British Columbia MEMORANDUM

To: Dr. J.C. Foweraker, Head
Groundwater Section
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Re: Isotope Analyses, Groundwater Inventory 1978-79

During the fiscal year 1978-79, isotope analyses were conducted on water samples taken from two areas, namely; the Saanich Peninsula and the Ribbleworth Creek area, east of Wood Lake. The proposed program was approved in October 1978 at which time costs of $4,790 were estimated from the budgeted allocation of $5,495 under Vote 09205-2001. At the end of the fiscal year, funds in the amount of $4,764 were spent on the program (Table 1). Apart from direct laboratory analyses costs, Mr. R. Drimmie from the Environmental Isotope Laboratory, Department of Earth Science, University of Waterloo was brought to Victoria to instruct our staff on sampling procedures for C^{14} analyses. As the C^{14} sampling techniques are somewhat involved it was particularly advantageous for our staff to receive instruction from the Waterloo personnel who would be analyzing the samples, interpreting and correcting the results. In this manner we could then be confident that our sampling techniques would be adequate and meaningful results would be obtained in any future C^{14} work. This memorandum summarizes the results of the 1978-79 program and makes recommendations for further work in 1979-80.

Saanich Peninsula

Isotope sampling on the Saanich Peninsula was undertaken in two specific areas namely;

1. analyses of surface water samples from Elk Lake to determine the seasonal variation in δO^{18} content to assist in determining whether groundwater inflow and outflow components are important in the lake system and;
2. analyses of groundwater samples from bedrock wells in North Saanich for C^{14}, δO^{18} and Tritium content to determine the age and origin of the groundwaters, sources of recharge, directions of groundwater flow and rates of groundwater movement. This latter work was follow-up work to studies undertaken in 1977-78 in the same area (Kohut and Petrie, 1978).

The results of these studies are discussed as follows:

Elk Lake

Since March 1978 surface water samples from a site on the northeastern shore of Elk Lake have been obtained on a regular basis at approximate 2 to 3 week intervals. During sampling, in situ conductivity and temperature

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24/1/80.

a. recorded using a YSI Model 33 S-C-T meter. Eighteen of the water samples collected principally in 1978 were also analyzed for δO^{18}. These data are shown diagramatically in Figure 1, and listed in Table 2.

From Figure 1 it is apparent that temperature and conductivity at the site behave similarly exhibiting an annual cycle with both parameters increasing during the period March to August thereafter decreasing from August to March of the following year. For the most part, the increasing trend can be related directly to climatic affects, primarily to available solar radiation (duration and intensity), subsequent warming of daily air temperature and evapotranspiration affects which concentrate dissolved minerals in the lake water. Decreasing trends of these parameters can be attributed primarily to a decrease in available solar radiation and dilution affects of precipitation and surface runoff into the lake system particularly during the latter fall and winter months. A somewhat unusual phenomenon observed in both 1978 and 1979 is the time at which both conductivity and temperature stop increasing and begin to decrease. This happens near the end of July in each year, at a time when daily air temperature and evaporation are still relatively high.

The δO^{18} values for 1978 show an increase during the period May to August which can be attributed to evapotranspiration which causes the enrichment of the heavier isotope O^{18} at the site. Instead of decreasing in August, δO^{18} values level off and remain relatively constant until the end of the year reflecting an isotopic equilibrium condition in the lake during the period August to January. During this period there must be a balance between evapotranspiration affects which would raise the δO^{18} values and dilution factors which would lower δO^{18} values, temperature and conductivity at the site. The only dilution (inflow) components, which might theoretically cause this would be groundwater inflow, surface inflow and precipitation. In August of 1978 and 1979 precipitation and surface inflow were negligible suggesting groundwater inflow could be important. On the other hand, if groundwater inflow was important, the conductivity of the inflowing groundwater would have to be less than the conductivity of the lake to cause a lowering in lake conductivity (i.e., groundwater conductivity < 150μmhos/cm). Available groundwater chemistry data in the area, however, shows groundwaters have conductivites greater than 150μmhos/cm. Inflow components to the lake system, therefore, cannot explain the decreasing trend in conductivity, temperature and stabilization of δO^{18} values which take place in late July of each year. This phenomenon, therefore, must be dependent upon some characteristics of the lake itself.

