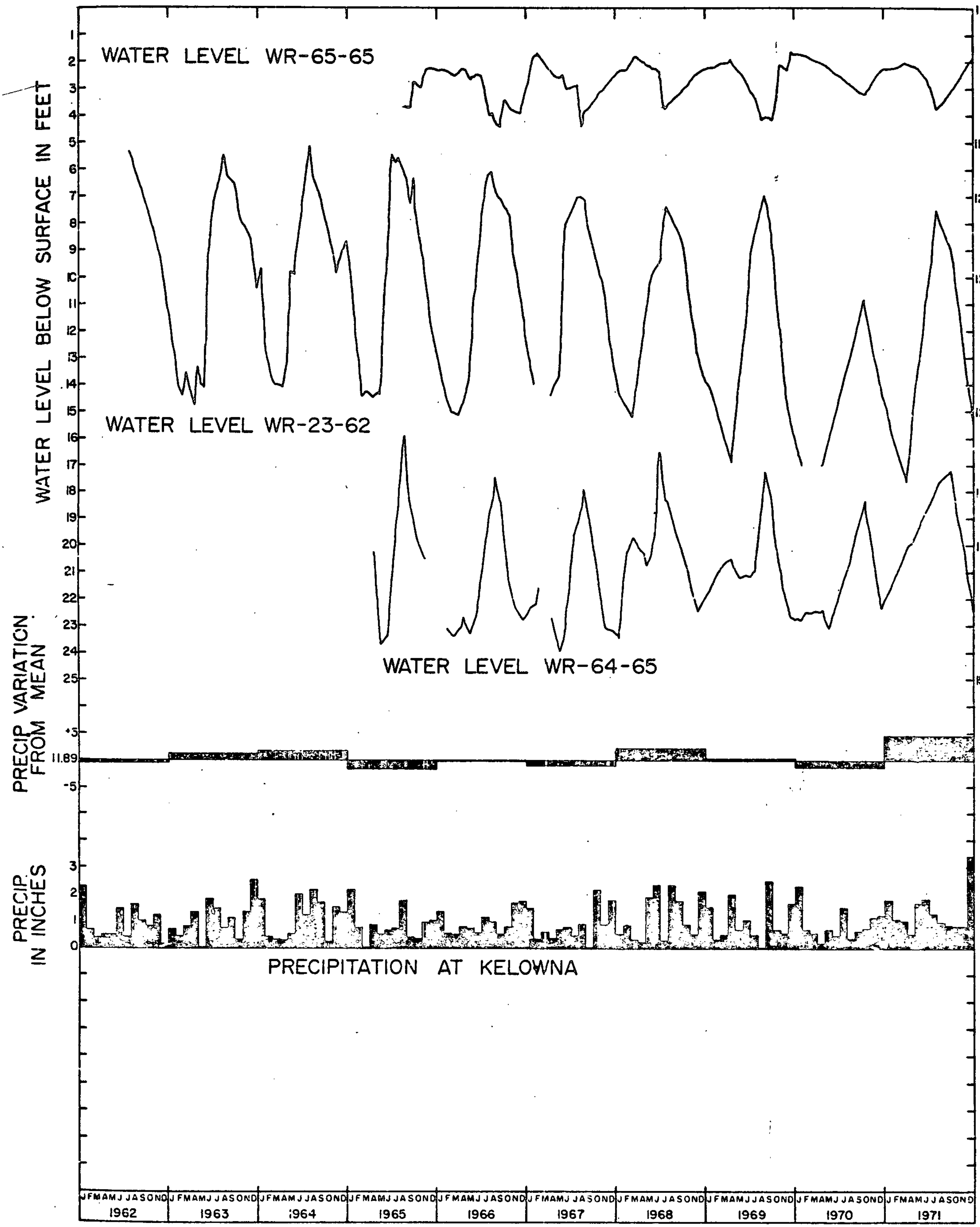
Well Hydrographs

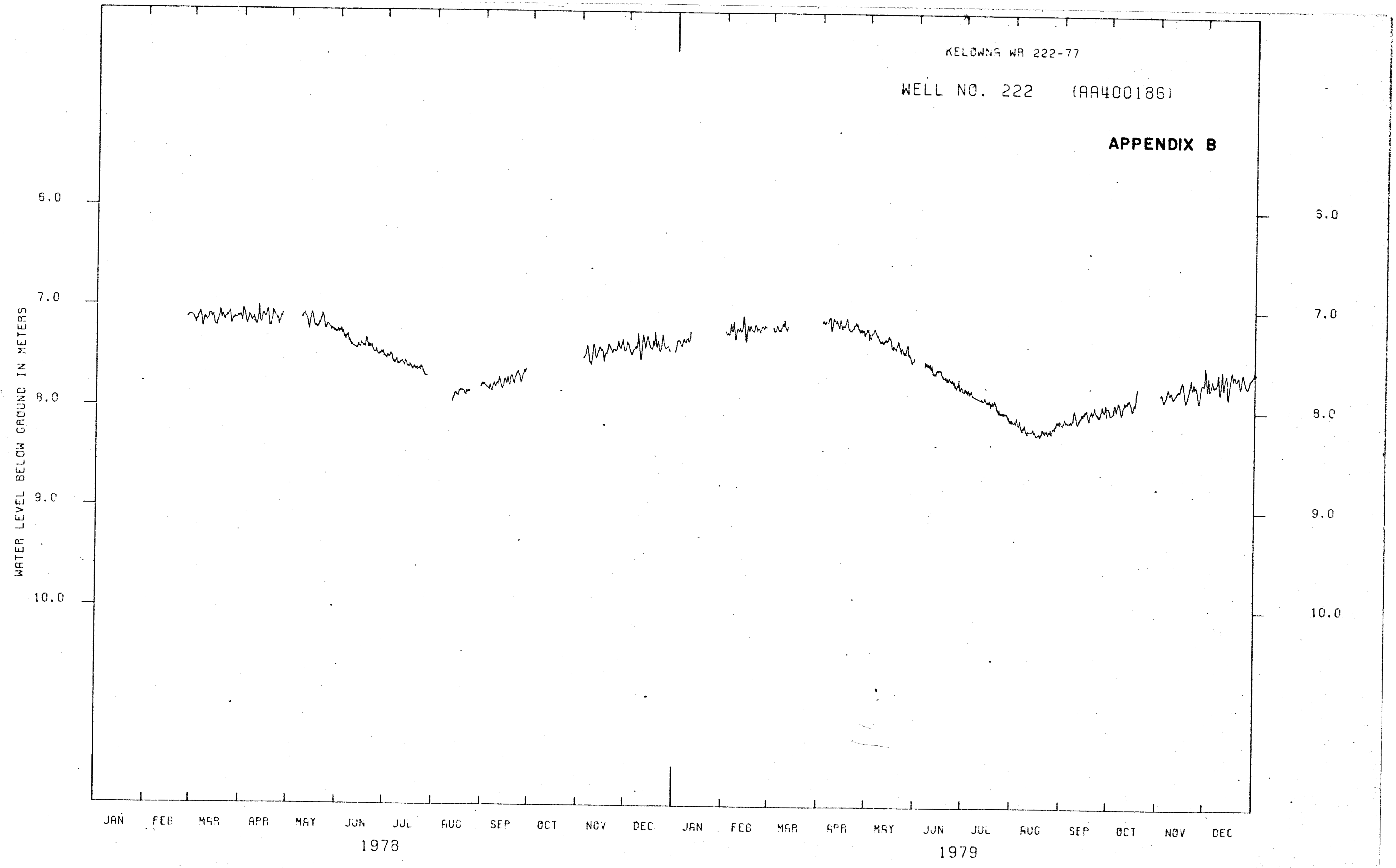
and

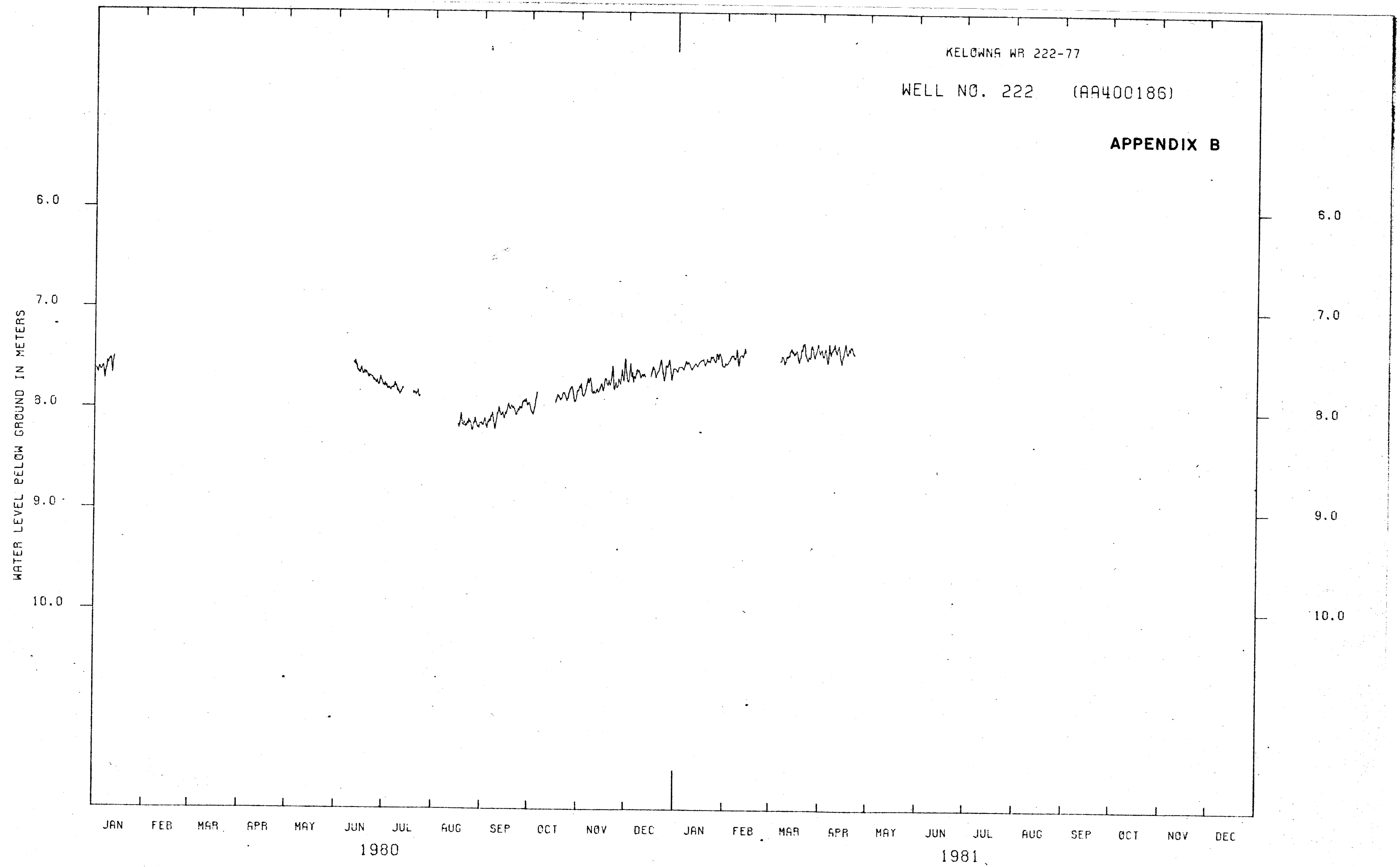
Precipitation Data

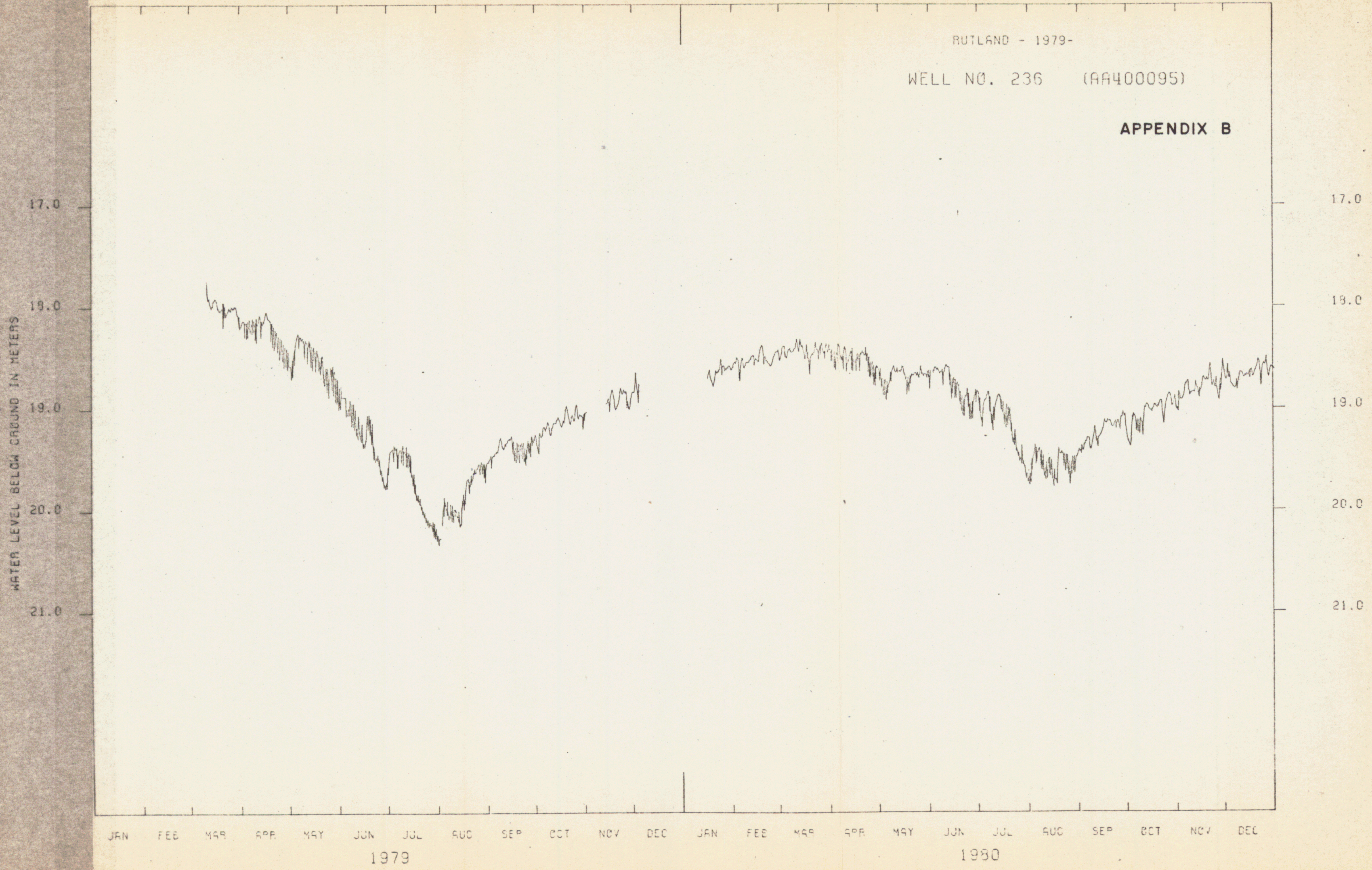
APPENDIX B

HYDROGRAPHS SHOWING WATER LEVEL FLUCTUATIONS