On the basis of depth and geographical setting, Elk Lake should be a monomictic lake (pers. comm. R. Buchanon, 1979). The lake should become thermally stratified during the spring and summer warming period. In the fall when average daily air temperatures begin to fall, the lake should then begin to mix. Mixing in late July (earlier than expected) could explain the temperature, conductivity and δO^{18} behaviour of the lake but why this phenomenon begins at this early date is not known. Mixing would bring colder, less mineralized waters at depth enriched in the lighter

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the O^{16} to the surface causing an overall lowering of surface water temperature, a decrease in conductivity and a decrease in δO^{18} content. The seasonal process which may be occurring is depicted in Figure 2.

The seasonal behaviour of temperature, conductivity and δO^{18} of Elk Lake indicate that groundwater is not a major inflow component in the lake system during the period May to January, i.e., there is no significant groundwater inflow component to the lake on a year round basis. Where groundwater inflow may be important is during the period January to May. During this period lake temperature and conductivity begin to increase while δO^{18} values are decreasing. It is surprising that, the lake conductivity would increase during this period when evaporation is low and precipitation and surface runoff are relatively high. These latter components should have a diluting affect upon dissolved mineralization in the lake. Inflowing groundwaters at temperatures close to 10° C and having conductivities greater than 100 µmhos/cm and δO^{18} concentrations close to -10 SMOW would cause an increase in lake temperature and conductivity while decreasing the δO^{18} content of the lake. This period also corresponds to the time when groundwater levels are normally at their seasonal high as evidenced by observation well data from surficial wells in the region. Careful monitoring of changes in lake storage would be required to quantify this groundwater component during this period. Outflow components including surface outflow and groundwater outflow if present would not be expected to have significant affects on lake chemistry although these components would have to be accounted for in any quantitive analysis.

North Saanich

All isotope data obtained under the 1978-79 program and from previous studies for bedrock wells is shown diagramatically in Figure 3. The analyses undertaken in 1978-79 are also listed in Table 3. Previous work in the area (Kohut and Petrie, 1978) described the occurrence of a north-easterly trending linear zone of brackish groundwaters (TDS in the range 1000 to 3100 mg/L) along a major structural lineament in the fractured granitic bedrock east of Patricia Bay. δO^{18} values ranging from -12.0 to -11.0 (SMOW) in the zone indicates the groundwaters were in part recharged under different (colder) climatic conditions in the past.

C^{14} age determinations obtained in 1978-79 (Figure 3) indicate that the brackish groundwaters found east of Patricia Bay range from 2500 to 9100 years in age. These older waters are bounded by younger waters generally in the range 400 to 1000 years old. Groundwater found in the recharge areas north and south of the brackish zone date around 400 years. The presence of some tritium in the waters of the northern recharge area (indicative of water less than 25 years of age) shows that the samples may represent a mixture of waters including relatively young water and water which has been in the ground for a few hundreds of years. This is not surprising considering the bedrock wells often intersect several water bearing fractures with depth. Subsequent pumping of the well would result in some mixing of older waters at depth with shallower younger waters in the well. From the aerial distribution of C^{14} ages, groundwater moving within the upper [illegible] feet or so of the bedrock appears to take about 600 years to travel 1000 metres suggesting a flow rate of 1.7 m/year (5.4×10^{-6} cm/sec.) from the northern recharge area to the discharge area east of Patricia Bay.

Ribbleworth Creek Area, east side of Wood Lake

Isotope data for the Ribbleworth Creek area was obtained through a sampling program carried out by G. Le Breton and A. Kohut in August 1978. Samples were obtained for δO^{18} and Tritium analysis to evaluate the applicability of isotope studies to the hydrologic results previously obtained (Le Breton and Coulson, 1975) on studies of return flow from irrigation in the basin. A summary of the isotope analyses are given in Table 4 and shown diagramatically in Figure 4.

δO^{18} values for springs originating from the bedrock at upper elevations are in the range -17.4 to -15.9 (Sites 10 to 13). Sites 12 and 1 are outside of the area shown in Figure 4, at higher elevations in the basin to the east. Ribbleworth Creek east of the main north-south highway shows a δO^{18} value of -15.7 (Site 9) suggesting that groundwater flow from the upland areas is the main contribution to the flow of Ribbleworth Creek at this point. Downstream of Site 9 the creek and spring samples become more positive, enriched in the heavier isotope O^{18} with values ranging from -14.9 to -14.3. In creeks north of Ribbleworth Creek the δO^{18} value are further enriched in O^{18} with values ranging from -13.5 to -13.4. A sample of the irrigation water taken from the pipeline from Oyama Lake, being applied in August 1978 had a δO^{18} value of -12.9. It is not known if this latter value is representative of applied water in general or whether there are large variations in the δO^{18} concentration of the applied water seasonally. Large variations on the other hand would not be expected from this lake source.