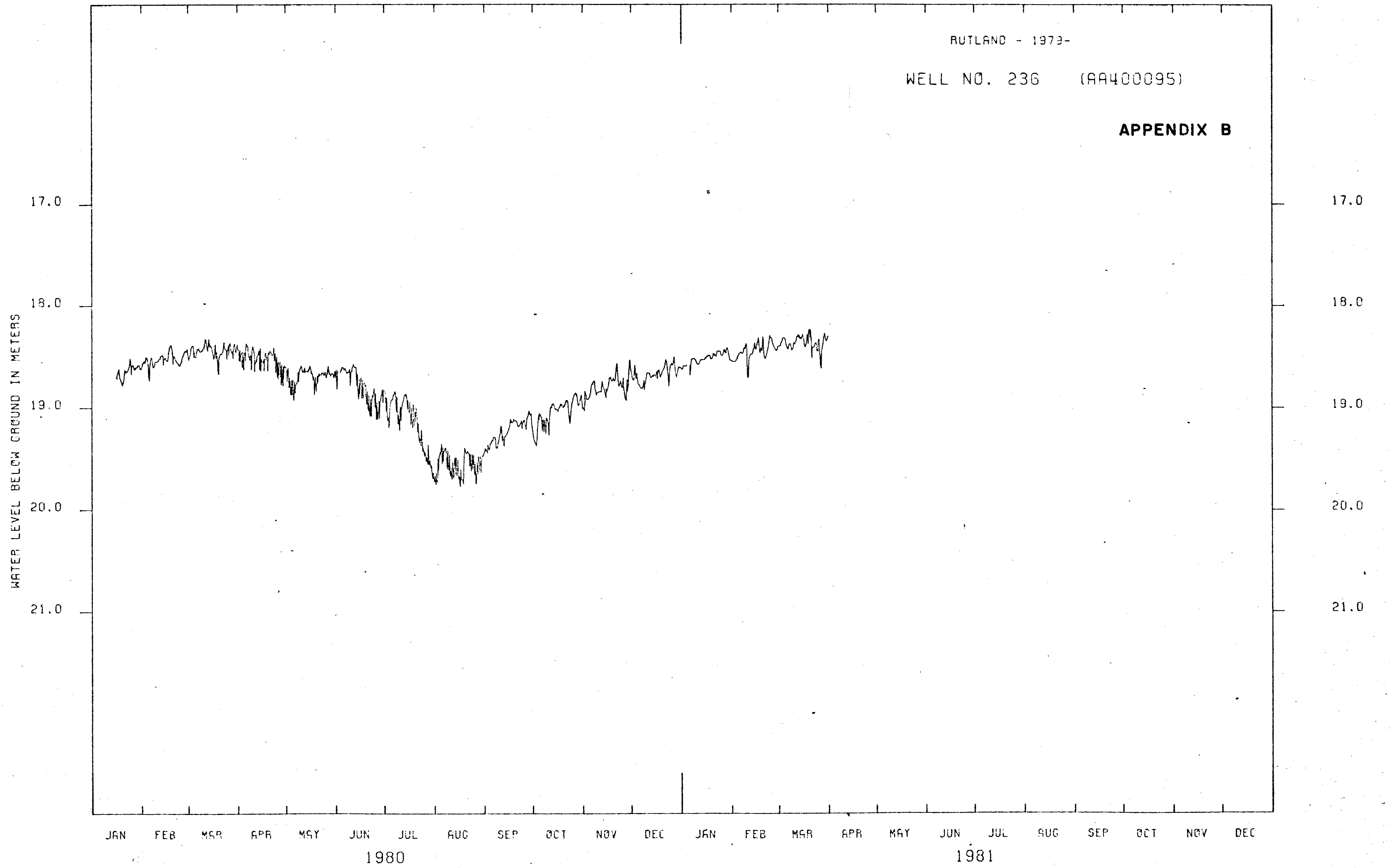

KELOWNA WR 222-77
WELL NO. 222 (AA400186)
APPENDIX B
WATER LEVEL BELOW GROUND IN METERS
6.0
7.0
8.0
9.0
10.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1978
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1979


KELOWNA WR 222-77
WELL NO. 222 (AA400186)
APPENDIX B
WATER LEVEL BELOW GROUND IN METERS
6.0
7.0
8.0
9.0
10.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1980
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981



RUTLAND - 1979-
WELL NO. 236 (AA400095)
APPENDIX B
WATER LEVEL BELOW GROUND IN METERS
17.0
18.0
19.0
20.0
21.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1979
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1980

APPENDIX B


RUTLAND - 1979-
WELL NO. 236 (AA400095)
WATER LEVEL BELOW GROUND IN METERS
17.0
18.0
19.0
20.0
21.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1980
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981

S.E.K.I.D. WR 262-80

WELL NO. 262 (AA401808)

APPENDIX B