Tritium values in the range 12 ± 8 to 74 ± 8 for samples taken from bedrock springs in the upland area east of the irrigation district (Site 10 to 13) and in the lower reaches of Ribbleworth Creek (Site 6) indicate these discharge areas must be recharged locally and the groundwaters are less than 25 years of age indicating rather short duration and shallow flow systems.

If a significant portion of the flow in Ribbleworth Creek was direct return flow from applied irrigation water, δO^{18} values for the creek would be expected to be more positive than the applied water due to evaporation affects. At the time of sampling, δO^{18} values of the creek were, however, more negative than the applied water suggesting one or more of the following:

1. Although irrigation practice may generate a groundwater component of flow into Ribbleworth Creek this return flow component is not necessarily a portion of the actual applied water during the season. The infiltrated water in other words, displaces water previously stored in the subsurface reservoir and this displaced water appears as flow in the creek. This concept has been observed elsewhere (Martinec, 1975). The magnitude

of the relationship between applied water versus the generated affect and the response time delays are not adequately known. Le Breton and Coulson (1975) noted a two month delay in the "full-effect" of irrigation upon the artificially generated component of streamflow in 1973 and a two-week delay in 1974.

2. δO^{18} values in Ribbleworth Creek in the range of -14.9 to -13.4 might be explained due to mixing of applied water (δO^{18} = -12.9) and natural groundwaters in the range -17.4 to -15.9.

3. A large portion of the groundwater in storage adjacent to the lower reaches of Ribbleworth Creek may be derived from precipitation recharging the aquifer directly over the area and contributions from irrigation may be minimal in relation to the amount of groundwater in storage.

To summarize, the δO^{18} data obtained in August 1978 indicates that applied irrigation water generates groundwater inflow into Ribbleworth Creek but there may not be a direct relationship between the quantity of applied water to the quantity of groundwater inflow generated during an irrigation season. This inflow is probably generated by increases in the hydraulic gradients adjacent to Ribbleworth Creek caused by infiltration of irrigation water in the upland areas adjacent to the creek. The magnitude of the groundwater head increases (changes in storage) in the upland areas that accompany resultant changes in creek flow are not known. The time required for irrigation infiltration to induce a widespread water-table rise could explain the lag time between the peak of the irrigation practice and maximum streamflow. Similar situations have been observed and discussed elsewhere for example in analyses of storm hydrographs (Freeze 1971; Martinec 1975; Sklash et al. 1975).

Additional avenues of approach which would help further define the role of the major hydrologic components in the basin or similar basins where return flow from irrigation is studied would be:

1. To establish monitor wells equipped with automatic water level recorders in the groundwater regime at representative sites in the basin locally:

   (a) close to the discharge end of the flow system near the major creek to monitor corresponding changes between the hydraulic head of groundwater with the changes in streamflow.

   (b) at an upland site in the basin above the area of applied irrigation water to monitor any natural seasonal fluctuations in the water table.

   (c) at a site near the center of the irrigated area to monitor maximum groundwater level changes associated with irrigation. These latter two sites have been moreover suggested by Le Breton and Coulson (1975).

2. To monitor δO^{18} and specific conductivity of the major creek twice a month near the stream gauging station to obtain temporal variations in the water chemistry which can be compared to the stream hydrograph to facilitate hydrograph separations.

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...mendations for Further Work

As the Saanich Peninsula is readily accessible for sampling and a hydrogeologic mapping program (pilot project) is being undertaken in this area by G. Le Breton, additional isotope analyses in this area are recommended for the 1979-80 fiscal year. As the end of the fiscal year is drawing near a limited sampling program for δO^{18} and tritium analyses which would include bedrock wells in the Cretaceous rocks at the extreme northern end of the peninsula, bedrock wells on the northern slope of Mount Newton and additional samples from Elk Lake is suggested. Costs for the proposed 1979-80 program would be $1,550 based upon 30 δO^{18} determinations at $35 each and 10 tritium analyses at $50 each. Funds in the amount of $5,000 have been budgeted for isotope work under Vote 05469-2001.

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References

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Le Breton, E.G. and Coulson, C.H. 1975. Groundwater Return Flow From Irrigation in the Ribbleworth-La Fleche Creek Basin, Okanangan Valley, British Columbia. Canadian Hydrology Symposium - 75, Proceedings, Winnipeg, Manitoba.

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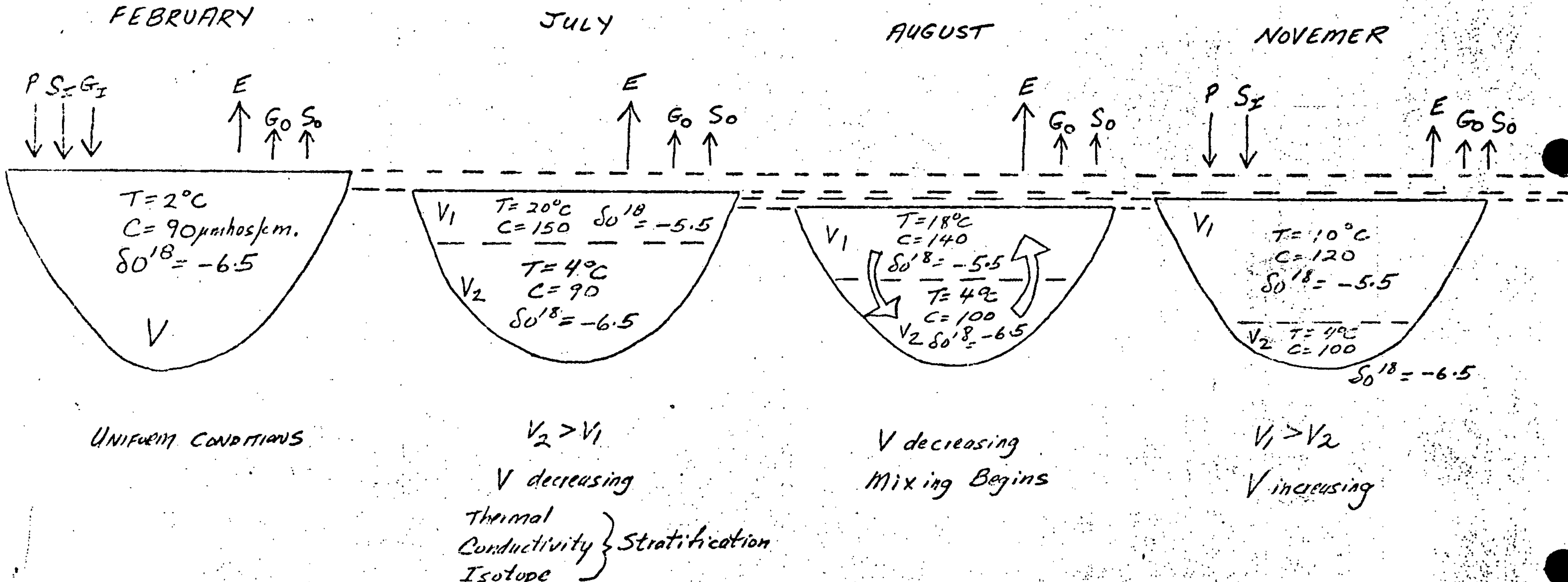
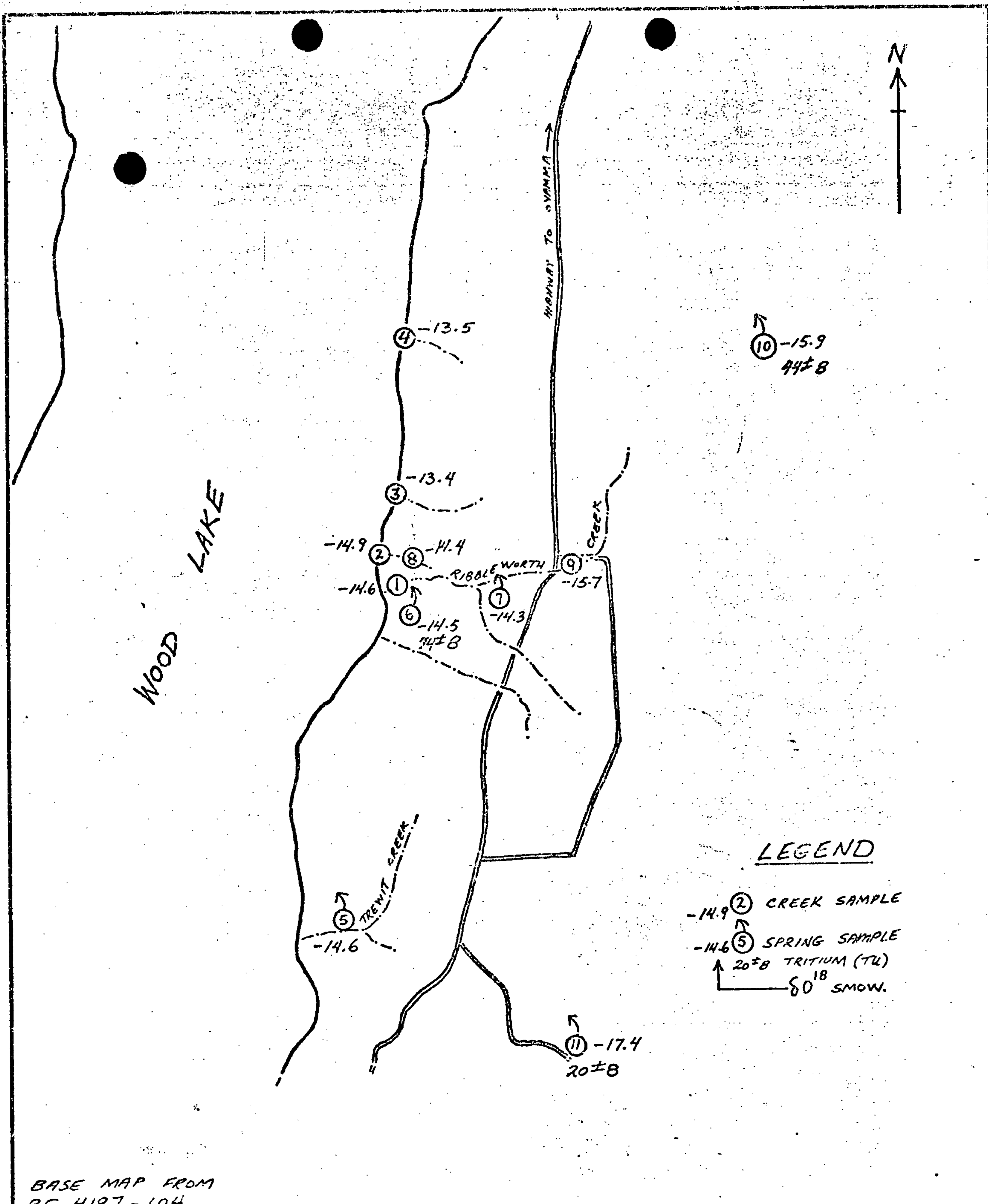
ANNUAL VARIATIONS IN TEMPERATURE, CONDUCTIVITY AND δO^{18} CONCENTRATION, ELK LAKE



P = PRECIPITATION
S_I = SURFACE INFLOW, S_o = SURFACE OUTFLOW
G_I = GROUNDWATER INFLOW
E = EVAPOTRANSPIRATION
G_o = GROUNDWATER OUTFLOW
V = LAKE VOLUME

Province of British Columbia Ministry of the Environment ENVIRONMENTAL AND ENGINEERING SERVICE WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON ISOTOPE ANALYSES 1978 - 79	SCALE: VERT. NA (schematic) HOR. NA APK ENGINEER FILE No. 0329563 DWG. No. FIGURE 2	DATE DEC 1979



BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON RIBBLEWORTH – LAFLECHE ISOTOPE SAMPLING δO18 DISTRIBUTION
SCALE: VERT. — HOR. 1" ≈ 1470'	DATE DEC. 79	AFK ENGINEER FILE No. 0329563 DWG. No. FIGURE 4

TABLE 1 COSTS FOR 1978-79 ISOTOPE ANALYSIS PROGRAM

Location and Items	Cost
A. Saanich Peninsula	
18 Elk Lake Samples for δO^{18} @ $35	$ 630
7 Bedrock Well Samples for δO^{18} @ $35	$ 245
7 Bedrock Well Samples for Tritium @ $50	$ 350
10 Bedrock Well Samples for C^{14} @ $150	$1,500
Sampling equipment for C^{14}	$ 200
Airfare and ground transport for R. Drimmie, Univ. of Waterloo (C^{14})	$ 504
Per Deim, R. Drimmie 5 days @ $140/day	$ 560
B. Ribbleworth Creek, Okanagan Valley	
15 Spring and creek samples for δO^{18} @ $35	$ 525
5 Spring and creek samples for Tritium @ $50	$ 250
TOTAL	$4,764

TABLE 2 SUMMARY OF ISOTOPE DATA, ELK LAKE 1978-79

Date Sampled	δO^{18} (°/oo) SMOW
March 26/78	-6.2
April 10/78	-6.3
April 30/78	-6.3
May 22/78	-6.0
May 29/78	-6.0
June 5/78	-5.9
June 29/78	-5.70
July 18/78	-5.4
July 24/78	-5.4
August 9/78	-5.2
August 29/78	-5.2
September 20/78	-5.2
October 8/78	-5.0
November 11/78	-5.2
December 10/78	-5.2
January 7/79	-5.2
January 21/79	-5.35

TABLE 3 SUMMARY OF ISOTOPE DATA ON BEDROCK WELLS, SAANICH 1978-79

Site Number	Sampling Date	Site Description	δO^{18} (°/oo) SMOW	Tritium (TU)	$\delta^{13}C$ PDB	% MOD.
1401410	March 15/77	R1W SEC 22 #2 Skorsgaard	-10.0	21±8	-	-
1401411	March 2/77	R1E SEC 15 #17 Boardman	-10.8	-1±8	-	-
1400058	August 5/77	R1E SEC 16 #1 Aylard	-10.8	-1±8	-	-
1400058	December 5/78	R1E SEC 16 #1 Aylard	-10.9	-	-16.7	72.7
1401420	May 3/77	R2W SEC 7 (800') Ardmore	-10.9	0	-	-
1401421	June 6/77	R1W SEC 8 #5 Patterson	-13.1	2±7	-	-
-	March 18/77	Wains Road Marco	- 9.1	15±6	-	-
WR 106-72	-	R1W SEC 20 #14 Pleasance	-10.2	44±8	-	-
WR 106-72	December 6/78	R1W SEC 2 #14 Pleasance	-10.4	-	-18.3	90.4
-	December 5/78	R1W SEC 17 #1 Kingswood	-10.4	-	-18.6	80.3
-	December 5/78	R1E SEC 15 #19 Reid	-10.9	-	-16.6	62.6
1400226	December 7/78	R1E SEC 15 #8 Jones	-12.0	-	-14.3	54.0
1401367	January 24/79	R1E SEC 15 #6 Williams	-12.9	-	-15.6 -15.8	16.7 -
1401415	December 7/78	R1W SEC 14 #5 Edgar	-11.0	-	-10.9	83.6
1400014	December 8/78	R2E SEC 16 #2 Mathews	- 9.4	-	-16.7	80.4
1401379	December 7/78	R2E SEC 16 #6 Kiwanis	-11.3	-	-15.5	71.9
1401380	December 6/78	R2E SEC 13 #8 Philip	-	-	-16.2	90.6

TABLE 4 SUMMARY OF ISOTOPE DATA, RIBBLEWORTH CREEK AREA 1978

Site No.*	Sampling Date 1978	Site Description	δO^{18} (‰) SMOW	Tritium (TU)
1	August 22	Ribbleworth Creek Falls at Railway Crossing	-14.6	-
2	August 22	La Fleche Creek at Railway Crossing	-14.9	-
3	August 22	Creek North of La Fleche at Railway Crossing	-13.4	-
4	August 22	Second creek north of La Fleche at Railway Crossing	-13.5	-
5	August 22	Trewit Creek, North Side Spring	-14.6	-
6	August 23	Sidehill Spring between Trewit and La Fleche Creeks	-14.5	74±8
7	August 23	Webber's Spring	-14.3	-
8	August 23	La Fleche Creek, Upper Site	-14.4	-
9	August 23	Ribbleworth Creek at Culvert, east of Main Road	-15.7	-
10	August 23	Ribbleworth Creek Bedrock Spring	-15.9	44±8
11	August 23	Spring North Side of McDonnell's Property	-17.4	20±8
12	August 23	Sommerville Mine Adit, Bedrock Spring	-16.7	51±8
13	August 24	Holt Creek, Bedrock Spring	-17.3	12±8
14	August 24	Oyama Irrigation Line from Oyama Lake	-12.9	-
15	August 24	Winfield Creek, Winfield	-14.4	-

* See Figure 3 for site locations.